The Use Of Genetic Engineering Methods In Breeding Ornamental Plants

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From the mid 1980s the use of recombinant DNA technology for plant improvement began to be developed commercially. Now, genetic modification methods can access genes for disease and insect resistance, modification of biochemical pathways and herbicide resistance from a much wider range of sources than previously available. Plant varieties can be modified with no loss of the original parental phenotype, saving many generations in back crossing. Genetic engineering programs in the ornamental area are focused on improving agronomic quality (e.g. disease resistance, keeping quality, pest resistance) and creating novelty (e.g. form, colour) in the important cutflower and pot plants crops. Progress in these areas will be reviewed. From the context of commercialisation, the areas of intellectual property, patent ownership (as opposed to plant breeder rights), government regulation of genetic engineering, and public perception of genetic engineering are central and will be briefly reviewed.

INTRODUCTION

The purpose of this article is to summarise the commercial aspects associated with marketing new ornamental crops developed using genetic engineering. The science behind the technology has been covered elsewhere in this symposium. The review has in mind the main foliage and flowering pot plants and the world's major cut flowers, despite potential applications of genetic engineering to ornamental forestry, turf management, orchards, and the hundreds of other foliage and flower crops. Genetic engineering methods can only economically be applied to major crops.

For further information interested readers are recommended to read recent articles by Boulter (1995), Goy and Duesing (1995), Hammerschlag (1995), and Owens (1995).

POTENTIAL OF GENETIC ENGINEERING FOR ORNAMENTAL PLANT IMPROVEMENT

Most work on plant genetic engineering has targeted major food crops, e.g. soybean, wheat, maize, potato, tomato, oilseed rape, and sugar beet (Goy and Duesing, 1995). In these crops the first commercial products, now available overseas, include varieties in which genes:

- Confer insect resistance by expression of insect toxin genes from the bacterium *Bacillus thuringiensis* (the Bt genes).
- Confer resistance to the herbicides bromoxynil, glyphosate, sulphonylureas, or Basta by insertion of "resistant protein" genes and detoxification genes. In this case, genes are from bacteria or plants.

- Improve postharvest quality of tomato by inhibiting expression of genes involved in the degradative process, i.e. ethylene biosynthesis or carbohydrate degradation.
- Modify fatty acid composition of oilseed rape (canola).
- Induce virus resistance in squash.

Ornamental plants have seen less development using genetic engineering. However, the technology is equally applicable (Hammerschlag, 1995). Owens (1995) lists in detail the type of genes which might be put to good use by breeders of ornamental plants.

Disease Resistance. Major pathogens such as *Botrytis*, *Fusarium,* and *Pythium* cost the ornamental industry a huge amount of money, in control and losses. By insertion of anti-pathogen genes such as chitinases, glucanases, and proteinase inhibitors, the plant will hopefully have an in-built defence against pathogen attack. This could be beneficial during both vegetative growth and post harvest, and projects are underway by government institutes in both the Netherlands and Israel.

Insect Resistance. In the cutflower industry particularly, any variety which could be resistant, or even immune to attack by insects (particularly thrips, aphids, and mites) would be very valuable. A survey of Dutch flower growers indicated insect resistance, after fungal resistance, would be the most useful application of the technology from their perspective.

Flower Colour. Flower colour is a primary selection trait for breeders of cut and pot flower crops. Novel colours attract attention in the market, and may also capture higher prices. The ability to produce colour ranges in very good varieties, or to create colour groups novel to particular crops is therefore one current use of the technology. Florigene has isolated the blue gene from petunia—a gene essential for biosynthesis of the blue delphindin pigments. By inserting this into the major cut flower crops novel blue, mauve, violet, and lavender flowers will be produced. It is also possible to produce white and pink colours from red and purple varieties.

Growth Form. The amount of flowering and the habit (e.g. branching, stature) of a plant can be controlled by application of growth regulators such as cytokinins and auxins. Insertion of genes for the biosynthesis of these compounds has been shown to affect growth habit of the pot-grown rose and ornamental tobacco by French workers.

"Anti-senescence" Genes. The production of, or exposure to , ethylene causes flower abscission or senescence in a number of very important cutflower and pot flower crops, e.g. carnation, begonia, lily, and rose. Technology is now available to prevent ethylene production by the plant and/or to confer plants resistant to exogenous ethylene. Florigene has genetically engineered carnation to last 2 to 3 times longer in water than the unengineered parents. Varieties containing these genes will prove beneficial at all levels in the marketing chain; grower, wholesaler, and consumer.

PROGRESS TOWARDS COMMERCIALISATION

Commercialisation of genetically engineered plants is complex, as the technology introduces the need to deal with commercial avenues not necessary for conventionally bred ornamentals. These are:

Intellectual Property. The technology used in genetic engineering is protected by broad patent protection. The promoters, genes, tissue culture techniques, and even the final trait, may be the subject of specific patents, usually owned by different companies. Commercialisation will therefore require the negotiation of licences, licence fees, and royalty payments to the owners of the technology. As the final product contains patented technology it is afforded the protection of patent law. This raises the question of whether it is useful to go to the additional expense of registration of a variety under plant breeder rights legislation.

Regulatory Approval for Release. All governments either legislate or enact guidelines to monitor and control the marketing of genetically engineered organisms, including ornamentals. In Australia, the Genetic Manipulation Advisory Committee (GMAC) does this work. Following a public enquiry in 1992 the intention is to legislate to control releases. The purpose of regulation is to assess whether the modification will have any undesired environmental or health effects.

For example:

- Could the inserted gene escape to weed populations and increase the noxiousness of these weeds?
- If the target crop is a food could there be any toxin production?
- For ornamentals, which are generally not consumed and are intensively cultivated, genetic modifications carried out to date do not pose any significant risk to the environment.

Of course, such assessments have to be made on a crop-by-crop, gene-by-gene, case-by-case basis prior to any commercial release. The only genetically engineered ornamental to be approved for market release anywhere in the world so far are Florigene's carnation flowers, which can be sold in Australia.

Public Perception. The public are aware of "genetic engineering" and are concerned that the technology be used carefully (Kahler, 1995). This has engendered debate on issues ranging from gene therapy, manipulation of germ lines, use of plants and animals as chemical "factories", or modification of food with DNA from divergent sources, including humans. The development of genetically engineered ornamentals is caught up in this debate. Commercially, this raises the question of whether products should be labeled as genetically engineered, and if so, what information should be, or can usefully be, conveyed on the label.

DISCUSSION

Because of the commercial factors listed above, and the cost of the research, genetic engineering is very, very expensive. Primary to any commercial project is therefore a consideration of the value of the crop, the likely benefit of the modification and the potential long-term income to the developer of the new variety. Effectively, this limits work to the most important cut-flowers (rose, lily, gerbera, carnation, chrysanthemum, tulip) and perhaps a few pot plants (*Ficus*, *Begonia*, *Dracaena*). Florigene has established a strong intellectual property position in colour modification, and post-harvest manipulation applicable to the major cut-flower crops. In the next few years we hope to commercialise the products of this research, in both Australian and overseas markets (Anon, 1994), beginning with carnation in Australia, Japan, Europe, and Israel.

Florigene's competitors in the world also have research on the genetic engineering

of ornamentals. They include Kirin, the Japanese brewer, who are interested in blue roses and blue chrysanthemum and Moet - Hennessey of France, also chasing the blue rose. Several cut flower breeders are now acquiring in-house gene transfer technology. In the Netherlands, Israel, Spain, Italy, Japan, United Kingdom, and the United States of America there are also numerous company- and government-based researchers working on smaller genetic engineering based ornamental projects. Whatever the outcome of the race to commercialise the technology, the industry will be the winner, thanks to the introduction of new varieties.

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Breeding Approaches to the Development of Selected Australian Native Daisies for Pot Culture

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INTRODUCTION

In the period 1990-94 Plant Growers Australia P/L conducted an extensive breeding program aimed at improving members of the Australian Asteraceae (daisies) for commercial pot culture. The specific aim was to develop novel and proprietary cultivars for markets in the northern hemisphere where a number of Australian daisy species had already achieved considerable success. Since commencement, over a dozen new cultivars have been commercialised and many are protected in this country by plant breeders rights. Cultivars derived from the project are now cultivated in Europe, North America, New Zealand, and Japan. This paper summarises the approaches adopted, both successful and otherwise, to improve this diverse flora. The aim is to provide some guidelines for horticulturalists wishing to pursue a program of plant improvement by breeding, and has particular reference to other Australian taxa which are yet to realise their full commercial potential.

PARENTAL BREEDING AND BREEDING OBJECTIVES

There are in excess of 100 Australian daisy species. Many Australian taxa are currently the subject of botanical revision, the results of which will be incorporated into the forthcoming volume of "Flora of Australia" dealing with this group. Recent publications (Wilson, 1992; Short, 1994; Salkin et al., 1995) provide useful insight into the current status of the genera targeted by this study. The broad aims of the breeding program were to develop compact, brightly coloured, free-flowering, vegetatively propagated, perennial types which would perform well in containers and garden situations. Specifically targeted was the widow box or "basket stuffer" market in the northern hemisphere, where there is growing demand for rapidly flowering vegetative material.

Over 150 taxa from all over Australia were assembled in a collection and comprehensively assessed according to the criteria above. Although perennial species were favoured, annuals with useful characters (e.g. flower colour) were also included. At the completion of this phase the genera *Brachycome*, *Rhodanthe* (syn. *Helipterum*), and *Bracteantha* (syn. *Helichrysum*) were selected for further breeding. Preliminary cytological analysis in *Rhodanthe* was useful in identifying likely "crossable" gene pools and eliminating others. Chromosome counts were obtained by observing mitosis in root tips (Salmon, 1995).

ASSESSMENT OF BREEDING SYSTEMS

Members of the Asteraceae are distinguished by their distinct combination of floral features. The inflorescence, often mistaken as a single flower, is a capitulum composed of numerous small flowers (florets) arranged on a compressed head. These florets can have a diverse morphology and sexuality, even across the same

capitulum, and the implications of this diversity for breeders is discussed in detail by Burtt (1977). In *Brachycome*, the ornamental feature of the inflorescence is the conspicuous outer whorl of ray florets. In *Rhodanthe* and *Bracteantha* the inflorescence is subtended by a series of brightly coloured involucral bracts which are papery, non-fertile, modified leaves (Sharman and Sedgley, 1988).

The complex nature of the capitulum provides many potential outcomes for pollination. It is generally accepted that the Asteraceae is well adapted for insect pollination and evidence from this study would support this view. Seed set in the absence of insect pollination was very low for most species of all genera studied and four species of *Rhodanthe* were found to be strongly self-incompatible (a failure to produce viable seed after self pollination). Detailed assessment of pollen/pistil relationships in *R. anthemoides* using florescence microscopy showed this species to possess a sporophytic type self-incompatibility system, where pollen tubes fail to penetrate the stigma (Salmon, 1995). Self-incompatibility would prove to be beneficial in hybridisation programs as it eliminates the need for emasculation (removal of anthers to prevent self-pollination) which is difficult with daisies where individual florets are often only millimetres long.

INTRA-SPECIFIC BREEDING

Several new cultivars were derived from intra-specific crosses (within a species) where naturally defined barriers to genetic exchange do not exist. Bulk pollination can be achieved by rubbing inflorescences of each plant together. More regularly however pollen was collected from florets where it had recently been presented at the tip of the anther tube, this can easily be achieved with a fine pair of forceps. Floral development is a fairly uniform process in this family. In *Rhodanthe*, pollen is shed from the anther tube well before the stigma is exposed. It is the extension of the style through the anther tube which presents the pollen as a globular mass at the tip of the anther tube, providing an ideal time to collect fresh uniform samples of pollen. Shortly after this time (within 24 h in *R. anthemoides*) the stigmatic lobes reflex and the pollen is dispersed. In *R. anthemoides* the stigma is receptive for at least 8 days after anthesis, with highest receptivity during the first 4 days (Salmon, 1995).

The mapping of floral development and identification of receptivity patterns on the stigma is an important preliminary objective with all new species. The aim of this study was to develop a uniform pollination protocol for all future cross pollination utilising fresh, viable pollen and receptive stigmas.

INTER-SPECIFIC HYBRIDISATION

Where there is insufficient natural variation within a species to meet certain breeding objectives, plant breeders often turn to wider crosses between species, and even genera, to bring new genes and character expressions to the fore. These methods were attempted with *Rhodanthe* and *Brachycome*, and whilst they were unsuccessful with the former some considerable success was achieved with the latter. Some members of this genus are known to hybridise freely (Salkin et al., 1995) and several cultivars were developed by simply crossing selected individuals, raising progeny, and selecting desirable forms. Novel flower colours, especially yellow in *B. multifida*, were introduced by inter-specific hybridisation.

The problem arises for plant breeders when inter-specific crosses are unsuccess-

ful, as one must decide how far to investigate the possible cause of the failure. Such investigations can be time consuming and expensive. Barriers to hybridisation prior to fertilisation often result from incompatibilities between pollen and pistil, often on the stigma or in the stylar tissue. Methods to observe pollen/pistil relationships in *Rhodanthe*, using fluorescence microscopy and the callose specific stain decolourised Aniline Blue, were developed and would most certainly have wider application among other Asteraceae (Salmon, 1995).

When fertilisation occurs but a viable embryo fails to develop it is often the result of; an arrest of embryo development, disintegration of the endosperm, or abnormal development of the ovular tissues (Raghaven, 1986). In such circumstances it is often possible to excise immature embryos (usually about 14 days old) and transfer these on to a nutrient medium where they can proceed to develop normally. These embryo rescue methods were adopted to derive various inter-specific hybrids of *B. formosa*. In this instance, mature seed from the cross *B. formosa* × *B. segmentosa* failed to germinate in the nursery. Upon dissection it was revealed that the embryo was withered and dead. Subsequent transfer under aseptic conditions of 14-day-old embryos onto half-strength M&S medium modified with 30 g litre^{-1} sucrose, 0.1 µm IBA, and 0.1 µm BAP, allowed for normal embryo development, germination and ultimately the selection of several new cultivars.

MUTATION BREEDING

The use of various physical and chemical agents to induce desirable mutations (genetic changes) in plant tissue has been practiced for some time but with limited success. Experiments with a cultivar of *R. anthemoides* aimed to use gamma irradiation to induce desirable colour change mutations in the involucre. Rooted cuttings were subjected to 6 krad (the dose was established in earlier trials) and 970 plants were subsequently propagated (by cutting) from regenerative shoots arising from these treated plants. Mutations were observed in 4.8% of the M1 progeny, however none were commercially important (Salmon, 1995).

Mutation is a single-celled event and treating the whole plant with a mutagen inevitably leads to problems with locating the mutated tissue, if it even exists. This problem can be compounded with recessive mutants which are difficult to isolate in the first generation and are usually revealed only after a generation of selfing. Methods such as those described above for *Rhodanthe* must be approached with a knowledge of the character(s) being targeted, the genetic inheritance of this character (which can be complex for flower colour) and an appreciation of the difficulty in locating and isolating the mutant. More recently these methods have moved into tissue culture laboratories where isolation problems can be overcome by regenerating plants from callus cultures, a method which in itself has been shown to promote mutagenesis (Larken and Scowcroft, 1981). Attempts to culture callus of *Rhodanthe* species on diverse media were unsuccessful.

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New Genetic Approaches to Plant Conservation

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INTRODUCTION

The horticultural and agricultural industries rely on plant genetic resources for the development of new crop varieties. Traditional breeding methods involve making new combinations of the genetic material from each parent with the aim of changing the characteristics from parent to offspring and exploiting the genetic diversity present in the parents. The diversity may include variation in flower colour or disease resistance which can be used to commercial advantage.

We have heard about the role biotechnology can play in the commercial horticulture field, and how new molecular techniques allow genetic material to be introduced in ways not possible using traditional breeding methods. I would like to discuss the ways that new techniques are being used in the field of conservation biology to address issues related to the conservation and management of both native plant communities and individual species. The difference between the use of molecular methods for conservation and the genetic engineering of new crops is that for conservation, the goal is to identify the level of genetic diversity and the population structures of naturally occurring species to devise appropriate management strategies rather than the introduction or manipulation of DNA.

Underlying population genetic analysis is the assumption that genetic variation is beneficial for most species because it allows populations to adapt to changing conditions (Barrett and Kohn, 1991). The more genetic diversity which is present in a species, the more choice there is in selecting individuals with desirable traits, e.g. lack of diversity in crop plants can make them susceptible to disease. The same principle applies to natural populations.

The application of population genetics to conservation issues can be useful in defining units for conservation and also for setting priorities for management and the conservation of genetic resources (Avise, 1994; Moritz, 1994; Volger and deSalle, 1994). Genetic information can be used to decide the size and design of reserves or what methods of sampling and replanting to apply to specific revegetation or rehabilitation sites.

THE TECHNIQUES

Molecular techniques can be divided into those that look: (1) indirectly at variation in particular genes by studying gene products (isozymes or allozymes) or (2) directly at differences in DNA structure (direct sequencing, differences in fragment lengths). Molecular techniques require only small amounts of material so that samples of rare or endangered species can be taken without being detrimental to individual plants. Sophisticated methods of defining genetic variation are usually not applicable to conservation issues for a number of reasons:

1) Often, little is known of the breeding systems and reproductive biology of species which are not commercially exploited.

2) Funding is scarce for research in areas which do not have the potential for commercially viable outcomes.

Table 1. Advantages and disadvantages of some techniques used for genetic analysis.

Techniques		Advantages	Disadvantages
Proteins	Allozymes	Simple relationship between gene and gene product (enzyme)	Only 20-30% of base substitutions in the gene result in detectable change in the protein using standard electrophoretic conditions.
		Codominant expression so heterozygotes can be detected.	Only a small percentage of the genome can be sampled using protein electrophoresis.
		Mendelian inheritance.	Modification of isozymes within the cell can result in patterns with low resolution which are difficult to interpret.
		Consistent location within cells.	
		Known biochemistry and structure of enzymes.	
		Similarity of apparently homologous isozyme loci and their allozyme patterns between different species.	
DNA	RAPDs	No previous knowledge of the targeted genome is required.	Each marker is considered a dominant locus (can only be present or absent) so it is not possible to distinguish between homozygotes and heterozygotes.
		Only a small amount of DNA (10 to 30 ng) is required for each reaction.	Technique is very sensitive to reaction conditions and banding patterns can differ from lab to lab.
		Relatively quick, simple and inexpensive compared to other techniques for genetic analysis.	Detects variation at random with no distinction between coding and non-coding regions.

Table 1. continued

	Markers inherited in mendelian fashion DNA preparation does not need to be as clean as other DNA techniques.	
RFLPs	Detects reliable molecular markers.	Requires previous knowledge of plant genome. Requires "clean" DNA. Relatively expensive and time-consuming.
DNA Sequencing	Good for comparison of specific regions. Suitable for phylogenetic analyses.	Requires previous knowledge of plant genome. Requires "clean" DNA. Time-consuming and relatively expensive.
Microsatellites	Can detect variation which is overlooked by other molecular methods.	Development requires expensive work intially. Not cost-effective unless the species will be the subject of detailed analyses.

3) Broad information over the species as a whole is more valuable than detailed genetic information on a small number of individuals.

ADVANTAGES AND LIMITATIONS

The different analytical methods have their own advantages and limitations (Table 1) Details are given by various authors (Hedrick and Miller, 1992; Misretta 1994).

Isoenzymes. Isozyme analysis has been used for population studies since the 1960s. It enables different forms of the same enzyme to be visualised on an electrophoretic gel because of differences in electrophoretic mobility. It remains a valuable tool and often complements more recently developed molecular methods.

DNA Analyses. Marker bands can be generated by cutting DNA with restriction enzymes to detect differences in the length of DNA fragments (RFLPs) or by PCR amplification of a stretch of DNA between specific sites to which short single-stranded primers attach and serve as starting and end points for a PCR. Molecular techniques generally survey DNA differences at random rather than loci which are adaptively important. Practical applications for molecular genetic analysis are given below.

PRACTICAL APPLICATIONS

Grevillea scapigera is a prostrate woody shrub which is close to extinction. It occurs in the wheatbelt of south western Australia where the isolated remnants occur within a 50 km radius. A genetic study using both isozymes and RAPDs was undertaken (Rossetto et al., 1995) to help select individuals which could be used in reintroduction trials as part of the species recovery program. It was found that the genetic variation was evenly spread throughout individuals in the remaining populations suggesting that the sites had become fragmented only recently from a more continuous distribution. It was recommended that plants from all populations could be used to create new populations without any detrimental effects.

Astelia australiana is a rare perennial lily endemic to some rainforest regions of Victoria. Like *G. scapigera*, it has also become endangered due to habitat loss. It grows up to 2 m tall with strap-like leaves which arise from tufts interconnected by rhizomes. The interconnections rot away over time making it impossible to determine whether individual tufts originated from a single genotype. Genetic analysis using RAPDs was used to see if the different sites were comprised of genetically different plants or single clones and whether a disjunct site at the Otway Ranges was a natural occurrence or the result of human-mediated transport. Genetic analysis showed that the diversity was not spread evenly over all the populations and that the Otways site was a natural occurrence. It was recommended that emphasis should be placed on conserving as many populations as possible including the Otways site to maximise the genetic diversity in the species.

Agrostis adamsonii is a rare Victorian grass which occurs in saline depressions within the western plains grasslands. It was not recorded between 1854 and 1985. It is similar to other native *Agrostis* species which grow nearby and it is suspected that it has always been rare and has been overlooked in the past. Genetic analysis in conjunction with a study on the breeding system will enable a conservation plan to be developed based on what can be deduced about the history of the species.

Poa fawcettiae is an alpine grass which is found in the Australian Capital Territory and Victoria. It is already used for revegetation. Seed is collected from alpine sites, grown at a lower altitude and the resulting seed is used to provide seedlings for planting out. Genetic analysis is to be used to compare the different populations. If they are similar, seedlings from any population can be used for revegetation in the alpine region. However, if there are marked differences between populations, then only seedlings from nearby areas will be used in revegetation programs.

Adriana quadripartita is a species belonging to the family Euphorbiaceae. It is distinguished from another species, *A. klotzschii*, by its glabrous leaves and fruit. Sometimes the plants are found growing together and it is suspected that they may be variable forms of the same species. By comparing the genetic variation between the two species growing separately and together, in conjunction with taxonomic characters, it should be possible to decide whether to retain the two species or consider them as one highly variable species. The implications for management change because if two species are recognised then *A. quadripartita* is protected under the Victorian Flora and Fauna Guarantee Act (1988) but the more common *A. klotzschii* is not. If only a single species is recognised the name *A. quadripartita* has precedence and so both the glabrous and pubescent taxa would be protected in Victoria.

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Sturt Peas: Propagation and Breeding Strategies for Different Markets

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INTRODUCTION

Sustained commercial production of Sturt's desert peas (*Swainsona formosa*) has not been successful, despite many attempts in several parts of the world, see Williams and Taji (1991) for some of the history. Barth (1990) summarised a study of cultivation and production requirements and a survey of three potential markets: cut flowers, cut runners, and pot plants. She emphasised the need for a breeding programme to produce cultivars suitable for each market. The great variability observed between plants grown from seed collected from natural populations showed that there was an opportunity for breeding Sturt peas in Australia for the different markets, particularly pot plants and cut flowers.

The Flinders University breeding programme began with a germplasm survey of plants grown in pots and a garden from seed collected from natural populations in Western Australia and South Australia. Plants with characteristics deemed most appropriate for each of the markets were crossed and the first few generations of selection were primarily aimed at increasing longevity (most plants from wild seed die of wilt disease at an early age), maintaining vigour and improving floriferousness (some plants from wild seed are slow to flower, especially in late summer and autumn). After a couple of years, these characters were much improved and breeding for particular markets became feasible.

NATURAL BREEDING SYSTEM

Although there are no quantitative data on the natural breeding system, experience indicates that it is a mixed breeding system based upon cross-pollination by birds, with the option of self-pollination when the birds are not sufficiently active. The amount of natural selfing is probably not high enough to purge the populations of deleterious recessive genes because inbreeding depression becomes severe after a few generations of selfing.

The Sturt pea offers the breeder a range of options for breeding strategies, unlike many species where the breeding system is relatively inflexible (autogamous or obligately allogamous). Thus the breeding programme for each market is driven by the preferred mode of propagation for that market with the consequence that each has a different breeding strategy. In many ways, Sturt peas are an excellent subject for breeding work because the large flowers are easy to either self-pollinate or emasculate and cross pollinate. In addition, each pollination usually produces 50 to 80 seeds: a good yield for relatively little effort.

POT PLANT MARKET

A good pot plant will have an upright growth habit and comes into flower quickly at a small size. Seed propagation is preferred, but modern growers demand a high

standard of uniformity in their crops. Open-pollinated cultivars may be too variable and inbred lines lack vigour, hence an F1 hybrid cultivar is our objective because it should combine vigour and uniformity. The necessary prerequisite is two unrelated inbred lines, at least one of which is sufficiently vigorous and fertile to produce seed efficiently. The first attempt to produce inbred lines failed after 3 to 5 generations of selfing when inbreeding depression in the form of a lack of vigour and/or fertility caused the termination of all lines. Some of the better lines were intercrossed and new inbreeding lines established. These have now reached the third generation of selfing and will need to pass through another 2 to 3 generations of selfing before they can be evaluated for the production of F1 hybrids.

HANGING BASKET MARKET

A good hanging basket plant produces many runners in a prostrate growth habit that cascades over the edge of a basket. This growth form appears correlated with the vigorous production of shoots from vegetative nodes on the runners, so there is an abundance of shoots that can be used for grafting or cuttings. In 1992, a plant of excellent form and flowering habit was selected, but because it was short-lived on its own roots, it had to be grafted onto a wilt-resistant species. Three species used by Sturt pea growers in Europe (*Clianthus puniceus*, *Colutea arborescens*, *Sutherlandia frutescens*) and a native, *Swainsona canescens,* were trialed as rootstocks. Grafted plants were vigorous and long lived, but the grafting process was too tedious to be successful commercially. Hence a breeding programme was started to combine the hanging basket growth habit with the longevity (wilt resistance) that was becoming apparent in the pot plant breeding lines at that time. The best hanging basket plant was crossed with several lines that appeared to have good longevity. The progeny of these crosses were selfed for two generations with selection for good hanging basket growth habits, floriferousness, and vigour. The best plants were intercrossed and from their seedlings, 24 plants with the right growth form have been selected for further evaluation. Currently we are assessing the survival of cuttings in the propagation unit, later we will evaluate longevity, growth habit, floriferousness, and production of cuttings from the surviving clones.

Cuttings are placed in Oasis® Horticubes® under mist with a bottom heat of 30C. Many plants produce cuttings that simply rot under these conditions, but a proportion are able to survive and quickly produce roots. Several good clones have been identified that are easy to propagate from cuttings, rooting in less than 2 weeks. Recent experiments have shown that rooting hormones do not significantly improve rooting speed and growth, although more replications may make the difference significant.

CUT FLOWER MARKET

This market demands peduncle (flower stem) lengths much longer than are seen on Sturt pea plants from natural populations. Thus a breeding programme to improve peduncle length and strength is essential. In addition, growers will want long-lived plants with minimal risk of root disease, which implies that grafting onto hardier rootstocks will be essential. The breeding strategy in this case is based upon avoidance of inbreeding (because we think this reduces peduncle length), the crossing of plants with long and strong peduncles, and near the end, the selection of a compatible rootstock.

A subsidiary objective is to introduce a variety of flower colours into this breeding programme so that the desire of the market for novelties can be satisfied. In addition to the traditional red flower with a black boss and the all red flower, we have introduced genes for pink, white and red-black-white flowers into this breeding programme. Although bright red colours are magnificent on pot plants and hanging baskets, the cut flower market may well prefer paler colours. Even South Australian florists admit that they cannot use red and black flowers very often because of the clash of two strong colours.

Looking to the future of cut flower breeding, there are several genes that change the size of flowers, the number of flowers per peduncle, and the arrangement of flowers on the peduncle, that could be used in the future when peduncle lengths have been increased sufficiently. At present, we actually select against large flowers because they hang further down the peduncle and effectively shorten the peduncle length that is available to the florist.

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Breeding New *Leptospermum* Cultivars

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INTRODUCTION

Leptospermum, commonly called tea tree in Australia, belongs to the family Myrtaceae. There are currently 85 recognised species, three of which occur only in South East Asia. One species occurs in both South East Asia and Australia. Another species occurs in southern Australia and over most of New Zealand. The remaining 80 species are endemic to Australia. They are often found on the edges of swamps or rivers, but may also be seen on rocky ridges or sandy sites. *Leptospermum* species are commonly shrubs 2 to 4 m high, however they can also occur as prostrate groundcovers or trees to 18 m high. Most species have ornamental merit and are easily propagated from seeds or cuttings.

Flower colour is generally white, although there are pink forms and a few species that are red or mauve. In our locality flowering begins in Sept. and you can have a continuous succession of species flowering for 5 to 6 months. Leaf shape and colour is quite varied and some species have strongly aromatic foliage.

Despite the large variation in the genus, and the wide range of habitats they occur in, the majority of cultivars have come from just one species, *L. scoparium.* This species is unfortunately susceptible to a number of insect pests such as scale and webbing moth. These pests cause concern amongst home gardeners and have resulted in an unfavourable reputation for tea trees in general. Over the last 9 years I have been working to produce attractive new cultivars in a range of colours and sizes. I have included a number of locally hardy species in an attempt to build in some pest resistance.

AIMS OF THE BREEDING PROGRAM

1) To produce new cultivars in a range of colours.
2) To produce plants that have disease and pest resistance.
3) To produce compact plants that flower in containers.
4) To produce plants suitable for cut flowers.

BREEDING TECHNIQUE

The pollination method for the species used so far is quite simple. Flower buds are emasculated just as they start to expand but before the petals open. Petals and stamens are removed from several flowers on a small branch and covered with clip lock plastic bags. In the morning 3 to 4 days later flowers from the male parent are brought to the emasculated flowers and pollen is dusted on to the stigmas. The flowers are re-covered, tagged and recorded. After approximately 7 days the bags are removed and the seed capsules allowed to mature. This takes between 4 to 6 months. Capsules can then be removed and dried. The seed which is released can be sown immediately or stored for several years.

LEPTOSPERMUM SPECIES AND CULTIVARS SUCCESSFULLY USED IN THE BREEDING PROGRAM.

L. deuense
L. grandifolium
L. lanigerum
L. macrocarpum
L. morrisonii (purple foliage)
L. novae-angliae
L. polygalifolium ssp. *polygalifolium*
L. rotundifolium
L. rotundifolium 'Julie Ann'
L. rupestre
L. scoparium 'Asbestos Range'
L. scoparium 'Big Red'
L. scoparium 'Kare Kare'
L. scoparium 'Nanum Rubrum'
L. scoparium 'Silver Fantasy'
L. scoparium var. *eximium*
L. spectabile

RESULTS

Seedlings from crosses of the above parents have been planted out for assessment. The results so far have been very encouraging. Plants with flowers in red, pink, purple, and mauve shades can be obtained fairly easily. Combinations of height, habit and flowering time are also achievable. Selections of the most promising lines are being made for further trial and possible release to the market.

Development of New Ornamental Plants in Australia

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As a fresh-faced young graduate some 15 years ago I was drawn towards the area of genetic improvement of Australian plants. This paper presents some observations and reflections on the present and future of ornamental plant cultivar development with Australian species.

WILD SELECTIONS

Early development of Australian plant cultivars relied on the selection and domestication of wild material. Some examples of this include:

***Telopea speciosissima* 'Wirrimbirra White'.** A pure white form of the normally red-flowered New South Wales waratah. Whilst the colour is certainly novel the culture of this plant is difficult.

***Banksia serrata* 'Austraflora Pygmy Possum' and *B. spinulosa* 'Stumpy Gold'.** These two cultivars are examples of prostrate selections of normally upright species. Prostrate growth habit is fairly common in coastal plant populations and examples of such variants can be found in many *Banksia* species. These dwarf cultivars are very popular with gardeners but difficulties with propagation have limited their availability.

GARDEN HYBRIDS

A second wave of Australian plant cultivars has resulted from chance seedlings which have arisen in cultivation. Such cultivars have often been selected on the basis of unique colour or growth habit, and like the wild variants often suffer from problems of difficult propagation or susceptibility to disease. Some examples of this include:

***Grevillea* 'Robyn Gordon'.** An outstanding, everblooming red-flowered *Grevillea* which arose as a chance hybrid between *G. banksii* and *G. bipinnatifida* in the garden of Mr. David Gordon in Queensland.

***Grevillea* 'Pink Surprise', *Grevillea* 'Misty Pink', and *Grevillea* 'Honey Gem'.** A spectacular group of *Grevillea* cultivars which have arisen from species such as *G. banksii*. The precise parentage of most of this group is often unknown given their garden origins. These cultivars are very long flowering and are characterised by large, colourful brush-type inflorescences. Propagation is particularly difficult for many of these cultivars.

***Ceratopetalum gummiferum* 'Albery's Red'.** This outstanding cultivar of the New South Wales Christmas bush was selected by Mr. Peter Albery of Sydney. It has bright red flowers and is reliably floriferous. Once again propagation is difficult.

DISCUSSION

The above mentioned wild selections and garden hybrids are spectacular and distinctive examples of the uniqueness of the Australian flora. Ultimately however these and many other Australian woody plant cultivars are not sold in commercial quantities. This is due in large to the problems encountered with their cultivation. To ensure the future for Australian plant cultivars, both here and overseas, investment in properly directed and funded breeding programmes is essential. To achieve international success, such a programme must examine very carefully the types of plants which are in greatest demand.

In my experience the world market is increasingly moving towards plants which flower continuously, have reduced reliance on pruning and chemicals, and are rapidly produced, e.g. 15 weeks from potting to flowering. Plants which fulfill these criteria have great market potential. An interesting example of what can be achieved by Australian plant breeders is the joint venture between the University of Sydney Plant Breeding Institute at Cobbitty and Glenfield Nursery of Sydney. A number of ornamental genera are involved including *Brachycome*, *Viola*, *Argyranthemum* (Marguerite daisies), *Petunia,* and *Gazania*. Early success has been achieved with new cultivars of *Argyranthemum*. The program has been operating for approximately 5 years. In this relatively short time several new cultivars have been released. These feature greater flowering capacity, more compact habit eliminating the need for growth retardants and reduced production time. Overseas sales are already in the hundreds of thousands of plants. This contrasts with the limited sales which many other Australian plant cultivars have achieved.

There are examples of commercially successful breeding programmes with Australian natives. Plant Growers Australia have invested heavily in a comprehensive breeding programme with the daisy genus, Brachycome. New cultivars such as *Brachycome* ' Pink Haze' and *Brachycome* ' Happy Face' meet the criteria outlined above for international success. The cultivars are compact ground-covering daisies which have already established an overseas market.

The "bush gems" kangaroo paw breeding programme is another useful model. An extensive germplasm collection was assembled, and techniques such as embryo culture and induced polyploidy using colchicine were used in an attempt to restore fertility to outstanding hybrids. The result was the release of several cultivars including *Anigozanthos* 'Bush Ranger'—a bright-red-flowered ever-blooming compact variety suitable for pot culture. Rapid multiplication by tissue culture has enabled the successful commercialisation of kangaroo paws on the world market.

SUMMARY

To enable Australian plant cultivars to be successfully exploited and earn significant export income for this country, the following points should be considered:

- Securing adequate funding for the breeding programme.
- Identification of the genera best suited to commercial success.
- Collection of a range of germplasm.
- Screening cultivars to ensure the necessary criteria for success.
- Market release and promotion.

In my opinion, many of the distinctive woody species will be more difficult to exploit than the herbaceous genera such as *Scaevola*, *Brachycome*, *Anigozanthos*, *Dampiera,* and *Viola*.

Propagation of Cape Proteaceae, Ericaceae, and Restionaceae from Seed

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The Cape Floral Region possesses the richest temperate flora in the world. *The dominant vegetation of the Cape Floral Region is the fynbos which is* typified by the presence of members of the Restionaceae (Cape reeds and grasses), the Proteaceae (sugarbushes, pincushions, and conebushes), Ericaceae (Cape heaths), and a number of endemic families. Many of the fynbos species are of outstanding horticultural potential. Seeds of most species are dormant and research has shown that very specific environmental cues are required for germination. It has also been shown that fire, a natural feature of the fynbos environment, provides the major cues for seed germination in the wild. During the last five years, considerable progress has been achieved in understanding seed dormancy mechanisms in the Proteaceae, Ericaceae, and Restionaceae.

INTRODUCTION

Fynbos is a unique type of vegetation which is dominant in the Cape Floral Region (CFR) in the south western Cape, at the southern tip of Africa. The CFR covers an area of 90,000 km^2 (35,000 sq miles), which is less than 4% of the area of South Africa, yet it contains 8600 plant species and is by far the richest temperate flora in the world. Over two-thirds of the Cape plant species and seven of the plant families are endemics. Fynbos, which is a community of small shrubs, evergreen and herbaceous plants, and bulbs, is exceptionally rich in species and contributes most of the species to the flora of the CFR. It is perhaps best known as the home of the South African proteas (sugarbushes, pincushions, and conebushes) and *Erica* (Cape heaths) and is also typified by the Restionaceae (Cape reeds or Cape grasses) (Brown et al., 1995).

Many of the species from these fynbos families are cultivated as ornamentals in parks and gardens around the world, or are of importance as floricultural crops. Propagation of fynbos plants from seed is difficult as seeds of many species are dormant when shed and require very specific environmental "messages" or cues before they will germinate (Brown, 1993). The fynbos occurs in areas with a Mediterranean climate (winter rainfall), and the environment is characterised by

a number of stress factors such as summer drought, low soil fertility and periodic fires. The fires have a frequency of 5 to 40 years and are a natural phenomenon in fynbos. Seeds of many species are adapted to germinate in response to one or more of the cues provided by fire. Heat from flames may fracture the impermeable seed coat of hard-seeded species (e.g. Fabaceae) resulting in the coats becoming permeable to water. Dry heat may also break dormancy by providing a heat-pulse which stimulates the embryo directly and results in germination (e.g. Restionaceae). Dry heat has also been reported to break seed dormancy of some South African *Leucospermum* (pincushions, family Proteaceae) by complete desiccation of their oxygen-impermeable seed-coats. When rain falls the dry coats, which are permeable to water, split suddenly and the embryo can then obtain sufficient oxygen for germination. Fires also provide chemical messages or cues, such as the gases ethylene and ammonia, which stimulate germination in some species of *Erica*. In addition to the more obvious cues provided by heat, it has recently been discovered that smoke from fynbos fires provides a major (yet unidentified) chemical cue which is responsible for stimulating the germination of seed of many fynbos species (Brown, 1993; Van Staden et al., 1995). Fire may also have an indirect effect on germination by causing changes in the soil temperature regimes in the immediate post-fire environment (Brown, 1993). Fire thus provides the major cues for germination in the wild and these cues have to be simulated when attempting to germinate seed in the laboratory and nursery.

SEED GERMINATION STUDIES

Cape Proteaceae. The seed biology of the family Proteaceae, with approximately 300 members, has been the most extensively researched and these findings have been reviewed by Van Staden and Brown (1977) and Brits (1996). The Cape Proteaceae have two distinct achene types. One type is rounded (often ellipsoid) relatively hard and nut-like and is stored in the soil. Germination is characterised by the splitting of the seed coat due to cotyledon expansion, which is then followed by protrusion of the radicle. In the second type, the achene is winged, plumed or hairy (often flattened), and relatively soft. The latter type is produced mostly by serotinous species, i.e. species in which seeds are stored in the living plant canopy. In serotinous species germination is first indicated by penetration of the seed coat by the radicle. Serotinous genera include *Protea*, *Aulax*, and most of the *Leucadendron* and make up approximately 37% of the Cape Proteaceae. The remainder, excluding *Brabejum*, being nut-like. Nut-like and serotinous achenes show different germination syndromes.

Proteaceae With Nut-like Achenes. These achenes do not germinate or germinate poorly in mature fynbos vegetation, but seedlings recruit en masse during the first winter after fire. The breaking of dormancy in species with nut-like achenes is strongly dependent on moderately low seasonal air temperature. This is not a stratification requirement but the low temperature requirement is a mechanism to promote germination during the favourable cool, moist western Cape winter period. High diurnal temperature is also required for maximum germination. A range of fluctuating temperatures is equally effective in stimulating germination, e.g. 4 to 10C (night) and 20 to 28C (day). Seed-coat-imposed dormancy by means of oxygen exclusion is a characteristic of most Proteaceae with nut-like fruits (10 out of 14

species of three genera tested), but not of serotinous species (13 out of 15 species of three genera tested). Germination of achenes of *Leucospermum* species can be improved by a single 24-h treatment with relatively low concentrations (0.01 to 0.1%) of hydrogen peroxide. A relatively slight increase in the level of oxygen available to embryos is usually sufficient to initiate germination under suitable environmental conditions (Brits, 1996).

Recommendations

- The intact seed coat is readily permeable to water but poorly permeable to oxygen. To improve oxygenation, soak seeds in 1% H_2O_2 before making commercial sowings in seed beds. In the laboratory, incubate seeds in oxygen.
- Seed germination is strongly dependent on seasonal low temperature. Therefore, sow seeds in seed beds during autumn or early winter. In the laboratory, incubate seeds at an optimum low temperature of 8 or 9C.
- High temperature is also required for germination and should be alternated with low temperature on a daily basis. Commercial seed beds should thus be constructed in full sun. In the laboratory the optimum high temperature of 24C should be maintained for 8 h per day followed by a period of low night temperature (16 h).

Serotinous Proteaceae. Serotiny is an adaptive response to cyclical fire in fynbos. In nature, seeds are shed following a fire and germinate en masse only after fire. Seeds have a low temperature requirement for germination (1 to 11C) which allows the avoidance of drought by synchronising germination with the first (wet) winter season following dispersal. In contrast to nut-fruited species, the pericarp in serotinous species apparently plays a lesser role in preventing oxygen diffusion to the embryo.

Recommendations:

- Use freshly harvested seed, as seeds lose viability with age.
- Germinate seeds at temperatures below 20C, preferably between 1 to 11C.
- If seeds are of uncertain age and viability and/or incubation temperatures are above 20C, these factors may be counteracted by presoaking seeds in a solution containing GA_3 or GA_4 and GA_7 (Brown and Drewes, 1991).
- Sow seeds in a well-aerated, well-drained, sandy soil and avoid waterlogging.

Cape Ericaceae - Ericoideae. Seed germination studies in this family have recently been reviewed by Brown et al. (1993). Ninety-five percent of the 857 species are confined to the southern tip of Africa and many are of importance in horticulture and floristry. Fire is very important in the ecology of the Ericoideae and the vast majority of species regenerate only from seed after a veld fire. Seeds are very small and are, in all but one species, shed when ripe. Serotiny is rare in this family and is found only in *Erica sessiliflora*.

Factors Of Importance In Germination.

1) Germination may be stimulated by dry heat and the gases ethylene and ammonia.

2) Germination is stimulated by soaking seeds in GA_3 or GA_4 and GA_7.

3) Alternating day/night temperatures, as occur during winter in burnt fynbos, are an important cue for germination.

4) Germination is stimulated by plant-derived smoke and aqueous smoke extracts. In the first major gemination study in this family, Brown et al. (1993), screened seed of 40 species to obtain an indication of how important the smoke cue was for germination. The improved germination following smoke treatment shown by 26 of the 40 species tested, suggested that under natural conditions smoke from fynbos fires provided an important cue for triggering seed germination in this family. It was also suggested that the nine species which showed a 1000% or more increase in germination following smoke treatment formed a group in which smoke was likely to be the major cue for germination. In those species in which there was a lesser response, smoke might be one of a number of cues which include heat and alternating high and low incubation temperatures. Amongst the species responding to smoke treatment were a number of species of particular horticultural importance. The smoke treatment ensures a much greater efficiency when propagating from seed and this is of importance in plant breeding programmes. It should also make more plants available to the horticulture industry.

Recommendations:

- Use fresh mature seed.
- Soak seeds in aqueous smoke solution for 24 h before sowing, or "smoke" seeds sown in seed trays. The trays should have a sand, loam, and bark mixture and be well drained.
- Alternatively, seeds may be pre-soaked in GA_3 or GA_4 and GA_7 solution prior to sowing.
- Incubate seeds under alternating night/day temperatures, e.g. 10C for 16 h per night; 15 to 25C for 8 h per day.

Cape Restionaceae. The Restionaceae is a family of evergreen, rush-like plants which is almost restricted to the southern hemisphere. There are about 320 species in Africa, (300 in Cape) and 100 in Australia. The African Restionaceae are relatively diverse in their seed dispersal mechanisms, which could be implicated in the survival of seeds during or after fires. The modes are: (1) wind dispersal of unilocular, indehiscent ovaries, with a persistent perianth which acts as a wing for the fruit; (2) myrmecochory of fruits containing elaisomes. The ovary is unilocular and indehiscent, and the ovary wall is heavily lignified (e.g. the "nut-fruited" restiads). These seeds are also serotinous and are retained on the plant until the next season's seed crop is mature; and (3) the so-called "basic" condition, showing dehiscent ovaries, with 1 to 3 locules. Here the seed is released from the ovary after maturation, but it is not known how it is dispersed after release (Brown et al., 1994).

Factors of Importance in Germination. The poor germination achieved with seed of many species has been attributed to the limited seed set of some species and the difficulty in determining when seeds are mature and ready for harvest.

1) Heat treatment of seeds at 120C for 3 min gave a significant improvement in the germination of seeds of some species.

2) In common with many other fynbos species, Restionaceaes require alternating high and low diurnal temperatures as a cue for germination.

3) Germination is stimulated by plant-derived smoke and aqueous smoke extracts. Brown et al. (1994) conducted a major study in which seed of 32 species were screened to obtain an indication of how important the smoke cue is for germination in this family. The results of this study represented the first occasion that comparative germination data for South African species had ever been obtained. Twenty-five of the 32 species tested showed a statistically significant improvement in germination following smoke treatment. Untreated seeds of 18 of the species responding showed a high degree of dormancy with only 0.1% to 2.0% germination. These results suggested that under natural conditions smoke from fynbos fires provided an important cue for triggering seed germination in this family. It was also suggested that the 16 species which showed a 1000% or more increase in germination following smoke treatment, formed a group in which smoke was likely to be the major cue for germination. In those species in which there is a lesser response, smoke is probably one of a number of cues which include heat, and alternating diurnal high and low incubation temperatures. The four species that did not germinate were all myrmecochorus, nut-fruited species, which possibly require a different or additional heat cue for germination.

Recommendations

- Use fresh mature seed.
- Seeds may be pre-soaked in aqueous smoke extract for 24 h before sowing; or seeds may be smoked once sown in trays. Fill trays with a sand, loam, and bark mixture which is well drained.
- Incubate seeds under alternating night/day temperatures of 8C for 16 h and 28C for 8 h for optimum germination.
- Nut-fruited species should be heated to 120C for 3 min prior to pre-soaking in aqueous smoke extract. Germination cues for nut-fruited restios require further study.

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Seed Orchard Systems for Herbaceous Indigenous Wildflowers

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INTRODUCTION

One limitation to the large scale revegetation of the Australian landscape is a lack of suitable seed. To restore the diverse flowering grasslands and herbaceous understoreys typical of south eastern Australia, enormous quantities of seed will be required (Lunt, 1994). Revegetating with seed collected from nearby remnant plant communities helps ensure that local forms of species are preserved and that plants are well adapted to the prevailing environment. A risk is that seed collection activities may harm remnant areas. Damage can be from physical impacts, such as trampling, and biological impacts, such as over collection or the inadvertent introduction of weed seeds and diseases by collectors.

The cultivation of wild species for seed production has the potential to reduce collection pressure on remnant communities and to ensure that reliable supplies of quality seed are available when needed. If local adaptations are to be preserved, seed produced in cultivation must reflect the genetic diversity of the population from which the original collection was made.

SEED PRODUCTION FROM HERBACEOUS PLANTS

Herbaceous plants from south eastern Australian understoreys and grasslands lend themselves to cultivation for seed production for a variety of reasons.

1) Most species are relatively easy to propagate and cultivate.

2) Most species flower and produce seed rapidly in cultivation, many within the first year.

3) Many species produce copious seed from a relatively small area, although this must not be taken for granted.

4) Because each individual occupies little space, numerous plants of each species can be grown. This may be important for the maintenance of local genetic diversity.

5) For species whose seeds store well, cultivation for seed production may be necessary only every few years, freeing resources for the cultivation of a wider range of species.

CAPTURING AND RETAINING GENETIC DIVERSITY

Writing on sampling strategies for the establishment of ex situ collections of endangered plant species, Brown and Briggs (1991) made a number of recommendations that seem to provide useful rules of thumb for local species seed producers. They concluded that collecting evenly from 10 to 50 individuals from the one site should capture most of the genetic diversity in that population. The collection can be in the form of seed or vegetative parts, as long as the individuals are genetically distinct. The cultivation of as few as 15 genetically distinct plants could be expected to maintain most of this diversity. If resources allow for collection and cultivation

of larger numbers of plants from each species, that is all to the good (Brown, A.H.D. 1996, pers. comm. 1 May).

An interesting question is whether the continued establishment of seed crops from seed produced in cultivation eventually changes the fitness of the progeny for survival in the wild. Until more information is available, it may be sensible to start again with wild seed after two or three generations in cultivation. For small, intensively grown crops it may be preferable to grow from wild collected material each time seed is produced.

SEED PRODUCTION SYSTEMS

The idea of cultivating herbaceous species for seed production seems straightforward. In practice a number of questions arise. Will the plants set seed in cultivation, how many, and for how long? Should the plants be grown in the ground or in containers? The research reported here has concentrated on wildflower species collected from grasslands and woodland understoreys in the vicinity of Melbourne (Table 1). Seedlings are raised following standard nursery practice. The rate and evenness of germination varies markedly between species. As seedlings emerge they are transplanted into cell trays. Ideally the seedlings should be moved into their final containers, or planted into field beds, as soon as they fill the cell volume. In practice, these plants can be stored in the cell tray for a number of months.

Both container-growing and field-growing systems have been trialed. Field growing reduces the day to day maintenance requirements, such as watering, and there is potential for large areas to be cultivated. The control of weeds is critical as they quickly outgrow the crop and it is vital that weed seeds are not present in harvested seed. A number of species failed to establish in field beds while others prospered (Table 1). It is likely that these problems can be overcome but more research is needed.

Container growing has much to offer for the small scale, intensive production of high quality, weed-free seed. Many of these herbaceous species will produce seed in containers as small as 25-mm tubes. Most trial plants have been grown in 140-mm standard containers, with one plant per container, in a conventional pinebark and sand medium with controlled-release fertiliser and micronutrients. The trials are grown on a sand capillary bed covered with weedmat. Overhead watering systems are inappropriate as seed must mature under dry conditions. An alternative is to grow in much larger containers with drip irrigation. Depending on the size of the container, each can hold a number of individuals of a given species. This may be a practical solution when the construction and maintenance of a capillary bed is not feasible. Drawbacks to multiple planting include some reduction in production flexibility and a tendency for diseases to move from one plant to another within the container.

PRODUCTION SCHEDULING

Flexible scheduling is one of the great benefits of producing seed within a containerised system. In spite of their seasonal character in the wild, many of these herbaceous grassland species continue to grow, flower, and produce seed for as long as they have access to appropriate levels of warmth, moisture, nutrients, and pollinators. For many species it is feasible to schedule intensive seed production for a portion of the season, collect the required seed, then replace that crop with another

Table 1. South eastern Australian understory and grassland herbaceous species cultivated for seed production. Plant names according to Ross (1993).

Species	Rate	Culture *(a) Pot	Culture *(b) Field	Flowering *(c)	Production *(d)	Cleaning *(e)
Arthropodium strictum	S	Y	Y	1	+++E	
Brachycome dentata	FY	Y	1	+++	E	
Brunonia australis	F	Y	Z	1	++	D
Bulbine bulbosa	F	Y	Y	1	+++	E
Burchardia umbellata	S	Y	Z	2	NT	E
Caesia calliantha	P	Y	Z	1	+++	E
Calocephalus citreus	F	Y	Y	1	++	D
C. lacteus	F	Y	Y	1	++	D
Chrysocephalum apiculatum	F	Y	Y	1	++	D
Convolvulus erubescens	Fii	Y	Y	1	++	E
Craspedia variabilis	F	Y	Z	1	++	D
Dianella revoluta	P	Y	Z	>2	++	E
Eryngium ovinum	F	Y	Y	1	++	D
Helichrysum scorpioides	F	Y	N	1	+	D
Hypericum gramineum	F	Y	Y	1	++++	E
Leptorhynchos squamatus	F	Y	Y	1	+++	D
Leptorhynchos tenuifolius	F	Y	N	1	+++	D
Leucochrysum albicans	F	Y	Z	1	++++	D
Linum marginale	Fiii	Y	Z	1	+++	E
Microseris lanceolata	Fi	Y	Y	1	+++	E

Patersonia occidentalis	S	Y	Y	2	+++	E
Pelargonium rodneyanum	P	Y	Z	1	+	D
Podolepis jaceoides	F	Y	Y	1	+++	D
Ptilotus macrocephalus	F	Y	N	1	+	D
Pycnosorus chrysanthes	F	Y	Y	1	++	D
Ranunculus lappaceus	F	Y	Z	1	+++	E
Rutidosis leptorrhynchoidus	F	Y	N	1	++	D
Stackhousia monogyna	P	Y	Z	2	++	E
Stylidium graminifolium	F	Y	N	1	++++	E
Thysanotus tuberosus	P	Y	Z	1	+	E
Velleia paradoxa	F	Y	Y	1	++++	E
Wahlenbergia stricta	F	Y	Z	1	++++	E
W. luteola	S	Y	Z	1	++++	E
Wurmbea dioica	S	Y	Z	>2	NT	E

*Notes:

(a) Rate

F - most freshly harvested, viable seed germinates within 6 weeks.

S - most freshly harvested, viable seed takes longer than 6 weeks to germinate.

P - protracted, spasmodic germination to be expected.

i - germination enhanced by stratification at 4C for 14 days.

ii - germination enhanced by scarification.

iii - germination enhanced by leaching in aerated water.

(b) Culture

Y - successful pot/field cultivation for at least one season.

Z - yet to produce seed in cultivation.

N - unsuccessful in pot/field culture.

(c) Flowering

1 - flowers during first season.

2 - flowers second season in cultivation.

3 - flowers third season in cultivation.

(d) Production

++++ - copious seed produced in cultivation.

+++ - heavy seed production in cultivation.

++ - light seed production in cultivation.

\+ - seed production rare in cultivation.

NT - not trialed in pot/field culture.

(e) Cleaning

E - seed easy to clean by hand.

D - seed difficult to clean by hand.

species. This same strategy can be applied if different provenances or collections of a particular species must be flowered separately to avoid cross pollination.

HARVESTING AND HANDLING SEED

Optimum harvest time and method has to be determined for each species and will depend on inflorescence type and the harvesting equipment available. Generally, seed will be harvested when it is about to be shed from the plant. For small-scale crops, both hand and vacuum harvesting allow a high recovery of mature seed. One of the considerable benefits of intensive cultivation is that seed can be harvested conveniently and regularly. Many species have small seeds that must be harvested with large volumes of other material such as flower parts, bracts, unfilled fruits, and seeds. Inspection under low magnification will confirm if filled seeds are present. Unless seeds clean readily by sieving, it may not be worthwhile spending the time needed to clean small lots of seed to normal commercial standards. The number of seeds per mass of harvested material can be determined by sampling. Seed should be air dried immediately after harvest and stored in a cool, dry place. Sachets of the desiccant, e.g. silica gel, will maintain a relative humidity of 45% in a sealed storage environment, ideal for medium term storage of most seed. While much is still to be learned about the storage potential of these species' seed, it seems that most will store for at least 2 or 3 years with little loss in viability.

CONCLUSION

The production of herbaceous wild species seed in cultivation can relieve seed collection pressure on local remnant plant communities and provide a reliable source of quality local seed for large scale revegetation. The processes described in this paper are well within the technical capability of most individuals and organisations producing plants for revegetation.

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Vegetables, Heirlooms and Marketing

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MEASURE OF DIVERSITY

The number of varieties of vegetables is a fair measure of their genetic diversity. The more distinct forms there are, the greater the genetic base of that type of vegetable. Any loss of varieties is an erosion of that diversity and the subsequent genetic potential of that type of vegetable. Some of the genetic diversity is present in the next generation of varieties, but unless the parents are maintained there is theoretically a potential for depletion of this diversity.

In 1903 the United States Department of Agriculture published *American Varieties of Vegetables for the Years 1901 and 1902* which listed all available varieties. When this publication was compared recently with an inventory of the varieties held in the National Seed Storage Laboratory in Fort Collins, Colorado it was found that only 3% of these early varieties had survived to the present day (Whealy, 1987).

In 1985 the Seed Savers Exchange of Decorah, Iowa compiled and published a comprehensive inventory of the U.S. and Canadian mail order seed industry, focusing on nonhybrid or open-pollinated vegetable varieties. A second edition, published in 1987, revealed that 54 of the original 230 inventoried companies had ceased to trade and there were 39 new companies. These new companies predictably were not offering as many unique varieties as those companies which had ceased trading. In 1987, 5291 varieties were listed as opposed to 4963 in 1985. Of these, 2860 (54%) were unique to one company. The decision to drop these varieties by only one company would mean they would probably be lost if not preserved by someone else. More alarming was the fact that 1271 varieties listed were new varieties offered by companies that specialise in heirloom varieties or were foreign specialty varieties. Even though the number of varieties had increased, a quarter of the varieties listed 3 years previously had been lost. (Whealy, 1987).

Little other quantitative research has been published, but a profusion of anecdotes suggests that similar trends are occurring elsewhere in the world and also in Australia where the range of available vegetable seed varieties is dominated by overseas producers.

REASONS FOR LOSS OF DIVERSITY

The causes for the loss of available varieties are many. One cause common to mature industries is when takeovers and consolidation lead to pruning of variety lists, with view to higher profitability. In the past this has mainly been on a local scale, but now large multinational seed companies are being formed with global rather than local seed inventories.

Government legislation in Europe has resulted in a significant loss of diversity. The European Community, in its efforts to standardise every thing it touches, turned its attention to vegetable seeds in 1980. The Common List is a list of those varieties that are legal to sell in Europe. To be listed, a variety must be sponsored by a seed company (which costs many thousands of dollars), otherwise it is illegal

to sell it. Many public-domain varieties were listed initially on the lists of individual countries and so duplications became obvious when they were amalgamated into the Common List. After consultation with the seed industry, 1547 varieties were deleted, but it is estimated that only 38% of these were true synonyms (Cherfas, 1994). Mooney (1983), in comments relating to the changes in the seed industry, stated that "Brussels offers the new seedsmen a golden collective opportunity to not only rationalise their own offerings, but also to get rid of the low-profit competition offered by nonhybrid or nonproprietary varieties", i.e. Europe's traditional cultivars that belonged to no one.

Trends in plant breeding have shown a predilection for F1 hybrid vegetables. Hybrids resulting from crosses of two parents to produce seeds that give a first generation with known uniform characteristics do not produce second generation offspring which are the same as themselves. Thus knowledge of the parents to be used in the cross means exclusive ownership and subsequent higher profit margins. There is little motivation to create open-pollinated varieties that other companies could also grow and list.

HEIRLOOMS VERSUS HYBRIDS

Heirloom vegetables maybe defined as old (pre-World War II) open-pollinated varieties that are generally no longer commercially available. They are varieties that have been maintained by individuals or communities because they have characteristics that the preserver values. These varieties have become land races, where by virtue of having been grown and selected in one area over a long period of time they have genetic characteristics making them more suitable to that area.

Because they are open-pollinated, heirloom varieties tend to be more variable and genetically diverse than present day varieties. This results in plants that are not suitable for modern farming practices which require produce to ripen all at once for machine harvesting, and to stand up to rough handling when being packed and shipped. The characteristics that the commercial grower requires, in many cases, are not those the consumer would prefer. Emphasis on these characteristics by breeders has meant that flavour and specific utility for various end purposes have been ignored in order to produce a standard crop.

With larger profit margins and branded exclusive varieties (F1 hybrids), more marketing and advertising effort is being used to sell these new varieties to commercial growers and subsequently to the public. These varieties are promoted by virtue of their supposed superiority to the old varieties with regard to disease resistance, yield, and manageability.

The tomato is an often quoted example of how plant breeders have lost their way in the breeding of new vegetable varieties. The editorial of a mail order seed catalogue included this attack on the modern tomato "That the 'Florida commercial tomato' was able to survive a 6 ft fall to the floor without damage was regarded as a great step forward in tomato breeding by commercial seed houses, for surely this is their ultimate goal—an indestructible tomato. This tomato was tested in the same laboratory which evaluates 'car bumper safety standards' and they found the tomato had an impact speed of 13.4 miles per h, which was 2.5 times the speed of the minimum safety of current U.S. car models" (Garden Annual, 1993).

The promoters of hybrid varieties cite pest and disease resistance as a primary concern of the plant breeder. Crops would be produced that require lower inputs of

chemicals. Many patents are pending in the U.S. for herbicide-resistant crops, very few have been made for disease-resistant varieties. Rather than develop varieties which are pest resistant, plants are being bred to be resistant to the chemical pesticides sprayed onto the plants. The use of chemicals in the food production cycle will be further entrenched.

Trials at Digger's Garden Company seed production farm at Trawool, north of Melbourne, have been conducted over several years to determine whether commercial hybrids are superior to heirlooms. Tomatoes have been chosen as the most suitable subject for comparison. The characteristics chosen to be studied were : yield per plant, date of earliest fruit, days to harvest, and flavour. The heirlooms have been consistently superior to the hybrids for all characteristics evaluated. Often the hybrids produced the majority of their fruit all at once which is a major disadvantage for home gardeners (Spring Newsletter, 1994).

Heirloom vegetable varieties are not always useful varieties for commercial growers but they have admirable characteristics for home gardeners and speciality vegetable growers. Heirloom varieties have been judged to have superior flavour. The extended harvest period combined with better yields makes them good value for the area cropped. There are varieties which can be used for specific purposes, i.e. different tomatoes are very suitable for paste, bottling, drying, slicing, or salads. The price of open-pollinated varieties is a fraction of that for hybrids. In 1993 the seed of 'Vivian' F1, a popular hybrid home garden tomato, cost $8720 per kg compared to $320 per kg for standard open-pollinated types (Garden Annual, 1993).

STATUS IN AUSTRALIA

The stewardship of heirloom varieties is essentially left in the hands of non-government organisations. However, some specialised seed banks are maintained by Government agencies where breeding work is being carried out, e.g. The Australian Tropical Field Crops Genetic Resources Centre, Biloela. The Seed Saver's Network of Byron Bay in New South Wales is one of the first to be concerned about the preservation of heirloom varieties. Over the last 15 years they have accessioned and distributed 3000 varieties of vegetables. Unfortunately very few of these are uniquely Australian, i.e. developed in Australia, most are varieties that have been brought here by migrants. The Heritage Seed Curator's Association of Buchan in Victoria was formed in 1992 to draw together voluntary curators of vegetable groups. One of their projects is to document previously and currently available vegetable varieties. It will then be possible to determine what varieties may be "lost", so that they can then begin finding and preserving them. Their journal, *The Curator*, published in the Summer of 1995, contained an article surveying the tomato varieties listed in old seed catalogues. They have found that 207 varieties were no longer available in either the seed trade or in private collections.

MARKETING

In 1990 Digger's Garden Company tested the demand for heirlooms in their mail order seed catalogue by listing a few varieties of tomatoes. In 1992, 40 varieties were listed. In the 1995 mail order catalogue three quarters of the vegetable offerings were marked as heirlooms. These varieties sell at a premium $2.50 per packet as against $1.50 for standard lines. In the catalogue, heirloom varieties have been

promoted as being more appropriate for home gardeners and having a superior flavour. Nostalgic visions have been created of how vegetables, particularly tomatoes, tasted much better in the past. The beauty as well as utility of these rediscovered varieties has enlivened the pages of this catalogue.

The promotion and subsequent interest in heirloom vegetables has given journalists and authors new stories to tell and colourful pictures to embellish their articles. The potential loss of diversity and the rescuing of these varieties from oblivion creates a nostalgic and powerful story. It is encouraging people to contemplate vegetable growing and is creating new mainstream markets.

The more creative chefs are always quick to pick up new food ideas. Mindful of this, a *Great Tomato Taste Test* was organised by Digger's Garden Company and Your Garden Magazine in March 1993. Representatives from the media, seed trade, and food experts were invited to determine the best tasting tomato. About 100 varieties were evaluated and 25 selected for the final tasting. A variety called Tommy Toe was a clear favourite on the day. Nearly half a million packets of 'Tommy Toe' have now been sold and it is commercially available nationwide as a seedling for home gardeners. Unexpectedly it has turned out to be a variety with outstanding disease resistance and it is adaptable to a wide range of climates. The taste test was a great success and the promotional momentum gained further strength from it.

The chefs began asking their wholesalers for heirloom varieties and some of the specialty growers responded. This past season you could buy, amongst others, 'Black Russian', 'Green Zebra', and 'Mortgage Lifter' tomatoes in Safeway's Supermarkets. A uniquely Australian heirloom (not known in other countries), *Beta vulgaris* 'Five Colour Silver Beet', has leaves and stems that are rainbow coloured. It is being produced by a specialty grower, harvested young and sold alongside other salad or mesculun greens in supermarkets.

The seed packet market has been steadily declining for decades. The interest in heirloom vegetables has revived interest in growing vegetables and is a segment of the seed market showing strong growth. This growth is reversing the trend towards fewer varieties being listed and the subsequent loss of genetic diversity.

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Research and Development in Horticulture: What Should Be Funded and How Should it Be Adopted?

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INTRODUCTION

The public sector has a long history of involvement in rural research and development in Australia through the state departments of agriculture, universities and various other State and Commonwealth funded bodies. However, until the establishment of the Horticultural Research and Development Corporation (HRDC) as a commonwealth statutory authority in 1988, there had been no formal and specific mechanism for support for R&D in horticulture that encouraged direct industry contributions.

This relatively new industry equity in, and ownership of, the R&D has significant implications for the direction, development, conduct, and commercialisation of the program. This paper will focus on two specific implications:

1) What research gets funded?

2) How can we best ensure that outcomes are adopted?

However, before these issues can be adequately explored, it is important to have some understanding of the role and operation of the Corporation.

The Corporation's mission is to improve the sustainability, profitability, international competitiveness, and value of Australian horticulture through efficient use of R&D resources.

The Corporation acts to direct and coordinate the financial support for research and development for all horticultural industries including fruits, vegetables, nuts, turf, nursery products, and cutflowers and foliage. In partnership with industry, the Corporation identifies industry needs and priorities and funds research into these areas. This coordination role not only includes production, but also postharvest and processing research and development.

THE OPERATION OF HRDC

The Corporation provides R&D funding by attracting industry funds and matching these dollar for dollar with Commonwealth funds. Commonwealth funds are provided only for industry contributions held by the Corporation up to a ceiling of 0.5% of the GVP of horticultural industries. These are the only funds the Corporation has available in an ongoing sense to support R&D and close consultation is required with industry on the areas of expenditure of these funds.

Horticulture is a diverse and fragmented industry when compared to some of its rural counterparts. Few nationally cohesive peak industry bodies exist and those that do, do not have a long history of support for and involvement in research and development. In recognition of this, horticultural industries can contribute to R&D by three main mechanisms; ad-hoc voluntary contributions, voluntary levies, and statutory national levies.

Voluntary contributions are a means by which industries lacking national coordination can participate at an individual or regional level to specific R&D

projects or programs. Examples of this are the tropical fruit industries such as those represented by the Queensland Fruit and Vegetable Growers and the amenity turf industry. Voluntary contributions also allow industries, associations and individual enterprises associated with horticulture to participate in R&D support and benefit from the Corporation coordination and management and matching funds.

Some horticultural industries have a significant regional focus within which there is strong cohesion and common purpose. In such cases voluntary levies may be struck to address R&D needs specific to that industry. Examples of this type of arrangement are the mushroom, processing tomato, and canning fruit industries.

Where there is a recognised peak industry body that represents a significant majority of both producers and production, a national statutory levy may be introduced at the request of industry. Such levies are now in place for the apple and pear, avocado, citrus, chestnuts, cherry, custard apple, macadamia, nashi, nursery, potato, stone fruit, and vegetable industries.

Since its inception in 1988 the HRDC has funded horticultural research and development worth over $70 million. The growth in the Corporation's expenditure is shown in Fig. 1.

It is important to appreciate that this growth has only been possible due to an increase in industry involvement. At its inception, the Corporation was supported by two levies, pome fruit and citrus, providing contributions of less than $1 million. In 1995-96 the Corporation is supported by 12 levies and voluntary contributions from a wide range of industry participants providing over $12 million. The 1995-96

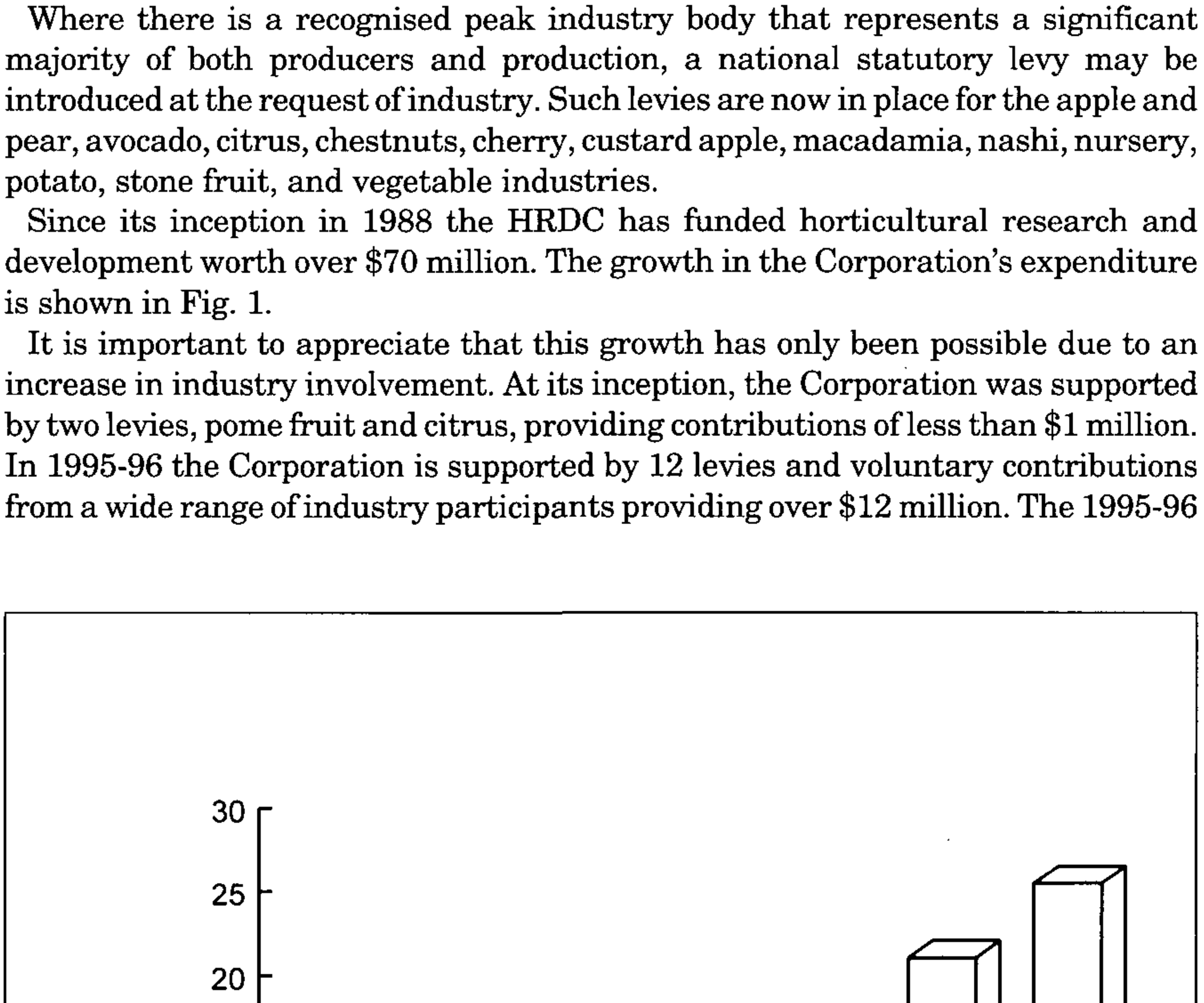

Figure 1. Annual R&D funding by HRDC: 1988-1995.

R&D programs of industries in partnership with the HRDC, in order of HRDC expenditure (highest to lowest), are :

1 Other fruit
2 Citrus
3 Apple and pear
4 Vegetables
5 Potato
6 Horticulture (general)
7 Nursery
8 Cherry
9 Other product
10 Chestnut
11 Turf
12 Processing tomato
13 Other nuts
14 Macadamia
15 Cutflowers
16 Mushroom
17 Avocado
18 Disinfestation
19 Nashi

The overall strategic objectives and priorities of the Corporation are established in the HRDC Strategic Plan. The Plan establishes 10 strategic areas of activity for the Corporation in 1995-96. These are, in order of expenditure (highest to lowest):

1 Pest/disease
2 Genetic improvement
3 Cultural/harvesting
4 Technology transfer
5 Postharvest
6 New/value added
7 Quality management
8 Disinfestation
9 Marketing studies
10 Waste management

However, equally important in the determination of the Corporation's R&D program are the individual Strategic Plans of the participating industries. There are 15 industry plans of varying sophistication and scope, however all represent a significant improvement over previous industry R&D planning and are a sound starting point for further development. National R&D Committees have been established by each industry to oversee the implementation their Strategic Plan.

THE DEVELOPMENT OF FUNDING PRIORITIES

While the ultimate responsibility for the R&D program funded by the Corporation lies with the Board, it is apparent from the process outlined above that what research and development gets funded is largely determined by the priorities established in each industry Strategic Plan and how that Plan is interpreted by the R&D Committee. The nursery industry's development of its Strategic Plan is a representative example of how this process occurs and some of the implications that flow.

The nursery Strategic Plan was developed at a meeting of representatives drawn from most industry sectors and all states in 1990. The plan documented the current situation and described the desired situation in 5 years. R&D objectives were then developed to get the industry from 1990 to 1995. It was an ambitious plan that concentrated on practical issues that affect farm productivity and costs such as cultural practices and pest and disease control. Nine key R&D programs have been established in two broad areas and Table 1 provides the total funding allocation, both levy and voluntary contribution, since 1990 against these priorities.

After 5 years there have been significant achievements in many of these areas and these have been well covered in other places. However, beyond the project-based

Table 1. Funding allocations against priorities: 1990-1995.

Priority	Description	Funding		
		Voluntary contribution	Levy	Total
A	Market research	$80,000	$179,000	$259,000
B	Technology (in order of priority)			
1	Technology transfer	$124,000	$564,000	$688,000
2	Pest/weed/disease control	$290,000	$872,000	$1,162,000
3	Product handling	$1,000	$391,000	$392,000
4	Soil quality and potting media	$183,000	$532,000	$715,000
5	Varietal improvement	$152,000	$256,000	$408,000
6	Efficiency and productivity	$293,000	$31,000	$324,000
7	Irrigation	$149,000	$221,000	$370,000
8	Value-added products	$0	$0	$0
	TOTALS	**$1,192,000**	**$2,867,000**	**$4,059,000**

output, equally important components of the evaluation of the Plan are whether the priorities are right and whether the appropriate balance of funds has been allocated between them.

CONSIDERATION OF PRIORITIES

In any consideration of priorities a number of issues must be addressed including, but not limited to:

- What technical problems does the industry currently have?
- What technical issues may arise in the future?
- Can R&D provide a solution to these?
- Which issues, if solved, will produce the greatest benefit to industry?
- Are other sources of funds being directed toward particular areas?
- What public good may be derived from work in a particular area?

I will use the priorities of varietal improvement and technology transfer to develop some of these issues.

Varietal Improvement. It could be argued that the number of new plant varieties and lines that are released onto the market each year in Australia indicate that commercial forces are sufficient to fund new developments in this area. Indeed, many members of I.P.P.S. are active commercial operators in this field. Despite the interest of research agencies in an area of research where significant intellectual property may arise, there would appear to be no market failure to support R&D in new varieties.

It could also be argued that our vast and unique flora is one of the few competitive advantages the industry has over its international competitors. This resource will

become increasingly important as the industry moves to expand and develop export opportunities. If the development of this resource is not undertaken promptly and in a coordinated and strategic fashion, the opportunity it offers may well be lost to the steady stream of overseas growers that visit these shores looking for new material. Do individual industry members have the resources, the coordination, and the commitment to undertake this task? In addition there are many areas of basic botany, ecology, and molecular biology that require considerable work if the full benefit of our flora is to be captured and preserved.

Technology Transfer and Adoption. One of the most important implications of the industry's 50% stake in HRDC funded research is that of responsibility for the application of research outcomes. Funding for research and development is now directed toward priorities, and indeed projects, that industry has chosen. Researchers are encouraged to collaborate and liaise with industry wherever possible, and to include significant technology transfer components in their proposals. One could reasonably expect this to create a strong desire to receive and adopt the results of industry funded R&D, this has not always been the case. Even where individual companies or regional groups have provided voluntary contributions to support specific projects, the responsibility for dissemination and encouragement of adoption is often seen to lie with the researcher.

The effective dissemination of research outcomes and their profitable adoption remains the greatest challenge facing the Corporation. Unfortunately the attitude captured so well by the I.P.P.S. motto of "Seek and Share" appears to be a rare commodity.

The Corporation recently undertook a survey of information and communication needs in the nursery industry. The results shed some light on this problem. Over half of all those surveyed (60%) stated that they received none or only part of the information they require on research findings; while 80% said they had to adapt information when they did receive it, mainly because it was not regionally relevant enough. Encouragingly, just under half were prepared to send up to $1000 a year to get the right information and 19% were willing to spend more than this !

As this Conference and indeed many of the activities of I.P.P.S. demonstrate, the most effective information exchange occurs in a social context. Of those surveyed 80% had attended an industry workshop, conference, or trade day in the last year. Such events were rated as the second most useful and efficient means of obtaining information bettered only by direct personal networks.

The Corporation acknowledges its responsibility to ensure that funded research produces practical outcomes and that these are presented in a useful and accessible way. It is however, ultimately the responsibility of individual industry members to adopt R&D outcomes for their own benefit and improved profitability.

While the Corporation has done much in recent times to improve the presentation, distribution, and usefulness of research outcomes, bodies such as the I.P.P.S. can play a vital role in creating industry interest and assisting in dissemination. I.P.P.S. has world renowned conferences and publications and is the focus of many important industry networks. HRDC, I.P.P.S., and, most importantly, the horticultural industries of Australia can all benefit from an improved use of these networks and information dissemination channels. The challenge for both HRDC and I.P.P.S. is to explore ways in which they can work together on this important task.

Recirculating Subirrigation Systems for Nursery Production

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Three recirculating subirrigation systems (constant-flow capillary mat, intermittent-flow capillary mat, ebb-and-flow) and an overhead spray irrigation system are being assessed for efficiency of water use and plant production, nutrient use and the amount of nutrient-laden leachate and run-off produced. Results to date indicate that plant growth is as good or greater than on overhead spray, on any of the subirrigation systems and that the subirrigation systems use 30% to 37% less water than the overhead spray. The ebb and flow system has produced the lowest levels (mg litre^{-1} N) and least fluctuation in leachate and run-off nitrate levels. The ebb and flow system also produces the least fluctuation in E.C. levels.

INTRODUCTION

In Australia, the principal method of irrigation for container nursery plants is the overhead sprinkler. It is an inefficient technology because (1) as much as 80% of the water applied fails to reach the container media, and (2) distribution is uneven, often resulting in over-watering. In addition, higher levels of nutrients are applied to compensate for high levels of nutrient leaching. Typically this leachate contributes to the pollution of waterways and groundwater.

Inefficient water and nutrient use by the containerised nursery in Australia is an issue that demands our attention. A recent initiative in New South Wales (The Clean Water Act, 1988) has alerted all of the Australian industry to the imminent introduction of guidelines or possible legal restrictions regarding nursery run-off.

In The Netherlands the year 2000 is targeted for a complete conversion of the industry to closed (no run-off) nursery systems (Runia, 1995); Australian best nursery practice needs to come in line with a growing world-wide trend to reduce nursery impacts on natural resources. There is an increasing awareness in the nursery industry of the finite nature of our useable water resources and the ensuing responsibility to conserve and protect this vital heritage.

MATERIALS AND METHODS

The research at Burnley College, University of Melbourne, is assessing four irrigation systems in a greenhouse environment. Five plant species; *Artemisia* 'Powis Castle', *Coprosma* ×*kirkii*, *Hebe traversii*, *Rhagodia spinescens*, and *Heliotropium arborescens* 'Lord Roberts' are being grown over four trial periods. Trials vary in duration from 5 to 9 weeks depending on the season. Plant material is grown on from tubestock that had been propagated as cuttings. Trials commence after potting the tubestock into 150-mm plastic capillary pots. The media used is bark-based and contains slow-release fertilisers. The 222 plants are set out pot to pot on each of four benches measuring approximately 1 m × 5 m. Plants are set out

in a series of five rows (one species per row) that is repeated in sequence on the entire growing area of the bench. The perimeter plants on each bench are designated as edge-effect plants. At the conclusion of each trial, 11 plants per species (including 4 edge-effect plants) per bench are harvested for dry weight analysis. Only above-ground plant material is harvested.

The benching and irrigation systems were designed and built at Burnley. Each bench is irrigated by a separate and differing method of irrigation. There are three subirrigation systems that recirculate the applied mains water and one overhead spray system that does not. The subirrigation systems are; a constant-flow capillary mat, an intermittent-flow capillary mat, and an ebb-and-flow. The overhead spray bench is engineered to collect leachate and run-off, but does not recirculate it.

The overhead spray system uses six spray heads designed to deliver 54 litre h^{-1}. It is used 1 to 4 times per day for 3- to 5-min cycles. The constant flow capillary system uses six drippers positioned at the higher end of a bench with a 1 : 100 slope. These drippers emit onto a spun polyester capillary mat that is covered by black plastic weed mat. The constant-flow capillary system emits continuously at a seasonally adjusted rate of 0.21 to 0.25 litres min^{-1}. The intermittent flow system is identical in design to the constant-flow capillary system except that its drippers emit on a cycle of 4 to 6 min h^{-1} for 12 h and 4 to 6 min every 2 h for the next 12 h.

Each irrigation system or treatment occupies a new position in the greenhouse in each of four trials. The experimental design is a Latin square.

The greenhouse is clad with polycarbonate sheeting and has no supplementary heat or lighting. Temperatures in the greenhouse vary from 4 to 35C. Vents automatically open at 25C and at 30C a fan-driven ventilation system starts. Mains water is used, which also serves as the control for leachate analysis, having an E.C. < 082 µs cm^{-1} and nitrate levels < 0.25 mg $litre^{-1}$ N. Leachate is collected as it drains from the bench and so it contains both leachate and run-off. Leachate from each system is sampled on a weekly basis and is tested for pH, E.C., nitrate, ammonium, phosphate, potassium, manganese, calcium, and magnesium. Data is also taken fortnightly on pH and E.C. levels in the container media for each of the systems, using the 1 : 1.5 volume extract method (Handreck and Black, 1984). Water consumption is measured per system, per trial, using meters installed on each system.

RESULTS

A considerable percentage of the water applied by our overhead spray system either fails to land on the media (run-off) or leaves the media as leachate. In trial 2, 63% of the applied water on the overhead spray system was collected as run-off and leachate. Similarly, in trial 3, 55% and in trial 4, 45% of the applied water was collected as run-off and leachate. In the trials to date, the recirculating subirrigation systems use 30% to 37% less water than the nonrecirculating overhead spray system (Table 1).

If we were able to disinfest the water used in the recirculating systems (and thereby avoid the between crop dumping and refilling of the recirculating tanks to permit disinfestation) the subirrigation systems would use 43% to 49% less water than the overhead spray system.

In 1971 the World Health Organisation set the upper limit for safe levels of nitrate contamination in water for human consumption at 10 mg $litre^{-1}$ N (Lawrence, 1983). Occasionally, leachate nitrate levels were in excess of 10 mg $litre^{-1}$ N on each of the

Table 1. Water use (in kilolitres) by irrigation system per trial.

System	Trial 2	Trial 3	Trial 4	Total to date
Overhead spray	1.39	1.41	1.95	4.8
Constant capillary	0.84	0.88	1.52	3.2
Intermittent capillary	0.79	0.88	1.36	3
Ebb and flow	0.96	0.97	1.42	3.3

irrigation systems.

The ebb-and-flow system gave the best performance (lowest levels and least fluctuation) in terms of nitrate levels in the leachate and run-off. This may be due to the relatively large amount of water leaching only the small portion of the media in the bottom of the containers. The ebb and flow system also gave the least fluctuation in leachate E.C. levels.

Plant dry weights were significantly greater for *A.* 'Powis Castle' and *H. arborescens* 'Lord Roberts' when grown on subirrigation systems. Plant dry weights for *C.* ×*kirkii* ', *H. traversii,* and *R. spinescens* indicate that these species grow equally well regardless of the type of irrigation. All five species grow as well or better with recirculating subirrigation, as they do with overhead spray irrigation.

DISCUSSION

Plant growth, as measured by plant dry weights, is greatest on subirrigation systems for the two larger leaved and more vigorously growing of the five plant species that are grown in this research. Plant morphology may be one factor in determining species that will benefit most from subirrigation. Certainly, the possibility of enhanced growth rates is species dependent.

Shoot extension of up to 20 mm in 1 day was recorded on *H. arborescens* 'Lord Roberts' on the constant capillary bench. This exceptional growth rate is produced by providing *H. arborescens* 'Lord Roberts' with appropriate nutrient and light levels and by minimising water stress. It may be possible to grow some species more quickly using subirrigation than with conventional overhead spray. Conventional overhead spray irrigation, due to its inherent inefficiencies, both utilises more water and creates more waste than does a recirculating subirrigation system. With appropriate disinfestation of the recirculating water, subirrigation systems offer a substantial reduction in water use and amount of nutrient-laden leachate and run-off that is produced. More research needs to be undertaken to investigate low-flow disinfestation technology specific to the use of recirculating subirrigation by the nursery industry.

Best nursery practice can be changed to incorporate more efficient water and nutrient use, and less pollution of waterways by nutrient-laden run-off. These changes can be approached by careful and extensive fine-tuning of the current and dominant technology of overhead irrigation or the challenge can be met by the adoption of recirculating subirrigation. It is in the interest of the nursery industry and the community at large to affect these changes.

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Propagation For Zoo Exhibits

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A zoo presenting a paper to a plant propagation forum reflects the changes that have occurred in zoos over recent years. The functions of today's zoo exhibit differ markedly from those of the 19th century menagerie. Naturalistic exhibits have become the standard. Whilst propagation techniques used for *plant production in zoo exhibits are for the main part standard, the applica*tions can often be unique. Botanically zoological horticulture is vast with some 1000 species of plants introduced to the Melbourne Zoo collection since the master plan was implemented in 1989. Some 60% of this material has been propagated on site. This paper will provide a background to zoological horticulture and discuss the implications and the associated plant production/propagation challenges and opportunities presented.

MASTER PLAN

The Melbourne Zoo master plan for redevelopment was devised in 1987 and represents a complete restructure of the zoo grounds and animal enclosures into bioclimatic zones. The bioclimatic approach enables animals to be displayed with other coexisting species, and is based on representation of habitats.

HORTICULTURAL IMPLICATIONS/PLANTING CONCEPTS

Many factors need to be considered prior to the planting of naturalistic exhibits. More than 18 months may elapse between the start of plant production/propagation and planting out. Generally, the most important factors determining the type of planting and plant material to be considered, relate to the exhibit theme, the animals displayed and the habitat to be represented. Obviously jungle exhibits will have a very different vegetation to that of a grassland exhibit, which in turn will differ from a desert exhibit. In all cases the aim is to offer vegetation representative of the habitat. Information is gathered through a variety of sources, i.e. regional vegetation surveys, ecological reports, and animal food plant listings.

MELBOURNE ZOO PLANT NURSERY

Most plants encountered, when researching regional vegetation, are not available

through the wholesale nursery industry, or even known to be in cultivation. The plant nursery at Melbourne Zoo is an invaluable resource and provides the capacity to source propagation material and to trial and assess the suitability of such plants. This provides an extraordinary capacity to create unique zoo environments and broadens the range of plant material that can be considered for specific projects.

PLANT PRODUCTION/PROPAGATION REQUIREMENTS

Depending on the project, the majority of the material to be planted would be propagated and produced by the Melbourne Zoo plant nursery, e.g. the pygmy hippopotamus and mandrill exhibit involved some 9000 plants made up of 80 plant species. Sixty-five hundred plants were propagated and produced at Melbourne Zoo, this represented approximately 60 species. No attempt was made to produce advanced plant material for the project, as all advanced and semi-advanced plant material required was purchased from advanced tree nurseries.

CASE STUDIES

The following are some specific examples of plant production and propagation at Melbourne Zoo.

Butterfly House. The butterfly breeding project is the most technically challenging task that the Melbourne Zoo has undertaken. Butterfly life cycles are complex and food plant requirements are demanding, particularly at the larval stage. The project has been in operation for more than 10 years and still the supply of host plants presents many challenges. Up to 6000 food plants are required to meet the requirements of some 35,000 butterflies released into the butterfly house each year. In essence, it is the success of the plant production that determines the overall success of this project. Therefore the development of successful propagation protocols for the various food plants required is essential. *Passiflora cinnabarina* is the host plant for a number of lacewing butterflies including the orange lacewing which forms an important part of the butterfly project. The propagation of this plant has proven difficult. Unlike other *Passiflora* species, seed has proven unreliable with sporadic germination occurring over an 18-month period. Cuttings tend to produce an inferior root system that is short lived due to lack of root vigour. We undertook to explore options and to trial various treatments to improve the results we were obtaining from sexual propagation. It is likely that the dispersal agents for this plant would be a forest bird or bat, and that in the process of dispersal the fleshy pulp containing germination inhibitors would be removed from the seed coat. Simply removing the pulp from the seed coat mechanically did not however improve germination of this plant. Trials with fermenting the seed in its pulp for 4 weeks prior to pulp removal were promising and we have now established that germination is greatly enhanced through this technique. The 18-month, sporadic-germination period can be replaced with uniform germination after a 15- to 21-day period. This year we will be undertaking trials to determine if grafting onto *P. caerulea* stock produces a more vigorous plant.

Gahnia sieberiana. This plant is the larval food plant for the sword grass brown butterfly. It is hoped that we can introduce this butterfly into the program but a reliable supply of *Gahnia sieberiana* needs to be established before undertaking a breeding program. As with many other Cyperaceae the germination of seed can be

difficult. We have stumbled onto a technique that works for this species and possibly has application for many other species. A trial undertaken to soak the seed, as we do with many rainforest species, resulted in the seed being moistened and placed into a snap-locked plastic bag. The intention was to leave the seed in the bag for about 2 weeks and sow directly. The seed bag was placed in the bottom of a drawer and forgotten. It stayed there in the dark for about 6 to 8 weeks and when rediscovered was left on a tabletop in the light. Within a week the seed was actually germinating in the plastic bag. We repeated the process with *Elegia capensis* seed, again a notoriously difficult plant to propagate, with the same results. The seed was given anaerobic conditions and darkness for an extended period, the same conditions as if the seed was inundated by a seasonal flood or period of extreme waterlogging.

Heath Mouse/Smoky Mouse. The native mammal section at Melbourne Zoo has undertaken a program to develop the husbandry procedures necessary to breed these threatened species in captivity. As the wild populations of both these species are declining, a formal breeding program may soon be essential. Included in our current research is the provision of elements of their wild diet in captivity. Once the Melbourne Zoo has established self-sustaining captive colonies, release into the wild will be undertaken. To condition the animals prior to release the Melbourne Zoo has established a large outdoor heath land enclosure in which the animals can learn to forage for food and to make nests. In Victoria, the heath mouse is found only in the south west, and prefers heathland habitats which have regenerated after fire. Heath mice feed exclusively on the berries, seeds, and flowers of various epacrids. The horticultural section has the task of providing the plant species of their wild diet in the outdoor heath land exhibit and the establishment of fodder plantations for harvesting. This requires an understanding of the floristic structure of their heathland habitat, and the capacity to propagate and grow the important food plant species. To date we have successfully established representative flora in the outdoor enclosure with the support of a number of specialist indigenous plant growers. There are still a number of challenges in the development of propagation protocols for many of the epacrids required for the long-term success of this program. The heath mouse and smoky mouse projects can only occur in organisations such as zoos. Zoos today are attempting to manage their collections mindful of the complex interactions and interdependencies of natural ecosystems.

Eidothea zyzoelocarya. We received an unusual request from the Melbourne Botanic Gardens in 1995 to explore the possibility of passing the seed of a particular native rainforest Proteaceae through the gullet of our resident Cassowaries. The species in question was the recently described *E. zyzoelocarya*. Indications are that the dispersal agent for this plant is a large bird, possibly a cassowary. The large rounded fruit is amongst the hardest of any plant in the rainforests of northern Australia. It is also possible that once the fruit is consumed by the cassowary it remains in the gullet of the bird, as a gullet stone, to aid in the digestion of other rainforest fruits. Whilst it remains in the gullet of the cassowary the seed is scarified, and over an extended period the endocarp is worn down or softened to allow germination to occur when finally passed. The seed may remain in the gullet for several years.

The propagation of this plant would represent a major botanical initiative. A quantity of seed was sourced by the Melbourne Botanic Gardens, and in the

interests of covering all possible propagation angles, the Melbourne Zoo was approached to feed some of the seed to our resident cassowaries. The progress at our end of this co-operative project is that the cassowaries are still with nut. Through more conventional means the Melbourne Botanic Gardens have germinated two plants to date. This was achieved by the scarification of the seed coat to the endosperm with a file. The seed took 6 months to germinate and plants have maintained a steady growth rate. Werribee Zoo has recently undertaken a similar project with the rare *Eremophila desertii*. They fed the fruit to their emus and then collected the subsequent dung. The seed was then separated from the dung, counted, and sown by conventional methods.

SUMMARY

The Melbourne Zoo Plant Nursery and its staff have demonstrated that it is possible for a zoo to be involved in a variety of plant production activities. Increasingly the nursery is being viewed as a significant "resource" by the Zoo board. With developments at Werribee Zoo in grassland plant conservation; at Healesville Sanctuary, with its ongoing revegetation project; and a seemingly never-ending list of potential projects at Melbourne Zoo; it is obvious that the challenges faced in propagation for zoo exhibits will continue for sometime.

Current Research into Water Disinfestation for the Nursery and Cut Flower Industries

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Water disinfestation in Australian Nurseries has mainly been done using chlorination either from sodium hypochlorite or direct injection of gaseous chlorine. Some nurseries in Queensland and northern Australia have bromination and chloro-bromination systems, and ultra violet light is used in several nurseries in Victoria. An important feature shown in a survey of water quality by Beardsell and James (1995) was that it is vital that nurseries and flower farms do a complete analysis of water quality over a 12-month period before choosing a water disinfestation strategy. A recent symposium on nursery substrate disinfestation held in Belgium (Vanacher, 1995) did not provide clear information on best practices; as few quantitative and economic analyses were presented. The following paper presents a summary of the best available information on water disinfestation for the nursery industry. Much of this information has been generated by projects currently being conducted in Australia.

CHLORINE (AS HYPOCHLOROUS ACID)

Limited field and anecdotal data suggests that a 1-min exposure of 2 mg litre^{-1} of free chlorine will control *Phytophthora cinnamomi* (Smith et al., 1985). However, extensive quantitative data on other fungal plant pathogens is lacking. It has been reported that above pH 7, the amount of available hypochlorous acid in solution falls rapidly from 100% at pH 5, to 80% at pH 7, 28% at pH 8 and 4% at pH 9 (Ellis, 1991). A recent survey of nursery waste water (Beardsell and James, 1995) showed that pH above 7 was typical for Australian nurseries (average 8 in Queensland), thus acidification is likely to be required in many nurseries. Other disadvantages of chlorination are that its efficiency as a disinfectant is reduced by organic matter, iron and nitrogenous compounds (De Hayr et al., 1994). Chlorination also produces toxic by-products including trihalomethanes and chloramines. Also the dangers of chlorine gas will cause transport of this chemical to be regulated in the near the future. Chlorination cannot be recommended as best practice for water disinfestation in Australian nurseries until further detailed work testing hypochlorous acid for control of a range of plant pathogens is completed.

CHLORINE DIOXIDE

Chlorine dioxide has been shown to be highly effective for disinfestation of a range of plant pathogens including *Fusarium oxysporum*, *Alternaria zinniae*, *Colletotrichum capsici*, and *P. cinnamomi* over a range of water pH (Mebalds et al., 1995). Work is currently in progress testing its ability to control *Pythium ultimum*. Chlorine dioxide needs to be applied at an available concentration of 3 mg litre^{-1} for 8 min to control water-borne fungal pathogens (Mebalds et al., 1995). Chlorine dioxide, like hypochlorous acid, oxidises iron (Langlais et al., 1991). Poor quality

water, typical of that obtained after recycling, requires higher concentrations of chlorine dioxide to overcome contaminants in the water. Sensors which regulate the amount of chlorine dioxide applied by automated equipment must be placed in such a position in the irrigation system to account for chlorine dioxide drawdown by impurities in the water.

Since Mebalds et al. (1995) also showed that the disinfestation properties of chlorine dioxide were unaffected by pH as high as 10, this method would have wide application to the nursery and flower industries in Australia which consistently have high water pH. Although chlorine dioxide equipment is more expensive than other chlorination systems, this method of disinfestation is likely to be more effective considering water quality in Australia. The only factor preventing a recommendation for chlorine dioxide as best practice for water disinfestation is that data is lacking on its phytotoxicity and on its relative efficacy on a wider range of organisms. Chlorine dioxide may be hazardous to plant and animal health, although this also has not been fully tested. A nursery in Victoria has successfully used chlorine dioxide without obvious phytotoxicity problems on a wide range of Proteaceae.

BROMINATION AND CHLORO-BROMINATION

Quantitative work on phytotoxicity and disinfestation by hypobromous acid and other bromine compounds has yet to be done on plant pathogens. This means that these cannot be considered as a best practice, although field observations indicate that chloro-bromination is effective in controlling water-borne diseases (Bodman, pers. com.). De Hayr et al. (1994) have concluded that bromine is likely to be an effective disinfestation agent, especially if nursery water has a high pH and high organic matter content.

OZONATION

The only published data on ozone control of a plant pathogen has been reported in a study on *F. oxysporum* by Yamamota et al. (1990). This work was only preliminary, and no recommendation can be made regarding control of *F. oxysporum* by ozone. Two groups in Australia, Mebalds and colleagues at the Institute for Horticultural Development and Alexander and van Lewin at the University of New England, are currently investigating the value of ozone for controlling plant fungal pathogens. At this stage ozone can not be recommended as best practice for water disinfestation, although it appears promising because of its lack of potential residual phytotoxicity. Hoigné (1994) has shown that ozone demand in water increases with ammonium, nitrite, ferrous, carbonate, and bicarbonate levels. High pH also reduces the half life of ozone. The high alkalinity (bicarbonate levels) of nursery water in South Australia may limit the application of ozone in that State.

ULTRA VIOLET RADIATION

Ultraviolet (UV) radiation is an effective and environmentally friendly method of controlling *P. cinnamomi, F. oxysporum, C. capsici* and *A. zinniae* if water has high UV transmission (greater than 50% UV transmission after filtration) and exposure dose is at least 5.0×10^5 $\mu W\ s^{-1}\ cm^{-2}$ (Mebalds et al., 1995). *Alternaria zinniae* has dark-coloured spores and is the most difficult to kill with UV radiation. This

organism should be used as a standard for testing the efficacy of UV equipment. Equipment for irradiating water with UV must be designed so that pressure changes in pipes between the pump and the UV reactor are minimised, otherwise protection of pathogens from the radiation may occur. Water must also be filtered and turbulent flow is needed in the UV reactor otherwise organisms may be protected from radiation exposure. Ultraviolet radiation can be recommended as best practice for nurseries which have recycled water with UV transmission greater than 50% at a wavelength of 254 nm because of its environmentally friendly operation and low cost. However few nurseries will have recycled water of such high quality. Dissolved solids are the major cause of poor UV transmission; the colour of the water strongly influences UV transmission (Beardsell and James, 1995).

HEAT

Although heat is used widely in Europe to kill plant pathogens in water it is likely to be very expensive in Australia. If waste heat can be used, it might be considered, however Runia (1995) has shown that water must be heated to 95C for at least 30 sec for adequate disinfestation.

FILTRATION

Microfiltration has been shown by Runia (1995) to be impractical due to clogging of filters by poor quality water in European nurseries. It is also very costly. Biologically active sand filtration has been shown to reduce pathogens in waste water; sand filters may not however control *F. oxysporum* (Wohanka, 1995) and some viruses (Berkelman et al., 1995). Filtration is an important pre-treatment to improve the efficacy of other disinfestation methods, and sand filtration may be useful in conjunction with these.

CONCLUSION

Water quality is the most important factor in choosing a water disinfestation method. Clean water with a high UV transmission can be successfully disinfested using UV radiation. Chlorine dioxide at a residual concentration of 2.6 mg litre^{-1} can be used to disinfest poor quality water, and has scope for greater use in the nursery industry. There is insufficient data available on ozone and bromine compounds for disinfestation of plant pathogens to make recommendations for their use in water of variable quality.

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An Alternative to Methyl Bromide: Electrically Produced Steam

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INTRODUCTION

The use of aerated steam for pasteurisation and sterilisation is not a new technique in our industry. It first gained interest in Australia following a visit by Dr. Ken Baker in 1960. The release of the *UC Manual for Container Growing Plants* by Baker led several nursery operators to embrace this technique. Alan Newport (Newports Nursery), Jack Pike (Pikes Nursery), and Gavin Wilton (Falg Nurseries), all introduced aerated steam into their bedding plant and house plant operations in the early 1960s. The traditional users of aerated steam have been the bedding plant and seedling producers, probably because of the critical importance of hygiene in raising seedlings.

In the last 2 years the use of aerated steam has gained momentum again in the nursery industry because of two key issues.

1) Methyl bromide which has been widely used as a disinfesting agent has been labeled as a serious ozone depleting gas. Through the U.S. Clean Air Act it will be banned from use in the U.S. The 1st of January 2001 was one proposed date, however it is currently uncertain when the final cut off will be. The Netherlands no longer uses methyl bromide. In Australia methyl bromide use is being reduced by gradually restricting imports with a proposed complete phase out around 2005.

Australia is one of 149 nations who are signatories to an international agreement "The Montreal Protocol" on substances that deplete the ozone layer.

2) With the creation of the Nursery Industry Accreditation Scheme Australia (N.I.A.S.A.), accredited nurseries need to have disinfesting programs in place for media and used containers which may contain disease organisms.

Under the accreditation guidelines the use of aerated steam, pasteurisation, methyl bromide, solarisation or Basimid® are accepted treatments for many soil borne diseases. Aerated steam (sterilisation), methyl bromide, and sodium hypochlorite solution used at 5000 ppm of free residual chlorine are the suggested treatments for used containers.

Our nursery operation continually reuses propagation tubes and growing on pots which needed to be disinfested. Methyl bromide had traditionally been used for disinfesting filled propagation media trays and used containers. Sodium hypochlorite solution used at 5000 ppm of free residual chlorine was used for manual hand washing of used containers because it was a more effective treatment than methyl bromide, but it was a very labour intensive operation.

At Redlands, we identified the need to find an alternative to methyl bromide gas disinfestation. We did our research and settled on steam. Initial planning started around 1990 with its inclusion in the budget and its entry on our 5-year plan.

REASONS FOR CHOOSING STEAM

1) Safety to employees: risk was reduced by removing the need for toxic chemicals such as methyl bromide and sodium hypochlorite.

2) To achieve an effective treatment of our propagation media and used contain-

ers: we weren't entirely happy with the results of methyl bromide, e.g. a perpetual *Rhizoctonia* problem in propagation and losses experienced in used containers after methyl bromide disinfestation.

3) To reduce labour costs and increase efficiencies in these operations: the number of operational steps with methyl bromide is reduced greatly in comparison to the use of heat treatment.

4) To work in with planned future automation and more effective materials handling.

5) To completely eliminate the need for methyl bromide well prior to its legislated unavailability.

SOLUTION

After consultation with other growers and David Spencer from South East Queensland Electricity Board (S.E.Q.E.B.) we settled on using electrically produced steam with a Mastersteam Generator produced by ACA Engineering, in Victoria.

Advantages Over a Fuel-Fired Boiler.

- The operator does not need a boiler ticket and the machine can be left unattended during operation.
- There is no requirement for either licensing and yearly safety inspection by the Qld Department of Workplace Health and Safety or the need for annual maintenance.
- The system is simple to operate and can be made fully automatic.
- The equipment is a compact unit which is easy to relocate and can be placed right at the point of usage.
- There is no flame or fire risk and no fuel storage is required.
- It is environmentally friendly generating the waste products of heat and steam.
- There is a lower capital cost involved.

EQUIPMENT

The equipment I am discussing in this paper is a 100 kW steam generator. The supplier, ACA Engineering, manufactures steam generators from 40 kW upwards. We decided on this capacity for both our present needs and with a view to our future requirements, coupled with the need for flexibility. However regardless of the size of the equipment the principles remain the same to achieve the desired treatment.

A secondhand steam vault was purchased. It is constructed of Bondor Insulated Panels with the dimensions being 2040 mm in height, 2650 mm in length, and 3000 mm in width. It has two barn doors on the front and its working floor capacity is 4×1.2 m^2 conventional pallets. Also included in the original purchase was 3 kW electric blower and 150 mm PVC pipework from the blower to the steam vault.

For the volume of the steam vault and the operational load, the manufacturer suggested a 100 kW steam generator. This has a power requirement of 140 amps per phase. To make the unit more flexible we had it fitted with a 40 kW and 60 kW option so that it could be used for small batches or a steam gun at 40 kW setting. For large media batches and with both the 40 kW and 60 kW buttons depressed, it gives a 100 kW power rating.

The steam vault was installed as a recirculating closed system to make a more energy efficient system. A closed system with little steam escaping during the

Table 1. Media and propagation tray combinations.

Media	No. of trays in batch (4 pallets)	Litres per pallet 1000 l = 1m^3	Total treated m^3 per batch (4 pallets)	Total number of cells
60% sand 40% peat or 40% peat 60% perlite	4 pallets of 42's (42's Kwikpots) = 468 trays	1 pallet of 42s = 527 litres	2.1 m^3	19,656
40% peat 60% perlite	2 pallets of 42s = 234 trays 2 pallets 50 mm tubes = 120 trays	1 pallet of 42s = 527 litres 1 pallet 50 mm tubes = 840 litres	2.73 m^3	23,028
40% peat 60% perlite	4 pallets of 50 mm tubes = 240 trays	1 pallet of 50 mm tubes = 840 litres	3.36 m^3	26,400

process requires a lower energy input. The S.E.Q.E.B. energy recommendation is 30 kW of electricity per cubic metre of media. Table 1 gives some of the different combinations of batch size, with the maximum being 3.36 m^3 on a 60 kW power setting (which is a 40% energy saving). This saving has been made possible by using a recirculating system.

The steam is fed into the steam vault through a register in the centre of the roof. It is then drawn from the room via 9 mm × 50 mm PVC pipe openings which are positioned 180 mm above the floor there is 40 mm between each opening.

Our power requirements to the property had to be upgraded to a 200 kva transformer, to provide for the extra need of the steam generator and for future property development. The main switch board was incorporated into the building housing the steam room, to reduce the installation cost of the cable needed to supply electricity to the steam generator.

The water supply is provided by two 4700 litre polypropylene tanks collecting rain water off the roof of the same building. It was decided to use rain water, as opposed to the town supply, to eliminate the need to add chemical to prevent scale build up in the steam generator. Also as the major use of the equipment was for pasteurising propagation media, it was necessary to use as pure a water source as possible. Water usage for a 100 kW unit at maximum steam usage is 136 litres per h. We budgeted on 75 min. therefore using 170 litres per session. We are currently only using the 60 kW setting which is using approximately 102 litres per session.

The water flows from the bulk tanks through an inline filter and a 20 mm copper pipe into the header tank via gravity feed and a 20 mm float valve. The recirculating pump which transfers water from the header tank to the steam generator has an output of 9 litres per hour. The water is pumped into a header tank inside the steam

generator before passing through a series of electric transformers which heat the water and produce the steam.

The control panel was designed by Procon Brisbane consists of two Shinko digital thermostat controllers with individual probes and a timer. The steam room controller is a moveable probe attached to a 8000 mm cable. The air temperature controller probe is fitted just above the inlet on the roof of the steam vault. Both are able to be set at the designated temperature.

At the end of the pasteurisation cycle of 30 min at 63C, the timer activates an alarm for the start of the purge cycle. Stainless steel butterfly flaps have been installed inside the pipework to direct steam flow into the steam vault during the heat up and pasteurisation cycle and during the purge cycle the flaps are repositioned to allow ambient air to be drawn from near the roof and the heat and steam from inside the vault to then be vented to the outside of the building.

The thermostat controlling air temperature is connected to an automatic steam valve to enable regulation of temperature and closing off the passage of steam at the end of the pasteurisation cycle. The racks holding the propagation trays allow an airspace of 15 mm between each layer, to ensure rapid and thorough circulation of the steam. Each aluminum rack holds 117 trays of Yates Kwikpots®. The trays are 295 mm wide and 365 mm long. Aluminum rack dimensions are 1520 mm in height 1 m in length and 1180 mm in width.

Two microswitches have been installed at the top of both doors as a safety precaution as the steam blower will not operate unless both doors are closed.

TREATMENT

Pasteurisation is used to control plant pathogens in growing media by raising the temperature to between 60 to 70C within 30 to 45 min, and then maintaining that temperature for a further 30 min before cooling the media down by pumping ambient room temperature air through it. This process controls most pathogens, without eliminating many beneficial organisms. This is used for filled trays of propagation media.

The media is thoroughly mixed at the moisture content for planting prior to steaming. The media filled trays are left for a minimum of 4 h before steaming to enable seeds and spores to absorb water. They are less resistant to heat when they are moist.

The spectrum of disease, weed, and pest control is widened by increasing the treatment temperature to 70 to 80C for 30 min. This will control most weed seeds and plant pathogenic bacteria, and is used for treating used containers, where inoculum levels of many pathogens are potentially higher.

The steam generator takes 15 min to build up steam then approximately 45 min to bring the steam room and its contents up to the required temperature. The cook cycle is 30 min duration. The purge cycle for cooling the media with ambient air and lowering temperature back to 40C is approximately 45 min.

A six-channel digital data logger was installed by S.E.Q.E.B. to produce graphs which identify temperature dynamics inside the steam vault, and to chart the hot and cold zones.

Our first batch of media showed a temperature differential of 4C between the highest and lowest temperature at 60 kW setting. We did one cycle at 100 kW which did not work successfully as it produced a temperature differential of 10C. The conclusion was that it raised the temperature too quickly in this case, therefore

sacrificing uniformity. This batch was done before the racking system was finished and the trays were only separated by 10 mm. The coolest zones were in the lower section of the pallet, at the front of the steam vault (facing the doors).

One problem we had been experiencing was a runaway system with the designated temperature being exceeded. We have overcome this problem by better regulating the manifold steam flow automatically by setting the thermostat controls as follows:

For pasteurisation cycle:

1) Steam vault thermostat set at 60C, when the temperature reaches 61C it activates the cycle 30-min timer.

2) The steam flow in thermostat is set at 65C which is our upper limit.

3) This thermostat is coupled to the automatic steam valve on the steam generator.

4) When steam-flow in probe reaches 65C it shuts off the steam valve.

5) The steam valve then reopens when the temperature drops to 63C.

6) This process continues through the pasteurisation cycle regulating temperature at 63C.

This strategy has increased our steam room heat up time to 1 h and maintains a constant temperature with only a 2C temperature differential. This is now achieved now on both the 60 kW and 100 kW setting.

The significance of this is the degree of temperature control an this enables the pasteurisation cycle to run unmonitored by the operator, effectively saving 30 min labour per batch. With a projected current usage of 80 treatments per annum it amounts to 40 h of labour saving.

The power controls will be modified shortly so that when the timer reads 30 min (at the end of the pasteurisation cycle) it closes the automatic steam valve and then activates a motor drive to change the position of the butterfly flaps thus starting the purge cycle and cooling the media with air at ambient temperature.

TREATMENT COST

The electricity tariff we are connected to in Queensland is the Non Domestic Heating Time of use tariff No. 37. The most economical hours of operation are 10:30 PM to 4:30 PM, a total of 18 h at the rate of 6.5 cents per kWh. From 4:30 PM to 10:30 PM, a total of 6 h, the rate increases to 16.2 cents per kWh.

In Table 2 a comparison of treatment costs is made between methyl bromide (applied by a commercial contractor, whose requirement was a minimum of 6 pallets) and electricity on the above tariff rates.

Table 2. Comparison between methyl bromide and steam.

	Methyl bromide	Steam
Treatment time	Minimum of 48 h Maximum of 72 h plus airing time of 12 h	3 h Use when media has cooled to 40C
Type of treatment	Fumigation (soil sterilant)	Pasteurisation (beneficials still intact)
Cost/pallet	$18.33 min/mm 6 pallets	$7.27 $1.82/pallet
Byproducts	Ozone depleting substance	Heat, steam, and water

PROBLEMS

We have made other observations:

- Always have the same type of media in the steam vault or uneven heating can be experienced.
- When sterilising empty containers a mixed load of different sized containers does not cause uneven heating.
- Do not have too great a depth in containers or try to do bulk media in the steam vault.
- Hygiene is extremely important and one weak link in the process can ruin the effect of the treatment. Therefore after treatment the media and used pots are shrinkwrapped. This both identifies treated media and pots, and keeps treated material clean until use.

CONCLUSION

As outlined earlier we will advance to fully automatic controls on the unit within a short time. We are currently researching the use of a steam gun for sterilising machinery and equipment, to eliminate chemically based wash-down procedures. At a design capacity of 130C at the gun tip it will guarantee control of all known pathogens, if used in the correct manner.

The unit was commissioned in Nov 1995. In that short time we have seen a difference in the efficiency of our propagation unit as a result of pasteurisation. A good example is our current azalea propagation system which now has a failure rate of less than 1%. In *Dipladenia* it has eliminated a perpetual *Rhizoctonia* problem which always presented a problem in propagation. Chemical needs and dependency are subsequently reduced.

We will see these results flow right through the production phase adding to the finished quality of our crops. Plants in reused steamed pots have performed better than those in chemically treated used containers.

The installation of the steam generator equipment is seen as stage 1 in a facility which will eventually house media manufacturing, tray filling, cutting and seed preparation, thus becoming an integrated system. The steam gun will play an important role in cleaning these work areas.

As we continually look at improving systems and production techniques we can use the experience of the past coupled to the technology of the future to make further advances and improvements in our industry and ultimately the crops that we grow.

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Gene Transfer and Interspecific Hybridisation: Two Approaches to Virus Resistance in Papaw (*Carica*)

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INTRODUCTION

Papaw or papaya (*Carica papaya* L.) is grown as a fruit crop in countries with tropical and subtropical climates. In 1988 the world production of papaw was 3.68 million tonnes. Papaya ringspot virus (PRSV) is the most serious disease of papaw (Purcifull, 1972) and poses the greatest single threat to papaw production in the world (Litz, 1985). It was first reported on the island of Oahu in Hawaii in 1945 (Lindner et al., 1945) and subsequently occurred in Africa, Bangladesh, Brazil, Colombia, Cuba, El Salvador, Sri Lanka, Venezuela, India, Thailand, Taiwan, and the Philippines. In the nineties it has been reported in Malaysia and South East Queensland.

PRSV is a member of the potyvirus family and infects plants in families Caricaceae, Chenopodiaceae, and Cucurbitaceae. Two closely related strains occur: P and W. Papaws are infected by strain P, which is aphid-borne and spreads rapidly in affected areas. The symptoms of PRSV-P in papaws are vein clearing and chlorotic spots followed by mottling and distortion of the leaves, and greasy ringspot patterns on the fruit and upper portion of the stem. Many trees die before fruit set and trees that do survive set few fruit. These fruit are of poor quality, have a low sugar content, are covered by greasy ring spots, and are unmarketable.

DEVELOPMENT OF PRSV-P TOLERANT VARIETIES

Since the pioneer work by Conover in the early seventies (Conover, 1976), there have been numerous attempts to produce tolerant lines by selection and crossing of various cultivars within the species *Carica papaya*. A number of lines that exhibit some tolerance have been produced including Cariflora (Florida), Know You, Red Luck, and Tainung (Taiwan). However, these lines have been ineffective and have not allowed re-establishment of commercial plantations in infected areas. When trialed in Australia, their performance against local strains of PRSV-P has been poor. Recently 'Sinta' has been produced in the Philippines and shows good tolerance to their PRSV-P strains (Mercado et al., 1995).

DEVELOPMENT OF PRSV-P RESISTANT VARIETIES

Currently two approaches are being used in Australia to produce papaw lines that are resistant to PRSV-P. Resistance to PRSV-P has been reported in the *Carica* species *cauliflora, pubescens, quercifolia*, and *stipulata* and an attempt to introgress genes from these wild species into papaw is being made using interspecific hybridisation. This work is a collaborative project between Queensland Department of Primary Industries and University of the Philippines at Los Banos and is being funded by the Australian Centre for International Agricultural Research. The second method involves gene transfer. Constructs of viral coat protein and viral replicase genes are being transferred to papaya via microprojectile bombardment.

This project is being undertaken by the Queensland Department of Primary Industries and the Queensland University of Technology and is being funded by the Queensland Papaw Industry and the Horticultural Research and Development Corporation.

COMPARISON OF TWO METHODS

The aim of this paper is not to present results but to compare the advantages and disadvantages of the two research methods. These are summarised in Table 1. Details of conventional breeding between papaw varieties are also presented, but since no resistance exists within *Carica papaya*, this technique is not discussed further.

Some wild relatives of papaya that are highly resistant, may even be immune to PRSV. After inoculation with high levels of PRSV followed by growth in the field with papaws exhibiting high levels of infection, no virus could be detected in either *C. cauliflora* or *C. quercifolia* by ELIZA testing (Persley, pers comm). Furthermore, this resistance has been stable for long periods in infected areas. Long-term field performance of coat-protein-mediated resistance is as yet untested. In some cases, other species transformed with coat protein constructs have shown reduced virus symptoms or tolerance rather than resistance. Single-gene disease resistance developed in plant breeding programs often breaks down in the field as virus strains mutate and this may occur with coat-mediated resistance. The useful life may be extended by the transfer of two genes for resistance (for example coat protein and replicase genes). To be successful resistance must be both stable and heritable.

When adding genes for PRSV resistance by either breeding or genetic engineering the genetic integrity of elite cultivars must be maintained. Interspecific hybridisation requires a long backcrossing programs (6 to 8 generations) to restore commercial cultivars. In theory, a major advantage of gene transfer is that one or two useful genes may be added to an elite genotype without altering the rest of the genome. However, in practice, transgenic plants are regenerated from cell cultures, which are prone to genetic variation resulting from somaclonal variation.

A laboratory phase is required for both methods. Embryo rescue and in vitro plantlet production are required following interspecific hybridisation as embryo abortion and death occur due to breakdown of the endosperm. Routine procedures have already been developed for embryo culture, embryogenesis, and plantlet production (Magdalita et al., 1996). Gene transfer requires the development of embryogenic cultures, high frequency gene transfer and stable expression, growth on medium containing kanamycin to select transformed cells, good regeneration of plants from these cells, and growth in vitro of a plantlet that can be acclimatised. These stages constitute lengthy laboratory phases and because this is a new field of research, unexpected problems and delays regularly occur. For example, transgenic papaw plants grow very poorly in culture and are extremely difficult to micropropagate.

Field evaluation of resultant plants is essential. Because interspecific hybrids are from wide crosses, incompatibility causes poor growth and development of plants and high levels of infertility. By comparison, in Hawaii transgenic papaw plants are growing normally in field plantings (Manshardt, pers. comm.). In Australia transgenic plants are growing poorly in culture and may lack vigour when grown in the field.

Transgenic plants pose environmental and legal problems and can be grown in the

Table 1. Advantages and disadvantages of conventional breeding, interspecific hybridisation and gene transfer as methods of developing PRSV-P resistance in papaw.

Conventional breeding within *Carica papaya*.	Interspecific hybridisation with *C. papaya*	Gene transfer of essential viral genes to *C.*papaya
No resistance only tolerance to PRSV	Species resistant over long period in field	Long-term field performance unknown
Requires long backcrossing program	Requires long backcrossing program	Potential to add 1 or 2 genes without altering remainder of genome
No laboratory phase, plants grow normally	Proven laboratory phase, no unexpected problems	Complicated laboratory phase with unexpected problems and delays
No growth problems	Hybrid breakdown, prone to growth problems in glasshouse and field	Reduced regeneration and poor growth after gene transfer and selection
Fertile hybrids	High levels of infertility	Infertility rare, somaclonal variants can occur
Field evaluation required - no complications	Field evaluation required - no complications	Field evaluation required - subject to legal and environmental restrictions
No patent limitations	No patent limitations	Patent obligations

glasshouse and field only after permission from (GMAC) Genetic Manipulation Advisory Committee. There may be patent obligations involving up front payments and/or royalties before these plants can be grown commercially. If PRSV resistance can be transferred from wild species there are no patent obligations or restrictions on field testing.

Both approaches should provide PRSV-P resistant papaya lines in the future although the first plants in the field are likely to result from the gene-transfer project.

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Getting the Most Out of Growing Media and Nutrition

David Nichols and Craig Godham
Debco P/L, 12 Mckirdys Road, Tyabb, VIC 3913

INTRODUCTION

Plants need carbon dioxide, water, mineral nutrients, oxygen in their root zone, and energy. In their natural state they acquire these for themselves. It ought not to be too difficult to help them along in a nursery, but somehow it often is. The typical Australian nursery is placed at various levels, somewhere between the maligned backyarder who recognises the simplicity of it all and the idealism of a Dutch grower nurturing a single variety with almost total environment control.

We can abridge the requirements of plant survival in nurseries into the following parts: the plant, the growing media, nutrition, the environment, pest, disease and weed control, and management.

THE PLANT

Universally, plants obey the same principle rules for survival but because they have to cope with different environments they modify their responses. In short, each plant is distinct and requires a different level of management. Most have wide tolerances of growing conditions. If this were not so then the nursery industry could

glasshouse and field only after permission from (GMAC) Genetic Manipulation Advisory Committee. There may be patent obligations involving up front payments and/or royalties before these plants can be grown commercially. If PRSV resistance can be transferred from wild species there are no patent obligations or restrictions on field testing.

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not survive in its present form. However, there are exceptions where growing conditions and nutrition, in particular, have to be precise (Fig. 1).

THE MEDIA

At one time the potting mixture was considered the most important part of container plant production and was often the means by which a grower gained an edge over competitors. Media knowledge has developed in stages to a level where we now understand the requirements to be a set of properties rather than a catalogue of different formulas (Australian Standard, 1993).

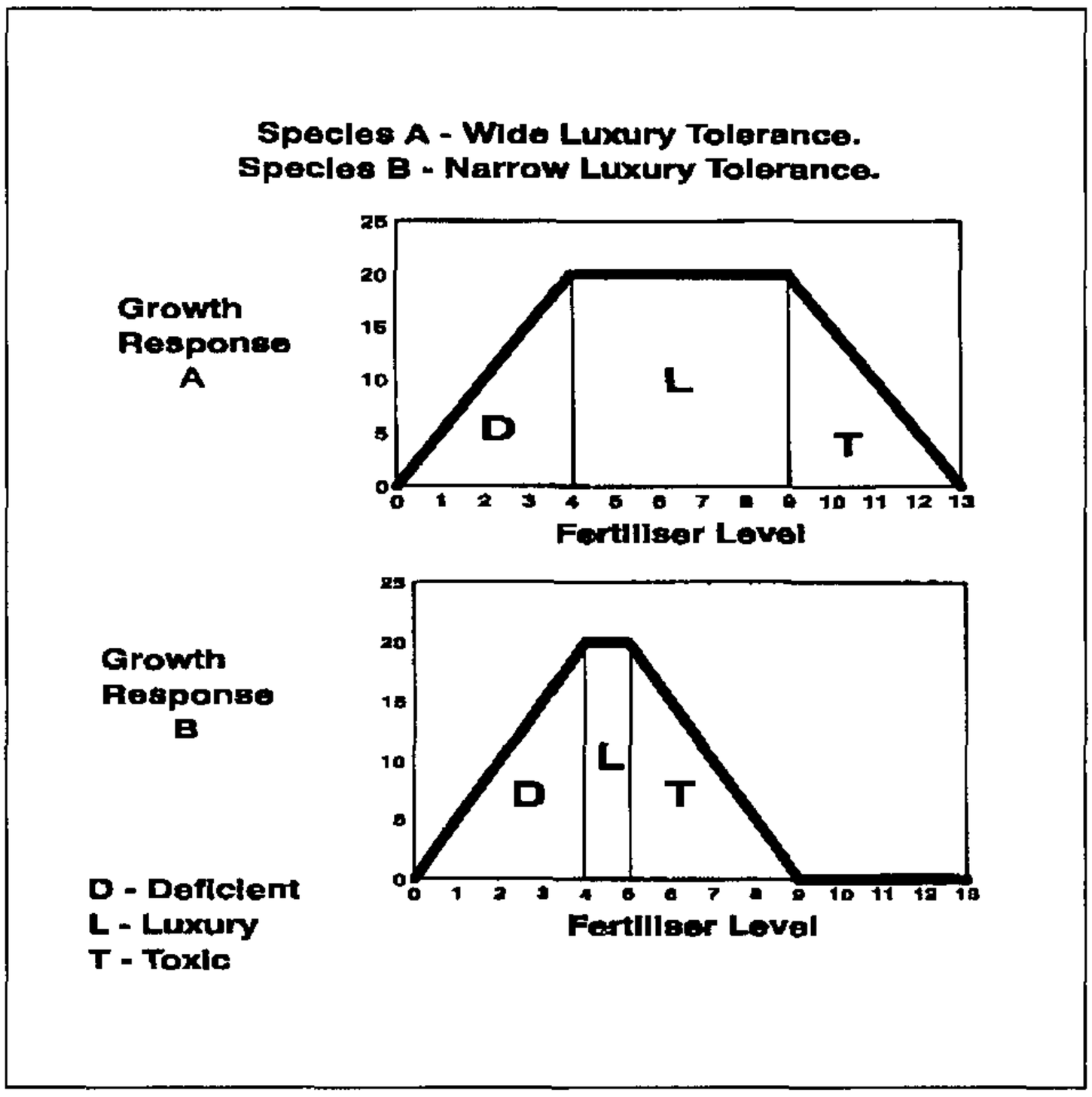

Figure 1. Schematic response of plants to increasing fertiliser. Species A - wide luxury tolerance; species B - narrow luxury tolerance.

NUTRITION

Nutrition is a subsidiary function of the media. Plants can take nutrients through their leaves but they do so much better through their roots and the roots are situated in the media. The supply of oxygen and water are important parts of this function. Plants also differ remarkably in their requirements for various nutrients. In nurseries today, nutrients are applied predominantly as polymer-coated controlled-release fertilisers (CRFs) or in liquid form.

ENVIRONMENT

Environmental factors impact heavily on the media, particularly in relation to nutrition.

Temperature and light have a dominant effect with each plant subject to optimum ranges for growth. With temperate species, plant metabolism slows down at levels above and below the optimum whilst tropical species, having few problems when grown in the tropics, suffer at the extremes experienced in cooler climates.

Controlled-release fertilisers can present a problem in this regard. Release is regulated by temperature, which is not a problem so long as the plants metabolic activity is also increasing at the same rate. However plants have limits to their ability to tolerate extremes in environmental temperature, beyond its optimum range their metabolism slows down, while the fertiliser continues to accumulate. In regard to CRFs, growers should be conscious of hot heaps of potting mixture, heat

sterilisation, heatwaves with temperatures above 35C, and heated greenhouses under conditions of low light.

PEST, DISEASE, AND WEED CONTROL

Plant pests and diseases represent an enormous threat to nurseries and have contributed to the loss of thousands of dollars worth of sales. Modern soilless composts are usually weed free and may actually contain disease-suppressing organisms. The relationship between disease and nutrition is obscure and often conflicting (Gladstone et al., 1990; Chase, 1988). Irrigation management is important because root diseases proliferate in an aqueous environment. There is ample scope for improvement in regard to nutrition and disease relationships because disease organisms are often discovered simply as secondary outcomes of nutritional failure.

However, because insects and disease spores are everywhere, it is simply not possible to prevent everything from going wrong. The answer to this is inherent in the principles of integrated pest management, wherein an approach can be taken involving such disciplines as strict quarantine, nursery hygiene, crop rotation, environment control (e.g. fans in glasshouses to dry leaves before spores can germinate), proper nutrition, irrigation timing, and biological control. It is at this juncture that the simplicity of the backyarder philosophy begins to collapse.

MANAGEMENT

Management is the key to the solution, growers need to make the most of the scientific advice on offer and their own accumulated experience to stay in business. One of the most critical areas is water management. Everyone appears to recognise that "too little" can be disastrous, but the converse of "too much" has sometimes subtle, sometimes glaring, effects on the final product. Whichever watering system is used, the best approach is to water when needed. This minimises nutrient and water wastage, while capitalising on media airspace. Media management requires a good balance between water-holding capacity and air-filled porosity, and rainfall being considered if necessary. Irrigation will always be difficult in situations where, as is often the case in Australian nurseries, the grower is dealing with a broad range of plants of differing watering requirements and in different stages of growth.

Being aware that the plant is responding to the interaction of environmental stimuli, and the raw materials and growing conditions we provide, adds another dimension to the art of nursery management. Good horticulturists are acutely conscious not only of seasonal change but more importantly of unexpected conditions such as heat waves, excessive cloud cover, frosts, prolonged winds, and subtle changes in temperatures. They will modify their practices to irrigate and fertilise accordingly.

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Effect of Saline Irrigation Water on the Production of Nursery Crops on Capillary Sand Beds

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Data on the effects of saline water on the production of nursery stock on capillary beds are presented. Growth comparisons are made between overhead irrigation and capillary bed irrigation in a range of saline sensitive and tolerant crops. Results from salinity trials where plants were irrigated with water up to EC 3.0 dS m^{-1} are presented. Leaching of excess salts and mulching treatments are shown to be effective as management tools for handling salt build-up in pots. Control of root emergence from pots onto the capillary beds can be achieved with dichlorophen.

INTRODUCTION

Subirrigation is commonly used in Europe for the production of high quality nursery stock. One advantage over overhead irrigation is a large reduction in water use (Stackhouse, 1993). Another is the potential of the system to minimise or eliminate egress of nutrients from the site. Many Australian nurseries are considering this method of irrigation, but are concerned about the effects of water quality and disease. This paper presents information for Australian conditions on the effects of saline water on growth under subirrigation of plants with a wide range of tolerance to salinity.

EXPERIMENTAL DESIGN

Of the several systems of sub-irrigation (ebb and flood, capillary mat, capillary sand bed) we chose capillary sand beds. The beds were constructed according to the principles developed at Littlehampton, England (Handreck and Black, 1994).

Early trials established that with the majority of nursery stock tested, salinities encountered in the range of 0.8-1 dS m^{-1} presented no major growth problems in capillary bed production. This range of salinity is that encountered in the nursery industry in South and Western Australia with municipal water supplies. Yield of plants on capillary beds was consistently higher than with overhead irrigation (Fig. 1).

Herbaceous plants, roses, and the majority of woody shrub varieties also responded to doubling the recommended rates of controlled-release fertilisers in the mix by increased yields with no loss of quality. Presumably, the lack of water stress at any time during the production cycle had a marked effect on the growth efficiency of the plants. Figure 2 shows an example of growth increase with doubling the fertiliser rates on capillary beds irrigated at water EC of 0.4 and 0.8 dS m^{-1} and overhead irrigation.

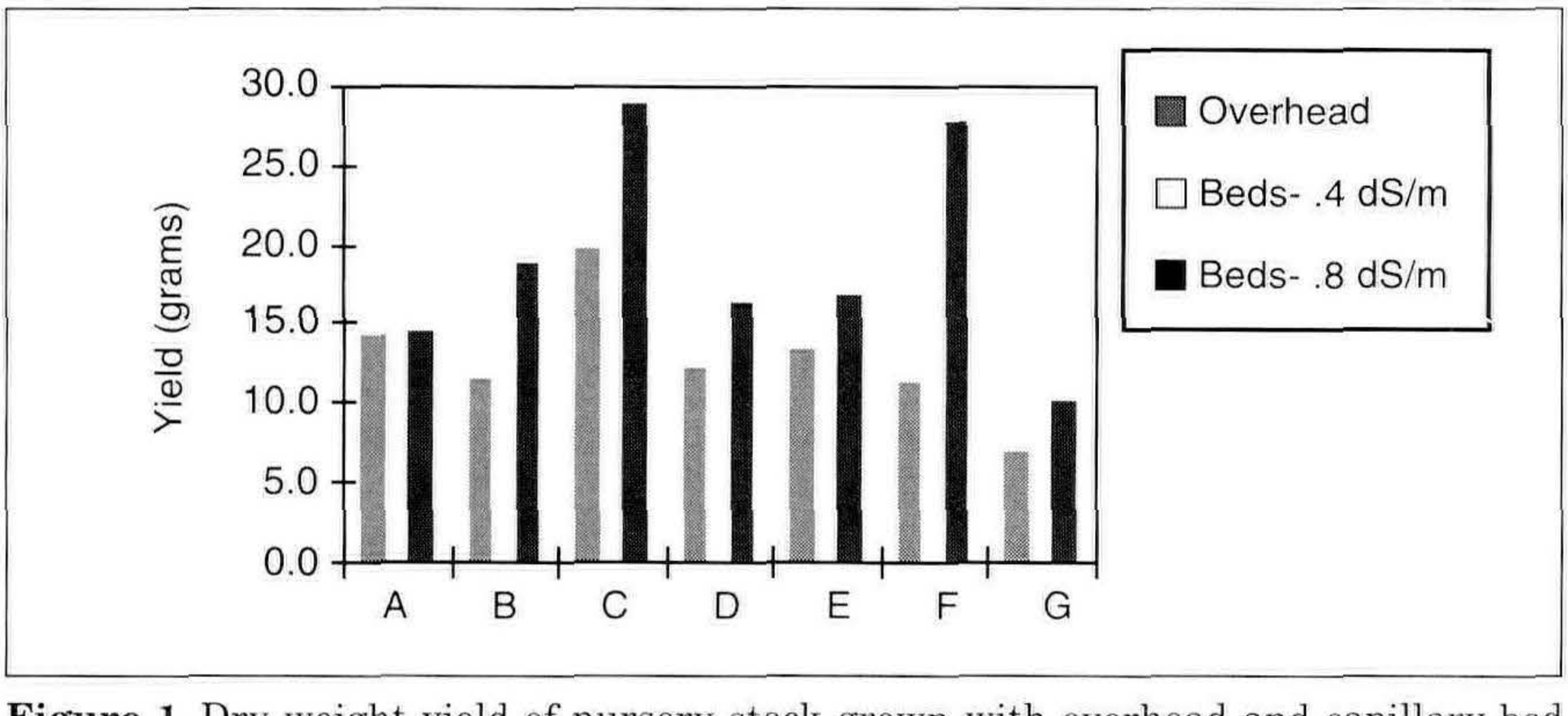

Figure 1. Dry weight yield of nursery stock grown with overhead and capillary bed irrigation. A - snapdragon, B - westringia, C - rose, D - melaleuca, E - chrysanthemum, F - marigold, G - abelia.

EFFECT OF HIGHLY SALINE WATER

The first salinity trial was conducted over the 1994 and 95 summer when the EC of Adelaide tap water was 1 dS m^{-1} at the beginning of the experiment and increased to about 1.2 dS m^{-1} during the trial. For this trial, the salinity treatments consisted of tap water, tap water diluted to about 0.6 dS m^{-1} (with RO water), and tap water to which had been added extra calcium, sodium, and magnesium chlorides and magnesium sulfate to produce ECs in the range 1.5 to 3.5 dS m^{-1}. The cation ratio of the tap water was maintained throughout, but bicarbonate was not used as part of the suite of balancing anions.

Trial plants had a wide range of sensitivity to salinity (Handreck and Black, 1994). Each was replicated 10 times on each of the 7 treatments.

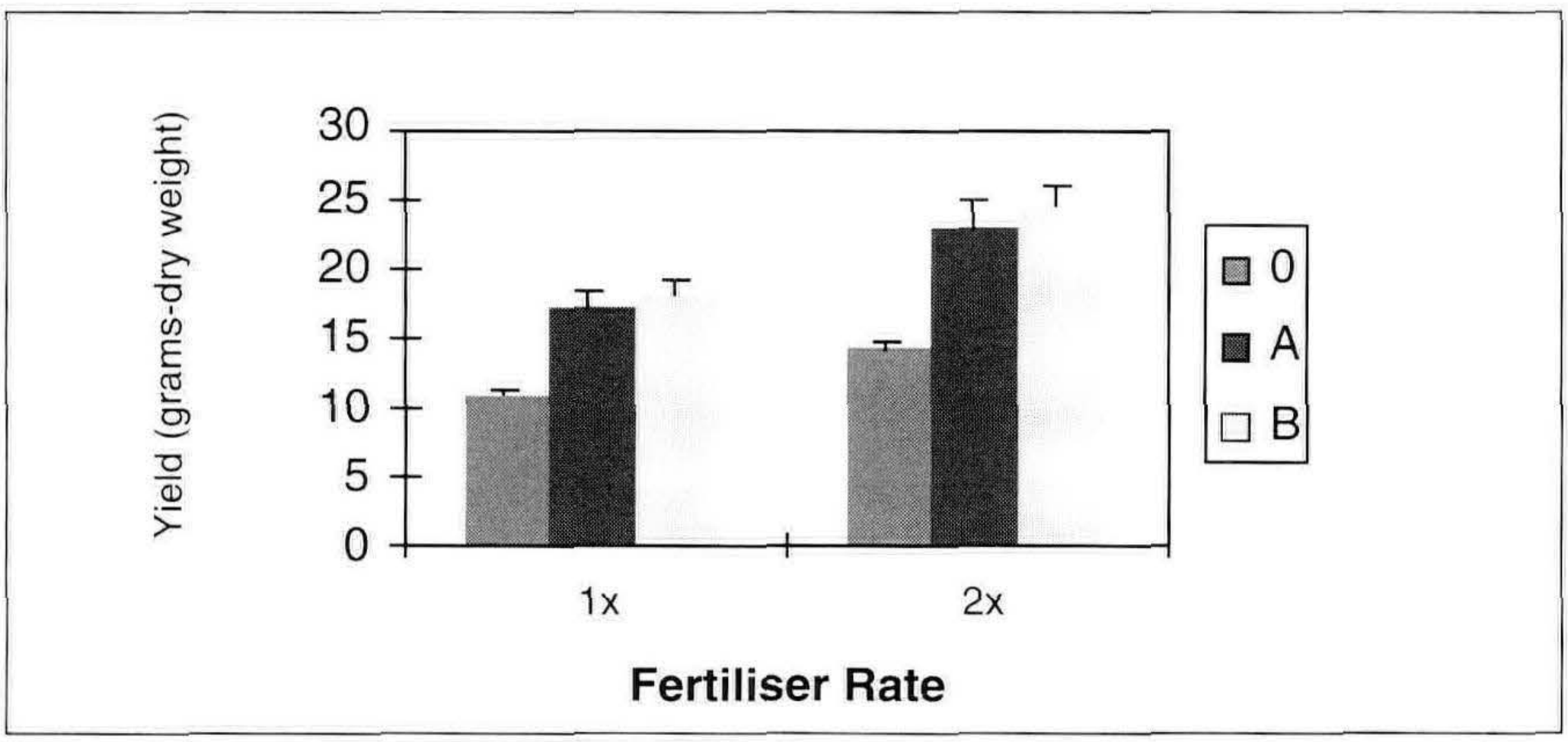

Figure 2. Comparison of growth of marigold 'Honeymoon' at recommended (1×) and double (2×) fertiliser rates with overhead (O) and capillary bed irrigation at EC 0.4 dS m^{-1} (A) and EC 0.8 dS m^{-1} (B).

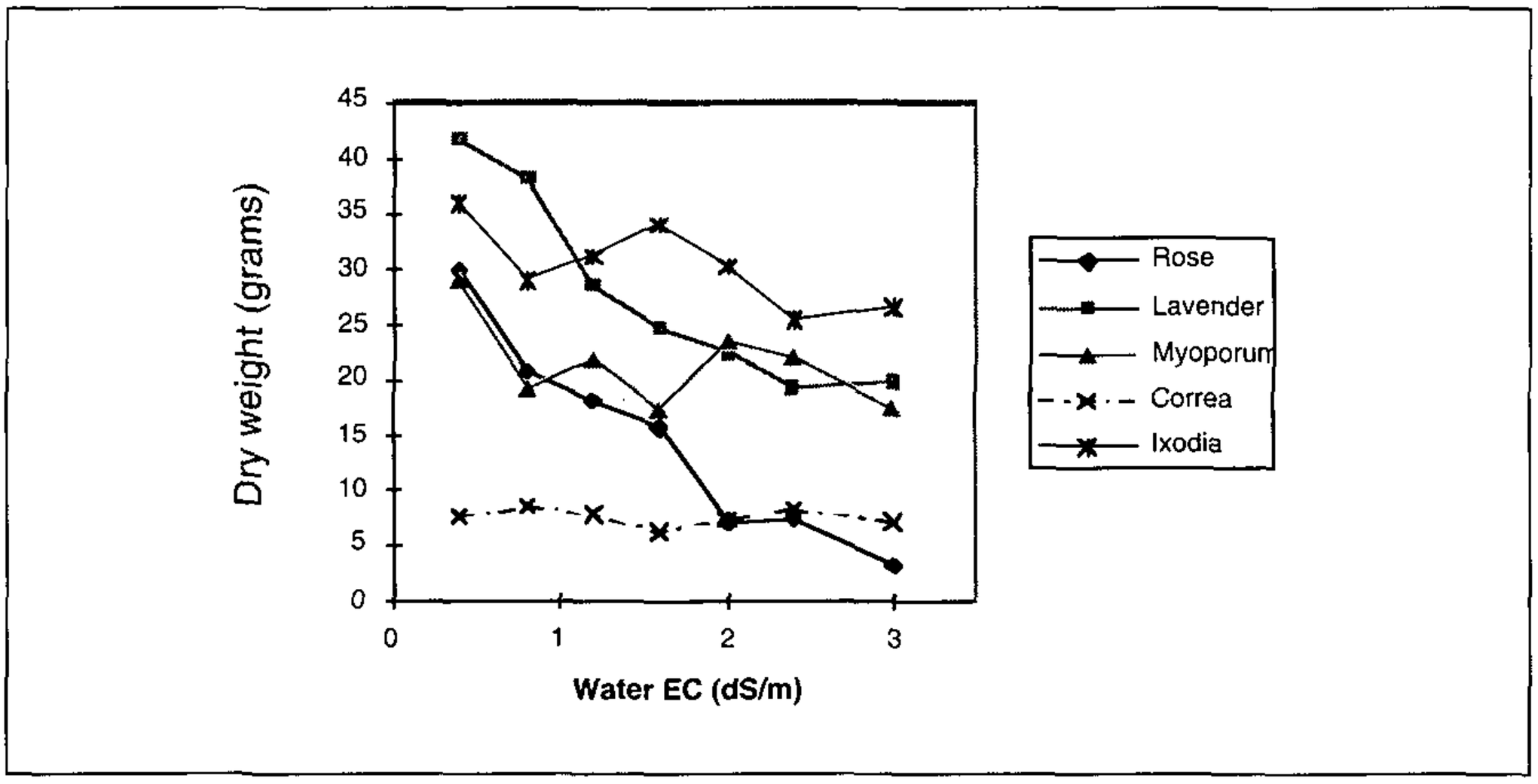

Figure 3. Yield of *Rosa* 'Meipitac' Carefree Wonder™ rose, *Lavandula ×allardii*, *Myoporum parvifolium, Correa alba,* and *Ixodia achillieoides* ' grown on capillary beds supplied with water of varying salinity.

There were significant responses in rose and lavender (Fig. 3) with stepwise decreases in growth from water EC of 0.35 through to 2.0. With salt tolerant *Myoporum, Ixodia*, and *Correa alba*, differences in yield were not significant and such species demonstrate that plants can be produced satisfactorily on capillary beds at water salinity levels three times that experienced by producers in Adelaide.

There was a continuous buildup of salinity in the pots during the growing period. With the saltiest irrigation waters, a crust of salt built up at mix surfaces. Typical EC readings at harvest are illustrated in Figure 4. The salts clearly concentrated in the uppermost 10 to 15 mm of the pot, where there was no root growth. While the plants remained on the capillary bed, growth and quality of the majority of species was not affected by the high salinity concentrated at the top. It would, however, be necessary to lower the salinity to acceptable levels before marketing.

LEACHING TRIALS TO LOWER SALINITY IN POTS

Figure 5 shows the result of applying 50 mm deionised water (roughly 2/3 rootball volume) to pots in which *C. schlechtendalii* had been growing. The application of this volume of water lowered the EC of the top 5 mm by 50% or greater in most cases. The leaching water had been poured onto the surface of the rootball over a period of about 3 min. Such rapid application probably did not allow enough time for salt in the surface crust to fully dissolve. It could be expected that the same amount of leaching water applied more slowly would remove a higher proportion of the total salt.

While these amounts of leaching removed much salt from the rootballs, there had been considerable redistribution of salt from the surface to lower parts of the rootball. The same effect could occur during a period of summer rainfall, where excessive levels of salinity might move into the root zone of the plants and cause injury.

One way of reducing salinity would be to remove the uppermost 5 mm of the rootball in a repotting process. The results of removal of the top of the rootball in

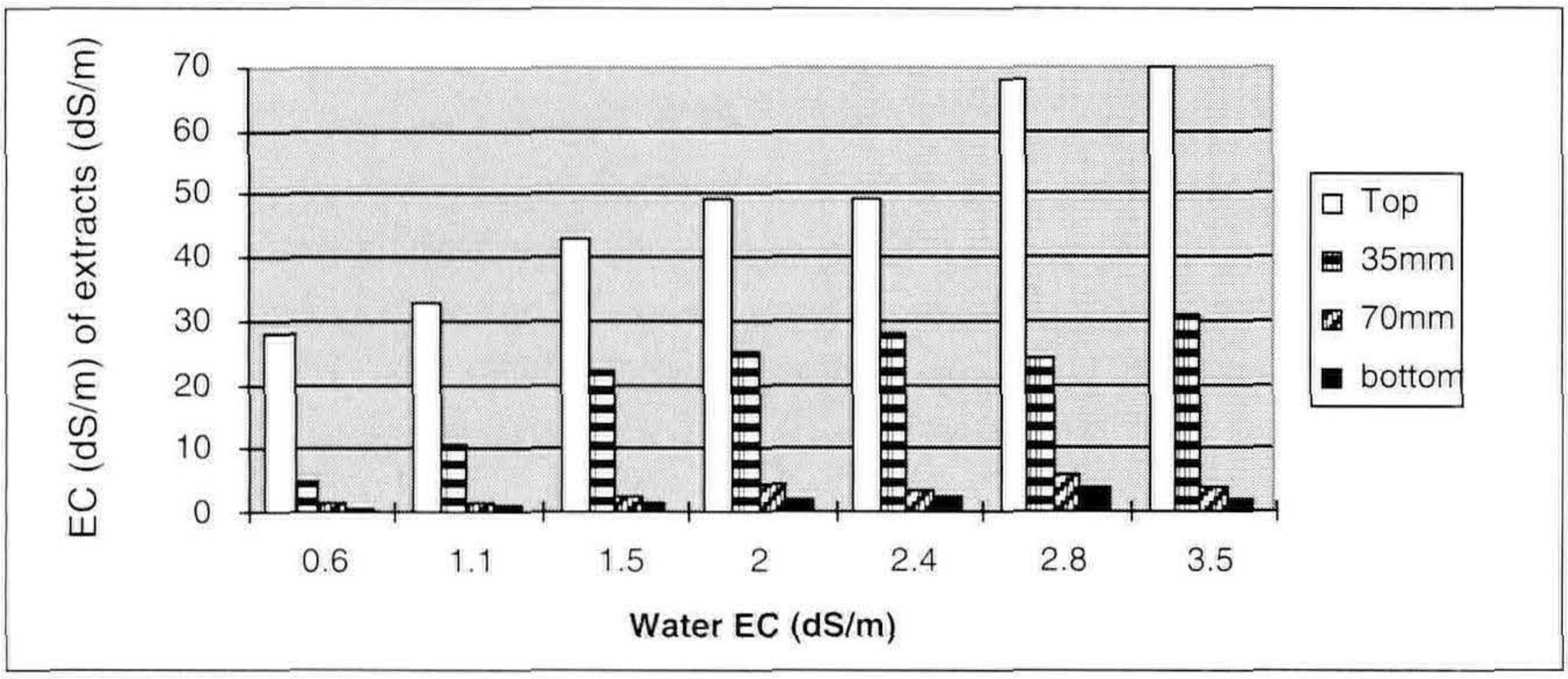

Figure 4. Electroconductivity (dS m^{-1}) of 1 : 1.5 (v/v) extracts of slices of mix removed from the pots at harvest.

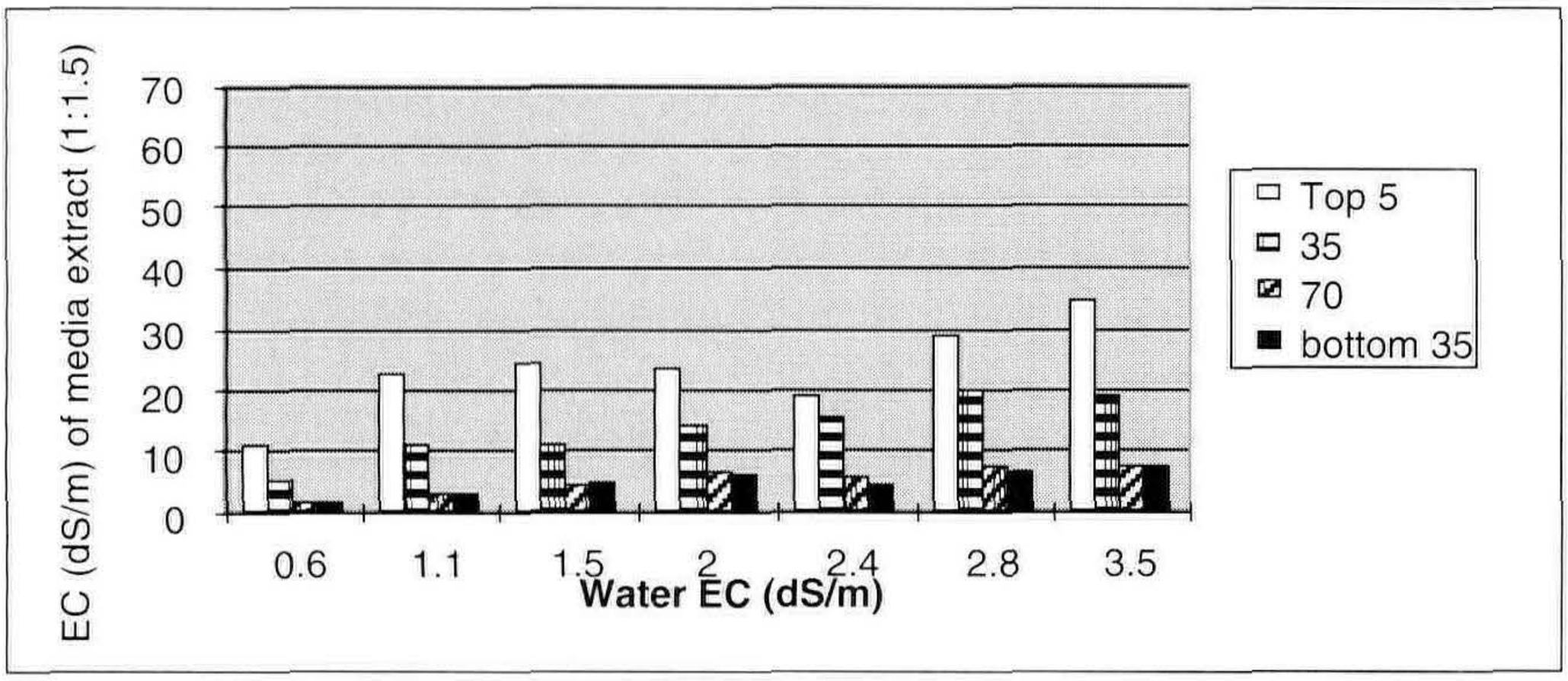

Figure 5. Effect on the EC of 1 : 1.5 (v/v) extracts of the media of leaching with 50 mm depth of water.

combination with leaching 1-pot volume of water are shown in Table 1. Leaching with 1 pot volume reduces the salinity in the top half of the mix without increasing the buildup of salt in the remainder of the pot. Further leaching would be recommended to establish safe salinity levels for marketing, however, the levels of salinity are not higher than that experienced by the pots during production. Removal of the top 5 mm prior to leaching is clearly beneficial in reducing total EC throughout the pot to acceptable levels in circumstances where extremely saline water is used for irrigation.

Table 1. Effect on the EC of 1 : 1.5 (v/v) extracts (dS m^{-1}) of various parts of a rootball of leaching with and without removal of the top 5 mm of mix.

Treatment	Top 5 mm	Next 35 mm	Next 35 mm	Bottom 35 mm
No leaching	41.3	3.9	1.9	1.7
Leaching, 1 pot volume	9	2.7	1.6	1.9
Top off, leaching 1 volume	-	1.2	0.9	0.7

We found that winter rains minimised any adverse effects on plants of saline irrigation water. Trial plants: *Camellia sinensis* 'Grace Albritton', *Rosa* 'Meidomonac' Bonica™ rose, *Viola tricolor, Dianthus barbatus*, *Grevillea* 'Scarlet Surprise', *Begonia* ×*carrierei* 'Olympia White', *Dietes iridioides*, *Lomandra longifolia*, *Acacia melanoxylon* experienced no adverse effects on yield or product quality as a result of irrigation with saline water up to 2 dS m^{-1} on capillary beds.

MULCHING REDUCES SALINITY BUILDUP

To control the build-up of excessively high salinity levels in the top of the pots, mulching treatments (bark, gravel, and weedmat) were incorporated into trials conducted in the winter and summer of 1996. Figure 6 presents an example of the reduction in salinity achieved in winter on a capillary bed irrigated at a salinity level of 2 dS m^{-1}.

In the unmulched controls, media extract readings of over 24 dS m^{-1} were recorded in the top 5 mm of pots of *D. iridioides* and *L. longifolia*. Significant reductions in surface salinity occurred in all mulching treatments, with coarse pinebark and gravel being more effective in reducing salinity than weedmat.

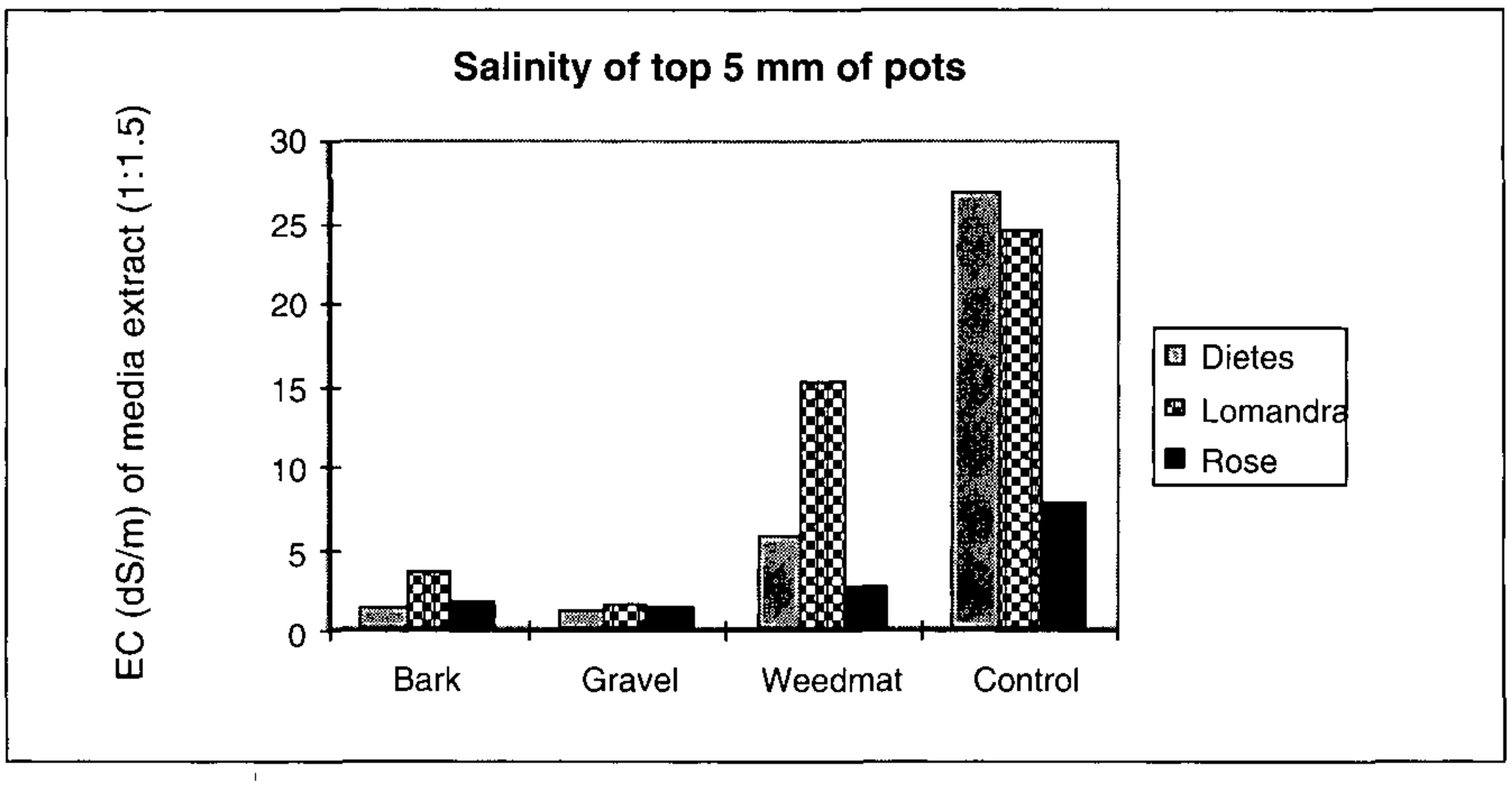

Figure 6. Effect of mulches on salinity build-up in the top 5 mm of nursery pots grown on capillary beds and irrigated with saline water (EC = 2 dS m^{-1}).

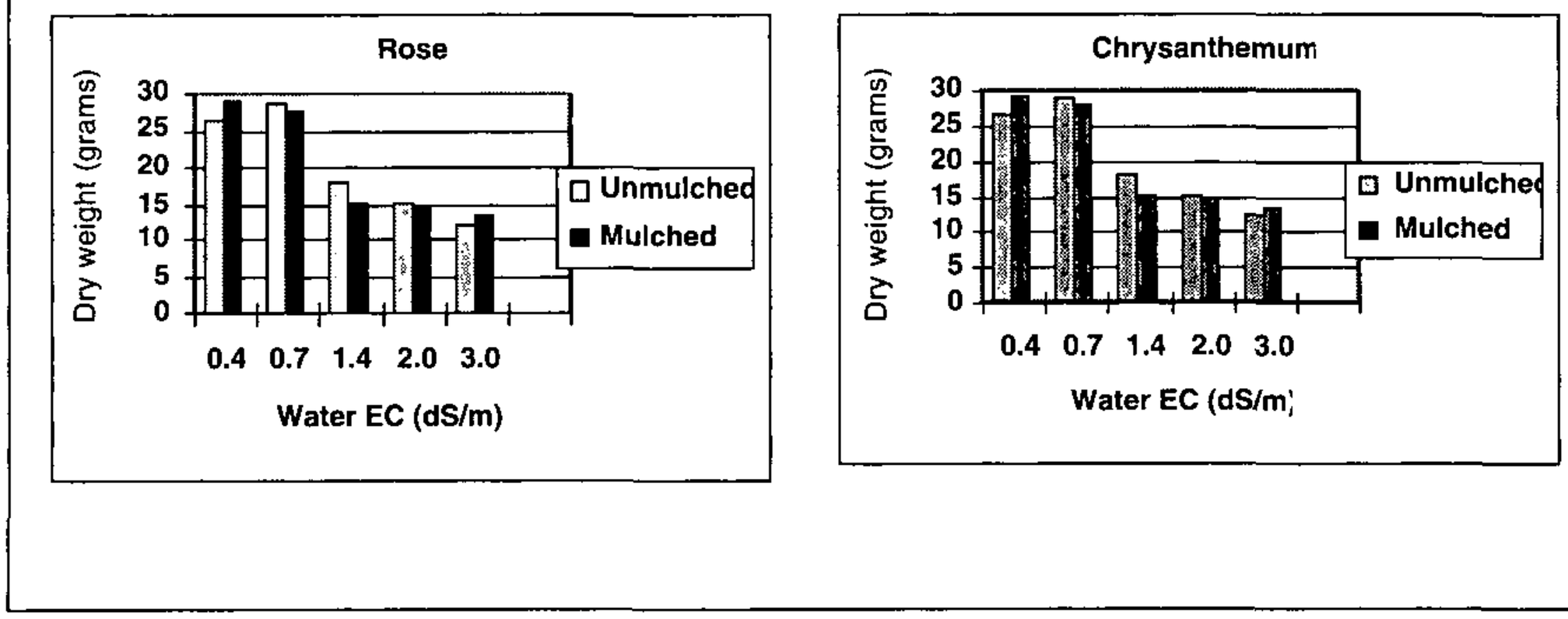

Figure 7. Effect of mulching on dry weight yield of (A) *Rosa* 'Meidomonac' Bonica™ rose and (B) *Argyranthemum frutescens* 'Double White' grown on capillary beds irrigated at EC 0.4 -3.0 dS m^{-1}.

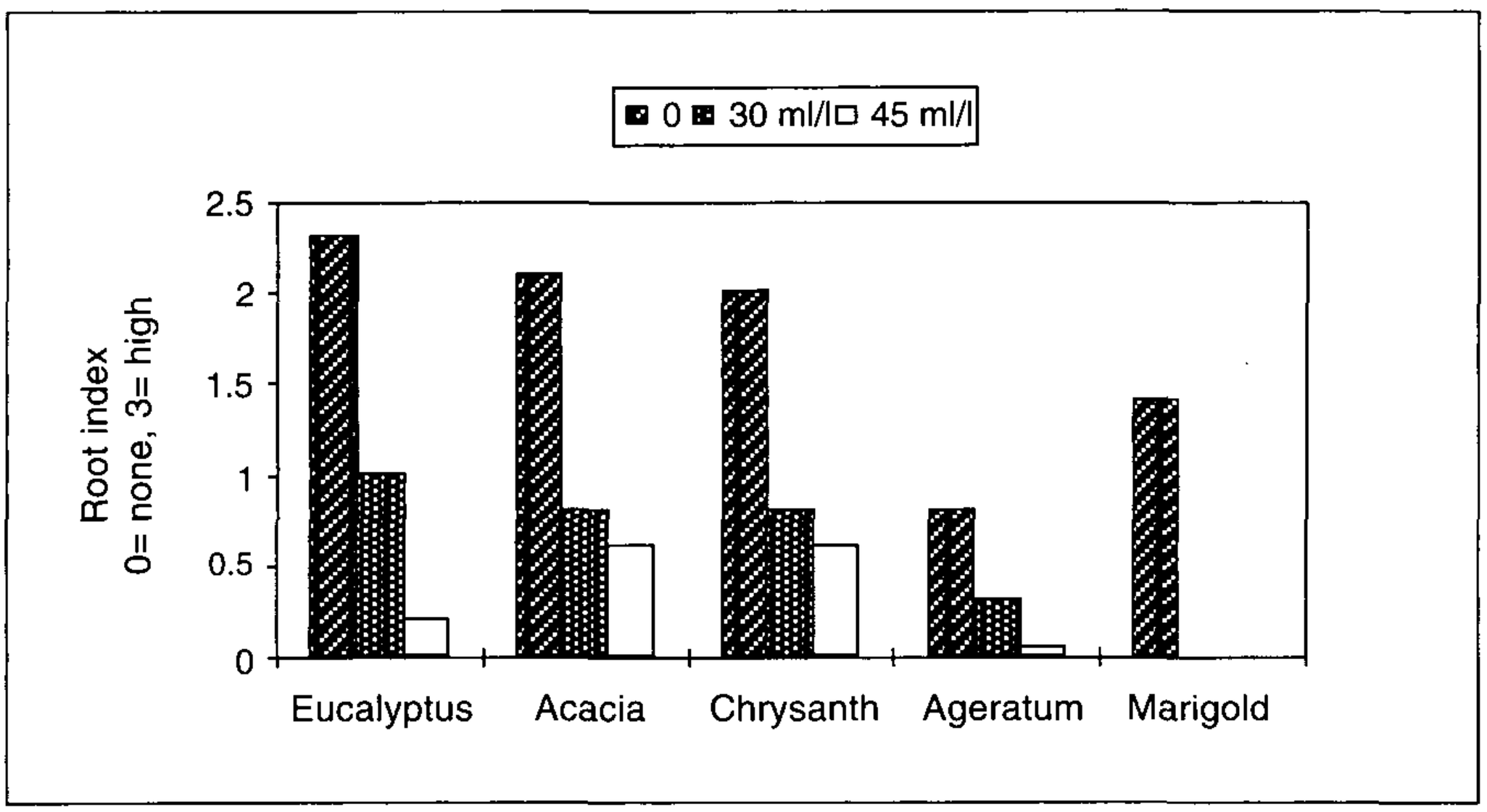

Figure 8. Effect of dichlorophen (450 g $litre^{-1}$) formulation as a root pruning chemical for capillary bed production of nursery stock.

Figure 7 shows the effects of mulching treatments on the yield of *Argyranthemum* (syn. *Chrysanthemum*) and rose grown during the summer of 1996 at six water salinities. The benefits of mulching on growth are more pronounced with chrysanthemum than with rose over the range of salinity treatments. There is, however, a pronounced beneficial effect of mulching at higher salinities in both species.

Growers who are thinking of using capillary bed irrigation with saline water in hot climates should analyse the effects of incorporating mulching into their production programs to assist in the reduction of salinity build-up.

ROOT-PRUNING CHEMICALS

The growth of roots through pots into the sand of capillary beds is a management problem which must be addressed for most species that are to be grown for longer

than 2 months. This problem is particularly evident with vigorous native plants with strong taproots, such as *Eucalyptus* and *Acacia* species. In our experience, fast growing herbaceous plants like petunia and lobelia will form a dense mat of roots outside the base of the pot once the plants have reached full size, which then makes them unsuitable for retail sale.

Commercial preparations of algicides based on dichlorophen have proven in commercial experience to not only control algae on the sand surface, but also to inhibit root growth in the sand. As there are no recommended rates of this chemical for root pruning uses, we incorporated treatments at four rates into two of our 4-month trials. We used Debco's liverwort and moss control preparation (450 g litre^{-1} dichlorophen). This active ingredient is also available in the formulation Kendocide® at 480 g litre^{-1}.

Rates of 5, 20, 60, and 100 ml of preparation were applied per m^2 in 2 litres of water. The lowest rates allowed rooting through of several species. There were no significant differences in shoot growth. The highest rates eliminated root penetration into the sand and there was no evidence of phytotoxicity. The effects of intermediate rates of 30 and 45 ml litre^{-1} suggest that 45 to 60 ml of preparation per 2 litres of water be used per m^2 of capillary bed for effective pruning of escaped roots over a broad range of nursery stock.

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Deciduous Ornamental Trees in Australia

Wesley J. Fleming and Liz Darmody
Fleming's Nurseries P/L, PO Box 1, Monbulk, VIC 3793

Public demand for, and therefore the importation of, deciduous ornamental trees is ever-increasing. This influx has the potential to greatly enhance our environment. As professional horticulturalists and home gardeners alike, we realise the advantages that these trees offer as landscape subjects.

There are many outstanding ornamental cultivars now available in Australia. The *Acer* (maple), *Cornus* (dogwood), *Tilia* (linden), *Lagerstroemia* (crape myrtle), and ornamental *Pyrus* (pear) are a few species which we believe have potential, but these represent only a sample of what is currently available.

Consideration must be give to a whole range of criteria before a species or cultivar is selected for planting, e.g. the existence of underground sewerage; height, colour and design of surrounding buildings; power lines and other overhead obstructions; narrow streets; soil type; drainage; and aspect. People tend to place a high emphasis on what the site looks like when a tree is first planted. They want an "instant effect". Instead we need to teach people to look ahead and imagine how it will look in the future; will the perfect specimen at planting mature into a rather large and expensive problem 10 years on? The right tree needs to be chosen for the site.

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Planting the tree is the easy part. To achieve the desired result in the long term is in fact quite complicated.

It is exciting to visit areas where careful forethought and planning have resulted in a harmonious landscape, where each tree can be appreciated on its own merits but also plays an integral part of the whole vista.

The range of ornamental trees available in Australia is continually increasing. Trees must be selected that reflect the given locality or site, they must seem to "naturally belong" by virtue of their form, texture, and colour. Trees that are aesthetically pleasing in all seasons are much sought after. A tree that is pleasing to the eye for only two to three months during autumn colour will be passed over for a cultivar which also displays lovely summer foliage and good branch structure in winter.

Colour is a very important consideration. The effect obtained by blending a combination of colours in the landscape or the use of one cultivar in a mass planting can be dramatic. Consideration also needs to be given to attributes such as tolerance to soil, and climatic conditions such as drought and heat, resistance to insect and disease attack. Consistent growth rate, good form, suitable root systems, and superior ornamental value are all criteria which should be thoroughly evaluated prior to species/cultivar selection.

Many thousands of dollars are spent each year on the purchase of trees. In Australia, street trees and their maintenance account for a considerable percentage of the public budgets. Correct tree selection from the outset would ensure significant savings by reducing pruning requirements, repairs due to invasive root systems, and replanting due to poor initial selection.

Australians appreciate beautiful trees, and they also have a keen environmental awareness. The presence of trees in our communities has a tremendous impact on improving the health of the city environment and the quality of life of its residents. Trees are invaluable in reducing noise levels, especially road noise pollution.

It is an exciting time to be involved in the Australian Horticultural Industry, with so many new plant species being introduced. We need to learn about the attributes and adaptability of any new introductions; cultural information from overseas must be used only as a guide. The performance of each new introduction must be assessed and evaluated under Australian conditions to ensure the delivery of a consistent product.

Crape Myrtle Propagation

Don Covan
Simpson Nurseries, PO Box 160, Monticello, Florida, U.S.A. 32345

Lagerstroemia indica (crape myrtle) has been a popular deciduous flowering shrub or small tree in the Southern United States since its introduction from Asia more than 150 years ago. Crape myrtle's popularity has steadily increased, but took a huge leap when Dr. Donald R. Egolf of the United States National Arboretum began releasing new hybrid cultivars. By crossing *L. fauriei* (a small tree from Japan) with *L. indica*, Dr. Egolf produced hybrid cultivars with features which truly make them "a plant for all seasons".

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Egolf's new cultivars display several wonderful characteristics throughout the year. In early spring their new leaves are often bronze or garnet tinged. In summer their blossoms are spectacular—sometimes continuing to bloom from late spring until late autumn. Their vibrant autumn foliage ranges in color from yellow to vivid oranges, and reds. As fall changes to winter the beautiful exfoliating bark can be observed, which reveals color extremes from cream to red-brown. This colouration remains vivid throughout the winter months.

Propagation of crape myrtle at Simpson Nurseries is vegetatively by softwood or hardwood cuttings. For a time we grew exclusively *L. indica*, for which only hardwood cuttings were used. Since the introduction of the new cultivars our methods have changed. In 1996 we will be propagating entirely from softwood cuttings. The move from hardwood entirely to softwood has been a gradual one, necessitated in part because the new cultivars are more difficult to propagate from hardwood and require large stock plants.

PRACTICES AND PROCEDURES

Softwood. When using the softwood method of propagation the cuttings can be taken from late May through to Sept., which is late spring through summer in Monticello, Florida (Lat. 30° 31'; Long. 83° 52'). Long shoots of the new seasons growth are taken each morning between 7 and 10 AM. The shoots are placed in a heavily shaded, wind-protected mist area. As the shoots are needed for propagation they are dipped into a 5000 ppm chlorine solution. The very soft tip of the shoot is cut off and discarded, while the remaining shoot is cut into 5- to 8-cm (2- to 3-in.) cuttings. For convenience the leaves are stripped off of the lower 2.5 cm (1 in.) of the cuttings.

The cuttings are held together in a bundle while the bottom 2.5 cm (1 in.) is quick dipped in K-IBA (potassium salt of IBA) at 3000 ppm. The bundles are placed in trays. When the tray is full the cuttings are taken to the mist area where they are stuck in flats filled with peat pots containing our own propagation mix. Our mix consists of pinebark, Canadian peat moss, 6 B Gravel, and perlite (6 : 1 : 1.5 : 1.5, by volume). Incorporated into each cubic metre of mix is 3.55 kg of 18-6-12 Osmocote® and 0.59 kg of Micromax®.

The mist system is in operation while the cuttings are being stuck. The cuttings are very soft and should not be stressed. We use a mist nozzle called a Parasol nozzle, made by Spray Systems, operated at 552 to 621 kPa (80 to 90 P.S.I.). This system is set to run every 4 min for 4 to 5 sec. The interval and duration are adjusted depending upon weather conditions and the elapsed time since first sticking the cuttings.

Root initiation can begin as early as 7 days, although overall it is normally between 10 to 14 days. The plugs are usually ready to plant in 4 to 6 weeks depending upon the cultivar.

Hardwood. Propagating crape myrtle from hardwood cuttings is very different from softwood. At Simpson Nurseries we usually take dormant hardwood cuttings in late Dec. and early Jan. The previous years growth of 1.2 to 1.8 m (4 to 6 ft.) is cut off the stock plants and piled in bundles. The bundles are taken to the propagation building where they are stripped of any side branches. Small bundles of the long shoots are then cut into 13-cm (5-in.) long cuttings using a table saw. These sticks

are then placed into boxes until they can be tied into bundles of approximately 100 sticks. The tops of bundles are painted with spray paint to indicate the color of the flowers and which way is up.

The bundles are then placed in fumigated cypress sawdust and covered with approximately 10 cm (4-in.) of saw dust. The bundles are kept warm and moist through winter until 1 April. The cuttings are then stuck in raised fumigated ground beds. As a reference, our last frost is usually 15 April. The cuttings are rooted and grown in the raised beds until the first winter when they are dug. The plants will be multi-trunked and range in size from 30 to 120 cm (1 to 4 ft.). At this stage they are ready to either sell as a bare-rooted plant or be potted on to grow to a larger size.

Propagating Herbaceous Perennial Liners and Plugs

David J. Beattie
Department of Horticulture, The Pennsylvania State University, University Park, Pennsylvania, U.S.A. 16802

INTRODUCTION

Herbaceous perennials or most often just called perennials are frequently planted in private and public gardens, and in the promotional gardens of landscape designers or growers. Perennials provide a unifying design influence between woody plants and annuals. They are even being used to beautify highway rest stops; I recently saw thousands of *Hemerocallis* 'Stella de Oro', the most popular daylily in the U.S.A., planted at a truck stop in Virginia.

In the past, perennials were often field-grown, dug, and sold directly to the consumer. Although field production of perennials continues to expand, container production has increased dramatically. Containerized plants are more marketable. In addition, this production method allows considerable mechanization, facilitates shipping, and circumvents several transplanting problems. Containerization has also resulted in a marked increase in the propagation of smaller plant sizes—liners and plugs—which can be easily produced by specialty propagators and shipped great distances.

Larger perennial nurseries in the U.S.A. routinely propagate and grow more taxa than woody nurseries or bedding plant growers. For example, there are nearly 40,000 registered cultivars of *Hemerocallis*. Some nurseries may carry several hundred cultivars and large specialty growers may grow several thousand.

The method used to propagate a particular perennial depends on the species, the propagation equipment available, and the time-of-the-year. For instance, tissue culture has been a particularly effective method to control disease and to quickly introduce new cultivars, but requires sterile lab facilities and special techniques. Although laboratory propagation can be done any time of the year, not all perennials can be propagated by this technique. In another example, the only effective time to propagate *Paeonia* is by division during the late summer and early fall. Finally, the use of mechanized methods and controlled germination environments has been most frequently used for seed propagation, but not all perennial cultivars taxa can be seed propagated. What this means for the perennial propagator is that they must

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be aware of many propagation methods and how they apply to a plethora of taxa.

PROPAGATION METHODS

Seed Propagation. Several perennials can be directly sown in the field, a method that is simple and requires little equipment. However, most perennials require the protected environment of germination rooms and greenhouses to achieve maximum plant numbers in the shortest time. Using modern seeders and seed pre-treatment methods are the same procedures used by bedding plant growers; however, the lack of consistently high quality seed, or seed that germinates uniformly without pre-treatment continues to be a problem for the perennial propagator. For instance, *Adonis* and *Gentian* seed are both short lived; legumes like *Lupinus* and *Baptisia* require scarification; *Cimicifuga* and *Acteae* require warm pre-treatment followed by stratification, but still germinate erratically; and *Helleborus* seed must be fresh-sown for speedy germination. Seeds like the annual impatiens that are routinely pregerminated or coated for seeder efficiency are mostly unavailable to perennial growers.

While seed may be the easiest, or even the only way to propagate, it is sometimes misused. For example, *Astilbe chinensis* 'Pumila' can be readily propagated by seed. However, the resulting plants are very heterozygous and mostly unlike the cultivar. Unfortunately, some nurserymen purchase on the basis of price and seed propagated *Astilbe chinensis* 'Pumila' are usually substantially cheaper. If you wish to have the uniformly short cultivar, then you must purchase asexually propagated plants. Another seed-propagated perennial is the lovely, bronze-leafed *Heuchera* 'Palace Purple.' Given cultivar designation, this *Heuchera* was originally asexually propagated. However, growers found that it readily propagated by seed, and it is less expensive to do so. However, the leaf color of seedlings varies from bright green to deep, shiny bronze, requiring that large numbers of seedlings should be discarded. Recently though, I have seen some very uniform seedling populations, indicating that, with care, seed propagation is possible. Further, from seedling populations of 'Palace Purple' several excellent new cultivars have been introduced, including 'Molly Bush' and 'Bressingham Bronze.' However, to maintain their cultivar identity these cultivars must now be asexually propagated. Harlan Hamerick presented an informative paper on how to treat stock plants with GA_3 in order to increase *Heuchera* cutting production. This paper will appear in volume 45 of the Combined Proceedings.

Cutting Propagation. Industry-wide, the majority of perennials are propagated asexually. Compared to woody plants, cuttings are generally easier to root and require little hormone treatment. Many propagators prefer to use polytents or to cover newly stuck cuttings with light weight fabrics rather than use intermittent mist. Fog generation, long used in Europe, is also becoming popular.

One of the most important considerations to propagating perennials is timing the harvesting of cuttings in relation to flowering. Often the rapid spring growth and flowering leaves little time to harvest cuttings before flowering slows rooting. The window of cutting opportunity can be extended for plants like *Coreopsis* and *Veronica* by shearing stock plants after the first cuttings are harvested to produce a new flush of growth. Several plants like *Artemisia* and *Perovskia* root poorly when greenhouse temperatures rise in the late spring. If greenhouse space is available,

bringing stock plants in and placing them under HID light with an extended day length will produce numerous cuttings. Several growers root *Scabiosa* 'Butterfly Blue' for more than six months each year by using this technique. New cuttings are harvested at 10-day to 2-week intervals and direct stock in 72- or 48-cell plug trays.

Another way to increase cutting production is to combine techniques. For instance, the Perennial Plant Association has chosen *Salvia* 'Mainacht' ('May Night') as the 1997 Perennial Plant of the Year. Past experience has suggested that demand for this plant will increase by 50% to 100%, so many propagators are concerned about availability. A 60 : 1 or greater plant increase can likely be achieved by purchasing field-grown transplants and removing and rooting the shortened shoots, sometimes called basal cuttings. These will root readily, then tip cuttings can be harvested from each rooted basal cutting. I recently did this and separated 30 to 40 cuttings from each field grown plant. Conceivably, successive cutting harvests will increase propagule numbers many times.

Root Cuttings. Root cuttings are an important propagation method for several plants, especially members of Acanthaceae, Boraginaceae, for several composites, and *Papaver orientale*. Fleshy root segments, 2 to 3-cm-long, are prepared in mid-to-late fall and placed in trays in the basipetal position. They can be placed in groups of 10- to 20-root pieces in clean cell trays. These trays are maintain at a high humidity by covering with polyethylene or by placing in a grafting case and keep at a temperature at 18 to 20C. Under these conditions adventitious shoots emerge, usually at the top of the root piece. When the shoots are 5 to 10 mm in length, they are removed and planted either in small pots or in cell trays. Planting depth is important and the base of the shoot must be below the medium surface to encourage new adventitious roots.

Division. One of the easiest ways to propagate perennials is by division. Usually no protected environments or special equipment is needed. This is how we propagate *Astilbe* and *Epimedium* at our nursery. Although we purchase some field grown divisions from Europe, we ensure cultivar correctness by dividing our own plants, producing large liners in 7.5-cm pots. Although both genera can be divided at almost any time from early spring to late summer, early spring division is usually best. The medium is shaken from the root system and the crown is pulled apart so that at least 1 bud is visible for each division. Increase rates vary depending on the particular taxon. *Astilbe* may produce 5 to 15 propagules while *Epimedium* usually produce fewer. To even out production, we continue to divide into late summer, but prefer not to continue past 1 Sept. unless propagules are placed in a heated greenhouse. Propagating before this date allows sufficient time for root re-establishment. A well-established root system is required so that under the decreasing temperature and day length conditions of the fall that plants will rapidly increase crown size and bud number for rapid growth the following spring.

Other popular perennials that are propagated mostly by division are *Iris*, *Hemerocallis*, and *Hosta*. The size of bearded *Iris* divisions usually preclude establishing liners in pots smaller than 10 cm. *Iris* can be divided in the early spring before shoots are more than 2 to 3 cm long, but most commercial propagation is done in mid-summer after they have bloomed. *Hemerocallis* is also done mostly in mid-summer. However, some fans, especially tetraploids, are so large that the only practical way to re-establish them is either in the field or in 15-cm containers. *Hosta* crown size

varies from miniature size plants like 'Ginko Craig' and 'Golden Tiara' that can easily be established in 7.5-cm pots, to very large eyed plants like 'Frances Williams' that is best replanted in pots larger than 10 cm. However, we have found that some cultivars seem to increase eye production when their root systems are restricted in smaller pots. *Hosta* is one of the easiest perennials to divide at almost any time during the growing season. Again, when divided after leaves are fully expanded, reduce leaf area, and shade.

Tricyrtis, an increasingly popular shade-tolerant perennial, has an interesting way of propagating itself in our climate. The crown of potted plants will usually winter kill leaving uninjured roots. Shoots will then form on these roots and begin growth. Separating new shoots from the medium in the spring may yield 50 or more new plants from a 10-cm pot.

Tissue Culture. Some propagators chose tissue culture to rapidly increase new varieties or to reduce disease incidence. Although *Hemerocallis* and *Hosta* have been widely propagated from tissue culture, some caution must be exercised. Some cultivars are very uniform, but others may be very variable. Many types of *Hemerocallis* 'Stella de Oro' are now in the trade because they have originated from tissue culture. Variegated hostas are even more of a problem. *Hosta* 'Patriot' is a relatively new and popular sport of 'Francee' that was introduced by John Machem, a long-time I.P.P.S. member. Some less reliable tissue-culture labs have shipped many 'Patriot' propagules that have not been rogued properly to unsuspecting U.S.A. nurseries. The best way to avoid this problem is to purchase propagules from reputable labs and to know what the cultivar should look like.

Although sales of perennials are booming, knowledge about propagation methods is just beginning to become general knowledge. This is due, in part, to the large number of taxa involved, but also to some proprietary knowledge which is now being shared. As methods and knowledge about perennial propagation become more available, even more of these popular plants will become available to the general public rather than residing in botanical gardens or in the gardens of the gardening elite.

Cultivar Integrity in Australian Tree Production

James Will
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In Australian tree production, many of the issues concerned with producing high-quality trees have been addressed. Root system research has lead to the production of trees that successfully establish post-transplanting. Also, tree cultivars of non-Australian origin are quickly imported by the major propagating companies, and are made available to the market for testing and sales, once quarantine requirements are met. This leaves three areas of deficiency in Australian tree production:

1) Formative pruning and the development of tree canopies to best suit the end use.

2) Trialing of taxa to ascertain their suitability for differing Australian landscape situations.

varies from miniature size plants like 'Ginko Craig' and 'Golden Tiara' that can easily be established in 7.5-cm pots, to very large eyed plants like 'Frances Williams' that is best replanted in pots larger than 10 cm. However, we have found that some cultivars seem to increase eye production when their root systems are restricted in smaller pots. *Hosta* is one of the easiest perennials to divide at almost any time during the growing season. Again, when divided after leaves are fully expanded, reduce leaf area, and shade.

Tricyrtis, an increasingly popular shade-tolerant perennial, has an interesting way of propagating itself in our climate. The crown of potted plants will usually winter kill leaving uninjured roots. Shoots will then form on these roots and begin growth. Separating new shoots from the medium in the spring may yield 50 or more new plants from a 10-cm pot.

Tissue Culture. Some propagators chose tissue culture to rapidly increase new varieties or to reduce disease incidence. Although *Hemerocallis* and *Hosta* have been widely propagated from tissue culture, some caution must be exercised. Some cultivars are very uniform, but others may be very variable. Many types of *Hemerocallis* 'Stella de Oro' are now in the trade because they have originated from tissue culture. Variegated hostas are even more of a problem. *Hosta* 'Patriot' is a relatively new and popular sport of 'Francee' that was introduced by John Machem, a long-time I.P.P.S. member. Some less reliable tissue-culture labs have shipped many 'Patriot' propagules that have not been rogued properly to unsuspecting U.S.A. nurseries. The best way to avoid this problem is to purchase propagules from reputable labs and to know what the cultivar should look like.

Although sales of perennials are booming, knowledge about propagation methods is just beginning to become general knowledge. This is due, in part, to the large number of taxa involved, but also to some proprietary knowledge which is now being shared. As methods and knowledge about perennial propagation become more available, even more of these popular plants will become available to the general public rather than residing in botanical gardens or in the gardens of the gardening elite.

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1) Formative pruning and the development of tree canopies to best suit the end use.

2) Trialing of taxa to ascertain their suitability for differing Australian landscape situations.

3) Making certain that the cultivars we are using are the cultivar they purport to be.

With trees, it is especially important that horticulturists plant known cultivars. Estimates indicate that street trees require expenditure of approximately $10,000 over an amenity life of 25 years (pers. comm, G.M. Moore, May 1996). This expenditure can be decreased greatly if the trees planted have functional qualities that will require less pruning, dead-wooding, and line clearance work over their lives. Some of these issues can be solved by appropriate formative pruning, but most of this expenditure can be decreased by planting selections known to have ideal form with little dead wood. Fruit drop in street trees also requires money inputs in removal; planting non-fruiting selections can eliminate these costs.

The use of sub-optimal cultivars can be readily shown. *Gleditsia triacanthos* 'Shademaster' is known to be a non-fruiting form of the honey locust that has improved form. Trees planted in Camberwell Victoria as 'Shademaster' bear fruit annually. Trees planted throughout southeastern Australia as *Pyrus ussuriensis* have been shown to be a poorly formed type of *P. calleryana*. Planting trees of mistaken identity will add to their cost: with the *Gleditsia* there are unsightly fruit to remove; the poorly formed *Pyrus* will need to be removed before they split.

These mistakes show that Australian horticulturists should be planting asexually propagated trees where the propagation material is taken only from superior (or elite) stockplants showing selected characteristics. To most horticulturists, this means that they should be planting cultivars. Unfortunately, "cultivar" can mean almost anything: "..a horticultural variety or race that has originated and persisted under cultivation..." (Bailey and Bailey, 1976). Since this term is so ambiguous, tree growers should know that the stock they grow goes beyond being a cultivar, and is asexually propagated from a known stockplant. These selections are best be known as "clones".

There are a number of reasons why appropriate clonal material has not been used. The horticultural community intends to use clonal material, but frequently this does not happen. Many times, the errors occur because:

- The importation process for tree cultivars is problematic. Shipping plants to Australia is a low priority to many international growers, and, if Plant Breeders Rights cannot be granted on these plants, it is of little financial value to the exporting nursery. A lack of care occasionally occurs with exporting nurseries. Later, these plants are kept in quarantine facilities for many months, or for many years, and labels can easily be lost or switched. Finally, budded plants can die back to their bud unions after methyl bromide treatment; this can lead to the understock being propagated as the selected cultivar.
- Incorrect names can often be used. We believe that one of the problems with the ornamental pear species in Australia arises since both *P. calleryana* and *P. ussuriensis* are frequently given the common name of "Manchurian pear". This can lead to translational errors and using the wrong name for the wrong plant.
- Understock material is sometimes used as propagation material instead of the clone budded. When budding is the accepted propagation method, this can lead to significant spread of an erroneous selection.

- Anecdotal information indicates that trees looking similar to a clonal cultivar are sold under the clonal name by some growers. Appearance of plants is not a sufficient basis to use the clonal name; physiological/functional differences are not obvious and the plant may perform quite differently from the clone it resembles.

Identifying the trees to clonal level can be extremely difficult. In assessing the putative *Pyrus ussuriensis*, using morphologic characteristics was adequate to prove that they were *P. calleryana* of unknown origin (Kellow and Will, 1995). Analysing individual clones to test for differences is normally more difficult and most often is successful using chemotaxonomic techniques.

There are three general classes of chemotaxonomic techniques that are of significant use to the tree grower to verify the clonal identity of a named plant; isozyme analysis, restriction-fragment-length-polymorphism analysis, and techniques that use polymerase chain-reaction technology. All of these techniques analyse the genetic constituents of the plant in some ways. Although great advances using PCR and RFLP mapping have been made in identifying plant clones (see the work of Thomas et al., 1994, identifying grapevines at The University of Adelaide), isozyme analysis should be considered the most suitable method for clonal identification. This recommendation is given because:

1) There is published reference to hundreds of genera in which this technique has been used successfully.
2) It requires moderately inexpensive laboratory equipment and chemicals. A well-organised laboratory can be established for approximately $20,000.
3) The technique can be used quickly, and results can be obtained within hours.

ISOZYME ELECTROPHORESIS TECHNIQUES FOR CLONAL IDENTIFICATION

Isozyme electrophoresis techniques have been used for over 20 years. Initial use was restricted to basic biological medical sciences, but the technique is now widely used in routine plant analysis. Isozyme analysis is based on the movement of proteins in a size-restricted matrix under voltage, then stained to show a specific protein type. Biologically, the system works for identification of individuals, since each individual produces proteins that are slightly different from each other and are therefore unique. Once these unique proteins are extracted from an individual, exposed to electrical charge within a size-restricted matrix, and are stained to become visible, they can be compared with other differing or similar individuals. Isozyme analysis produces a protein "fingerprint" of an individual that will remain constant given unchanging techniques of assessment.

Isozyme analysis is not a new technique, and has been used to "fingerprint" many plant clones. In the I.P.P.S., the first discussion of this technique occurred in 1985, with a paper discussing the identification of apple clones (Larsen et al., 1985). Isozyme analysis has been used to describe plant clones ranging from raspberries (Cousineau and Donnelly, 1992) to turf grasses (Vermeulen et al., 1991). Tree growers should find papers on *Acer rubrum* clones (Tobolski and Kemery, 1992) and *Taxus* clones (Greer et al., 1993) of special interest.

In work done at Burnley College identifying the *Corylus avellana* clones currently grown in Australia, we have further developed the isozyme technique to make it quicker and easier without losing any quality of results. In improving the work of Ahamad et al. (1987), we have developed an isozyme electrophoresis system that

can distinguish more than 35 clones. This system uses a minimum of tissue, approximately 50 mg is harvested from 2-year-old stem material. This stem material need be only about 1 cm in length, and it can be analysed during any season. Using a relatively simple extraction buffer, we have obtained zymograms (patterns on polyacrylamide gels that are the "fingerprints") showing 3 or 4 regions of variability using a peroxidase staining system.

This simplified method allows for extremely rapid screening of plants to assess clonal identity. It takes approximately 4 h total time, with 3 h of labour to analyse 40 samples. Further, we have found that the method is suitable for other crops and other staining systems (e.g. *Guichenotia* spp. using aryl esterase stains). Because this technique is efficient, it should bring costs of isozyme studies to a level at which tree growers can afford to use them. A detailed description of the technique will be available later in 1996 (Griffiths and Will).

Isozyme electrophoresis techniques are not perfect. Proteins for cultivar analysis must be selected carefully to eliminate the possibility of artifacts appearing because of plant vigour/health, tissue age, and time of year. Further, some enzyme stains may not be suitable as they may not show variable (polymorphic) forms of protein, thus making the individuals apparently identical. Finally, isozyme electrophoresis techniques can have limited application, as they are protein fingerprints, not exact maps of DNA or other genetic material. For this reason, isozyme analysis without further protein purification cannot link a specific trait possessed by the plant with a specific protein (Chen, 1991). If these possible problems are avoided, isozyme electrophoresis techniques are still valid for quick and cost-effective clonal identification.

CONCLUSION

Tree growers should be using chemotaxonomic methods, possibly including isozyme electrophoresis techniques, to guarantee the use of clonal stock. As plant quality continues to improve, correctly identifying the tree cultivar to clonal level will become more important. Isozyme electrophoresis is a valid technique for clonal tree identification that is accurate, of reasonable cost, and can be done quickly without the use of large amounts of plant tissue.

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Propagation of Wilga, *Geijera parviflora*

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Successful propagation of *Geijera parviflora* from seed and juvenile cuttings was achieved. Seed dormancy was overcome by removing the hard seed coat (testa). Both naked embryos and embryos with endosperm intact, germinated readily at 20C with a 12 h photoperiod. No seed with any part of the testa intact germinated. Naked embryos placed on crushed testa failed to germinate, indicating a chemical inhibition. Cuttings harvested from nodes 1 to 12 showed reduced rooting potential at higher nodes, with 100% strike at nodes 1 and 2 to 0% strike at node 12. Cuttings from branches between nodes 1 to 12 also showed reduced rooting potential to those from the main stem. Hypocotyl cuttings formed roots within 20 days. Hypocotyl cuttings treated with IBA 500 ppm, had a greater total root length than cuttings with no treatment. Semi-hardwood cuttings harvested from mature trees in late autumn were unsuccessful.

INTRODUCTION

Geijera parviflora (Lindley), is a small tree in the Rutaceae family commonly known as wilga in Australia, and Australian willow in the U.S.A. The species is typically found in arid shrubland and woodland communities of eastern Australia (Allen, 1992; Harden, 1991), and is classified as endangered in Victoria (Allen, 1992). This species has a low water requirement which may prove it suitable for use as a street tree (Meakin-Poor, 1984). In the past, Wilga has been used as a fodder supplement in periods of drought (Cunningham et al., 1992). While recognised as having potential application in both horticultural and agricultural situations (Costermans, 1983; Cremer, 1990; Elliot and Jones, 1986), *G. parviflora* has a seed dormancy which restricts its use (Allen, 1992). Preliminary trials indicated that germination is possible, but that it is typically slow and erratic with a low percentage success. Coumarin, a known germination inhibitor found in the embryo coverings of many seeds (Bewley and Black, 1994), is reported to be present in the leaves (Lahey and McLeod, 1967) and fruits (Dreyer and Lee, 1971; Chen and Joullie, 1984) of *G. parviflora*. It may be that a period of leaching is required to remove inhibitors from the seed. This would be consistent with observations of germination in the species natural habitat where prolific germination has occurred following high summer rainfall with follow-up autumn rains (Allen, 1992). Propagation by cuttings is also reported to be difficult (Wrigley and Fagg, 1988).

The aims of this research were to develop methods of propagation for *G. parviflora* through: (1) Developing a technique to overcome or remove the reported seed dormancy and; (2) Asexual propagation by cuttings.

EXPERIMENTAL PROCESS, RESULTS AND DISCUSSION

Part 1—Seed Propagation.

Stage 1: Preliminary Germination Trials and Viability Tests. A technique for embryo extraction was developed. This involved removal of the testa by fracturing it with controlled pressure. Each seed was placed in a micrometer, which allowed pressure to be applied gradually. Once fractured, the testa fell away from the embryo and endosperm. The endosperm was then removed by making an incision at the point of attachment (Fig. 1), and then soaking in deionised water. At this stage some embryos "floated out". If embryos did not float out, gentle pressure was applied with the finger tip to the radicle end of the embryo (opposite end to location of cut), forcing the embryo out of the endosperm. Naked embryos germinated readily on moist filter paper in a lit cabinet (12-h photoperiod) at 20C.

Stage 2: Nicking and Leaching Trials. The aim of this stage was to determine the effects of nicking and leaching, and combinations of both, on germination. Leaching treatments aimed to remove germination inhibitors from the embryo coverings. Seeds were held in a micrometer and using a small engraving tool, an incision was made in the testa at either the radicle or cotyledon end (Fig. 1). Several treatments involved complete removal of the testa, but left the endosperm intact. Leaching was achieved by placing seeds in gauze material which were then placed in water with constant oxygenation. Water was replaced weekly. No seed with any part of the testa intact germinated, but a large percentage of seeds with testa completely removed did (Table 1). This indicated that the dormancy is imposed by the testa and not the endosperm. Leaching treatments did not appear to have any significant effect on germination.

Table 1. Germination in nicking and leaching trials.

Treatment	Percentage germination
2-week leaching period, nicked at the cotyledon end.	0
2-week leaching period, nicked at the radicle end.	0
2-week leaching period, no nick.	0
2-week leaching period, testa removed, endosperm intact.	50
1-week leaching period, nicked at the cotyledon end.	0
1-week leaching period, nicked at the radicle end.	0
1-week leaching period, no nick.	0
1-week leaching period, testa removed, endosperm intact.	30
1-day (19 h) leaching period, nicked at the cotyledon end.	0
1-day (19 h) leaching period, nicked at the radicle end.	0
1-day (19 h) leaching period, no nick.	0
1-day (19 h) leaching period, testa removed, endosperm intact.	45
No Treatment.	0
Nicked at cotyledon end, no leaching.	0
Nicked at radicle end, no leaching.	0
Testa removed, endosperm intact, no leaching.	60
Testa removed, incision made at point of attachment on endosperm, no leaching.	27

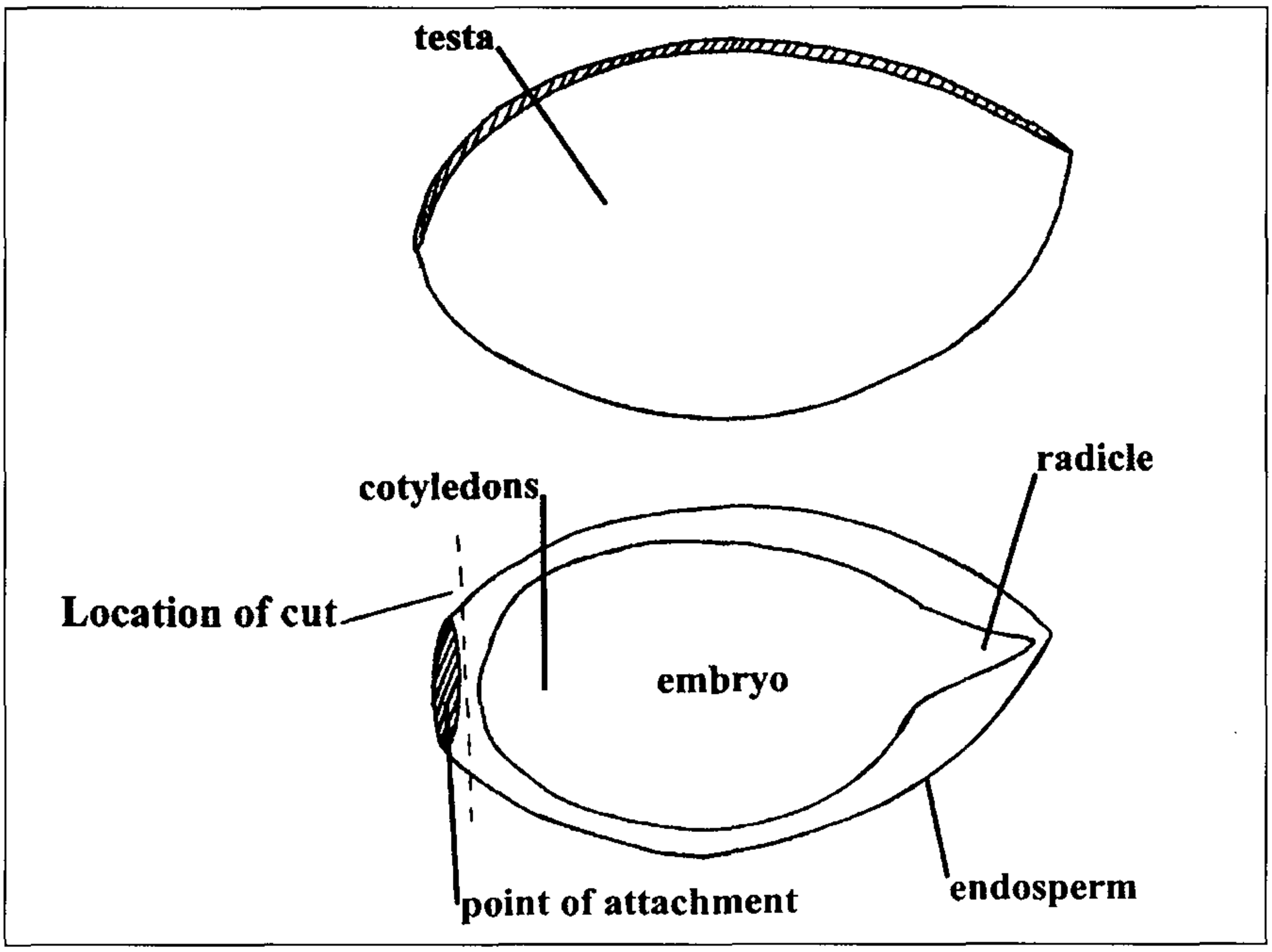

Figure 1. Seed morphology of *Geijera parviflora.*

Stage 3: Seedling Production. Seedling numbers were built up to provide a source of cutting material for use in Stage 6.

Stage 4: Investigation into the Possible Inhibitory Effects of the Testa on Germination. This trial aimed to determine whether the apparent dormancy imposed by the testa is due to chemicals contained within it, or due simply to the physical restriction of the hard coat (or a combination of both). Naked embryos were placed on crushed testa and crushed endosperm. Embryos with endosperm intact were placed on crushed testa only. Naked embryos on crushed testa failed to germinate, indicating a chemical inhibition. Naked embryos placed on crushed endosperm germinated, but radicle extension was small when compared with embryos that had endosperm left intact. This could be due to the importance of the endosperm as a food reserve for the germinating embryo.

PART 2—ASEXUAL PROPAGATION

Stage 5: Mature Growth Cutting Trials. Cuttings using mature growth harvested in late autumn and placed in a fog house with bottom heat, were unsuccessful. Within 2 weeks, cuttings in all treatments had desiccated.

Stage 6: Juvenile Cutting Trials.

Hypocotyl cuttings. During Stage 3, seedling numbers were built up to provide a source of juvenile cutting material. Forty seedlings were harvested using a sharp knife at the surface of the media. Four treatments were used with 10 cuttings in each. These were; IBA 500 ppm for 5 sec, IBA 500 ppm for 1 min, methylated spirits

for 5 sec, and no treatment. All but one cutting formed roots. Total root length was greater in cuttings treated with IBA 500 ppm than other treatments, indicating earlier root initiation and therefore a response to applied IBA (Fig. 2).

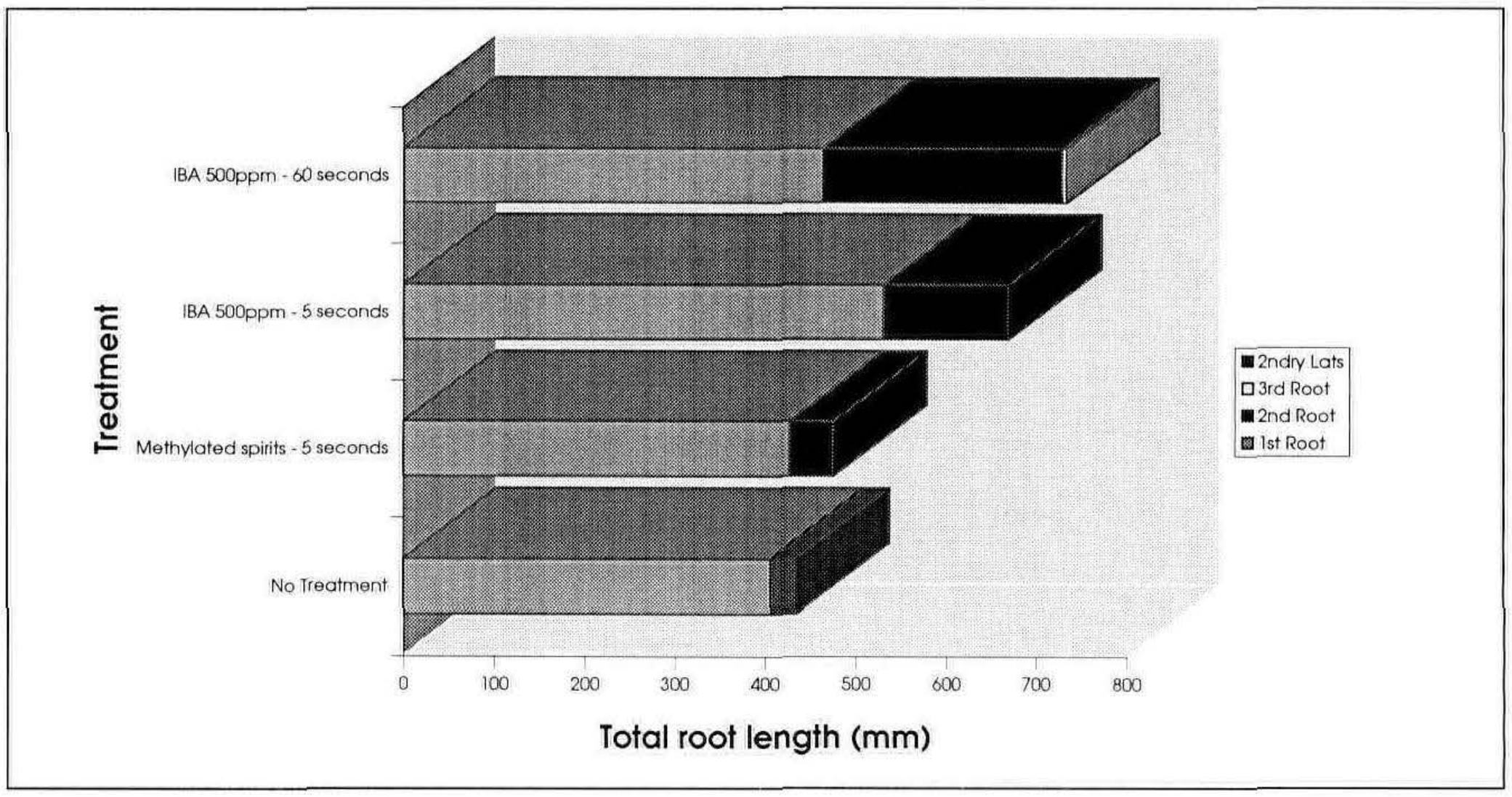

Figure 2. Total root length (mm) of hypocotyl cuttings.

Relationship between node height and relative rooting potential. Young plants grown on from trials in Stage 1 were used as a source of cutting material. Due to the low numbers of seedlings and variation between seedlings, treatments had very low numbers of replicates. Although the trend is for reduced rooting potential with higher nodes (Fig. 3), insufficient replication make these results inconclusive.

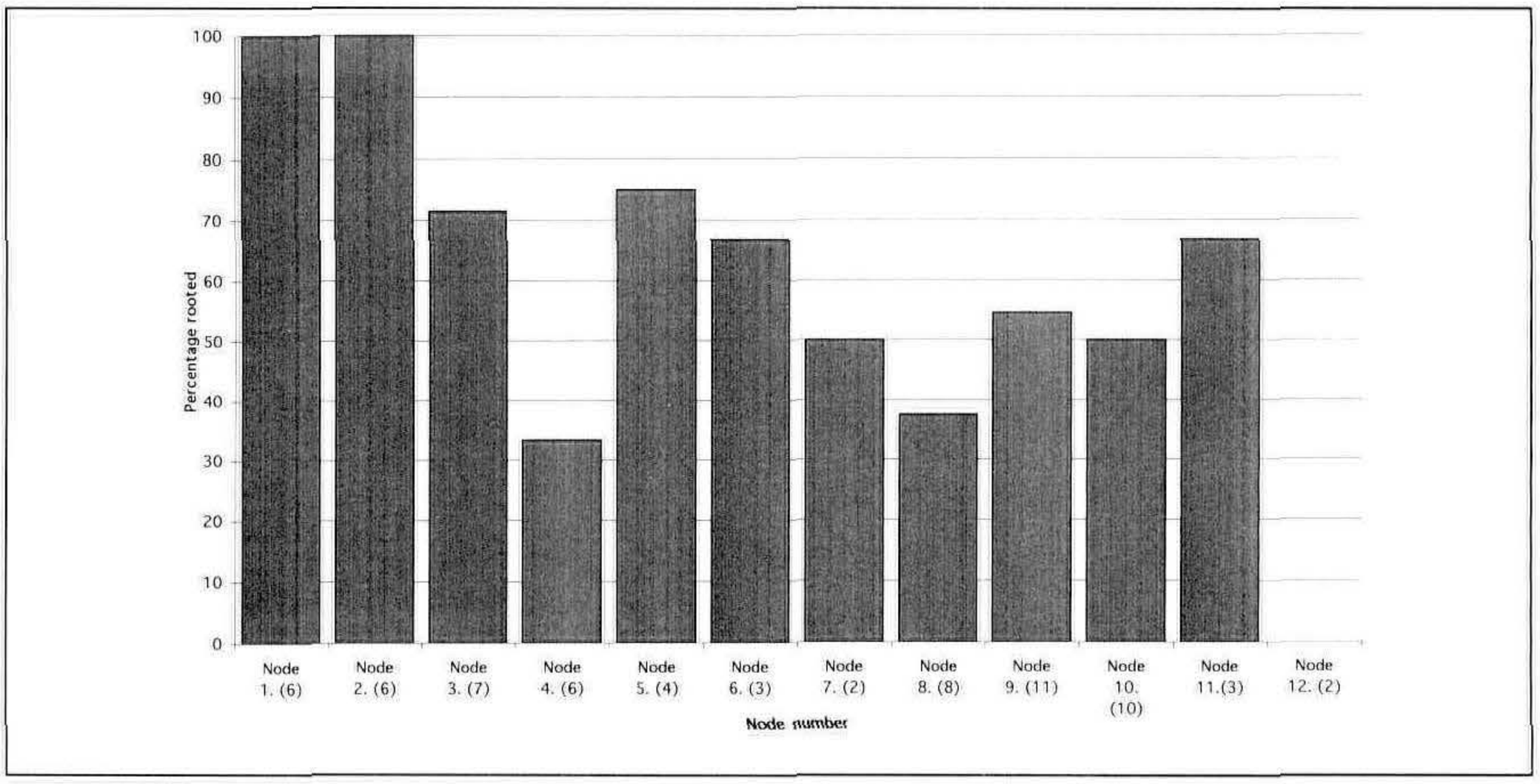

Figure 3. Percentages of juvenile cuttings to form roots in relation to node number. The number in brackets ( ) represents number of cuttings.

CONCLUSION

Trials have demonstrated that propagation of *G. parviflora* by seed is possible, and that the techniques involved, i.e. testa removal, while initially slow, are viable in a production nursery situation.

The mechanism for dormancy appears to be located in the testa, and is likely to be due in part to a chemical inhibition. Although leaching treatments trialed were unsuccessful in removing the inhibitor, longer leaching periods should be trialed.

While the trend in vegetative propagation trials was reduced rooting potential with increasing node number, low numbers of replicates make these findings inconclusive. Success achieved in juvenile cutting trials demonstrate that asexual propagation is possible and the species may be suited to micropropagation techniques where rapid propagation of large numbers is desired. Clonal propagation of mature trees, for desired form or other characteristics, warrants further research.

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Marketing Australian Plants Internationally

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WHO ARE KOALA BLOOMS?

Koala Blooms is an Australian-owned company which markets Australian plants internationally. Koala Blooms was formed in 1989 as a result of marketing research undertaken in Europe and U S.A

The following aspects highlighted the need for Koala Blooms to be formed·

1) Demand existed worldwide for plants new to the horticultural industry

2) Australian plants had proved successful in overseas markets but foreign companies were involved, with little or no return for the Australian horticultural industry

3) There was no Australian company to develop and market Australian plants as export products.

4) The international image of Australia was positive and advantageous in marketing Australian plants.

5) There was not much cultural knowledge on Australian plants as propagation and growing protocols were not provided.

Koala Blooms was set up to provide a structure enabling Australian plants to be marketed in international markets by Australians, with benefits flowing back to the Australian horticultural industry We work jointly with breeders, nurseries, Australian plant enthusiasts and are in the process of having discussions with various university research departments.

MARKETING STRATEGY OF KOALA BLOOMS

Koala Blooms has a marketing philosophy of maintaining control of plant products via brand names and patents which inherently identify plants as of Australian origin. The brand names are *Koala Blooms* and *Outback Plants* This is a novel concept for the nursery industry overseas and has met with intrigue, interest, and enthusiasm in the U S.A. It is paramount for ultimate control of a plant's position in the marketplace and the protection of benefits returning to Australia.

Successful plants selected by Koala Blooms are protected (if eligible) by Koala Blooms on behalf of the breeder/introducer under Plant Breeders Rights or similar legislation overseas

TYPES OF PLANTS MARKETED

There are two distinct programmes:

- Herbaceous plants.
- Woody plants.

These two groupings have distinctive nursery production times Herbaceous plants are ready for sale within 8 to 16 weeks from potting-on as liners or tubestock. Woody stock production time is extended—varies from around 25 weeks to 18 months

Koala Blooms herbaceous selections include *Anigozanthos, Brachycome, Bracteantha, Chrysocephalum, Rhodanthe, Scaevola, Viola*, and strange as it may

seem, *Pandorea* which fits into this category. The woody group includes *Astartea, Bauera, Beaufortia, Callistemon, Calytrix, Chamelaucium, Chorizema, Dampiera, Derwentia, Hardenbergia, Kunzea, Lechenaultia, Leucophyta, Leptospermum, Olearia, Pimelea, Prostanthera, Syzygium, Telopea, Thryptomene*, and *Westringia*.

KOALA BLOOMS AUSTRALIAN OPERATIONS

We are always seeking new plants from breeders, growers, and enthusiasts for introduction into our programmes, but we have strict criteria to enable them to reach the stage of being marketed overseas.

Plant Selection Criteria. The product attributes should be aimed at marketable features.

- Uniqueness—needs to be different, but if too different nurseries are often reticent to grow it.
- Size—must be fitted into a nursery production program to get marketed. In the U.S.A. 1-gal size dominates the market but 4- and 6-inch pots as well as flats are now more common.
- Appearance of the plant in a pot is paramount.
- Degree of flower production and flower size—big is not necessarily best!
- Flowering period longevity. Many Australian plants in the herbaceous program flower for an extremely long period which has impressed many overseas growers.
- Plant longevity. This covers transportability and presentation at garden centres. Consumers have different perceptions on longevity. For Chicago 2 to 4 months is usually adequate, as outdoor plants are bought for spring and summer display, whereas in California gardeners expect 2 to 5 years or more.

Nursery Propagation and Growing Trials. We thoroughly monitor response to nursery production in the areas of propagation and growing as container plants in a range of different trials.

Garden Cultivation Trials. Ease of growing in gardens. Response to varied conditions and locations is examined over 1 to 2 years or more. Often the introducer has also trialed the plants for an extensive period.

EXPORT

Ease of Preparation for Shipment Overseas. Rooted cuttings or seedlings usually must be transported bare-rooted. Some plants are very easy to prepare, such as *Brachycome*, whereas *Bracteantha* and some of the woody species or selections are more time consuming. Some plants are damaged more easily than others when preparing them for shipping.

Reaction to Exportation. Often soft-foliaged plants or those with brittle roots can suffer. Tissue-culture material poses the least problems, as long as they can be kept in an upright position while in transit! We have had some very expensive disasters involving shipping from Australia and now personally escort mother-stock as certified cabin hand-luggage. This has overcome many of the problems in

transportation. During inspection procedures by overseas Agricultural Departments we are always in attendance in case any emergency issues arise.

KOALA BLOOMS OPERATIONS IN THE U.S.A.

Propagation and Growing Trials. These are initially undertaken at our head propagator's nursery in California. When plants are distributed to our other licensed propagators they also undertake trials. Detailed propagation and growing protocols prepared by Koala Blooms are provided for all plant introductions into the U.S.A. Regular visits are made to our head propagator and other licensed nurseries by Koala Blooms Australian staff.

The results of these trials indicate which plants are to be marketed in the U.S.A. and into which marketing program they are to be placed.

Quality control of propagation stock is of paramount importance. Whenever possible propagation stock is regularly renewed through tissue culture and also virus-testing procedures are undertaken.

Koala Blooms Program. This brand is directed to independent garden centres and is based on licensed growers, who are fully trained to grow our plants correctly. It represents over 135 plant cultivars now firmly established in the U.S.A.

- Licensed propagators undertake production for sale of liners or plugs to licensed growers or in some cases the growers are also the propagators of selected plants.
- There is a limited number of selected licensed growers who then sell finished stock to licensed garden centres.

Outback Plants Program. This brand is directed to mass merchants and is based on exposure and availability to over 4500 U.S. wholesale growers. It represents a current product line of 26 plants which are relatively easy, as well as quick, to grow. All plants are packaged into marketing programmes which utilise a colourful logo, labelling, point of sale material, and promotional activities.

The Outback Plants Program has been a most difficult undertaking but one of which we are very proud of, as Koala Blooms has created the only plant marketing structure specialising in our country's native plants, with Australians, and resulting in benefits flowing to Australia and especially the Australian horticultural industry.

Licensed Propagators. Currently we have three licensed propagators. Our head propagator is at Fresno, California, with other propagators in Washington State and Florida. This will be expanded shortly to include propagators in the northeast and mid-west regions of the U.S.A. as well as in Canada.

Brokers. Plant sales to mass merchants operate differently in the U.S.A. to here in Australia. A broker system is used and we are working with 15 brokers including the four largest in the country. The brokers seek sales of Outback Plants products from the wholesale growers and the orders are placed with the licensed propagators who then supply liners or plugs to growers. The growers are then free to sell the plants to any mass merchant they wish. All plants are supplied with a special Outback Plants label by the propagator. A royalty to Koala Blooms is incorporated in the label cost, which enables marketing promotion and payment of a royalty to the original introducer in Australia.

Promotion. Wherever possible we aim to have the Koala Blooms and Outback Plants brand names and products brought before the nursery industry, landscape industry, and home gardener.

Print Media. We have had invitations to submit articles, which have been subsequently published, in trade magazines such as Greenhouse Grower, Grower Talks, and Greenhouse Manager. We submit articles and press releases to trade magazines. Articles for home gardening magazines are also prepared.

Electronic Media. We have had limited access to radio gardening shows but these have been extremely successful when we were doing trial releases. There are invitations to be involved in more of radio programmes as the plants become more readily available on a wider market. There is also the possibility of TV exposure, now that things are really beginning to happen with the first major release via mass merchants occurring as I talk to you.

Ohio Short Course. In July this year we will have a stand at the prime Horticultural Industry Show in the U.S.A. Brokers and growers from all over northern America with some visitors and exhibitors from overseas view attendance at this show as a must. Koala Blooms will be there with an eye-catching display of current and future releases.

KOALA BLOOMS OPERATIONS IN EUROPE AND JAPAN

Negotiations are being undertaken with brokers and growers in both of these regions for the introduction of the Outback Plants Program. Propagation and growing trials will begin as soon as agreements are finalised.

CONCLUSION

After 6 years of concentrated effort and often including many disheartening times, Koala Blooms believe they can now offer a wonderful opportunity for the Australian horticultural industry to have Australian native plants marketed overseas as an Australian product which will in return provide royalties for breeders/introducers in Australia. Please do not hesitate to make contact with us. As a result of this success overseas Koala Blooms is also releasing a range of plants in Australia from spring this year.

Plant Breeding Legislation in Europe

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INTELLECTUAL PROPERTY AND ADMINISTRATION

It seems that some people today believe that breeders, researchers, and others, who are devoted to the development of new plant varieties, be it agricultural or horticultural species, are akin to the "alchemists" of ancient times. Convinced that they are able to transform any base metal into the most precious of all: gold! Influenced by a deep belief in the mystical teachings of chemistry, the alchemists had faith that they would, eventually, reach their ultimate goal.

After more than 10 years in close contact with breeders and researchers, I have realised, that modern breeding programmes truly do include techniques and methods far beyond the "golden" eggs. Consequently it is of the utmost importance for the plant breeder to protect his invention. This paper is an attempt to inform you of the basic ideas of intellectual property legislation in Europe and the practical implementation of such systems through plant variety rights legislation. I will also highlight a positive approach to the necessity of royalty collection.

You may consider plant novelty protection as an insurance as well as an investment, i.e. protection of your product will ensure that you are able to recoup the development costs.

Seen from an investment point of view, you can consider two angles:

1) Product protection of a variety or a concept, which includes an improvement of the product, will enable a larger market share and consequently a bigger turnover
2) Product protection of a variety or a concept, which is providing a more efficient production cycle, will result in a better GROSS PROFIT.

There is more to this than just the protection of the product. It may be a novel plant variety, a method for transforming specific characteristics from one plant variety or plant species to another, i.e. a distinct colour (blue roses); or a technical solution of a production method, which will reduce the use of resources or otherwise enhance productivity; it could be a new way of presenting or marketing the product; or a characteristic logo or label connected to the identification of the product itself or its origin. All these aspects need protection.

I will now concentrate on plant variety protection through the legislative measures, which are enforceable in Europe today:

The aim of the legislation is to protect the breeders' intellectual property through an approved right to claim certain rights in connection with commercial exploitation of a protected plant variety. This includes the collection of royalties in order to ensure a financial gain to the breeders, which will enable—or at least contribute to—the continuation of their breeding programmes.

The UPOV convention has formed basis for the national legislation in most European countries. In fact, legislation in accordance with the recommended UPOV stipulations has been operational for a number of years in the majority of European countries producing or consuming plant varieties. However, the list of

protectable species has been limited in certain countries. In the past a plant breeder domiciled in or represented by a national of the specific country files an application in each country which they consider appropriate.

As of 27 April 1995, any breeder, being citizen of, or domiciled in, any member state of the European Community or in a UPOV member state, can file an application for their plant variety directly with the European Community Variety Office located in Brussels, Belgium.

Based on the UPOV (1991) Convention, the EU Directive prescribes that it is necessary to obtain the approval of the variety owner's (the breeder's) in order to:

- Produce or reproduce (by multiplication) the variety.
- Conditioning for the purpose of propagation.
- Offer the variety for sale.
- Selling or other marketing of the variety.
- Exporting the variety from the Community.
- Importing the variety to the Community.
- Stocking the variety for any of the purposes listed above.

In addition to the stipulations of the UPOV Convention, the EU Directive further entitles the variety owner the right to prescribe conditions and limitations to his authorisation.

The legislation also includes stipulations for the initial breeder's influence on essential derived varieties as well as the concept of farm-saved seed, which is of the utmost interest to breeders and producers of agricultural crops.

This protection is valid for up to 25 years, however for grape and tree varieties this period is extended to 30 years.

In order to commercially exhaust a protected plant variety, the variety has to have been given a name which is then approved and registered by the appropriate plant novelty authority. The variety should then be designated by this approved variety name, even beyond the expiry of the protection period.

It should however be noted, that filing of applications for national protection in one or more single European countries is still an alternative.

WHAT IS A PLANT NOVELTY

It Should be Distinct. At least one essential characteristic should differ from any known variety of the same species;

It Should be Uniform. Homogenous within the specific generation; and

It Should be Stable. The variety should, by continued propagation, maintain the characteristics claimed for this variety when propagated in accordance with the methods prescribed by the variety owner.

In the European system, the majority of DUS-testing—the so-called comparative trials—is performed at centralised testing stations. But due to the fact, that within the implementation of the new legislation [EU Directive and UPOV (1991) based national legislation], any plant species can be protected, the need for extended testing facilities has arisen. This has resulted in the development of contractual testing facilities, which even may be at the breeder's own facilities. You may recognise this system, and indeed, we have borrowed the idea from this part of the world.

It would take too long to explain the newly developed standardised licence agreement system fully. The following is a brief outline of the concept.

The contractual system consists of a basic licence agreement, outlining the rights and obligations of licensor as well as licensee. In addition, the licensee will have to sign an addendum for the specific use of certain varieties, valid for a specified period. The addendum may also include further restrictions or conditions, i.e. territory of exhaustion, limits to production quantities, compulsory use of trade marks or labels, etc. The addendum could allow the propagation and sale of propagation material; the propagation and sale of the finished product; the production of finished plants only; or, the production of cut flowers. Special licence agreement arrangements with trade organisations and distributors are also available.

The mere mention of the word ***royalty*** raises the blood pressure of many flower growers around the world. Why is it necessary to pay extra for a plant with a fancy name? The subject is often avoided because it causes controversy, but consider this idea: you are paying a rental fee to the variety owner for use of his/her invention. In other words, you do not buy the variety, you only rent the right to use it.

If I develop a new plant with characteristics that you want to produce and sell, why not rent my technology? And why complain about the rent? Aren't you using my inventiveness for your own gain?

The question of how much rent or royalty is another issue. If you think the rent is too high, you do not have to rent my technology. But just because you think it is too high, does not give you the right to use my technology without paying the rent.

Royalty payments are not just an add-on cost for the propagator. A royalty pays the inventor for his inventiveness and the development cost of a new cultivar. One new plant cultivar that is truly superior must support the development costs for itself, as well for all its sisters and brothers that didn't make the grade. Royalty payments for use of superior plant cultivars are essential in our industry. New plant cultivar development depends on it. Honesty demands it. If you do not support the concept of royalty payments the development of new cultivars will suffer a serious set back.

If you think the royalty is too high, grow a different cultivar. But if you choose to grow a cultivar with a royalty, figure the cultivar rent as a necessary cost. Remember, some day, we will all have to account for our excesses; it is just a deferred settlement.....!

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The Diversity of British Columbian Native Plants for Nursery Production

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The extremes of British Columbia's climate and natural landscape are primary reasons for its diversity of native plants. British Columbia's geography encompasses alpine meadows in the mountainous regions of Revelstoke, Whistler, and Manning Park; the rainforests of the Queen Charlotte Islands and the west coast of Vancouver Island; the arid regions of the Okanagan Valley in the interior of the province; and the lower altitude areas of the Fraser Valley.

Visitors to British Columbia will soon become aware of its provincial flower—*Cornus nuttallii* (Pacific Coast dogwood). This deciduous tree is renowned for its large white flowers in the spring. However, it is not an easy tree to grow in the urban landscape as it does not like root disturbance and its bark splits if exposed to excessive sun. In addition, the last decade has seen an increasing incidence of anthracnose caused by the pathogen *Discula* sp. Dogwoods which are under stress from a long hot summer are particularly prone to infection.

The potential of this native tree for plant breeding was seen by Henry M. Eddie, one of the province's pioneer nursery growers, who emigrated from Scotland in the early part of this century. In the 1940s he began to hybridise *C. nuttallii* with *C. florida* (East Coast dogwood) and some of its pink selections, to try to bring together the best qualities of both species. He developed a number of selections with white or pink flowers, as well as compact and pendulous habits. During a major flooding of the Fraser River these *Cornus* selections at his nursery in Chilliwack were washed away with the rapid turbulence of the water. However, all was not lost; the previous year he had planted his most promising selection in a field adjacent to the present-day Vancouver International Airport. Subsequently named *Cornus* 'Eddie's White Wonder', this cultivar brings together the best attributes of both species—pure white flowers, intense fall colour, and a compact small to medium size for the urban landscape.

Modern technology in coniferous forest tree production has been successfully adapted for native plant production. Innovations in container design, mechanical handling, and changes in the environment for precision growing have significantly reduced the production period and improved subsequent establishment in the landscape.

The last 5 years in particular has seen an increasing number of nurseries specialising in native plants to satisfy the wholesale demand for reclamation, highways, and commercial landscapes. Through public education programs, the home gardener is now also much more aware of the diverse uses of native plants. Some retail centres have set aside sections in their displays specifically to promote these plants. However, specific cultural information on native plants, such as low nutrition and moisture requirements, is sometimes lacking.

To meet this increasing demand for native plants, the Plant Introduction Scheme at the UBC Botanical Garden (PISBG) has given much attention to the evaluation

and introduction of improved clonal selections and/or plants which are little known but have great commercial potential.

The most successful selection has been the evergreen ground cover *Arctostaphylos uva-ursi* 'Vancouver Jade'. Well over 1.5 million plants are now produced annually in British Columbia. Its success is due to its ease of propagation, dense habit, attractive flowers and diverse use in the landscape. It has also provided a significant export market to Washington State and Oregon.

Dr. Wilf Nicholls, Research Scientist at the Botanical Garden, has undertaken a systematic collection of many species in the province. One of his priorities has been *Penstemon*, which are ideal for dry sunny locations. The introduction, *Penstemon fruticosus* 'Purple Haze' has made a considerable impact in the interior of the province, Vancouver Island, and in the Pacific Northwest of the United States. It is a plant that does not tolerate excessive overhead irrigation or excessive nutrition which cause stem dieback and restriction in root development. This selection is now being hybridised with *Penstemon rubicola* and other U.S. species to encourage diversity in both habit and flower colour.

Two native broadleaved evergreen introductions which should be trialed in Australia are *Paxistima myrsinites* 'Emerald Cascade' (syn. *P. myrtifolia* 'Emerald Cascade') and *Vaccinium ovatum* 'Thunderbird'. 'Emerald Cascade' is a compact weeping form of the myrtle boxwood (Oregon box), while 'Thunderbird' is a very floriferous soft-pink-flowered selection with outstanding reddish-coppery new growth.

As earlier indicated, native plants are not necessarily the easiest to propagate and subsequently produce under nursery conditions. Some of these problems include:

- Inconsistency in propagation, e.g. *Arctostaphylos uva-ursi* and *Shepherdia canadensis;*
- Poor growth with the standard nutrition, growing media, and irrigation regimes used in most nurseries;
- Genetic variation leading to a lack of crop uniformity;
- When grown in containers the plants may be too tall or their flower colour reduced at the point of sale. As some native plants have a very short flowering season, followed by dead seed heads and foliage, they may be unsightly and unappealing.

It is likely that in southeastern Australia and Tasmania there are already five British Columbia (BC) native plants which are either grown as the type species or as their selected cultivars. These are *Ribes sanguineum, Potentilla fruticosa, Arctostaphylos uva-ursi, Mahonia aquifolium,* and*Cornus sericea* (syn. *C. stoloni–fera*). The following BC native plants also have great potential in the region.

***Philadelphus lewisii* (mock orange).** A hardy drought-resistant multistemmed shrub to 2 m, with masses of fragrant white flowers in May. It occurs throughout southern Vancouver Island, with its Mediterranean/Californian climate and, is absent from the wetter Lower Mainland but common again in the Okanagan Valley, a dry belt with intensely cold winters.

***Eriogonum umbellatum* (sulfur buckwheat).** A hummock-forming perennial from subalpine areas of south-central BC. Mounds of leafy rosettes are covered in creamy yellow inflorescences in summer.

***Fragaria chiloensis* (sand strawberry).** An excellent evergreen herbaceous

groundcover with lustrous deep-green leaves that grows best in sun and sandy soils. A parent of our cultivated strawberry.

***Rosa woodsii* (Wood's rose).** A slightly dwarf selection is showing great potential for bank and roadside plantings, as suckering stabilises soil. Compared to the wild type, brilliant red stems and petioles accent the finer glaucous leaves. Festooned for 2.5-cm pink flowers in June.

***Cornus canadensis* (bunchberry).** An excellent flowering herbaceous groundcover for a woodland garden. In dappled shade and organic soils it will give carpets of white flowers, red berries, and dense foliage. Intense sun and drying winds can burn this plant.

***Penstemon fruticosus* 'Purple Haze' (shrubby beardtongue).** A superb rock garden plant or groundcover in exposed sunny spots. Good drainage is important for this naturally occurring scree-slope species which produces masses of purple flowers in spring. Low nutrients and low water keep this plant as a tight tussock.

***Camassia quamash* (camass lily).** A bulbous plant of the coastal prairie areas of southern Vancouver Island. Intense blue-purple flowers in early spring are held above linear leaves. Perfectly adapted to summer drought, the plant flowers using stored winter moisture.

***Prunus virginiana* var. *demissa* (chokecherry).** A drought-hardy deciduous shrub or small tree. Pure white inflorescences of small flowers are held horizontally or droop rather like *P. padus*. The fruit is bitter but makes fine jelly and jam. A few cultivars exist including a weeping form.

***Holodiscus discolor* (ocean spray).** This wonderful deciduous arching shrub is crowned with foam-like inflorescences of tiny white flowers in spring and early summer.

***Allium cernuum* (nodding onion).** An excellent perennial onion with pink flowers hanging in pendulous inflorescences atop a robust tuft of linear foliage. Flowering in spring, it remains a healthy green throughout droughty summers.

***Lonicera ciliosa* (western honeysuckle).** Scentless but beautiful trumpet honeysuckle covered in orange blooms in early summer, followed by attractive masses of red berries. It can climb on fences, other shrubs, and trees.

CONCLUSION

The demand for native plants will continue to grow, especially for reclamation, highway plantings and commercial landscapes. However, whether for the home garden or the large-scale urban landscape, native plants should not always be used because they are native. Some native plants are inappropriate as they may sucker, become invasive, be unsightly or short lived. The majority of good garden plants in use today within British Columbia are not native to western North America but originated in Asia, Europe, and other areas of North America. Native plants should be used in balance with non-natives to beautify gardens and public landscapes.

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The Need for a Region of the I.P.P.S. in South Africa

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On the 2 Feb. 1990 F.W. de Klerk, who was the president of South Africa at that time, made a momentous announcement. The African National Congress (ANC) was no longer banned as a political party. The South Africa Communist Party was free to operate without restrictions. A number of political figures who had been in jail for many years were to be released, and the way was paved for the first multi-party, multi-racial, truly democratic elections in South Africa (SA). Apartheid was at last being dismantled. With those words, South Africa stepped back from the abyss of chaos and anarchy looming before it, and re-entered the world from which it had been excluded.

For most people like ourselves, the relief was immense. We could now start taking greater control of our lives and plan our future in SA. However this posed a number of problems for SA business people. South Africans were now exposed to the full cut-throat competition of world trade. Previously SA business had been able to shelter behind a whole host of protective tariffs, sanction busting activities, and a wide range of bureaucratic regulations.

Two years down the line and certain old attitudes still exist. There is a tendency for South Africans, when exposed to competition, to retire into a laager, the traditional circle of locked ox-drawn wagons. The attitude of "if you can't control it, ban it !" still exists—a prime example of this is the ostrich industry which with co-operation could have become a world industry with SA as an equal partner. As a result of banning the export of live eggs, birds, and expertise, SA has now been sidelined in the industry. Eggs were eventually exported illegally through Nambia and the industry is now flourishing, without SA. An example of a successful co-operative venture is the protea industry, which is expanding throughout the world together with SA growers who have not tried to keep the flowers to themselves and who have co-operated with growers overseas. Regulations such as "banning" do not stop trade in a commodity, they merely drives it underground. We are now seeing the emergence of a group of people who feel that SA's plants belong to us and us alone. It is "our" flora, and no one outside SA should be allowed to make money out of it either horticulturally or in any other way. We see this as a threat to our entire flora, as at present, we are unable to look after it adequately on our own. There are insufficient people interested in our native plants to be able to exploit or manage them in the most profitable way.

As South Africans we need to change our attitudes, become responsive to competition, become more cooperative and open, and break down the laager mentality. We need to become part of the world again, and joining international organisations is one method of sharing and learning.

Historically a number of organisations have served the interests of researchers and horticulturalists working in the nursery trade both in the public and private sectors. Firstly there is the SANA, the South African Nurserymen's Association. This looks after the interest of the nursery and landscaping industries, but it is mainly concerned with marketing and deals little with mastering horticultural

problems. The newsletters published by this organisation do not mention "growing" anything—only selling or landscaping it.

Serving the public sector is the Institute for Parks and Recreation Management. In the past this organisation served horticulturists, but it has now been taken over by managers and administrators, and is little concerned with the practical application of basic horticulture. This organisation focuses on meeting the needs of greater urbanisation, park development, bowling greens, etc. and growing of plants is rarely mentioned.

To some extent the needs of propagators working in the field of native plant growing have been met by a group called the "Indigenous Propagation Group" based in Natal. Members of this organisation receive the informative journal 'Plant Life', and at one stage the membership seemed to be growing but it is now fighting for existence. In the words of the chairman, "there are plenty of willing followers, but insufficient leaders" and somebody has to drive the bus ! Another problem is that the group has become firmly established in Natal, no members from other areas have attempted to establish their own local groups. This means that Natal has regular meetings and outings to botanically interesting places or nurseries, but the members who live in other areas do nothing. On speaking to the chairman of the Indigenous Propagation Group in Natal about their recent problems, he stressed that the secretary is the driving force behind the organisation. The organisation needs to constantly look for new members and all new members must be in the same geographical region to facilitate communication.

Another example of this is the Indigenous Bulb Society of SA (IBSA). The committee of the organisation is based in Cape Town, and it is therefore only the Capetonians that are active in the Society. This is an extremely open and informative organisation with members sharing knowledge freely, but rarely do members from other regions become involved. Is this the fate for a new region of the I.P.P.S. in South Africa? It is something we will have to think about carefully.

Apart from these two organisations, there are also several others operating in specialised fields, e.g. SAPPEX—the Protea organisation which funds research into propagation of Proteaceae, The Succulent Society, The Pelargonium Society, and a few others. All are open, useful organisations, but are obviously limited in their interests. The Botanical Society through its magazine *Veld and Flora* publishes a number of horticultural articles, but can only print submitted material so these are not a regular feature.

For researchers and academics working in the botanical field there is SAAB, the South African Association of Botanists. This organisation has many members throughout SA, some of whom are working in horticulturally related fields. Most however are still very much research orientated with little experience in practical application. We recently attended a SAAB congress in Cape Town where a number of innovative propagation techniques were presented in papers. Out of several hundred delegates there was only a handful who, to put it bluntly, could apply this knowledge with a view to "turning a buck" or saving our endangered flora.

In the rapidly changing world there are two types of people in our economic communities, those who create information and those who use and apply it. Most researchers fall into the former category and may not be of a practical disposition, although their ideas may be very innovative. Propagators and horticulturists tend to be of a practical but imaginative disposition (or at least the good ones are). They

are experimenters rather than innovators and will apply a range of tried techniques to many groups of plants in order to propagate and grow them successfully. We feel that an organisation such as the I.P.P.S. in SA would help to mix the two types of people mentioned above, and get us out of our laager. It would provide a forum where researchers and propagators, the creators and the users, could meet and exchange information. With honesty and openness it could be a highly symbiotic arrangement.

The I.P.P.S. embraces academics, the public sector, horticulturists, commercial nursery people, cut flower growers, farmers, and conservationists. In all of these occupations plant propagation is an integral part of their livelihood.

The wealth of South Africa's native flora is sufficient reason for establishing a Region of the I.P.P.S. in SA. A few years ago our local botanical institution used the catch phrase "Conservation through Cultivation". The Institution no longer uses the phrase—but it still applies. South Africa is home to about 22,000 species of plants of which 8500 species occur in less than 4% of the land area. This area is the Cape floral kingdom, and of the 8500 species, 2000 or more are rare and endangered. Cultivation is their only hope for survival. In many cases the threat endangering plants is habitat destruction, both by urban and farming development, and by alien or exotic vegetation encroachment. Many of the plants are difficult to grow, and seed germination protocols are lacking.

At present there is no forum in South Africa for sharing knowledge gained through experience. One propagator may work out how to grow a particularly difficult species, but at present this knowledge is not shared at all. This is one of the reasons we are ill equipped to save our native flora and must seek help from abroad. At present the attitude in South Africa, if one mentions propagation of native plants, is that "Kirstenbosch, Roodeplaat, or Elsenburg should do it", these are all government organisations. However Kirstenbosch, for example, is financed mainly by the state and funding is becoming increasingly limited. No matter how good the staff or their intentions they can not solve the propagation problems of all 22,000 plants. The time has come for individuals like us to take more interest and initiative in growing and preserving our native flora, not wait for government institutions to lead the way. Many propagation techniques established for flora in other parts of the world may be extremely useful in helping us to propagate our own plants. But sharing goes both ways. We can not deny access to our flora on one hand and expect to get help on the other.

CONCURRENT SESSIONS

The remaining papers from the Australian Region were part of four concurrent sessions. The papers are grouped under each session.

SESSION 1: EDUCATING THE PROPAGATOR

Training the Plant Propagator—A Burnley College Perspective

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Burnley College is a specialist institution providing training and education in urban/amenity horticulture. It is currently affiliated with the University of Melbourne's faculty of Agriculture, Forestry & Horticulture as part of the Victorian College of Agriculture and Horticulture. Burnley has been training students in horticulture for some 100 years. This long history, as well as our combination of higher education and TAFE (Technical and Further Education) programs gives us a perspective on horticultural education which is unusual.

In the 16 years since Burnley's programs were last discussed at an I.P.P.S. Conference (1980 Australian Region) much has altered. We now provide training beyond diploma level and have a much wider range of courses on offer. We have been offering a degree (B.App.Sci.[Hort]) since 1985 and a postgraduate research degree (M.App.Sci.[Hort]) since 1992. This provides the horticulture industry in Victoria and Australia with the opportunity of employing people with a training profile not available previously. We also offer a more vocationally oriented two-year course (Dip.App.Sci. [Hort]) and a range of TAFE programs.

We are not the only providers of higher education courses in horticulture in Australia, but we are one of the largest, and in fact we have a faculty of horticultural staff which is possibly one of the largest in the world.

We believe that our programs meet the current and future needs of potential employers and also the needs of our potential and actual students. Demand for places in our courses is high and this reflects both interest in careers in horticulture and Burnley's reputation. The high-calibre students on offer can contribute to change in industry. We have provided clear pathways for articulation from TAFE to higher education courses and believe we are pioneers in that field. These articulation pathways not only apply to our own students but also to people with qualifications from other TAFE colleges.

All of this sounds very promising but where does the nursery industry benefit from this? There is a possibility that the benefit might be slight. At present, students are not attracted to the nursery industry. The majority of our students are specialising in areas related to environmental and landscape management. They may see these areas as "greener" and almost certainly many of them believe that the nursery industry will not reward them for their qualifications and years of study. While industry argues that degree-trained people do not have adequate skills for employment, this is at odds with trends in many other industries where the employment

of educated professionals is seen as being desirable for the industry as a whole. Furthermore it is contrary to trends in the U.S. and Europe.

I believe that the nursery industry will have to assess its attitude to the employment of professionally trained people as the level of service provided to it by government invariably declines and as nurseries themselves become more complex. *I am also confident that collaboration in training between employers*, TAFE providers, and higher education institutions can provide the range of people that a dynamic industry needs, but such collaboration requires the active support and involvement of all the players.

Competency-Based Training—Implications for Horticultural Education

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Competency-Based Training (CBT) can be defined as an approach to learning which places primary emphasis on what the learner can actually do in the workplace as a result of training. It is focused on the outcomes or competencies rather than on the learning processes or the time spent on these processes. This reflects a major shift away from the conventional approach to education and training.

MAYER REPORT

This report identified seven key competencies; collecting, analysing and organising information, communicating ideas and information, planning and organising activities, working with others and in teams, using mathematical ideas and techniques, solving problems, and using technology. In Australia a set of National Horticulture Competency Standards have been developed. They reflect the above key competencies and will be used as a basis for developing all new courses in vocational education and training.

WORKPLACE TRAINING

All levels of vocational education and training will involve workplace experience and employers/supervisors/managers will be encouraged to become qualified workplace trainers and assessors. There is an acceptance that training will involve both 'on' and 'off' the job training. This means that providers of training will need to develop a closer relationship with the horticultural industry and negotiate training strategies which reflect true industry needs. Module delivery rather than whole course delivery is likely to become more common.

ASSESSMENT

The statement has been made that the CBT system will be made or broken by the effectiveness of its assessment processes. Fairness and validity are important. In Australia, the National Centre for CBT is of the view that the assessment 'grades' ought to be simply Competent or Not Yet Competent. The philosophical questions such as "are you creating winners/losers or promoting mediocrity" by not issuing

of educated professionals is seen as being desirable for the industry as a whole. Furthermore it is contrary to trends in the U.S. and Europe.

I believe that the nursery industry will have to assess its attitude to the employment of professionally trained people as the level of service provided to it by government invariably declines and as nurseries themselves become more complex. *I am also confident that collaboration in training between employers*, TAFE providers, and higher education institutions can provide the range of people that a dynamic industry needs, but such collaboration requires the active support and involvement of all the players.

Competency-Based Training—Implications for Horticultural Education

Frederick C. Hellriegel
Eastern TAFE, 369 Stud Road, Wantirna South VIC 3152

Competency-Based Training (CBT) can be defined as an approach to learning which places primary emphasis on what the learner can actually do in the workplace as a result of training. It is focused on the outcomes or competencies rather than on the learning processes or the time spent on these processes. This reflects a major shift away from the conventional approach to education and training.

MAYER REPORT

This report identified seven key competencies; collecting, analysing and organising information, communicating ideas and information, planning and organising activities, working with others and in teams, using mathematical ideas and techniques, solving problems, and using technology. In Australia a set of National Horticulture Competency Standards have been developed. They reflect the above key competencies and will be used as a basis for developing all new courses in vocational education and training.

WORKPLACE TRAINING

All levels of vocational education and training will involve workplace experience and employers/supervisors/managers will be encouraged to become qualified workplace trainers and assessors. There is an acceptance that training will involve both 'on' and 'off' the job training. This means that providers of training will need to develop a closer relationship with the horticultural industry and negotiate training strategies which reflect true industry needs. Module delivery rather than whole course delivery is likely to become more common.

ASSESSMENT

The statement has been made that the CBT system will be made or broken by the effectiveness of its assessment processes. Fairness and validity are important. In Australia, the National Centre for CBT is of the view that the assessment 'grades' ought to be simply Competent or Not Yet Competent. The philosophical questions such as "are you creating winners/losers or promoting mediocrity" by not issuing

percentile ranking grades may well be asked. But is it easy to identify who wants traditional grading?—teachers/students, industry or universities? Universities primarily select on academic merit, whereas the VET system will be based on competencies achieved.

An holistic approach to grading is the ideal : a system needs to be designed which can measure knowledge, skills, and attitudes. The future will be challenging but the rewards will be greater skills achievements, productivity, and therefore opportunities for the Australian horticultural workforce.

LITERATURE CITED

Mayer, E. 1992. Putting general education to work. The key competencies report. The Australian Education Council and Ministers for Vocational Education, Employment and Training 1992.

Training Programs for the Horticulture Industry - from Research to Practice

Robert Sward, Jenny Beaumont, Bernadette Swanson and Tony Slater
Institute for Horticultural Development (IHD), Agriculture Victoria, Dept of Natural Resources & Environment, Private Bag 15, SE Mail Centre VIC 3176

The Institute for Horticultural Development (IHD) is one of Australia's major research and development institutes supporting the horticultural industry and its allied trades. A critical part of the Institute's core business is to provide training to assist producers, processors, and product and produce managers to develop the skills and knowledge needed to adopt world competitive practices.

Continuing industry-based research and development programs within and outside the Institute provide information and technology that is at the forefront of international science. However, the information derived from current and past research is not often in a form in which can easily be adopted and integrated by industry personnel into the management practices of their workplace. A further complication is that the horticulture industry is comprised of a number of diverse sectors producing a multitude of different commodities, on farms of different types, and processing and marketing them through a wide range of different enterprises, e.g. the growing, handling, and marketing of hydroponic tomatoes is very different to that of wine grapes, apples, Asian vegetables, cut flowers, or nursery plants.

The ability of such a heterogenous industry to respond to changing consumer demands and new market opportunities is reliant not only on the provision of information and new technology, but its adoption by all industry personnel involved in any aspect of the production, handling, or marketing chain. Training courses designed to be of real value to the horticultural industry need to be carefully adapted and tailored to suit the special needs and priorities of each component activity of the various sectors.

IHD is registered with the State Training Board under the category of Industry Based Private Provider. Courses are carefully designed in response to needs outlined by industry personnel. They are delivered by "trainer-researchers" who

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are staff with scientific and technical expertise, as well as relevant trainer-training. This combination of skills assists the targeted delivery of complicated scientific information and technology in a manner acceptable to adult learners from a range of educational backgrounds. In some special cases, language, literacy, and numeracy assistance is also provided for course participants prior to, or in tandem with, the industry training course.

An important element of IHD training courses is the use by participants of new information and technology to solve problems or improve practices in their own work situation as part of the actual course. In many cases this leads to instant adoption by some industry personnel who can then call in a more informed and constructive manner for changes to be made to allied activities in their industry sector.

Courses that can and are being delivered to industry groups include: Postharvest Handling; Plant Protection (Integrated Pest Management); Farm Chemical Users Course; Writing a Whole Farm Plan; Quality Assurance for Horticultural Producers; and Short Courses such as: Asian Vegetables; Insect Identification; Plant Disease Diagnostics; Introduction to Quality Assurance; and Biotechnology for School Teachers.

SESSION 2: PROPAGATION FOR REVEGETATION

Supplying Plants for Revegetation: A Buyer's Expectations

Roger Lord
Environmental Officer, Melbourne Water Waterways and Drainage Group, 14 Leoni Avenue, Heathmont, VIC 3135

Revegetation or the use of indigenous local provenance plants for rehabilitation or restoration of plant communities is the accepted practice in Melbourne Water Waterways and Drainage Group and is used as part of waterway management. Revegetation programs within Melbourne Water are included in:

- The Stream Frontage Management Program which is an incentive scheme to encourage rural land owners to fence and revegetate waterway reserves in their property;
- Revegetation associated with capital works, e.g. waterway stabilisation using rock;
- Drainage Schemes which are funded by developers of subdivisions and provide a means of 'greening' a new development along installed drainage infrastructure, ie. open drains and modified watercourses;
- Significant sites which involve community/"friends" groups.

Revegetation demands a plant supplier who has a degree of knowledge in botany, ecology, and genetics and has a willingness to incorporate these disciplines into horticulture.

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Revegetation demands a plant supplier who has a degree of knowledge in botany, ecology, and genetics and has a willingness to incorporate these disciplines into horticulture.

Main Expectations. The main expectations the buyer has of the supplier is their ability to: provide indigenous plants of local provenance; provide quality stock; manage time schedules (flexibility); be flexible in product size, i.e. tubestock versus plugs or speedlings; and be cost competitive.

Local Provenance. Ideally the supplier should supply indigenous plants of local provenance. Purchasing plants from a supplier who can provide indigenous plants of local provenance is a relatively simple process given the plethora of indigenous nurseries within the Melbourne Region. It is obviously more comfortable and desirable dealing with suppliers who illustrate their commitment to preserving local gene pools, i.e. by providing information on the source of plants; accept variability in stock due to genetic variation; and show a willingness to further experiment with the sexual propagation of indigenous species.

Quality of Stock. Plants should be obviously healthy and show vigour/juvenility in both shoot and root systems, as well as some genetic variability or level of non-uniformity. Obviously a potting mix which is weed and disease free is critical. Soilless media is preferred and media produced by products such as composted tree prunings or rice hulls is desirable but not a critical expectation. This may change in the future.

Ability to Manage Time Schedules. A knowledge of the different maturing times for indigenous plants is important to ensure they are ready for a forecasted planting date. This is critical when plant supply is to be coordinated with a planting contract for revegetation. Ideal planting times vary across Melbourne and some species will establish only in warmer periods, e.g. aquatic plants. The supplier's knowledge of an area in relation to plant establishment is very useful to the buyer. Ability/facilities to hold stock over is also desirable if planting conditions have become suboptimal due to construction delays or inclement weather.

Flexibility in Product Size OR Tubestock Versus Plugs. Tubestock is probably the accepted standard for plants for revegetation but plugs or speedlings are particularly practical for grasses and sedges and may be appropriate for some woody species. The advantages of plugs are cost, short maturity times, ease of transport, and ease of planting. Plug production should become a standard practice by indigenous nursery growers.

Cost. Tubestock prices are generally around the $0.75 mark although can vary from $0.60 to $1.20 depending on the plant form, the numbers ordered and means of production, i.e. seed versus cutting. Plugs range in price from $0.20 to $0.30.

Future Expectations. The future expectations of buyers might include a register of quality assured indigenous nurseries which meet an industry standard. This may include a labelling/information system which provides the buyer with details in regards to the seed/cutting source of plants and registers a site as a future seed/cutting source.

Operating an Indigenous Plant Nursery: My Experience in the Field

Graeme L. Stockton
West Coast Indigenous Nursery, 50 Coppards Road, Newcomb, VIC 3219

INTRODUCTION

Indigenous plant nurseries are a relatively new concept in the horticultural industry. In Victoria most have developed within the last 15 years. These nurseries are essentially based on ecology rather than horticulture, therefore, the way they operate is vastly different and sometimes contradictory to conventional nurseries.

DISCUSSION

Plant Identification. Growing indigenous plants requires a good knowledge of the local flora. Some plants are extremely small and in a horticultural sense do not attract the client. Others may only flower every now and then (e.g. some monocots) or are life forms which are under the ground for part of the year (e.g. lilies, orchids). This can make the task of positive identification a long process. In situations where the existing indigenous flora is to be removed prior to job commencement it may be necessary to dig up some plants and grow them on in the nursery. This can result in the introduction of new weeds and diseases into the nursery.

Original Flora Depleted or Non-existent. On the Bellarine Peninsula where I work over 90% of the original flora has disappeared. It is therefore necessary to use historical records, photographs, advice from long-time residents, and locate small remnant reserves to build up a better picture of the local ecology. This is important for the selection of plants in future vegetation projects.

Seed Collection. Seed collection is done mainly through the summer months from December to late January. Variation in the time of seed collection can be due to local weather patterns (either too wet or too dry), variation in seed set from one population to another, or the lack of pollinating agents. Some seed needs to be collected quickly after it has matured, e.g. native pea species with explosive seed dispersal mechanisms. A range of provenances from each species is also highly desirable, as is the collection of seed from a number of individuals within a population.

Ability to Supply. In a large revegetation project it is necessary to allow indigenous nurseries at least one summer of seed collecting time. Planting out in the field is usually best done in autumn. Complicating factors include variation in seed supply from year to year and place to place, and seed maturity occurring outside the summer period, e.g. *Bursaria spinosa* has a short seed viability but the seed does not mature until autumn, or *Themeda triandra* which is dormant in the winter months. In both cases it could be best to carry the revegetation project through until the spring.

Compulsory Competitive Tendering. The collection of seed using the guidelines outlined above means an increase in plant costs due to the extra labour and time involved. Some nurseries who are not ethically aligned to these guidelines may produce large numbers of plants ignoring provenance diversity. As the question of provenance cannot be easily proved or disproved, the opportunity for less reputable operators to take advantage of their clients is becoming more apparent as the market for indigenous plants increases.

Environmental Weeds. This is an issue that threatens the viability of vegetation communities the world over. Up to 65% to 70% of exotic species in Victoria have been introduced deliberately for ornament (most species) or utility (Carr et al., 1992). Many plants invading the Australian bush are ideal horticultural subjects, e.g. *Pittosporum undulatum* (sweet pittosporum) which is an Australian plant that is invading many other native vegetation communities. The horticultural industry sells it because it has a good form all year round, has highly perfumed flowers, is extremely hardy, and is easy to propagate. The selling of this species is now listed as an "environmentally threatening process" under the Victorian Flora and Fauna Guarantee Act. Similarly, hybridisation in the field between indigenous and introduced plants of the same genus has also assisted weed invasion (Carr et al., 1992).

LITERATURE CITED

Carr, G.W., J.V. Yogovic, and **K.E. Robinson.** 1992. Environmental weed invasions in Victoria - Conservation and Management implications. DCNR & Ecol. Hort. pp. 5-10.

Some Observations of the Effect of Smoke on the Germination of South-Eastern Australian Native Species

Greg Bain and David Lockwood
Melbourne Indigenous Seedbank (MIS) Greening Australia Victoria Inc, 377 - 379 Burnley Street, Richmond, VIC 3121

INTRODUCTION

An initial "screening" program was initiated in 1995 by the Melbourne Indigenous Seedbank (MIS) to investigate the effect of smoke on selected Victorian plant species. These traditionally difficult-to-germinate species were selected because they belonged to the families discussed by Dixon et al. (1995) as being responsive to smoke treatment in Western Australia. The seed of species that were selected for testing came from the seed storage facilities of the MIS or from donations of seed from the community. Species not acquired from storage or donation will be collected and tested through 1996-97 to complete the "screening" process. Additional information in relation to the effect of plant-derived smoke upon germination has come from "smoking sessions" facilitated by Greening Australia Victoria, which have enabled nursury growers to smoke treat seed from selected species and then propagate these under conventional nursery conditions.

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Table 1. Preliminary germination results (germinants per gram) of treated (smoked) and control samples of seed undertaken in the MIS germination cabinet.

Family	Species Name	Common name	Collection date	Unsmoked	Smoked
Poaceae	*Bothriochloa macra*	red-leg grass	29-01-93	27	155
Liliaceae	*Burchardia umbellata*	milkmaids	28-12-92	39	72
	Dianella revoluta	black-anther flax-lily	04-01-90	23	67
	D. tasmanica	Tasman flax-lily	14-01-94	25	67
Myrtaceae	*Eucalyptus camaldulensis*	river red gum	09-09-94	689	830
	E. cephalocarpa	silver-leaf stringybark	01-12-92	147	248
	Leptospermum myrsinoides	silky tea-tree	15-03-95	881	1495
	Melaleuca ericifolia	swamp paperbark	19-01-94	1084	2154
Apiaceae	*Trachymene anisocarpa*	wild parsnip	14-01-93	66	112
Chenopodiaceae	*Enchylaena tomentosa*	ruby saltbush	1995	51	97

Table 2. Preliminary germination observations (germinants per gram) of treated (smoked) and control samples of seed undertaken under nursery conditions.

Family	Species name	Common name	Collection date	Unsmoked	Smoked
Poaceae	*Stipa rudis* ssp. *rudis*	veined spear-grass	03-01-95	2	13
Cyperaceae	*Gahnia sieberiana*	red-fruited saw-sedge	Unsure	0	24
Proteaceae	*Banksia marginata*	silver banksia	04-05-95	0.9	2.2

OBSERVATIONS AND RESULTS

Laboratory Germination Testing. Table 1 shows the response of species tested to date in the "screening" MIS germination tests. The number of germinants per gram for each of the treated and control seed batch has been recorded. Please note that this data is based on one sample of seed from a single seed batch and therefore cannot be considered statistically significant. The purpose of this project is to gauge the range of Victorian species on which further and more detailed laboratory and greenhouse germination testing may be warranted.

Nursery Greenhouse Observations. Seed that was smoked was also sown under normal conditions in several Melbourne nurseries specialising in the propagation of local native species. These nurseries differ in the equipment, procedure, and conditions they employ to raise seedlings. Therefore the inclusion of these observations cannot be regarded as comparable with the data obtained from the laboratory experimentation or between the nurseries involved in the project. Table 2 shows germination results for treated and control seed of species sown on seedling trays under nursery conditions.

THE FUTURE

The results of these "screening" tests represent a starting point for the further development and refinement of smoke-induced germination improvement as a procedure for south-eastern Australian species. Species on which smoke treatment has been shown to increase germination rate will need to be confirmed with more extensive tests in both laboratory and greenhouse conditions. This future testing should involve a range of smoke application techniques to determine the most cost-effective and convenient method of application for those involved in the vegetation restoration industry. Such a range might include direct-smoke application (as in these tests), smoked water samples, smoked substrate (seed-raising media or filter paper), or artificial compounds which may contain the active constituent within the smoke that is responsible for increasing germination.

Acknowledgments. Greening Australia Victoria would like to thank the following community groups, nurseries, and individuals who kindly forwarded results of nursery germination following their involvement in "smoking sessions" : Victorian Indigenous Nurseries Co-operative (VINC), Friends of the Helmetted Honeyeater, Friends of Braeside Park, Lenister Farm, St.Kilda Indigenous Nursery Co-operative, Greenlink Oakleigh, Otways Indigenous Nursery, Murray Ralph, Friends of Warrandyte State Park, Operation Revegetation, Candlebark Community Nursery, CRISP Nursery, Nunawading Indigenous Plant Project, Box Hill Greenlink, La Trobe University Wildlife Reserves.

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Dixon, K.W., S. Roche, and **J.S. Pate.** 1995. The promotive effect of smoke derived from burnt native vegetation on seed germination of Western Australian plants. Oecologia. 101:185-192.

SESSION 3: MANAGING THE PROPAGATION ENVIRONMENT

Monitoring Variation in the Propagation Environment

Ken James
Burnley College, Melbourne University, Swan St, Richmond, VIC 3121.

INTRODUCTION

Environments in greenhouses never stay constant, varying between day and night, and often having different zones within a greenhouse to such a degree that the microenvironment of propagating trays and pots may not stay within acceptable limits. Greenhouse environments and designs are detailed in texts such as Garzoli (1988) but little information is available on microclimate changes within a greenhouse. Five greenhouses at Burnley were monitored over several weeks using electronic data recording equipment and infrared thermal imaging techniques. Spatial and temporal variation of temperatures were monitored in the macroenvironment of the greenhouse and the microenvironment of the propagating pots.

Significant variation of temperatures occurred in a glasshouse heated with an overhead radiant gas heater located along the gable ridge. A gas burner produced hot gases which passed along the length of the tube causing it to heat up and radiate heat to the plants below. The hot gases pass out of the greenhouse and are exhausted to the atmosphere. The macroenvironment of the greenhouse is controlled by a thermostat which switches on the heater when the air temperature falls below the set point of 18C. During the monitored period over a cold night, the air temperature in the greenhouse (monitored under the bench) remained relatively uniform at 18C, whilst the outside air temperature dropped to 9C. Whilst the macroenvironment in the greenhouse, as seen by the thermostat, was stable and within acceptable limits, there was considerable variation in the soil surface temperatures of the propagating pots and trays, ranging from 31C at the hot end of the greenhouse, to 20C at the cooler end. Thermal imaging equipment recorded the spatial variation along the length of the greenhouse and results indicated a dramatic variation in the microenvironment of the plants.

Large vertical variations in temperature were also recorded in 150-mm pots of marigold seedlings. The base of the pot remained at 17C, whilst the soil surface at the top of the pot rose to 20C. Foliage temperatures were considerably higher with the very uppermost leaves absorbing most radiant heat which raised their temperatures above 25C.

Comparison of the microenvironment in two propagating trays showed quite different temperature profiles for a polystyrene tray to that of a black plastic tray. Two trays placed alongside each other recorded variations of 4C in the soil temperature. The temperature in the polystyrene tray (maximum 31C) was consistently higher than the black plastic tray (maximum 27C). The radiant energy absorbed at the soil surface of the polystyrene tray, was unable to leave the soil by

conduction, because the side walls of each cell are heavily insulated. In the black plastic tray with thin walls for each cell, the same absorption of radiant energy occurs, but more heat is lost to the surroundings via conduction through the walls and so the soil does not heat up as much. This difference is also noticed when radiant heat from direct sunlight causes the polystyrene cells to heat up more than plastic trays, and also during a clear cold night when the radiant heat loss of the soil is lower in a polystyrene tray than in a thin-walled plastic tray.

Another heating system for propagating plants uses heated beds or mats, providing heat from below via conduction. Heat passes upwards from the base to the top of the pot. The air is not heated. A 150-mm pot on a heated mat (set at 25C) was monitored and the thermal environment varied dramatically on two successive nights. On a mild cloudy night where little radiant heat loss occurred, conditions inside the pot remained nearly constant at 20 to 22C. On the following cloudless night, significant radiant heat loss occurred from the top of the pots resulting in pot temperatures falling to 12C whilst the mat temperature rose to 35C in an attempt to provide more heat. This under-pot heating system did not maintain a good pot microclimate under the colder conditions

CONCLUSION

Thermal imaging techniques and electronic monitoring equipment have been successfully used to monitor variations in greenhouse macro- and microenvironments under different thermal conditions.

LITERATURE CITED

Garzoli, K. 1988. Greenhouses: Handbook for nurserymen, horticulturists and gardeners. AGPS Press, Canberra, Australia.

Design and Construction of a Controlled Environment for Propagation of Ornamental Plants

Clive Larkman
Larkman Nurseries P/L, PO Box 567, Lilydale, VIC 3140

A controlled environment is one where all climatic variables are controlled and set by the grower.

DESIGN CONSTRAINTS

We were using in-bed electrical cables which were proving inefficient and expensive to run. Determined to reduce the heating costs by at least 40% for our 60 m^2 of heated propagation beds which were costing us approximately $800 per winter month to run, the first decision was which irrigation system to use? Fog, mist, or high pressure mist? The second was to determine which method of heating and therefore what fuel type to use. We were working with an existing tall tunnel, 18.5 m × 6.2 m × 3.4 m (l×w×h) which was used to house stock plants.

IRRIGATION SYSTEM

In the early nineties the buzz word in the propagation world was fogging. It seemed

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IRRIGATION SYSTEM

In the early nineties the buzz word in the propagation world was fogging. It seemed

that it was the way of the future; the answer to all those hard-to-strike plants. The theory behind fogging made sense and the general feeling at the time was that it improved strike rates and times. The only negative aspect to fog appeared to be the cost. It was suggested that we use a single row of nozzles down the tunnel centre. However we chose to go with two rows. This reduced the chance of damage from a blocked nozzle, it also meant quicker fogging.

HEATING SYSTEM

This is where the greatest headache arose. If we had wanted to heat the whole tunnel there was no problem, as hydronics heating is used in many areas. As we were only going to heat the root zone in one tunnel, we wanted to install a system that would allow for Melbourne's cold winter days but also make efficient use of energy. The only energy consumption figure for hot beds available was obtained from Queensland, 2.7 kW m^{-2}. After some investigation into average mean temperatures, average minimum temperatures, and actual minimum temperatures, I decided that we were about 10% colder, thus we would require 2.97 kW. At that time there was work being done in Canberra and by private companies on energy efficient tunnels and heating systems. Much of this work was centred around phase-change systems. These involved using principles similar to that used by the common refrigerator. Basically, when a chemical changes from one phase to another it requires an energy transfer. This energy transfer either comes from or goes to the environment around the equipment. A Sydney-based company had developed commercial units for domestic usage. They had two systems, one for heating the water and one for direct heating the relevant area. The first unit was prohibitive in its capital cost. The second was not able to withstand the chemicals used in a nursery situation. Being environmentally conscious we also looked at solar power. The capital cost of solar cells capable of generating sufficient energy were large and extremely expensive. Also the back-up system required for winter usage would still be quite large.

As we had 80 m^2 we decided to use 3 kW m^{-2} (as it made the calculations much easier). This meant that 240 kW of power per day was required. At $0.20 per kWh during the day and $0.041 off peak we would have had a hefty power bill. We were back where we started. Off peak rates are substantially cheaper but to use them we had to generate and store 240 kW of power in 8 h. In other words we needed a 30 kW heater. The heating companies told me this was quite plausible. After visiting some places with wood/coal burners, we felt that our system was too small to justify the boiler size needed to make it efficient. Diesel was too expensive, plus it was likely to go up with government taxes being predicted to rise. Another option was waste oil burners. We felt that these would be too dirty and that it wouldn't be too long before they started charging for the oil (remember that LPG was originally a waste product of petrol production that was burnt). This left gas boilers. Direct comparisons between electricity and gas consumption were nigh on impossible as gas consumption is calculated in kilojoules whilst electricity is calculated in kilowatts. It seemed that at a quoted price of $0.25 per litre of LPG it would cost $10 per day, compared with $9.84 with off-peak electricity. This gas rate involved using a large tank at more than $1 per day rental. This left us with one further problem; how much water would be necessary to store 240 kW of energy? After a fair bit of arithmetic and many phone calls we decided on 5000 litres.

HEAT BEDS

I have always questioned the efficiency of raising propagation beds off the ground. We accepted that it was not ideal to place the beds directly on the ground for both hygiene and work practice reasons. Dr. Garzoli's work showed that rocks and alike are good heat sinks. So we decided to build beds with approximately 300 mm high walls using hollow concrete blocks. The beds were then back filled with volcanic scoria, as it is largely filled with air it was light to carry and shovel into the beds. It also acted as an excellent heat sink, and insulator. We then put a layer of 25-mm polystyrene foam on top of the scoria. This was then covered with aluminum foil to further reduce downward heat loss and to stop the sand from falling through into the scoria.

TUNNEL COVERING

We looked at double skinning as this has been proven to greatly reduce heating costs. As we wanted to create two separate compartments, a fixed 65% shade screen was our original choice (currently we had 10% shade). This was instead of double skinning. The fixed screen acted as a heat transfer barrier, reducing upward heat loss during winter and excess heat build up during summer. The volume of air that needed to be maintained at a set humidity level was greatly reduced. The installation of a large exhaust fan at one end of the tunnel above the fixed screen allowed the exchange of hot air with cooler air from outside without affecting the main growing area.

HINDSIGHT

Having the beds at 300 mm high has proven a bonus in heat reduction during summer. It may be 40C at head height, but is still only 25C at bed height. We use a looping system which created some flow problems as well as uneven heat at the ends, a manifold system is much easier to install and gives better flow rates. The tank we chose was large enough but not the ideal shape. We found that the original solenoids failed after about 2 years, due to corrosion of the centre pins. This was due to the grade of stainless steel used which was not corrosion resistant in very hot water. The fixed screens work well as heat barriers. The down side is that the screens support algal growth and thus light transmission after 2 to 3 years is greatly reduced. We, like many people, assumed that if we were to maintain a high humidity then the tunnel must be made fairly airtight. However we soon started leaving the doors open to allow the tunnel to dry out. This has not caused any significant stress to the plants, but has significantly reduced fungal outbreaks. We have recently installed a large fan that is constantly running and changes the air every 10 min.

Managing the Environment for the Production of Quality Plugs

Russell Slobodiuk
Wall's Floriana P/L, Cnr Greens & Perry Roads, Keysborough, VIC 3173

The essence of plug production is in the ability to control the environment. For plug production to be cost effective maximum outputs must be achieved for each square metre of available greenhouse space. The provision of optimal conditions must be the aim throughout the production process, which can take between 3 and 12 weeks depending upon species grown.

Seed Storage. The process begins by using the highest quality seed which has been stored in a dry conditioned atmosphere between 12 to 15C and 35% to 40% RH. Seed will tolerate fluctuations in temperature, but viability and vigour are greatly reduced with fluctuations in RH, particularly if levels increase.

Sowing. Sowing is done mechanically on either drum or needle seeders depending upon the shape of the seed. Accuracy is the key, not speed, so the control of dust, wind, temperature and light in the sowing area is important. Seeders must always be kept clean and well maintained.

Germination. The highest percent germination will always be achieved under optimal conditions. Ideally chambers should be used which will maintain temperature at +/-1C ranging from 15 to 28C and 80% to 95% RH. If possible incandescent lighting should be used. At Floriana we grow over 360 different cultivars from 60 species, each has its own optimal set of conditions for germination. We have four chambers, each with the flexibility to provide a range of environments.

Germination can be quite rapid so accurate labeling of trolleys, showing actual time and date sown, is crucial in the timing of when to house the trays. Just visible radicle emergence is classed as germination. Hygiene in the chambers is also critical as the warm, humid conditions are ideal for fungal growth.

Growth Stages. All germinated trays are moved into controlled-environment greenhouses, onto wire benches. Control of this environment is not as critical as that for germination, however the better the conditions, the better the results. In some cases microclimates may be needed for special crops that require short-term exposure to higher or lower humidity or light levels. This can be achieved by the use of thermal screens or blankets within the growing house.

Preset growing conditions should be monitored and controlled in the correct sequence so as to achieve optimum growth, as well as to be cost effective. Small computers are ideal for sensing and controlling temperature, humidity, and light levels by operating exhaust fans, heaters, evaporative coolers, and screening as required. Automatic control is most effective as growth is rapid and conditions can be changed easily by re-setting the parameters on the computer—rather than moving the crop to another environment. The aim of this housing stage is to achieve maximum root development with minimal top growth.

Conditioning. The only move necessary after the final growth stage is to a cooler environment for conditioning or hardening off prior to transplanting. Controlling this area is not critical if short-term storage is planned. Cooling is an important consideration and this can be achieved simply by using cold greenhouses, with roll-up sides to maximise air flow and correct shading or screening to allow maximum light levels. Long-term storage of plugs is possible but this requires specialised environmental control.

The conditioning stage is important and should result in a plug that has reached ideal root ball development and foliage that is hard enough to withstand the stresses of transplanting, yet have the vigour to quickly re-establish and grow with minimal setback.

SESSION 4: SPECIALIST PROPAGATION TECHNIQUES

Horticultural Research at the Royal Botanic Gardens

Rob Cross
Royal Botanic Gardens, Birdwood Avenue, South Yarra, VIC 3141

INTRODUCTION

The Royal Botanic Gardens Melbourne has recently established a formal horticultural research program. The main areas of research are *Phytophthora*, prospecting Proteaceae for the horticultural industry, and the photoautotrophic micropropagation of *Banksia* for the horticultural industry and *Caladenia* for conservation.

PHYTOPHTHORA

The control of *Phytophthora* in cultivated areas is essential to prevent restrictions on the range of plant taxa that can be grown. The Royal Botanic Gardens is currently undertaking a collaborative project with the School of Botany at the University of Melbourne to test the possibility of using antagonistic microorganisms to eliminate *P. cinnamomi* from infected soils. The trial has been running since Sept. 1995, and will continue until May 1997.

PROSPECTING PROTEACEAE

The generic diversity in the Proteaceae of north-eastern Queensland, and New Caledonia, is being looked at for their potential as landscape plants or as new floricultural crops. Research on the optimal propagation methods for taxa showing horticultural potential will follow.

PHOTOAUTOTROPHIC MICROPROPAGATION

Photoautotrophic micropropagation trials are currently being set up for two areas of work;

1) The micropropagation of *Banksia* with the aim of having an asexual propagation technique that will enable superior selections to be made for the cutflower or nursery industries.

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2) The micropropagation of endangered terrestrial orchids, in particular *Caladenia* spp., with the aim of producing plants for ex situ conservation collections and for reintroducing into natural habitats.

Research by Kirdmanee et al., (1995) using *Eucalyptus camaldulensis* suggests that the survival of plantlets ex vitro will be improved using this method.

Photoautotrophic micropropagation differs from standard micropropagation by maximising the potential of the explants/plantlets to photosynthesise and metabolise normally. It is an attempt to provide the conditions that allow for normal development of the plant. That is:

- Light is increased in the incubators using metal halide lights;
- Carbon dioxide in the atmosphere is increased so that it is not limiting for photosynthesis;
- Sucrose, which is implicated in the inhibition of the RubPcase enzyme, is not incorporated into the medium.

Horticultural research is now an important part of the Royal Botanic Gardens research program.

LITERATURE CITED

Kirdmanee, C., Y. Kitaya, and **T. Kozai.** 1995. Effects of CO_2 enrichment and supporting material in vitro on photoautotrophic growth of *Eucalyptus* plantlets in vitro and ex vitro: anatomical comparisons. Acta Hort. 393.

Micropropagation of *Evolvulus pilosus*

T. Yamamoto, T. Kiyohara, N. Ikeda, and K. Toki
Minami-Kyushu University, Takanabe, Miyazaki, 884, Japan.

INTRODUCTION

In Japan *Evolvulus pilosus* Nutt. 'Blue Daze' also known as "American Blue" has been popular as a potted ornamental for several years. Although the plant is easily propagated by softwood cuttings, micropropagation is expected to be the better technique for obtaining a large number of the elite clones of this plant. This paper describes the regeneration of the plant through organogenesis using three types of explants; nodal segments, shoot internodes, and leaf cuttings.

MATERIALS AND METHODS

Nodal segments (3 mm in length), shoot internodes (10 mm in length), and leaf cuttings were taken from a donor plant grown in a greenhouse. After sterilisation with 1% sodium hypochlorite solution, these explants were rinsed three times in sterile water and then placed on Murashige and Skoog (M&S) media supplemented with cytokinins. All media were adjusted to a pH between 5.7 and 5.8, and solidified with 0.2% Gelrite. In some experiments, nodal segments and shoot internodes taken from plantlets in vitro were used as explants. Shoots formed by the explants were transferred to a rooting medium supplemented with NAA. Cultures were kept at 25C with a 16-h photoperiod.

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RESULTS

Axillary buds were rapidly induced from axillary meristem of the node explant. Induction of axillary buds in the range of 87% to 100% was achieved after 13 days in culture. Benzyladenine (BA) at 0.5 to 2.0 mg litre^{-1} had no effect on the induction of axillary buds. The rooting of axillary shoots was promoted by the addition of NAA at 0.05 mg litre^{-1} to the medium. Through this procedure genetically stable plantlets were ready for acclimatisation in approximately 75 days from the start of culture.

When the shoot internode explants were cultured on the media with BA added, callus and adventitious shoots were formed on the cut end of the explant. The formation of adventitious shoots was best on the medium supplemented with 1 mg litre^{-1} BA.

A large number of plantlets were produced using leaf cuttings as explants. Two types of shoot formation were observed. One was from the cut section of the leaf (by which it was divided into distal and proximal halves) and callus was often induced from the cut surface. The other was from the mid-vein near the petiole of the proximal half of the leaves. Benzyladenine had a greater positive effect on organogenesis of these explants than did isopentyladenine (2iP). Benzyladenine at 2 to 3 mg litre^{-1} resulted in the highest adventitious shoot formation per explant. The formation of adventitious shoots from the cut section of the distal half of the leaves was greater than that from the proximal half.

SUMMARY

Micropropagation can be used successfully to obtain a large number of clonal plantlets. Three types of explant material can be used; leaf cuttings on M&S medium supplemented with 3 mg litre^{-1} BA, shoot internodes on M&S medium supplemented with 1 mg litre^{-1} BA, and nodal segments on M&S medium with no added BA. Adventitious shoots or axillary buds will be induced depending upon the source of the explant material. All plantlets should be transferred to a rooting medium (M&S plus NAA at 0.05 mg litre^{-1}). Once roots have initiated the plantlets can be acclimatised and eventually moved to a greenhouse environment for growing on.

Propagation of *Michelia* and *Manglietia*

Don Teese
Yamina Rare Plants, 25 Moores Road, Monbulk, VIC 3793

SEED

Plants produce clusters of seed pods varying from a few to 20 or more capsules, each containing one or two seeds. Hard black seeds are surrounded by flesh varying in colour from orange to pink or red. Pick the capsules when they first begin to split or show colour when exposed by cutting. Split open fully to remove seed from capsules, squash the flesh or remove from around the seed. Some growers recommend washing the oil from the seed with detergent in case this inhibits germination. The only species for which we find this may be necessary is *Michelia champaca*, which has been difficult to germinate. Most varieties germinate easily if the seed is fresh. The seed should not be allowed to dry out as viability drops markedly. Under

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Australian conditions the seed can either be sown inside or outdoors. Inside provides greater environmental control and may be necessary for colder regions. No pregermination treatments are required. Netting may be necessary to prevent losses to birds.

CUTTINGS

Most *Michelia* and *Manglietia* strike well but there are exceptions. Young stock plants are important to obtain good results. Stock plants should be clean and free of mites and other pests. Terminal or side shoots both strike but the maturity of the wood is the limiting factor. Cutting material is usually taken in January and February, however this will vary according to climatic region. The material is cut to 10 to 15 cm lengths with 2 or 3 leaves which have been trimmed to reduce size. A shallow side cut is made in the base and the cuttings are then dipped in 0.75% IBA talc. The cuttings are stuck into the propagation media and watered in with Previcur fungicide or similar product. These are placed under mist with or without bottom heat. Strike rate varies from 40% to 60%, sometimes higher. However, disaster can also occur with rates as low as 5% to 10%. Stock kept in the same light level as the propagation house may help to prevent leaf drop which often occurs quickly after cuttings are made. High humidity in the first 1 to 2 weeks is essential to prevent cutting stress.

AERIAL LAYERING

Aerial layering is traditionally used in Asia but is very time consuming. Needs constant checking to prevent drying out. Not a technique to use when large quantities of plants are required. Scoring or etiolating the stem before tying the cover may hasten root development.

GRAFTING OR BUDDING

This is a successful method of propagation for *Michelia*, however, *Manglietia* has not yet been tried to any extent. The graft type used varies depending on stem thickness. Scions of some species are thick and pithy, making them awkward to work with. Others are thin with very few side buds, e.g. *Michelia alba*. Side veneer is best due to the thin cambium and pithy centre, although other methods could be used with careful understock and scion selection. Understocks should be vigorous and healthy. Grafting onto *Magnolia*, although initially successful, has had long term problems with overgrowing. More research into the selection of *Magnolia* understocks is required.

Budding works well with those varieties which have thicker stems and large buds. Some varieties have tiny buds and thin wood making budding difficult. A chip bud is usually used. Buds should be cut shallow and leaves are usually removed from the bud or scion but with a piece of petiole left on the buds to act as a handle, these can then be stored in the refrigerator until needed. The graft should be tied with plastic or rubber ties. Budded or grafted plants should initially be kept shaded and in a humid environment. After 1 or 2 weeks these can be hardened off.

TISSUE CULTURE

This is a definite possibility for these genera as many *Magnolia* species are now routinely micropropagated. This technique will require some initial research to

avoid weaknesses or distortions occurring in the resultant plants. These problems have restricted micropropagation of *Rhododendron*, *Kalmia*, and other genera. This method may not be the cheapest but has great advantages in building up numbers quickly and in the export of material overseas.

Propagation Techniques for a New Flower Bulb Crop (*Lachenalia*)

Josephine G. Niederwieser
ARC-Roodeplaat Vegetable and Ornamental Plant Institute, Private Bag X293, Pretoria 0001, South Africa

A NEW CROP

Lachenalia is a bulbous genus endemic to the south western Cape in South Africa (SA) and belongs to the Liliaceae family. The genus comprises approximately 110 species and a number of these are grown commercially on a small scale, e.g. *L. aloides*. ARC-Roodeplaat developed, through breeding and selection, a number of cultivars which are currently being test marketed in Europe as both garden and potted bulbs.

CHALLENGES REGARDING PROPAGATION

Lachenalia, like *Ornithogalum*, is susceptible to Ornithogalum mosaic virus (OMV) and to a lesser extent tobacco necrotic virus (TNV). Unfortunately the disfiguring symptoms are displayed soon after infection. Compounding this, is that OMV generally occurs in the natural habitats and in bulbs of commercial growers in SA who are situated mostly in the northern provinces of the country. Experimental plantings became totally infected after 2 years. ARC-Roodeplaat had to successfully overcome this problem if *Lachenalia* was to be introduced into the very competitive international flowering bulb market.

SOLUTION

Although the propagation of *Lachenalia* is presently insignificant, a plant improvement scheme consisting of four stages has been implemented. The problem of viral infection appears to have been solved. Fortunately the system was developed at a very early stage in the commercial production of this genus.

The scheme consists of the following phases:

I) Through selection and repeated testing for virus, virus-free nuclear plants have been isolated and are being maintained in an insect-free greenhouse where the guidelines of the European and Mediterranean Plant Protection Organisation are applied.

II) In vitro propagation of virus-free stock plants.

III) Production of propagation material by means of leaf cuttings. Tissue-cultured plants are transplanted into a gauze house some 2 km away from other plantings.

IV) Bulblets produced during phase III are further multiplied by leaf cuttings, chipping and natural offsets. No other bulbs are grown in a radius of 5 km from this nursery.

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A possible fifth phase is anticipated for the future. Bulblets produced during Phase IV may have to be grown to marketable size by a specialist grower. Optimal conditions for multiplication by leaf cuttings and preparation of bulbs for the end product appear to be different (temperatures and light intensity).

TECHNIQUES

Virus Indexing. Electron microscopy and immunological.

Tissue Culture. Adventitious bud formation using leaf explants through 3 to 6 generations. New in vitro stock is initiated every second year to avoid possible variation. Plantlets are rooted in vitro. (Nel, 1983; Niederwieser and Vcelar, 1990).

Leaf Cuttings. Techniques have been described by Duncan (1988).

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Reflections on the History of Irish Gardening: Thelma Swash Memorial Lecture[1]

Donal Synnott
National Botanic Garden, Glasnevin, Dublin

In 1995, was the bicentenary of the founding of the National Botanic Gardens, Glasnevin, which gave many of us at the Gardens the excuse to reflect upon the history of Irish horticulture and on Glasnevin's place in that history.

History is sometimes seen as the story of influences from abroad and this approach can certainly be applied to the history of gardening in Ireland. The Romans, as far as we know, didn't get to Ireland, or if they did they just came over for occasional forays, so we wouldn't expect any Roman influences in early Ireland. The first wave of invaders of which we have any record is that of the Vikings and, from archaeological investigations, we know that gardening was not high on their agenda although fruit was gathered wild from the surrounding countryside.

A monastic tradition has existed in Ireland since early Christian times and continued after the Norman invasion. There is evidence that the Normans were responsible for introducing a large number of garden plants, and wild plants which are found significantly near Norman towns, castles, and monasteries. Wallflowers, mallow, good King Henry, wall pellitory, hemlock, milk thistle, and henbane are all found with remarkable regularity near Norman habitations. On the limestone rocks by the great buildings of the Rock of Cashel, wild parsley is found. This is not a native Irish plant. It doesn't occur in many other places throughout Ireland, is generally associated with Norman habitations, and its introduction must be attributed to them. Yellow wallflowers grow on the old town walls of Drogheda.

Following excavations at Trim Castle, mallow and black horehound came up all over the excavation site. Many of these plants have a medicinal value and give little indication of decorative gardening by the Normans. For indications of a move in that direction we have to jump a few centuries. The abolition of the monasteries by Henry VIII is, generally speaking, considered to have been an unfriendly act. However, inquisitions taken during his reign are useful and show that the gardens of the monasteries were about an acre in extent. Their main function was to provide medicinal herbs and vegetables. There must have been some development of gardening in Ireland in Elizabethan times. Although there is controversy about the original introduction of the potato we do know use of the potato spread faster in Ireland than in England. In 1663 Robert Boyle, the Earl of Cork, had a bag of potatoes sent to him in London by his Irish gardener to show to members of the Royal Society, suggesting that they were a novelty in England. We also know that Irish emigrants later introduced the potato to Virginia. The often quoted paper by Joseph Walker, published in 1790 on the history of gardening in Ireland, attributes the introduction of edible cherries to Walter Raleigh. Raleigh is also supposed to have introduced a sweet smelling yellow wallflower from the Azores.

The Seventeenth century was one of great political upheaval in Ireland with many changes of land ownership not conducive to such a peaceful pursuit as gardening. However, following the Battle of the Boyne a century of relative peace was

[1]This is an abridged version of Donal Synnott's lecture.

established. The end of the 17th century brought a great influx of Protestant refugees and settlers to Ireland. Palatines, Bavarians, Walloons, and English Quakers came to live here. They settled in places that the late Sheila Pim described as "still characterised by a curious neatness". Because of our favourable climate, the range of plants from all parts of the world grown in Ireland is very extensive. That tradition of naturalising exotic plants began, it is believed, with Sir Arthur Rawdon of Moira in County Down. He grew plants from North America such as *Robinia pseudacacia* and *Yucca filamentosa* for the first time here.

The tradition of growing decorative flowers we have to attribute mainly to the Dutch. They, like the French, were interested in evergreens and topiary, but they also extended greatly our interest in carnations, pinks, tulips, anemones, ranunculus, hyacinths, auriculas, and polyanthus. Artificial hybridisation was another century away but gardeners were selecting seedlings and extending greatly the range of decorative plants in cultivation. Fashion in plants is a curious thing. It is as fickle as the fashion in garden ornament. We know that plants go out of fashion or favour from overuse or the wrong kind of use. Discerning gardeners nowadays do not plant *Lonicera nitida* nor *Populus* ×*candicans* 'Aurora'. Yet these are widely planted by naive or independent-minded gardeners. *Fuchsia magellanica* has not suffered the same ignominy. Who was it who first decided that *P.* ×*candicans* 'Aurora' was not for by the discerning gardener? Was this consensus plucked out of the air or did it have a leader in the formation of such an opinion? There is no accounting for tastes, as much tastes in garden plants as in garden ornament. We must be grateful that people have chosen and choose to go their separate ways.

I suspect that in gardening, as in other walks of life, strong characters really have great influence on what the rest of us choose to believe. Charles Nelson in *The Brightest Jewel* quotes an anecdote from Sir. Frederick Moore. When Moore was just 22 years old he became Curator of the Glasnevin Botanic Gardens and, although his appointment was supported by the majority of people who knew him, there was some concern that such a young man would not be able to do the job. So a self-appointed horticultural tribunal comprised of John Bennett Coe of Nenagh, Edward Woodall from Scarborough, and William Edward Gumbledon, the senior member of the party — escribed by Dr. Nelson as "an opinionated gentleman who had developed his passion for gardening only a decade earlier" — came to visit Moore at Glasnevin and to see if he was up to the job. Sir Frederick Moore recalled the episode nearly 60 years later: "It was with much trepidation that I started to take them around the garden, for three more dissimilar men could scarcely have been brought together and trouble soon began."

"In the Aquatic House Mr. Gumbledon took me to task severely for my pronunciation of a plant, emphasising his remarks by banging his umbrella on the flags. Mr. Woodall wanted to see the orchids. Mr. Gumbledon wanted to see the florists flowers out of doors. Mr. Bennett Coe was willing to go anywhere and kept the peace between the other two. In front of the Curvilinear Range Mr. Gumbledon denounced a plant as a 'tush' plant, his term for any plant he did not like, and proceeded to beat it to bits with his umbrella. I was too timid to do more than mildly remonstrate and bemoan the loss of a recently arrived plant".

Gumbledon was later to make amends by donating his valuable collection of illustrated floras to the library at Glasnevin.

William Robinson was another self-opinionated Irishman who had a great influ-

ence on the progress of gardening, mainly through his writings but also through the force of his personality. It seems as if Robinson didn't suffer fools gladly but I suspect his definition of a fool was anyone who did not share his own views. I have avoided mentioning the names of William Henry Harvey, Patrick Browne, Ninian Niven, the Drummonds, J.C. Lyons, Daniel Robertson, Robert Lloyd Praeger, or Augustine Henry; or the important places like the Burren, Powerscourt, Mounts Usher and Stewart, Birr Castle, etc., in this tiptoeing through the tulips of the history of Irish gardening. The daily practitioners of the art of gardening are as important as the great and enduring names.

Let us listen to the advice of a father to his 18-year-old son who is about to embark on a career in gardening at Glasnevin in 1898. William Parnell, Foreman at Glasnevin, wrote:

"My dear son Fred, I have received your note stating willingness to accept employment in the gardens here so that you may have the opportunity of learning the business. I will write down a few plain rules for your guidance[...] 1st as to God[....] 2nd to your parents[...] 3rd personal appearance[...] 4th when at work. Do it quickly and well, not putting over time at it, nor slauming it over in a hurry and half done. Attend to small details and be always studying the best way of doing it. Never be found standing gossiping or smoking (a dirty unnecessary habit) and while civil and friendly to all, make no close friendships unless with a worthy man. 5th leisure hours[...] 6th Sundays[...] 7th If admitted as you may be on next Thursday morn, your commencing pay will be eight shillings a week, to be raised as circumstances permit and as your conduct deserves. The half of this sum goes to your mother, 2/6 to be put up for clothes. The remainder is to be left in my hands for emergency calls such as tram fare, holidays calls, and such like. I don't want a penny of your earnings for myself. You will thus have 6d each week for pocket money to be increased as your wages advance. I would not like you to have more at present and if you give up the dirty habit of smoking you wont have to spend your pennies on cigarettes or tobacco. And now I have said all I have to say at present."

"Don't throw this letter away and call it a long sermon. Read it now and then and mind it. Hereafter you will find that every word of it was needed. Your affectionate Father, W. Parnell."

The letter was preserved by the Parnell family and donated by Fred's son, Jack, last year for Glasnevin's archives.

Gardening is as much about personalities, individuals, and eccentrics as it is about great movements influencing taste and practice. Although the great institutions and great gardens, the plant collectors and writers about plants, do influence what we do and what we plant, the garden is, in the end, a great independent republic where we can be free of public tastes and influences — a kingdom where we are absolute masters.

Such freedom has given us 18th and 19th century garden features such as clipped hedges and topiary, Victorian frivolities like the chain-tent pergola from Glasnevin and some features of the flower garden like the great herbaceous border, carpet bedding, and the essential spring and summer bedding of public parks which are the result of many centuries of changes and influences in gardening and gardening tastes. It has given us the great glasshouses which were built in Ireland, especially those at Glasnevin.

Among the outstanding characters in the history of Irish gardening is David

Moore, who was responsible for most of the glasshouses which we have at Glasnevin and for many of the plants in the collections of Irish gardens. During his time at Glasnevin, from 1838 until his death in 1879, he introduced many thousands of plants from various parts of the world.

David Moore did a great deal to persuade the Royal Dublin Society to build and expand the glasshouses at Glasnevin. The greatest of these projects was the building of the Curvilinear Range which was mainly the work of Richard Turner. It was begun in 1843, and completed in its first phase in 1848. A second phase was built in 1868. A major restoration of this glasshouse has just been completed by the Office of Public Works. The Great Palm House at Glasnevin is a later building. It was supplied by Boyds of Paisley in Scotland and was built in a very short time in 1884, replacing a wooden structure which had fallen down in a gale force wind. It too is in need of some serious restoration.

Today, garden tourism is very important for the Irish economy, gardening now brings more people to Ireland than golf does. Many great Irish gardens are being restored with grants partially funded from the E.U. Thanks to the diligence and skill of plant propagators the range of good and interesting garden plants is being dramatically extended and made available to a wider public. All of this activity is of course promoting gardening within Ireland as well as attracting more people to the country from abroad. The future looks bright.

The Right Rootstock for a Good Graft Stick

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INTRODUCTION

Propagation by grafting is expensive in terms of resources and labour input and is justified only because of the potential for enhanced returns for the finished, often highly desirable, plant. Failure of grafts can therefore be very costly and must be avoided.

Use of the correct understock is fundamental to success but there is such a confusing range of terminology applied to planting stock that while propagators know the size and type of stock required, they cannot be certain of asking for it correctly, let alone receiving it. There is, therefore, a need for a simplified and generally accepted specification for stocks and planting material. The aim of this short paper is to address some of the misunderstandings current within the trade and to propose the adoption of specifications and definitions already used in forestry.

TERMINOLOGY AND DEFINITIONS

Stocks are produced either vegetatively or from seed and are used at various ages and differing sizes in a wide range of grafting and budding techniques. It is this diversity of practice that has given rise to the range of descriptive terms in common use and misuse. Terms such as stocks and bedded stocks, seedlings and undercuts, transplants and liners, plugs and potted liners, stems etc., which in themselves give little indication of age, size, and usage could be made more meaningful if combined with the simple definitions commonly used for forestry and hedging, giving age and cultivation type (Table 1).

With the application of a little further specification refinement and detail, all types of understocks and liners could be more accurately described and identified (Table 2).

SPECIFICATIONS

The girth of the rootstock or stem to be worked is the most important consideration and is usually expressed as "collar diameter". An indication of working height should be given and this is essential for top working.

Grading to stem diameter is normally to a tolerance of 23 mm depending on species and can range from 4 to 6 mm for seedlings for potting; through the normal 6 to 8 mm (7 to 10 mm), or 8 to 10 mm for lining out stocks; up to 10 to 12 mm and even 15 to 20 mm for the heavy stocks for bench work.

Specification should also take account of growth and development during the preparation for working. This is particularly important when producing pot-grown stocks for later bench working as quite small seedlings will often make a considerable girth increase during establishment. The same applies to stocks for summer field budding. Plants for immediate bareroot, bench, or top working must be secured in the exact range of size required.

The practice of specifying stock by overall height, without reference to age or girth (except the statement "pencil thick") surely leads to problems.

The understock is the vital and first component of a quality grafted plant. We have scion and budwood from purpose grown, healthy mother plants, we provide good land and facilities to match our propagation skills. We must, therefore, use the right rootstock to ensure success.

Table 1. Plant specification for forestry and hedging.

Age specification	Type of Plant
0+1	1 year cutting
0+1+1	1 year cutting + 1 year transplanted
1+0	1 year seedling
2+0	2 year seedling
1 u 1	2 year seedling (undercut)
1+1	1 year seedling + 1 year transplanted
1+2	1 year seedling + 2 year transplanted
1/2u1/2	1 year seedling (undercut)

Table 2. Plant specification for understocks and liners.

Age specifications	Type of plant
0+1	1-year stock from stool bed or cuttings (normally graded 5 to 7 mm, 6 to 8 mm, or 8 to 10 mm)
0+1+1	2-year stock bedded for 1 year or transplanted (normally graded 6 to 8 mm, 7 to 10 mm, or 8 to 12 mm)
1+0	1-year seedling for potting or lining, (normally graded 4 to 6 mm or 6 to 8 mm, with leader if specified)
1 u 1	2-year seedling (undercut at end of first year) normally stocks 5 to 7 mm, 6 to 8 mm, and 8 to 10 mm (or plants with leader for lining to grow on)
1+1	1-year seedling + 1-year transplanted stocks 5 to 7 mm, 6 to 8 mm, 8 to 10 mm, or 10 to 12 mm (or plants with leader for lining to grow on)
1+2	1-year seedling + 2-year transplanted, heavy stocks 8 to 10 mm, 10 to 12 mm or larger stems for top-working at 60 to 150 cm.
1+1P	1 year seedling, potted for 1 year, normally in P9 or 1-litre pot for grafting or lining
1+0P	1-year seedling pot grown for grafting or lining

Liner Production Management and Ergonomics

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INTRODUCTION

Fitzgerald Nurseries is a new nursery business, specialising in the production of liners and plug-rooted cuttings. It was found that attention had to be given to planning the short-term and long-term objectives of the business simultaneously. Without proper care and planning these two objectives may be self-conflicting, for example, the provision of proper facilities may be at the cost of production materials. It therefore became necessary to put resources into producing our crops at a profit and to a high standard to generate a cash flow. Many liner nurseries must take such broad factors into account as they develop, expand, and become more efficient.

The management of limited resources in such a situation is of paramount importance. The use of these resources has to be optimised and each mistake made must be a resource in itself. If a mistake is not too major the business will continue provided the error is corrected and the procedure documented for all staff to take note — a new information resource has been added to the business. The big question is, how many of these can you afford? It is obviously cheaper to learn as much as possible from mistakes made elsewhere, or observed by others who have already developed solutions to many of your problems, so this should be where the new business begins to build its knowledge base.

Below are some points which this business has considered and which may serve as a starting point for some in the search for answers to various topics:

- **Vision.** Do you know what your aims are and have you documented them? Do the key staff understand these aims and do they understand how these aims will affect their jobs?
- **Strategy.** Is there a long-term plan in place, which takes into account your resources and the abilities of your staff? Do your staff know what the plan is?
- **Skills and Staffing.** Is there investment in training and are staff encouraged to develop as the business grows?
- **Structure.** Is the nursery structured in such a way that it can be managed properly, and have staff been made accountable for the efficiency of their work? Is there a regular review of all aspects of performance?
- **Reviews.** Do you systematically examine all practices and procedures on the nursery, attend seminars, read relevant literature, look at new concepts and technology with a view to constant improvement of the nursery and its staff?

MANAGEMENT OF RESOURCES

The most valuable resource any new business will have is its founder and the key staff. If these people have ability, are interested in their work, have a will to succeed, and can work together as a team then the nursery is off to a good start. There will

be many other requirements of these key people and possibly the least obvious is the patience required to stick with a business until it turns the corner to profitability. If these people do not have such qualities you will just have to regard them as a liability and take the proper action.

In an industry where a high level of attention to detail is required over a long production period, to get the product to a marketable state, it is essential that proper attention is paid to training and personal development of staff. These people may change from time to time, especially in a new business. It is therefore essential that the time given to training an individual is not entirely lost to the business if that individual leaves. This can be achieved by ensuring that all staff have access to the information obtained on training courses, or built up by the business, and see its practical application. I believe this to be the best way of ensuring that a "pool" of valuable training remains the property of your nursery. This can only be achieved if proper procedures and work practices are in place and documented to ensure proper consistency from one worker to another.

The managers within the nursery will have to become more than plants people, they will need the ability to spot qualities and weaknesses in their staff, and act as the catalyst to enhance the former and reduce the effects of the latter. Each key staff member, in turn, will have to be given the proper training to do their jobs to the best of their abilities and, in this industry, this is usually the responsibility of the owner. Do we always take this responsibility? It is too easy to allow time to slip without acting upon what should have been obvious. It is necessary however, once the need has been identified and the resources made available, that the key staff are made accountable for applying the training they have received.

The other resource that the new nursery will need can be summed up quite simply and it is "capital investment". There are many ways one can acquire capital and many people to advise on it. Extensive advice should be taken as the production of liners is one of the more capital intensive businesses in this industry and make-shift facilities resulting from lack of capital cause loss of profit. It is therefore important that a proper business plan is made out, with realistic estimates for the provision of proper facilities for your crops and a realistic repayment period set for any loans procured. Once the appropriate resources have been obtained it is the management of them that will determine whether you can pay your investors back. It is therefore your competence in their eyes which will determine whether you get that capital or not.

Ultimately it is customer demand for our product that determines how we fund our business and we must be concerned about what is good for our customer. Without good quality customers the business is like a yacht without a sail and totally dependant on where the current brings it. The profitable filling of that demand will be the source of much of the businesses funding for production.

If we are targeting a market where we must produce plants in large quantities at a low sales value and profit, this factor is obviously going to determine the outlay on the facilities. What is certain in this situation is that every cost-saving provision that is put in place will ensure the survival of the business against its competition. We must provide what our customers require for them to make a reasonable profit, too. When that demand on price exceeds reason the liner producer must find new customers who can pay a reasonable price.

When the business can no longer either reduce costs or find new customers a decision has to be made as to whether liner production can be the sole activity of the

business and alternatives may have to be looked at.

Knowingly selling at a loss or an unsustainable profit may mean either the producer or the staff will have to accept a low income and as not many of us willingly volunteer for this option we must ensure that we do not end at that situation through bad planning. This situation may be hypothetical but it is a point where some of us may come to in the future if some haven't already.

What is the value of our product to our customer? It may be solely dependant on what our customers get for their product and if our customers are not making a reasonable margin or have low sales volume, the chances are we will not prosper. All these points, if carefully studied, should show the need for a good cost analysis system. If we do not account for costs such as lost production time (down time) or other latent costs we run the risk of having high sales but a bankrupt business. On the other hand if we have bad and inefficient work practices, fuelled by unfocussed staff or management but get-by through making our customers pay too much, we may see lean times in the face of competition. The identification of costs on a product category basis is the only way to ensure particular products are not under or over priced. There is potential for loss of profit in both cases. There are many examples in other industries of how this is done, but many of us are slow to develop such a system as there are so many other concerns to attend to which seem more important.

ERGONOMICS

In the view of this author, the study of ergonomics has not been given proper attention and its rightful place on college courses. While a lot of people have a natural ability to lay their work out ergonomically many do not. Those not already studying this subject as part of the overall management of a liner nursery should seriously consider adding it to their reading list.

Ergonomics is a way of thinking about the layout of workplaces and growing areas, the organisation of work and the adoption of tools and equipment for the effective and safe completion of tasks. This, in effect, is common sense to us all but there can be many instances where a more in-depth study and application of ergonomics could prove useful - and ultimately profitable - to many of us. There are many tasks which require people to spend long periods of time seated or standing in one position. There are also supervisory jobs which require excessive moving around the nursery. The design of any nursery should take these factors into consideration. If staff do not have a well thought-out work environment it will have adverse effects on their psychological and physiological approach to their work. The following are just some practical examples of how the study of ergonomics can help the liner producer.

Design of Chairs Used for Staff Preparing Cuttings. This should take into account stress on the spinal column which should be as straight as possible when sitting. Chairs should be adjustable to suit different members of staff and different tasks. The chairs should be chosen with worker comfort in mind, not just price, as a little investment in an ergonomically designed chair should be repaid in output if all other management is good.

Light, Heat, and Surfaces. At the proper room temperature the body can function efficiently. However, nurseries often have over-heated work areas yet don't have proper facilities to heat the propagation hall in winter. This can be easily overcome by thermostatically controlled heating. On this nursery, we use radiators bought

second hand and run from the glasshouse heating system. It is now law to have lighting installations to an approved standard but sometimes the light emitted is too little, too much, or reduced by dust deposits on tube covers and absorption into dark walls or work surfaces. Poor work surfaces can also reflect too much light and cause stress to workers eyes. All these elements result in worker discomfort which in turn reduces the output and well being of staff.

There are many other, more serious, examples of poor workplace provision, such as faulty appliances, untidy work areas and badly maintained equipment, which can have more serious implications for the well-being of staff and the survival and profitability of the nursery.

An ergonomically sound nursery provides proper work conditions so that management and staff can progress their nursery in a safe, focused, and productive manner. Many ergonomic topics are either already covered by law or may soon be. It is already mandatory to provide a Safety Statement for businesses. Why not produce an Efficiency Statement, where loss risks can be identified and solutions put in place? This statement would be reviewed by all key staff to ensure a better future for all. One of the very important lessons learned on this nursery is that attention given to the needs outlined above has a very positive effect on how people work as a team and the interest shown by an employer for the well being of staff will be mutually beneficial.

I believe that the study of ergonomics by nursery owners and managers will ultimately lead to the following:

- The reduction of worker stress.
- The health and safety of staff.
- Staff motivation.
- The reduction of costs.
- Improved productivity and product quality.
- More realistic profit margins.

Pest Control and Production Systems for Liner Production

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VINE WEEVIL CONTROL

Since withdrawal of approval for the pesticide Aldrin, 10 years ago, life has been difficult and expensive. It is not acceptable to supply vine-weevil-infested liners, so on this nursery controlling vine weevil takes top priority, with a strict hygiene programme on the nursery combined with the latest chemical controls. In the view of this author, pesticides as toxic as Aldrin are inappropriate for liner production in any case, because of the dangers associated with application of such chemicals, handling plants afterwards, and the safety of workers and customers.

The nursery has also experienced problems with pesticides introduced as Aldrin replacements, for example, poor control (promises of a miracle product which isn't always the case), damage to crops, and high purchase cost.

In the last 2 years, the most promising development in vine weevil control has been the introduction of nematodes. All liners on this nursery will be treated with nematodes in Autumn 1996 and again in Spring 1997 at a cost of approximately £4000. Good results have been achieved by some other nurseries and at last there may be a good method for the control of vine weevil at an affordable cost. The author looks forward to reporting back to interested members when our results are available in June 1997.

PRODUCTION MANAGEMENT AT L&K DUNNE NURSERIES

The nursery produces 120,000 cuttings per week. This has been made possible because of an efficient system which has been built up over the years and the availability of highly skilled people who we have trained ourselves, aided by summer students aged between 15 and 22 years. Attention to detail right through the production cycle is vital for success. Among the most important points are:

- Type of worker — honest, hardworking, and willing to learn.
- Quality and evenness of cuttings.
- Quality of work.
- General good planning and organisation in advance.
- In order to achieve maximum results each year, good records of previous years are a must. This gives an ability to adapt to and overcome changes such as different weather conditions and other problems that arise in production.
- Good planning is essential to optimise use of modern machinery, material and technology.

The 10 most important elements of the management system at L&K Dunne are:

- Organisation and planning.
- Quality cuttings stored in a cooler at 3C.
- Good team work.
- Good compost. We use Bord na Mona blended Irish peat (70% 6 to 12 mm, 10% 6- to 12-mm peat nuggets, 20% 0- to 10-mm fine peat plus 10% granite grit).

- Insert cuttings as soon as possible.
- Check all cuttings 2 days after inserting for water and other problems and then every 3 days after that.
- Spray fungicide every 10 days.
- When rooted, harden off as soon as possible and preferably harden off at night or on dull days.
- Spray all cuttings with a suitable herbicide 2 weeks after hardening off.
- Tidiness and hygiene right through production.

Experiences with Carbon Dioxide Enrichment for Production of Rooted Cuttings

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INTRODUCTION

Trials at the Research Station for Nursery Stock at Boskoop have already shown that carbon dioxide (CO_2) enrichment has a positive effect on rooting and growth of cuttings, particularly rooting percentage and fresh and dry weight (Table 1). In 1992 these positive results from the Research Station encouraged Sanders Nurseries to invest in CO_2 enrichment equipment and to use it in all propagation. The technique has proved to be very beneficial for this nursery and has never given negative results, though sometimes there has been no difference between use and non-use of CO_2 enrichment.

When producing cuttings under low polythene covers, if there is no CO_2 enrichment, carbon dioxide levels under the polythene may drop below the threshold for plant growth. For example, measurements at Willem Sanders Nurseries on 1 day in March showed 3000 ppm CO_2 under the polythene produced by plant respiration during the night. The day started with fog but the sun broke through between 9 AM and 9:30 AM. Within 1 h the CO_2 level fell from 3000 ppm to 75 ppm, which is below the CO_2 level needed for growth of the cuttings. At this point the cutting will be metabolising its own stored energy reserves, if it has any. In such weather conditions some CO_2 generating equipment may not be able to generate enough CO_2.

CARBON DIOXIDE ENRICHMENT REGIME

On this nursery cuttings are rooted under close polythene film. For the first 2 weeks condensation (or traditional) film is used. As soon as good callus is seen the film is lifted approximately 10 cm. From now on, anti-condensation film is used in order to obtain more light and better humidity around the cuttings. As there is now more air volume around the cuttings, computer controlled injection of carbon dioxide to generate up to 800 ppm CO_2 is started.

Qualitative observation on the nursery has shown that cuttings remain in a much better condition with reduced incidence of fungal infection when CO_2 enrichment is used. For example, the leaves of *Magnolia, Rhododendron*, and *Camellia* cuttings are greener and healthier. Blue conifers start growing a little before rooting and the young shoots are very blue and healthy. The cuttings do not seem to start rooting earlier, but when they do root, rooting is more simultaneous across the crop and each cutting produces more roots.

EARLY ERRORS IN USING CO_2 AT SANDERS NURSERIES

At first, when anti-condensation film was used during the CO_2 enrichment phase, there was too much light in summer for some taxa. For example many *Photinia* and *Pieris* cuttings were lost. Now the anti-condensation film is covered with fleece in summer to obtain better balanced rooting conditions.

Table 1. Summary of significant effects of CO_2 and light and significant interactions of four experiments in the period 1991-1993 on rooting percentage, number of roots, and fresh and dry weight (with permission, Research Station for Nursury Stock, Boskoop).

		Effect											
		Light				CO_2				Interaction			
Date	Plant	%	N	F	D	%	N	F	D	%	N	F	D
Sept 91	*Juniperus scopulorum* ' Skyrocket'		++			++	+++	+++	+++				
	×*Cupressocyparis leylandii*					+	++	+++	+++				
	J. chinensis 'Plumosa Aurea'		+			+++							
	J. horizontalis 'Wiltonii'		--			+++	+++	+++	+++		*		
Sept 92	*J. scopulorum* 'Skyrocket'			+++	+++	+	+++	+++	+			*	
	×*C. leylandii*			+	+++		++	+++	+++		*	**	*
	J. squamata 'Blue Star'		+	+	++	+++	++	++	+++				**
	×*C. leylandii* 'Golden Triumph'		--	--								*	
Feb 93	*J. scopulorum* 'Skyrocket'		+	+	++			+	+				
	×*C. leylandii*		-		++								*
	J. chinensis 'Plumosa Aurea'		-		+	+			+				
	×*C. leylandii* 'Golden Triumph'	-											
Sept 93	×*C. leylandii*		+		+					**			
	J. chinensis 'Plumosa Aurea'				++								

[1] Abbreviations and symbols: rooting percentage (%), number of roots (N), fresh (F) and dry weight (D); + means a positive effect of the factor ($p<0.05$), ++ means a positive effect ($p<0.01$), +++ means a positive effect ($p<0.001$), -(--) means a negative effect, and *(**) for interaction effects.

In some cases the concentration of rooting hormone was reduced because the cuttings grown under CO_2 enrichment are more active and produce more of their own auxins.

SITUATIONS WHERE CO_2 ENRICHMENT MAY NOT BE OF BENEFIT

When cuttings are rooted in large volumes of peat, for example in deep open trays or beds rather than in cell trays, CO_2 is produced through the composting activity in the peat so enrichment is not necessary.

The Effect of Type and Rate of Controlled-Release Fertiliser on the Performance of Hardy Nursery Stock in Containers

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Four controlled-release fertilisers (CRFs): Ficote 140 (14N-3.5P_2O_5-6.5K_2O), Multicote 8 (18N-2.6P_2O_5-9.8K_2O), Osmocote 12-14 month (15 : 4 : 9), and Plantacote 12M (15N-4.3P_2O_5-12.5K_2O) were compared for the production of hardy nursery stock. These fertilisers were incorporated into a peat compost at three rates to provide 450, 750, and 1050 g N m-3. Five plant subjects were studied: ×*Cupressocyparis leylandii* 'Castlewellan Gold', *Choisya ternata, Ligustrum ovalifolium, Ulex europaeus* 'Strictus', and *Ozothamnus ledifolius*. The four fertilisers and three rates were applied in a factorial design for each subject. Rooted cuttings were potted up into 2-litre pots in May and placed in a bed with overhead irrigation. The plants were evaluated in December and May for vigour, colour, height, fresh weight, and marketability. Higher rates of CRF resulted in increased fresh weight and other characters evaluated for most of the plant subjects and fertilisers tested. Plants were more responsive in terms of vigour and marketability than in colour and height. Ficote and Osmocote were the most consistently successful of the fertilisers. Multicote gave poor results with *Ligustrum* but was satisfactory with the other subjects. *Ulex* performed poorly with Plantacote. These results may be related to trace element nutrition.

INTRODUCTION

Controlled-release fertilisers (CRFs) are widely used in Great Britain and Ireland for the production of nursery stock plants in containers. Small plants are commonly potted into 2-litre pots in spring, grown on during the summer and autumn, and are ready for sale in the autumn and following spring. The present experiment compared four CRFs that are available in Ireland for this type of production schedule.

METHODS

Four CRFs — Ficote 140, Multicote (8-10 month), Osmocote (12-14 month), and Plantacote (12M) — were incorporated into a peat compost at three rates to provide nitrogen at 450, 750, and 1050 g m^{-3}. The actual rates of fertiliser used are shown in Table 1.

Rooted plants of ×*Cupressocyparis leylandii* 'Castlewellan Gold', *Choisya ternata, Ligustrum ovalifolium, Ulex europaeus* 'Strictus', and *Ozothamnus ledifolius* were planted into 2-litre pots in May and stood down on a gravel bed with overhead irrigation. Half of the plants were harvested in December and the remainder in May. At the same time plant height was measured and the plants were assessed for vigour, colour and overall marketability.

Table 1. Amounts (kg m^{-3}) of controlled-release fertilisers used in the experiment.

Fertiliser	Specification (N-P_2O_5-K_2O)	Rate 1	Rate 2	Rate 3
Ficote 140	14-3.5-6.5	3.21	5.35	7.49
Multicote 8	18-2.6-9.8	2.50	4.16	5.82
Osmocote (12-14 month)	15-4-9	3.00	5.00	7.00
Plantacote 12M	15-4.3-12.5	3.00	5.00	7.00

Three samples of 60 granules of each fertiliser, excepting Plantacote, were taken from the pots at assessment time. These were ground with a mortar and pestle, made up to 250 ml with distilled water and analysed for residual nutrients. This same procedure was also carried out with unused granules and the results of the residual analysis were expressed as a percentage of the original values.

The four CRFs were added to silica sand which was poured into plastic cylinders which had a mesh secured at the bottom. The cylinders were placed in a funnel and then transferred to a glasshouse in June. Every 2 weeks, over a 20-week period, the cylinders were leached with distilled water and the leachate was collected and analysed.

RESULTS

As there was no significant interaction between CRF type and rate, the results for each factor are presented separately. The effect of rate of CRF on the fresh weights of the plants at the end of the experiment are shown in Table 2.

Table 2. Effect of rate of controlled-release fertiliser on the fresh weight (g per plant) of five subjects.

Rate	×*Cupressocyparis leylandii*	*Choisya*	*Ligustrum*	*Ulex*	*Ozothamnus*
Low	196.0	93.1	35.5	160.8	134.6
Medium	228.3	135.2	41.5	211.8	139.9
High	299.0	158.3	68.3	231.9	162.1
F-test	***	***	***	***	***
S.E.	13.4	8.61	5.52	9.64	5.04

There was a very positive response to increases in the rate of CRF in all five plants. In order to summarise the large amounts of data obtained, the values for each character recorded were expressed in relative terms with the highest value being assigned 100 and the other values expressed as a percentage of the highest value. The results were then averaged across the categories to obtain a single value for each rate which gave a measure of the overall performance of that rate for the particular subject. The results of this exercise are shown in Table 3. This clearly shows that the

high rate of CRF gave the best overall performance. *Ozothamnus* was the least responsive of the five plants.

Table 3. Relative performance of five subjects at three rates of controlled-release fertiliser (CRF)—May rating.

Subject	Rate of CRF		
	Low	Medium	High
×*Cupressocyparis leylandii*	88	90	100
Choisya	79	94	100
Ligustrum	74	77	100
Ulex	88	96	98
Osmanthus	95	93	99
Mean	85	90	99

The effect of the four CRF types on fresh weight are shown in Table 4. There was no significant effect with ×*C. leylandii* and *Ulex* but the other three species performed better with Ficote and Osmocote than Multicote or Plantacote. The relative performances at the final harvest, calculated as for the rates, are shown in Table 5. This clearly shows that Ficote and Osmocote performed better overall than the other CRFs. *Ligustrum* did particularly badly when Multicote was used (Tables 4 and 5). The results of the leaching experiment for nitrogen and copper are shown in Fig. 1. All the fertilisers showed a controlled release of nitrogen and this result was also obtained with the other major nutrients. Ficote released nitrogen more rapidly than the other fertilisers. The picture was quite different for the trace elements. Only Ficote and Osmocote had a consistent controlled release pattern for the trace elements tested [copper (Cu), zinc (Zn), manganese (Mn), and boron (B)]. Multicote released no Cu for 10 weeks and then only very small amounts. Plantacote, by contrast, released over 60% of its Cu content at the first leaching and thereafter only very small amounts. A similar pattern of an initial flush followed by little subsequent release was found in the case of B both for Multicote and Plantacote.

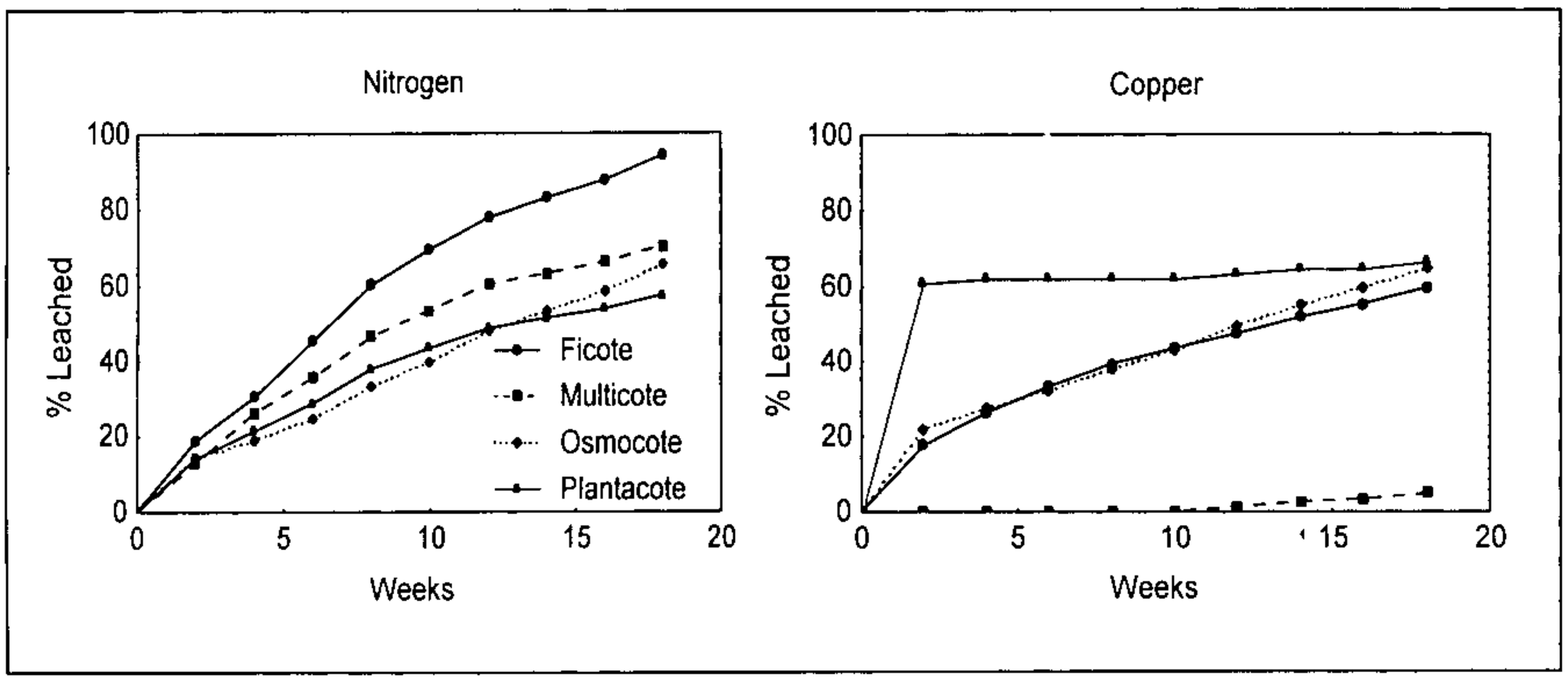

Figure 1. Release pattern of nitrogen and copper in four controlled-release fertilisers.

Table 4. Effect of type of controlled-release fertiliser (CRF) on the fresh weight (g per plant) of five subjects.

CRF	×*Cupressocyparis leylandii*	*Choisya*	*Ligustrum*	*Ulex*	*Ozothamnus*
Ficote	241.0	160.4	62.3	202.0	148.9
Multicote	256.0	97.6	18.7	188.6	132.6
Osmocote	232.4	151.9	64.1	220.8	155.0
Plantacote	234.9	105.5	48.7	194.6	137.3
F-test	NS	***	***	NS	*
S.E.	15.5	9.94	6.37	11.1	5.82

Table 5. Overall relative performance of four controlled-release fertilisers (CRFs) at the final harvest.

CRF	×*Cupressocyparis leylandii*	*Choisya*	*Ligustrum*	*Ulex*	*Ozothamnus*	Mean
Ficote	97	97	99	98	92	97
Multicote	92	84	65	91	85	83
Osmocote	98	98	93	97	96	96
Plantacote	91	87	90	89	96	91

Table 6. Residual analysis of controlled-release fertiliser granules in December and May as percent of original values.

	EC[1]	N	P	K
December, 1995				
Ficote	22	13	40	25
Multicote	30	21	45	37
Osmocote	35	25	51	33
May, 1996				
Ficote	8	2	20	7
Multicote	21	12	41	24
Osmocote	17	10	34	12

[1] Electrical conductivity

The residual analysis of the fertiliser granules is shown in Table 6. They agree with the leaching results in showing that Ficote had the quickest release of nitrogen and therefore the lowest reserve in the residual analysis. At the end of the experiment, Ficote was almost entirely depleted of N while Multicote and Osmocote still had some reserve. Nitrogen was depleted more rapidly than K, and P was slowest of all. The EC values were intermediate.

DISCUSSION

The results on the rate of CRF indicate that growers risk a loss of crop quality if they reduce the application rate of fertiliser. Although CRFs are expensive fertilisers in terms of the unit cost of N, P, and K, reducing rates to save on costs is almost always a mistake. If a CRF costs IR£75 for 25 kg and is used at a rate if 5 kg m^{-3}, then the 10 g of CRF in a 2-litre pot will cost 3 pence. The product at the end of the growing period of 12 months will have a sales value of IR£1.20 to IR£1.50. Any savings made by cutting back on CRF will clearly be outweighed by any negative impact on product quality and therefore sales price. The prime consideration, apart from environmental concerns, in deciding on fertiliser application rate is the effect on product quality.

Osmocote and Ficote gave more consistent results than either Multicote or Plantacote in these experiments. The results from the leaching experiment indicate that the release pattern of some trace elements in the latter two fertilisers is erratic and their overall poorer performance may be related to this. For instance, tissue analysis showed that the copper content of plants grown with Multicote was lower than with the other fertilisers. However, copper supplementation experiments would be necessary to prove that this was the factor affecting plant performance.

Residual analysis of the CRF granules gave results that were in agreement with the leaching results, in differences between the fertilisers and in the rate of depletion of N, P, and K. This could be a useful and simple method for checking on the growth potential of a compost. Although nitrogen is probably the most critical element to measure, if the relationship between N and EC are fairly constant then the EC could be used as an indication of residual nutrient levels. If this is the case then it should be possible for growers to carry out the test on the nursery and obviate the need for a laboratory analysis.

Nutrient Survey of Nursery Stock in Ireland and U.K. Including Nutrient Reserve Analysis in Controlled-Release Fertiliser and Leaf Analysis

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Bord na Móna Horticultural Division is providing technical support to growers in Great Britain and Ireland, involving measurement of available nutrient, nutrient reserve in controlled-release fertiliser(CRF) and analysis of foliage. There was a significant inverse relationship between the nutrient reserve in CRF and time of potting. This relationship is not linear and there are strong indications that for the 12 to 14 month formulations of CRF, most of the nitrogen has been released, by 8 to 10 months. From the data obtained in 1993/95 we have compiled "normal" levels of major nutrients of over 50 species. In addition the frequency distribution of micronutrients from over 100 samples has been compiled. This type of information will be invaluable for diagnostic purposes and to make an informed decision whether to top-dress in spring.

INTRODUCTION

Soil (substrate) testing and plant analysis is a normal facet of certain areas of agriculture and horticulture (Westermann, 1990). However, there is relatively little detailed information on desirable levels available for nursery stock (Aendekerk, 1982; Alt, 1989; and Smith 1978). In addition, information of this type on most of the species grown in Great Britain and Ireland is generally lacking. Information that is available may not be directly relevant to conditions in Great Britain and Ireland.

Substrate analysis for nutrients gives only a snapshot of the nutrition level at that particular time. In order to make use of such analysis, regular monitoring is required but cost of analysis precludes this. However, pH measurement is more worthwhile as, under normal conditions it will not change dramatically during cropping. In the nursery industry the use of controlled-release fertiliser (CRF) is widespread and because the rate of nutrient release is dependent on many factors, e.g. temperature, growers often wish to know how much nutrient reserves are available in order to decide whether they need to top-dress.

In 1993, Bord na Móna started to provide a technical support to the nursery stock growers in Ireland and this was extended to three regions in the UK in 1995/6. This technical support consists of substrate analysis based on 1 : 1.5 water extract, determination of nutrient reserve in CRF, and leaf analysis. The substrate and nutrient reserve analysis is carried out in mid summer and spring whilst leaf analysis is done in mid summer. This type of information helps avoid possible nutrition problems and allows growers to optimise nutrition for plant growth. This paper surveys the results obtained from CRF analysis and foliage analysis.

MATERIALS AND METHODS

The number of properties sampled were as follows: Ireland, 1993, 15; 1994, 12; 1995, 14; and 1996, 14; Great Britain: 1995, 10 and 1996, 8. Substrate samples were taken in mid Summer except in 1996 when samples were taken in spring. Leaf sampling was taken in mid Summer (June to early August). Occasional samples were also taken in November.

Available Nutrient. Substrate samples were generally taken from at least 10 pots. The samples were extracted with water in the ratio of 1:1.5 (Dutch method). pH, conductivity, NH_4-N, NO_3-N, P, and K were determined in the extract. This analysis gave the amount of nutrients immediately available to the plant.

Nutrient Reserve. The samples were extracted as before except that all the granules were crushed prior to extraction. In the extract soluble N(NH_4-N + NO_3-N), P, and K were determined. Subtracting the available nutrient from this value gave the nutrient reserve or nutrient left in the granules. The percentage reserve was then calculated using the amount of CRF originally added at potting.

Leaf Analysis. Leaf samples were taken from at least 10 plants. They were dried, ground and analysed for N, P, and K using a sulphuric acid and selenium digest using an auto analyser (O'Neill and Webb, 1970). Ca, Mg, and micronutrients were analysed after ashing using an AAS.

RESULTS AND DISCUSSION

There was a highly significant inverse relationship between the amount of nitrogen left in the granule (N reserve) and the time of potting (Fig. 1). In other words, as expected the longer the time from potting the lower the N reserve. These results which are from 1995 and 1996 data showed that the release from CRF granule (12-14 months) is not linear and there are strong indications that after 8 to 10 months from potting, most of the N appears to have been released. Any N that is still left in the granule appears to release very slowly and may not be adequate for the flush of growth in spring. However the proviso should be made that if the fertiliser granules

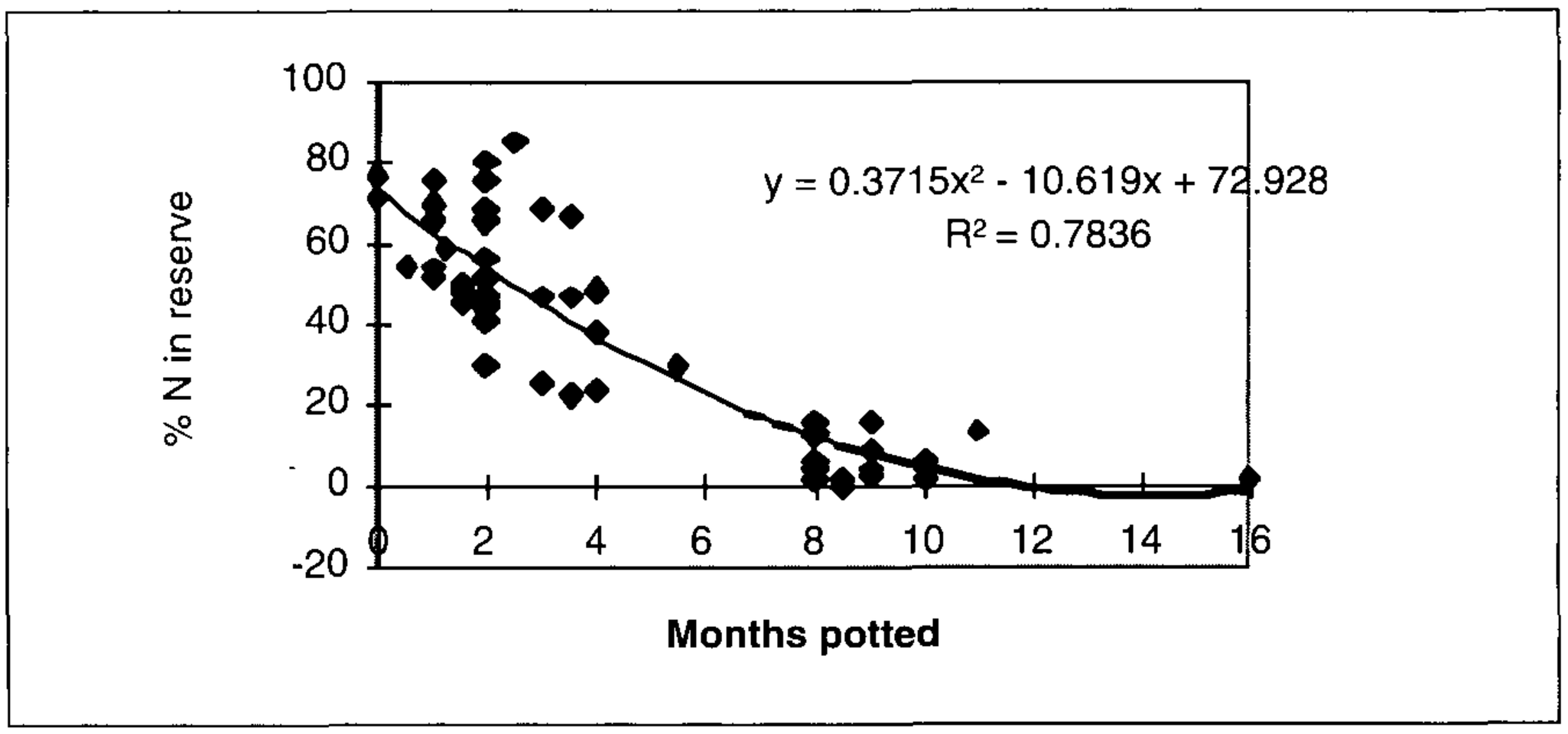

Figure 1. Relationship between time of potting and nitrogen (N) reserve in control-release fertilizer.

were not mixed properly in the substrate the values presented here could either overestimate or underestimate the reserves. Other data where the granules were analysed separately, however, would support these findings. In addition it was found that N is released faster than K from the granules. The measurement of N in the granule rather than K or soil conductivity is more relevant because N has such a major effect on growth.

Leaf nutrient levels are given in Table 1. The values can be considered "normal" as most of the plants in this survey were growing well and looked healthy. These crops have been classified on basis percent N. This basis can be used as a starting point in deciding the rate of fertiliser application and/or composition of liquid feed. Because there is a large assortment of cultivated crops, this is one way to group crops having approximately the same N concentration. If these values are to be used for diagnostic purposes the time of sampling is critical as most nutrient levels fall sharply with age while Ca actually increases. These values are therefore valid only for the same sampling time (Fig. 2). As further data is available the classification of some of the crops may need to be adjusted.

The frequency distribution of micro nutrients is given in Fig. 3. For iron levels in the leaf, 74% fell in the range 50 to 200 ppm; for manganese, 71% fell in the same range; for zinc, 78% fell in the range 10 to 60 ppm and for copper (Cu), 84 fell in the range of 4 to 8 ppm. These values can also be considered as sufficient or 'normal' levels for nursery stock growers in Great Britain and Ireland. The Cu levels found here are lower that those found by Smith (1978) in the U.S. and as described by Reuter and Robinson (1987).

In conclusion, some very valuable information is now available on leaf macro- and micro-nutrient levels of more than 50 species and cultivars commonly grown in Great Britain and Ireland. More results are needed to obtain more consistent values

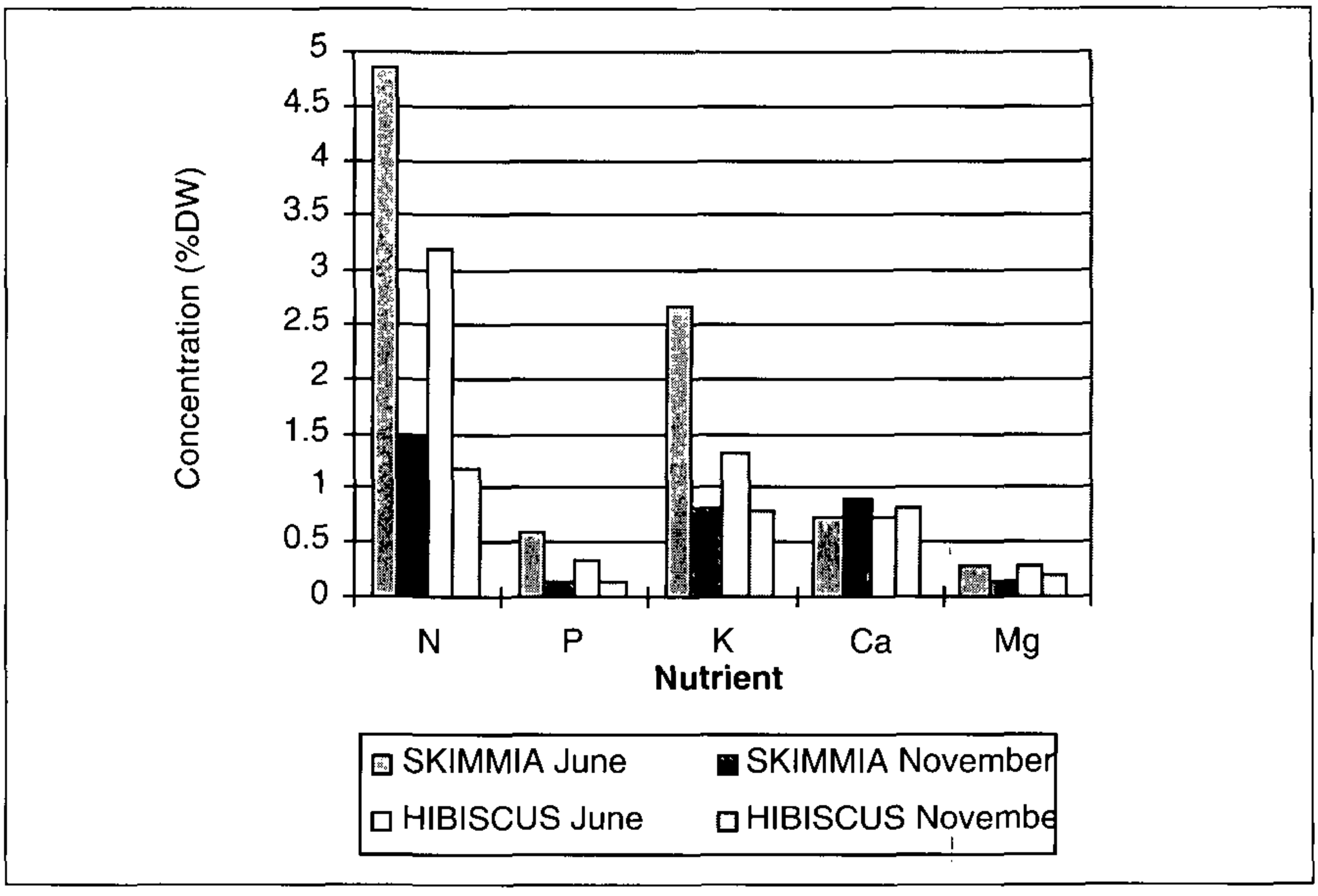

Figure 2. Effect of sampling time on leaf nutrient levels.

Table 1. Leaf nutrient levels (%D.W.) of nursery stock plants (June-August sampling)

	Low N				
	N	P	K	Ca	Mg
Azalea deciduous *(Rhododendron)*	0.7-1.27	0.8	0.33-0.57	0.42-0.64	0.17-0.64
Azalea evergreen *(Rhododendron)*	2.15-2.38	0.21-0.27	0.60-0.69	0.65-0.73	0.35-0.38
Berberis	1.53-1.89	0.13-0.15	0.47-0.99	0.35-0.66	0.16-0.17
Calluna	1.54-2.48	.08-0.23	0.54-0.83	0.41-0.69	0.16-0.27
Camellia	1.61-1.77	0.13-0.15	0.54-1.17	0.62-0.84	0.18-0.28
Coreopsis	2.17	0.42	1.09	-	-
Erica carnea	1.59-2.46	0.14-0.21	0.92-1.75	0.63-0.65	0.30-0.31
E. ×*darleyensis*	1.51-1.93	0.13-0.17	0.89-0.99	0.42-0.50	0.21-0.26
E. 'Springwood'	1.53-2.20	0.15-0.22	0.68-1.09	0.35-0.50	0.16-0.20
Hebe	2.15	0.24	0.81	0.63	0.28
Hosta	2.11	0.38	1.16	-	-
Hedera 'Monty'	1.34	0.08	0.42	-	0.72
Lavatera	1.58	0.57	0.88	1.69	0.53
Viburnum tinus	0.99-1.88	0.14-0.15	0.47-1.30	0.42-1.61	0.19-.31
V. davidii	1.58	0.13	1.04	1.10	0.35
Viburnum	1.3-1.88	0.09-0.23	1.10-1.36	0.57-1.71	0.30-0.55

Table 1. (continued) Leaf nutrient levels (%D.W.) of nursery stock plants (June-August sampling)

	Medium N				
	N	P	K	Ca	Mg
Ash (*Fraxinus excelsior*)	2.28-3.21	0.24-0.58	1.33-2.25	0.46-0.47	0.23-0.25
Camellia 'Donation'	1.68-2.65	0.15-0.23	0.54-1.12	0.33-0.62	0.22-0.28
Cordyline	1.62-2.54	0.16-0.19	0.32-0.94	0.27-0.38	0.53-0.66
Gooseberry (*Ribes uva-crispa*)	2.70	0.21	0.81	1.18	0.53
Green beech (*Fagus sylvatica*)	2.63-2.70	0.12-0.16	0.82-0.85	0.74-0.91	0.20-0.27
Hypericum 'Hidcote'	1.69-2.95	0.20-0.34	0.92-1.35	0.45-0.76	0.21-0.27
Juniperus	1.81	0.08	1.05	0.85	0.27
Leucothoe	2.47	0.49	1.53	-	0.13
Rhododendron	2.43	0.19	0.31	0.85	0.58
Brachyglottis Dunedin Hybrid	2.55	0.18	1.79	2.16	
(*Senecio greyi*)		0.80			
Skimmia	1.93-4.87	0.12-0.60	0.87-2.66	0.36-0.75	0.27-0.75
Taxus	2.92	0.29	1.78	0.60	0.34

Table 1 (continued). Leaf nutrient levels (%D.W.) of nursery stock plants (June-August sampling)

	High N				
	N	P	K	Ca	Mg
Azalea (evergreen) (*Rhododendron*)	2.38-3.18	0.23-0.40	0.69-1.04	0.46-0.71	0.27-0.53
Apple (*Malus*)	3.60	0.81	4.34	0.66	0.68
Acer pseudoplatanus	3.36	0.66	1.35	1.80	0.69
Buddleja	2.83-4.99	0.21-0.43	0.91-2.55	0.74-1.11	0.35-0.65
Astilbe 'Kohl'	3.13	0.21	1.45	1.48	0.32
Ceanothus	3.91-4.40	0.28-0.36	1.24-1.53	0.78-2.43	0.19-0.26
Chaenomeles	1.4-3.25	0.39	1.08-1.48	1.14	0.43
Cotoneaster	2.44-5.22	0.23-0.33	1.43-1.58	0.70-0.93	0.21
Cytisus	2.11-3.99	0.15-0.58	0.80-1.17	0.74-0.83	0.16-0.36
Eucalyptus	1.55-3.99	0.12-0.25	0.65-0.88	0.64-0.78	0.29-0.45
Euonymus	3.54	0.48	1.14	1.15	0.73
Jasminum nudiflorum	3.26	0.38	1.91	0.74	0.40
Houttuynia	3.25	0.28	1.29	0.65	0.83
Hibiscus	3.19	0.34	1.33	0.71	0.28
Lavatera 'Rosea'	2.76-3.29	0.24-0.49	0.73-1.40	0.49-1.05	0.52-0.68
Lavender (*lavandula*)	2.84-3.70	0.29-0.35	1.58-1.80	1.07-1.10	0.67-0.88
Miscanthus sacchariflorus	234-4.74	0.25-1.16	0.92-4.16	0.31-0.66	0.25-0.45
Oak (*Quercus*)	3.21-3.38	0.34-0.35	0.99-1.03	0.30	0.30-0.38
Prunus	3.85	0.48	1.68	0.59	0.15
Prunus domestica 'Victoria'	3.61	0.21	1.24	0.80	0.41
Prunus laurocerasus	2.43	0.29	1.75	1.96	0.45
Sambucus	2.44-5.08	0.23-0.93	2.01-4.90	0.94-3.74	0.69-1.54
Tradescantia	4.66	0.40	3.22	0.32	0.89
Weigela	3.46	0.43	1.83	-	0.45

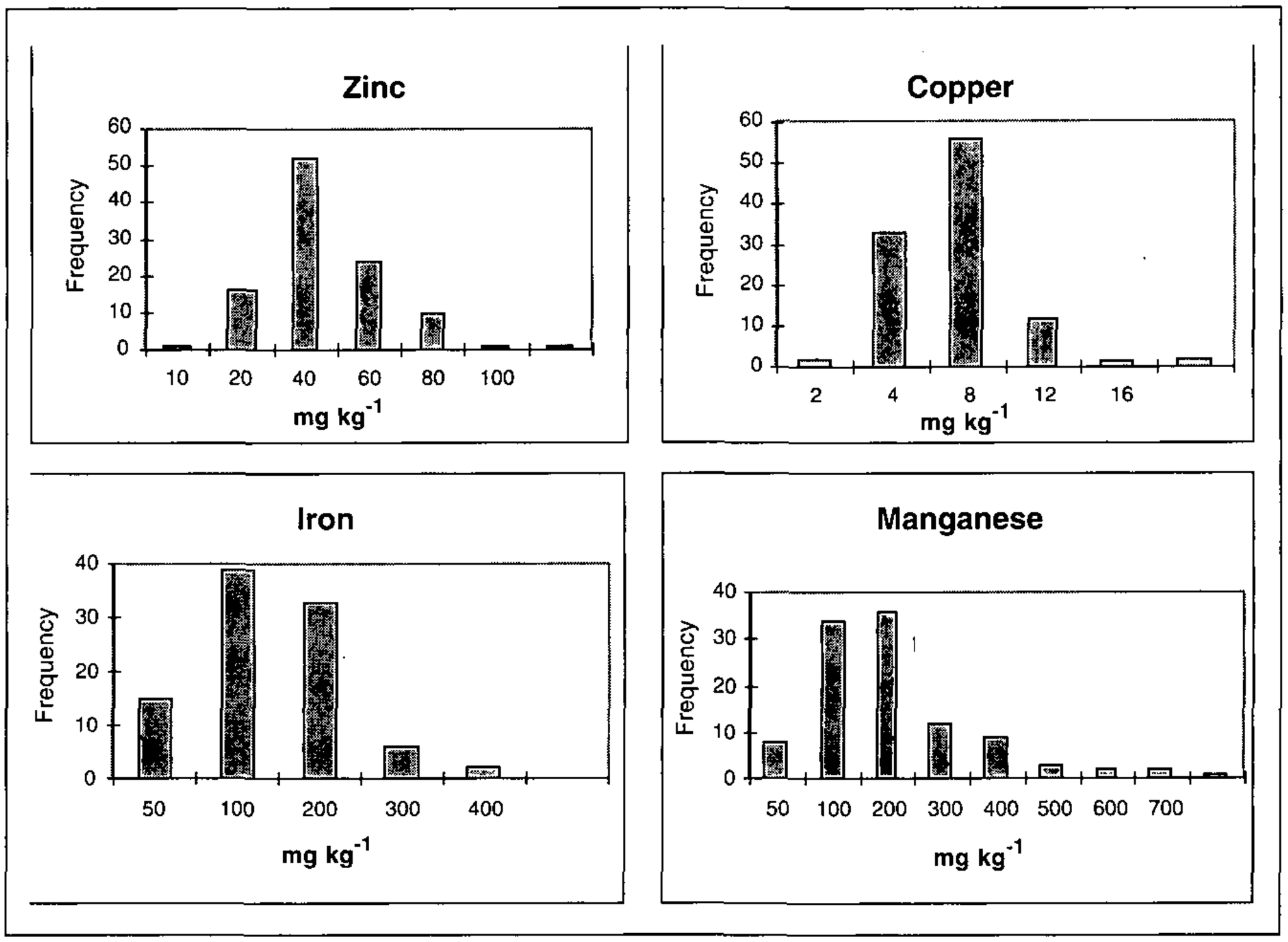

Figure 3. Frequency distributions of percent leaf micronutrient levels in nursery stock from Ireland and the United Kingdom.

for some crops, e.g. *Chaenomeles*. In addition, the determination of CRF reserves has given valuable information on nutrient reserves available and there are strong indications that in some situations the reserves may be unexpectedly low. The decision to top dress or liquid feed e.g. in spring before the flush of growth, can be decided rationally on basis of N reserve analysis.

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Propagation of Rhododendrons at Millais Nurseries

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INTRODUCTION

Millais Nurseries is a specialist rhododendron and azalea nursery producing around 650 different varieties ranging from tiny dwarfs to large forest trees. It was started as a retail nursery in 1970 by Ted Millais, the author's father. Current production is approximately 40,000 plants per year. The market ranges from retail customers wanting one or two rare plants for their collection either from our plant centre or by mail order throughout the world, to large garden centres. The nursery also undertakes contract growing for the wholesale market.

Rhododendrons are not the easiest plants to propagate, but Millais Nurseries offers such a wide range that most have to be propagated in-house. In order to improve efficiency and output, a new propagation house was installed in 1993 with 70 m^2 of roller benching, thermabed hot-water heating, and mist and wean facilities. The house contains five beds and each is individually controlled by electronic thermostat and electric leaf. The house itself is a Solspan Alloy 20 with automatic vents and a fixed thermal/shade screen. The complete development cost £13,000 and is proving highly efficient and maintenance free. Oil heating costs are averaging £200 per year.

Propagation techniques for rhododendrons include cuttings, seed, tissue culture, grafts, and layering. However, layering is no longer practiced on this nursery due to economics and the poor quality of the plants produced.

CUTTINGS

The standard rooting substrate used at Millais Nurseries is a mixture of bulrush medium peat and bark (2 : 1, v/v). When sticking cuttings in trays Cambark 100 with 0.5 kg m^{-3} Osmocote 12-14 month formulation is used. For direct sticking into cells the fine grade Cambark plus 0.5 kg m^{-3} Osmocote Mini is used.

All cuttings or rooted cuttings are treated with nematodes in September as a precaution against vine weevil, prior to incorporation of Suscon Green from the liner stage onwards. Routine fungicides include Benlate, Octave, Rovral, and Bravo on a 2- to 3-week cycle. Pesticides (Ambush and Nemolt) are used to control aphid and sciarid fly if these become a problem.

Basal temperature is maintained at 18C. During the summer, humidity is maintained by a simple Macpenny mist unit operating under white polythene which is vented at the edges on hot days. In September, the mist is progressively limited by 24-h timer at night, and then by day, to prevent the compost getting too wet. By the end of September a clear polythene tent is used to replace white polythene and the mist restricted to 2 or 3 bursts per day. Through the autumn and winter the mist is operated manually just occasionally and the tunnels vented 2 or 3 times per week to help drain off excess moisture.

Our cuttings propagation season starts in June with deciduous azaleas. Many writers have suggested forcing stock plants under lights or polythene to enable

sufficient growth before autumn for the cutting to survive winter. However, by taking the cutting in June as soon as 75 mm to 100 mm of new growth is made, we have not had any problems as long as the cutting is kept in active growth with Osmocote.

If the cutting is soft, the tip is removed to prevent wilting, and if it is firm a scrape wound is made to the base. Rooting hormone is usually Seradix 2 (0.3% IBA) or Rhizopon AA (0.5% IBA). However, Seradix 1 (0.1% IBA) has proved better for white cultivars, and Seradix 3 (0.8% IBA) better on deep red cultivars. The occidentale hybrids are some of the first to root after about 5 weeks, followed by the Exbury types. The small flowered Ghent hybrids, and white cultivars, prove more difficult.

In early July many of the more difficult species rhododendrons will root with some persuasion, but this does vary considerably from year to year. Typical hormones would be Seradix 1 or 2 or Rhizopon AA. Three or four leaves in a fan shape are selected to stay on one side of the cutting and the remaining leaves taken off. The leaves are reduced to 40 mm long if necessary to avoid touching each other, and reduce transpiration. The base of the cutting is wounded on the same side as the remaining leaves and the cuttings are arranged neatly within the tray so that all the leaves point South towards the light. This procedure helps to ensure that all the roots develop in the same direction away from the light, and aids separation of cuttings at the time of potting on.

Most dwarf rhododendrons and evergreen azaleas are easy to root in July. These are best taken as 40-mm to 50-mm cuttings preferably, with the terminal bud present as this helps branching at the liner stage. Sometimes the growth is very soft and the cuttings tend to wilt but this can be prevented by refrigerating the cuttings in moist polythene bags for 48 h. Most cuttings respond to Seradix 2 without any wounding. Cells of about 30 mm × 30 mm are used for rooting as this prevents transplanting shock and potting is quicker.

Some of the dwarf species rhododendrons are particularly prone to rotting-off before rooting. For some of the fine foliage taxa, such as *Rhododendron anthopogon*, better results are obtained by taking a short piece of the previous year's wood with a clump of 4 or 5 young shoots which are just resting on the surface of the compost. Rooting can happen either from the new or old wood.

Cuttings of *R. yakushimanum* hybrids and other hardy hybrids are taken in August, varying the hormone according to the hardness of the cutting. Records of hormones used have been kept for many years for many varieties but the greatest variable is the condition of the cutting and not the cultivar. For the softer cuttings Seradix 1 or 2 and Rhizopon AA are used, with Synergol (liquid quick dip) in strengths ranging from 1 : 9 to 1 : 3 (1000 ppm to 2500 ppm active ingredient IBA and NAA) for the woodier material.

Softer cuttings have been most successful when use has been made of trimmings from liners or young crops during the growing season. The aim is to finish cuttings by the end of August but rooting is quite possible in October and November.

SEED

The opening up of China with permits for western plant collectors since 1990, and exchanges with institutes such as Kunming Botanic Gardens, has resulted in good quality seed being collected for the first time since Frank Kingdon-Ward in the 1930s. Ted Millais has collected regularly in Yunnan, Sichuan and Tibet at altitudes

of up to 16,000 ft in the last few years with other enthusiasts. The nursery now has several species in cultivation for the first time ever and these are being distributed to other collections.

Identification in the field is the first important hurdle, and this is often followed up with confirmation at the Royal Botanic Gardens, Edinburgh. Natural hybrids are particularly confusing, taxonomically.

Seed is collected from September onwards. After a mild winter it may still be possible to collect in the following spring. Paper envelopes are best for storage but often self-destruct with damp seed on a wet mountain. Zip-lock polybags are good for dry seed, but damp seed will rot in them. Once home, the seed pods are placed in small containers and left to open on a radiator shelf. After a week or two they open and seeds fall out if shaken. They are then sieved with a kitchen sieve and the chaff blown gently away. The prepared seed is stored dry in new paper envelopes and placed with an antidessicant in an airtight container in a domestic fridge or freezer until sowing at the beginning of January. Seed can be kept for several years like this.

Seed is sown into half-size seed trays filled with bulrush medium peat passed through a 10-mm sieve. This makes a fibrous peat with a fine surface. Seed is sown on the surface and pressed in lightly. Each tray is covered with a clear propagator lid and misted daily by hand using boiled water (cooled) to reduce disease and liverwort growth.

Germination takes about 3 to 4 weeks and supplementary H.P.SONT lighting is then given, using cheap rate electricity between midnight and 7 AM until the end of March. This has proved particularly beneficial, giving good colour and short internodes.

From late April seedlings are pricked out into 35-mm cells with 0.5 kg m^{-3} Osmocote Mini granules. These are placed under mist until June and then moved to a double skinned polytunnel with a 50% shade net over. Watering and prevention of high temperatures is critical throughout the summer. In August the larger plugs can be moved on into 9-cm pots with either 1.5 kg or 2.5 kg Osmocote depending on variety. Most taxa will be in 1.5-litre pots for their 2nd year and be marketable in their 3rd year in 3-litre pots.

TISSUE CULTURE

Millais was the first U.K. nursery to bring in plantlets from Briggs Nurseries in America. Plants are also obtained from U.K. laboratories. Tissue culture is an excellent way of importing and bulking up new cultivars of guaranteeing production targets of hard-to-root cultivars, particularly where contracts are involved. Most cultivars perform well and are bushier from the base. Some people have argued that tissue-culture grown plants are weaker and take longer to flower but, in the author's experience, problems are not encountered providing the laboratories have done their jobs properly. However there are some cultivars, such as *R.* 'Crest' in which the whole character of the plant is changed, becoming much bushier with paler, smaller flowers than the original. Incorrect naming has also been a problem.

From experience it is best to receive plugs in early October and pot them up, giving a few weeks of basal heat to encourage new root development before winter.

GRAFTS

Wherever possible plants are produced on their own roots. However there are 25 types grafted on contract. These are mainly specific clones of species or late flowering hardy hybrids which we are unable to root.

A reverse saddle graft is performed in January and held together with mini clothes pegs. *Rhododendron ponticum* liners in 9-cm pots have been used as understocks but consumer resistance means that *R.* 'Cunningham's White' is now used. The success rate is around 80% overall and the 1-year grafts are supplied to the nursery in 1.5-litre pots in the following March.

CONCLUSION

Millais Nurseries makes use of all four methods of propagation and experience over many years has shown which method is best for each variety propagated.

Eucalyptus as a Cut Foliage Crop

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Single stem, 1-year-old specimens of *Eucalyptus gunnii* were planted in four treatments of single, double, triple, and quadruple rows at a spacing of 1.75 m between plants, both between and within rows (densities of 1937, 2431, 2657, and 2787 plants ha^{-1}). In each year of the experiment foliage was harvested from autumn until early spring. Length, weight, and form of foliage, whether juvenile, adult or discard, was noted. The plants were then coppiced. The cumulative weight per treatment was measured. There was no significant difference between treatments or in the treatment/year interaction. The mean weight of material harvested per plant planted in consecutive years was 0.58, 1.92, 1.07, 1.02, 1.07, and 1.43 kg and is within the range reported from England and Germany (0.5 kg to 3.0 kg per plant). The percentage of juvenile foliage harvested in each consecutive year was 19.9%, 28%, 68.6%, 76.6%, 73.6%, and 66.8% and this indicates the effect of severe pruning on the production such foliage.

INTRODUCTION

The term "cut foliage" describes the material, generally evergreen, which is used to create lines and as a filler in floral decorations. In recent years the cut foliage content of floral decorations has increased from 5% to 30%. For the producer, species grown as cut foliage must be fast growing, attract few pests and diseases and regenerate after the yearly harvest, while the florist requires material with attractive leaves, pliable foliage, and which is long lasting in water. *Eucalyptus*, the Australian genus of some 600 species of trees, is well represented in Irish plant collections and is cultivated for cut foliage purposes in the Alpes Maritime, France; Imperia and Liguria, Italy; and Cornwall, England. Prompted by the success of this genus, and the increased demand for cut foliage, experiments to develop a production system for *Eucalyptus* cut foliage were established at Belfield, University College Dublin in 1990. This paper describes the effects of planting configuration on the yield of marketable cut foliage.

MATERIALS AND METHODS

In April 1990, single-stem, 1-year-old *Eucalyptus gunnii* were planted on single ($1 \times 8 + 1 \times 8$), double (2×8), triple ($3 \times 5 + 1$), and quadruple (4×4) rows at a spacing of 1.75 m between plants, both between and within rows. The four treatments with 16 plants in each were replicated five times and represented densities of 1937, 2431, 2657, and 2787 plants per hectare respectively. Each year between autumn and spring stems longer than 50 cm and greater than 20 g were harvested and a record taken of the plant number, length, and weight of each stem and the form of foliage, whether adult (narrow, alternate leaves); juvenile (round,

opposite leaves); or discard (damaged or woody portions of stems). The plants were then coppiced to 10 cm in 1991, to ground level in 1992, 1993, and 1994 and to 5 to 10 cm with short shoots remaining on the plant in 1995 and 1996. Throughout the experiment the ground has been maintained weed free. There was some infestation of psyllid suckers (*Ctenarytainia eucalypti*) but apart from the first season the pest population did not warrant an application of insecticide.

RESULTS

The cumulative yield weight per treatment, after 6 years, was 5.77, 7.57, 7.94, and 7.14 kg respectively, for 1-row through 4-row (Table 1). There was no significant difference between treatments or in the treatment/year interaction. The mean weight in consecutive years per plant planted was 0.58, 1.92, 1.07, 1.02, 1.07, and 1.43 kg.

Table 1. Mean annual weight (kg) of stems/plant planted of *Eucalyptus gunnii*.

Treatment	1991	1992	1993	1994	1995	1996	Cum. yield	Cum. yield t ha^{-1}
1-row	0.56	1.65	0.86	0.79	0.85	1.06	5.77	11.70
2-row	0.64	1.91	1.26	1.08	1.12	1.56	7.57	18.40
3-row	0.62	2.20	1.30	1.16	1.12	1.54	7.94	21.09
4-row	0.51	1.95	0.86	1.07	1.19	1.56	7.14	19.89
Mean	0.58	1.92	1.07	1.02	1.07	1.43		
Level of signif.	NS	NS	NS	NS	NS	NS		

The percentage of juvenile foliage which had been increasing from 19.9% in 1990-91 to 76.6% in 1993-94 decreased in 1995-96 to 66.8% (Table 2).

Table 2. Juvenile, adult and discard stems (percent of total harvest) of *Eucalyptus gunnii* over 6 years.

Year	Juvenile (%)	Adult (%)	Discard (%)
1990-91	19.9	80.0	0.1
1991-92	28.0	41.5	30.5
1992-93	68.6	6.2	25.0
1993-94	76.6	5.8	17.4
1994-95	73.6	6.8	19.4
1995-96	66.8	12.4	20.7
Total	58.6	19.2	22.0

DISCUSSION

The yields achieved in these experiments fall within the range reported from Germany (Maync, 1985) and England (Pollock, 1982), between 0.5 kg and 3 kg per plant. Indications are that the trial plants may not have attained their maximum yield. The pruning regime has a major impact on yield, both in terms of the weight of stems and the number of juvenile stems. Italian producers prune to a pollarded system, and with the exception of 3 or 4 main stems, all side shoots and foliage are removed in April. From this experiment, it appears that when the plants are severely coppiced to ground level, juvenile foliage (the form preferred by the market) rather than adult foliage is produced. However some plant losses occurred, possibly due to severe pruning of the plants, poor soil conditions in certain areas of the site, and the genetic variation within the plants themselves.

CONCLUSIONS

At a plant spacing of 1.75 m, planting configuration had little effect on the yield of cut foliage. Some individual specimens in the experiment produced particularly good quality cut foliage each year and these genotypes are now being propagated clonally in vitro.

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Recent Research on Propagation at the Research Station for Nursery Stock, Boskoop

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INTRODUCTION

This paper gives an overview of some of the propagation research projects of the Research Station for Nursery Stock at Boskoop. There are several current research projects, this paper concentrates on the following subjects:

- Improvement of seed germination
- Propagation of *Acer platanoides*
- Propagation of nematode free perennials
- Conditions during rooting
- Rooting leafless hardwood cuttings

With cuttings, research was undertaken on CO_2 enrichment; stock plant treatments; rooting conditions of cuttings; reduction of flowering during rooting of *Pieris*; development of systems for rooting of leafless hardwood cuttings and improvement of the quality of cuttings. Use of cuttings for nematode-free production of perennials was also trialled. Tissue culture techniques were developed to propagate rootstocks for fruit trees (*Malus, Pyrus,* and *Cydonia*) and for propagation of *Acer* and *Paeonia*. The research on seeds concentrated on the effect of pretreatment conditions on dormancy breakage and viability and the effect of storage conditions of pretreated seeds on germination capacity and viability.

The most resent results of tissue culture, propagation of perennials by cuttings, rooting conditions of cuttings, and seed germination, will be presented.

IMPROVEMENT OF SEED GERMINATION

There are problems in the germination of many tree species. Firstly, seed quality is not always adequate. Secondly, seeds of several species need a period of stratification before they can germinate. This has to be carefully timed so that dormancy is released without premature germination.

Currently, research concentrates on developing treatments which result in a complete release of dormancy without premature germination. This can be obtained by controlling the moisture content of the seed and the duration of the cold temperature treatment. This treatment is done without any stratification medium. Stratification at optimum moisture content and for optimum duration results in a fast germination under a wide range of climate conditions in the field.

The effect of temperature pretreatments on germination was tested at several germination temperatures in the laboratory, in a greenhouse, and in the field.

If the humidity during stratification is too high this may induce premature germination during the dormancy breaking treatment (e.g., *Acer pseudoplatanus*). The longer the dormancy-breaking treatment (at the optimal moisture content) the wider was the range of germination temperatures resulting in good germination and the faster was the germination. So, with controlled dormancy breaking treatments,

the speed and percentage of germination could be improved and the range of temperatures over which a good germination occurred was widened.

Two groups of species can be distinguished, one which requires cold stratification (e.g., *Fagus sylvatica, A. platanoides, A. pseudoplatanus, A. palmatum, Pseudotsuga menziesii, Malus sylvestris, Syringa vulgaris*, and *Berberis thunbergii*) and the other requiring a warm stratification followed by a cold stratification (e.g., *Fraxinus exelsior* and *Tilia cordata*). For each of these species the optimal stratification conditions (humidity and time) has been determined.

PROPAGATION OF MAPLES

Traditionally, *Acer* for forestry purposes is propagated from seeds. *Acer* cultivars used for street or avenue trees are budded or grafted on a seedling rootstock. However, *Verticillium* wilt is a severe disease in *Acer*. Therefore, in several countries, there is a scheme for selection of verticillium-resistant cultivars and rootstocks. However, these cultivars clearly must be propagated vegetatively. Propagation by tissue culture and propagation by leafy softwood cuttings is studied at Boskoop.

Softwood cuttings were propagated in a fog house. For good rooting, stock plants had to be juvenile and in a good growing condition. In general, shoot tip cuttings rooted better than nodal cuttings and the growth of these cuttings after rooting was better. Buds of nodal cuttings often were dormant for several months.

In tissue culture of *Acer*, initialising aseptic cultures is a problem. Several species and clones are internally contaminated with fungi and bacteria. One of the major objectives of current research is to reduce contamination. This has been achieved by hot-water treatments of the plant material before starting the culture and trials have been conducted to determine optimal hot water temperature and duration of the treatment. The results with several cultivars of *A. pseudoplatanus* (sycamore maple) and with other *Acer* species were similar but the levels of hot water damage to the tissue and the efficacy in reducing of contamination were cultivar specific.

After initiation, propagation in tissue culture is rather slow but rooting is easy. The rooted plants can be weaned and used as stock plants for propagation by cuttings. In collaboration with the CPRO-DLO institute in Wageningen, the techniques described here are being used to build up stocks of verticillium-resistant clones of rootstocks.

PROPAGATION OF NEMATODE-FREE PERENNIALS

Nematodes are responsible for severe losses in the commercial production of perennials and a wide range of species can be infected. In some species the main problems are caused by leaf and stem nematodes, in other species root nematodes are more important. Nematode infestation reduces growth and quality of the plants and nematodes can act as virus vectors.

The objective of this project is to develop a system of propagation and production of perennials to reduce nematode infestation. To keep the system clean it is essential to start with healthy plant material. This can be done by propagation of stockplants from tissue culture and by warm-water treatment of stock plants before planting.

One species propagated by tissue culture was *Paeonia*. These plants were healthy although the propagation rate was limited. Warm water treatments were used in

several species (*Phlox, Paeonia, Geranium,* etc.) The effect of the warm-water treatment on the elimination of nematodes and on the survival of the plants is still being evaluated but not all species can survive the temperature and treatment duration necessary for elimination of all nematodes.

The stock was cultured in containers on special beds or in greenhouses to keep it nematode free. The mother stock can be used for propagation by division and/or cuttings. The method chosen depends on propagation rates but also on the risk that they can be reinfected by nematodes and the type of nematodes (leaf, stem, or root) which causes the problems.

ROOTING ENVIRONMENT

In many difficult-to-root species the way to success is to start with the right stock plant material. Inferior cuttings cannot be rooted properly even under optimal conditions. But with excellent cuttings from well-grown stock plants rooting can be improved by using the optimal rooting environment.

Quality criteria for rooted cuttings are: a high number of roots per cutting; a short rooting period; and quick regrowth of the rooted cutting. For some species there are additional requirements, such as batch uniformity and absence of flower buds.

At Boskoop Research Station the effect of different environmental components on rooting has been studied. The components were CO_2 concentration, air temperature, bottom heating, humidity, light intensity, and light colour.

Apart from the positive effect of CO_2 on rooting percentage, it has not been possible to make general conclusions about the reaction of the different species to different environmental components.

CO_2 enrichment increased the rooting percentage but this increase was limited in most species to between 10% and 20%. But the quality of the rooted cuttings (fresh and dry weight), and especially of the root system, was improved dramatically.

Another general conclusion was that the speed of rooting was mainly determined by the root temperature.

Day length and light wavelength (colour) had no clear effect on rooting. The effect of light intensity on rooting was very species specific and cultivar specific. Bottom heating often improved rooting. But the effect of the temperature of bottom heat depended on the air temperature and, in some species, on the season in which the cuttings were taken.

The conclusion is that optimal rooting conditions have to be determined for each species or even for each cultivar. For nursery stock, with many species it is not a realistic option to optimise for every cultivar.

ROOTING OF LEAFLESS HARDWOOD CUTTINGS

For some years the heated bin method, developed by Brian Howard of East Malling Research Station, (East Malling, Maidstone, Kent, U.K.), has been used to root leafless hardwood cuttings of several species. A method has now been developed to root such cuttings in plugs which can be planted in the greenhouse or in the open after rooting. This improves the growth of the rooted cuttings in the first growing season.

In hardwood cuttings of *Tilia, Malus* and *Pyrus*, rooting quality was determined by stock plant and stock plant condition. In these species the rooting capacity was related to dormancy. In other species like *Platanus ×hispanica*

(syn. P. ×*acerifolia*) and *Morus alba* the effect of dormancy was less obvious.

The best method of rooting and weaning the cuttings depends on species. Some have to be rooted under controlled conditions to prevent premature bud burst. In other species rooting and bud burst were simultaneous processes. In species from the latter category it is very important to prevent excessive water loss by evaporation from the young cuttings. These species are rooted in a greenhouse with a combined fog and mist system. Bottom temperatures of 17C, 20C and 23C were used. The optimal temperature depended on the species. In general, species originating from more temperate regions, rooted better at higher bottom temperatures. After the rooting period (6 to 10 weeks) the plants are weaned. They can be potted and grown in a greenhouse or they can be planted in the open.

Propagation of Perennials at Schram's Nurseries

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INTRODUCTION

The nursery was established in February 1981 to supply perennials for the author's landscaping business. At the time, perennials were not grown in Ireland on any commercial scale and the nursery soon started to supply perennials to the trade. In 1987 it replaced the landscape business as the author's sole occupation.

At present 88% of plants produced are sold to garden centres, 4% to the wholesale trade, 4% to export, mainly Northern Ireland, and 4% to the landscape trade.

Because of Ireland's location in the EU and because it is an island with a small population, it is important to offer a diverse range of plants and a good service. Therefore, approximately 1500 different taxa of perennials are grown, from propagation stage to final product. Marketing, promoting, and delivery are all undertaken in house. Recently, several new perennial nurseries have been established in Ireland and it is now not so important to carry such a wide range. Instead, it is important to become more efficient to be able to compete. The nursery now aims to specialize, mechanize, and automate while still trying to offer an interesting range to the trade. New lines are continually introduced, each with their own propagation problems to be overcome.

PROPAGATION

Most propagation is undertaken in house. The main reasons for this are:

- To have guaranteed availability of young plants.
- The weakness of the Irish pound makes imported young plants expensive.
- 17.5% VAT is charged in England which is not reclaimable in Ireland.
- The timing of deliveries from abroad of young plants does not always suit the growing season.
- The range available in the trade is limited and the danger exists that those varieties which are available will be overproduced by this nursery's competitors.

Perennials from Seed. Most perennials from seed are purchased as plugs. This is the most economic way, as these plugs are cheap and the nursery has no facilities for plug sowing. There is only a limited range of easy-to-sow plants available, but these plants are in big demand, so quantities involved are big. The most difficult taxa, such as *Lewisia*, *Gentiana*, and *Helleborus*, are grown from seed on the nursery. They are given a heat treatment of approximately 6 weeks at 20C; then stratified for 3 to 8 weeks depending on species, and then sown in mid January in trays under polythene and covered with aeroboard. After the first signs of germination the trays are put under low tunnels of perforated white polythene, either inside or outside the glasshouse. When the first set of true leaves appear, trays are put

under shading, which is removed later. Before seedlings are potted they are hardened-off outside.

Perennials from Root Cuttings. *Anemone* (Japanese anemones), *Papaver orientale*, *Morisia*, *Anchusa*, *Brunnera*, and some *Geranium* taxa are done from root cuttings. *Anemone*, *Morisia*, *Geranium*, and *Brunnera* cuttings are taken approximately 2.5 cm long and laid flat in a tray and covered with approximately 1 cm of peat. *Anchusa* and *Papaver* are also taken a 2.5 cm and stuck in forestry cells. From 1997, most root cuttings will be stuck in cells.

Shoot Cuttings. The majority of perennials on this nursery are either propagated by division or by shoot cuttings. Most cuttings are stuck in cell trays to prevent root disturbance when potted. These are easy and quick to take out of the tray, easy and quick to pot, and will give very few losses.

The trays are placed on mobile benches under low tunnels with clear polythene. Shading (35%) is given during sunny weather. During the hot summer in 1996 additional shading was required with milky white polythene, which was pulled over the hoops. This simple enough system worked well.

Basal Cuttings. These are mainly taken in spring but *Sempervivum*, *Saxifraga*, *Geranium cinereum* 'Ballerina', *Viola* spp., *Campanula* spp., *Heuchera*, *Artemisia dracunculus* (French tarragon), and *Aubrieta* are autumn propagated.

Division. This is the technique used for most taxa offered by the nursery. Plants propagated by this method include: *Aconitum, Astilbe, Hosta, Aster, Cimicifuga, Crocosmia, Filipendula, Gunnera, Hemerocallis, Iris, Kniphofia, Rodgersia, Schizostylis, Tradescantia,* and *Zantedeschia*. Most plants are divided between February and June.

The Effect of Irrigation Systems and Peat Grade on the Production of *Hebe* 'Mrs. Winder'

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The performance of ebb and flood, capillary, and overhead irrigation systems was compared using rooted plants of *Hebe* 'Mrs. Winder' in 2-litre containers, with peat-based growing media having air filled porosity (AFP) values ranging from 5% to 25% and containing standard recommended doses of controlled-release fertiliser. The plants attaining the greatest height were produced on the ebb and flood beds. Plants on the capillary beds were smaller and attained the lowest root index. Plants on the overhead-spray beds were like those of the capillary beds but scored more highly for marketability. Even with Mypex sheeting, rooting-through occurred on the ebb and flood beds but not on the capillary beds. The most water efficient irrigation system was ebb and flood. Overhead was the poorest.

INTRODUCTION

Within Ireland, the nursery stock industry produces plants mainly using overhead irrigation systems with plants growing in a peat medium, fertilised by a controlled-release fertiliser (CRF). In such circumstances excess water supply drains away to become waste water. However, concerns about environmental pollution, water shortage and, to a lesser extent, water prices, may in the future lead to the introduction of regulations governing the capture and recirculation of water, as in Germany (Bruns, 1994).

This trial compared the performance of the plants grown on ebb and flood, capillary, and overhead sprayline irrigation systems, using CRF. The use of five growing media with a range of air-filled porosity (AFP) values with each irrigation system was included, to determine whether AFP interacts with these irrigation systems to affect plant performance (Verdonk and Gabriëls, 1988; Michiels and Hartman, 1993).

MATERIALS AND METHODS

Peat fractions were obtained by passing peat through graded sieves. (Prasad and Maher, 1993). These fractions were used alone or in mixes to attain a range of AFP values determined using test cylinders (Byrne and Carty, 1989) (Table 1). Rooted cuttings of *Hebe* 'Mrs. Winder' were potted into 2-litre pots, which were placed on the

irrigation beds in May 1995 Twelve independent irrigation beds, each measuring 5 m × 2 m were used. The beds were each plumbed back to an individual reservoir The plants were irrigated using water direct from the reservoir Nutrition was provided by 12-14 month Osmocote Spring (15N-9P_2O_5-11K_2O), at 5 kg m^{-3}

Table 1. Peat grades used in the experiments and their corresponding AFP value

Peat grade	AFP (% volume)
100% 0-3	5
100% 0-10	10
Nursery stock grade[1]	15
80% 6-12 mm, 20% 0-10mm	20
80% 10-25 mm, 20% 0-10mm	25

[1]A commercially available blend for 2-litre pots for the nursery stock industry

The experiment was of a split plot design. Each plot of three irrigation systems was replicated four times The five AFP treatments were replicated four times within each irrigation system.

The plants were assessed in December 1995 for height, marketability, and vigour of the plants; and April 1996 for height, fresh weight, and a root score Marketability and vigour were subjective assessments, based on the attractiveness of the plant relative to others and the plants' overall growth rate in terms of height, branching, and density of foliage. Plants received a score on a scale of 1 (poorest quality) to 10.

Table 2. The effect of peat grade on the performance of *Hebe* 'Mrs Winder'

	December		April			
Peat AFP	Vigour	Marketability	Height (cm)	Height (cm)	Fresh wt (g/plant)	Root index
5	6 0	5 9	36 4	37 9	190 7	8 8
10	6 0	6 0	35 3	37 3	194 6	8 8
15	5 9	5 9	35 4	36 7	184 7	8 5
20	6 2	6 0	36 1	37 5	191 3	8 7
25	5 8	5 7	34 9	36 2	171 9	8 3
F test	NS	NS	NS	*	***	*†
S E	0 15	0 14	0 41	0 41	3 84	0 11

RESULTS

The effect of AFP on plant performance is shown in Table 2. At the December 1995 assessment, there was no significant effect of AFP on plant growth within any of the irrigation systems for the characters assessed. But there was a significant effect of AFP on fresh weight, height, and root index at the April 1996 assessment. Plants grown in the peat grade with the highest AFP value (25% volume) were the smallest in height and scored lowest for fresh weight and root index. Plants with the greatest fresh weight were those growing in peat with 10% AFP. Very little additional growth was recorded between December 1995 and April 1996 because of the late start to the 1996 growing season.

Plants on the ebb and flood (E/F) bed were the most vigorous, tallest and had gained the greatest fresh weight by the end of the trial (Table 3). Those on the capillary beds (Cap) scored lowest for height, fresh weight, and root index. Plants grown under overhead spraylines (OH), although smaller than those of the ebb and flood beds, attained a higher marketability score because they were more compact with shorter internodes and a better foliage colour.

Table 3. The effect of irrigation on the performance of *Hebe* 'Mrs. Winder'.

	December		April			
Irrigation system[1]	Vigour	Marketability	Height (cm)	Height (cm)	Fresh wt. (g per plant)	Root index
E/F	6.3	5.7	36.0	37.4	203.8	9.8
Cap	5.2	5	33.4	35	155.8	7.3
OH	5.1	7.1	34.0	35.5	181.9	9.0
F test	***	***	**	**	***	***
S.E.	0.24	0.23	0.39	0.42	5.94	0.19

[1] Abreviations: E/F, ebb and flow; Cap, capillary; OH, overhead spraylines

Table 4. EC and Ca levels on the top and bottom half.

	EC(mS cm^{-1})		Ca(mg $litre^{-1}$)	
Irrigation system[1]	Top	Bottom	Top	Bottom
E/F	1.57	0.56	121	55
Cap	4.10	1.71	210	98
OH	0.75	0.72	55	41

[1] Abreviations: E/F, ebb and flow; Cap, capillary; OH, overhead spraylines

Plants grown on the capillary (Cap) beds scored the lowest root index. This was because root growth was concentrated in the centre of the pots and were poorly distribution in the upper and lower regions of the growing medium.

At the end of the trial the growing medium electrical conductivity (EC) levels for containers from the capillary beds were more than double those of media in containers from the ebb and flood beds, and more than five and a half times those for media which had been under the overhead spraylines (Table 4).

Plants grown on the E/F beds rooted into the gravel under the Mypex. This was not the case with the plants grown on the capillary beds. Rooting through occurred to a lesser extent on the overhead spray lines.

DISCUSSION

The low scores recorded for plants grown in peat with an AFP of 25%, may have been because the high air filled porosity reduced water availability to the plants. This reduction may have been a limiting factor for plant growth. A significant difference between the peat grades was expected (Bragg and Chambers, 1988).

The poor performance levels attained by the plants grown on the capillary beds, may be a result of the build up of salts within the pots, as shown by the EC levels recorded at the end of the trial. The summer of 1995 was unusually warm and dry. This resulted in little or no leaching of salts from the pots by rainfall and the continual build up of salts in the upper section of the pots by evaporation from the surface of the peat. Beel (1988) recorded a similar situation with greenhouse plants where, after 4 weeks, the salt concentration in the upper part of the pots was twice as high as the bottom. The base of the pots on the capillary beds was also continuously saturated because of the capillary action of the water. This basal saturation, combined with the build up of salts in the upper regions of the pot, reduced the volume available for root growth.

The high water table of the capillary beds prevented rooting through of the plants. Rooting through occurred on the ebb and flood beds which provided stability during windy weather but caused problems when removing the plants from the beds. These results are contrary to those found of Labous and Willis (1994), which showed rooting through to be most severe on capillary beds and negligible in gravel beds. The reason for this difference, may be because the pots on the ebb and flood beds, in the Writtle trial, were flooded to a depth of 12 mm for 1 h, while in this trial the pots were flooded to a depth of 5 cm for 5 min. This reduced the time of basal saturation during which the roots are deprived of oxygen and may die.

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The Nursery Stock Industry In Northern Ireland

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INTRODUCTION

The nursery stock industry in Northern Ireland is relatively small and diverse, when compared to that in Great Britain, with growers often also involved in retailing and landscaping. The domestic market is characterised by limited opportunities, given that Northern Ireland is a small region with a total population of 1.5 million. Growers tend to grow what they know they can sell and expansion of the industry is dependant on exports.

At present the level of exports is low, being estimated at approximately £500,000 per annum, mainly going to Great Britain.

THE SIZE OF THE INDUSTRY

Nurseries in the Province are basically all family businesses with an average size nursery growing 100,000 plants and probably employing 4 or 5 people. Nurseries range in size from those which are quite small and perhaps specialising in alpines, heathers, or other crops to those which grow in the region of 200,000 plants. Of the 80 or so businesses involved in growing plants, approximately 55 have their main activity in production. Another 25 businesses are retail nurseries or garden centres producing around 25% of their own stock for sale. Total output is approximately £5.5m to £6m at wholesale prices. There is a lack of structure in the industry with no formal marketing groups.

CROPS GROWN

The climate is suitable for growth of a wide range of temperate ornamental plants. There are fewer climatic extremes than in Great Britain, with lower summer temperatures but milder winters. Rainfall averages from 60 to 72 in. in the west to 25 to 30 in. in the east. Crops which grow well include shrubs such as *Hebe*, *Ceanothus*, and *Escallonia*, as well as roses, climbers, alpines, and heathers.

There are a few small-scale growers of trees from seed. Production of field-grown trees (by budding) is limited. There is little, if any, bench grafting due to lack of tradition.

There are readily available sources of peat from a large number of suppliers.

AMENITY AND PUBLIC SECTOR MARKET

The amenity or public sector market is static or declining. The main reasons for this are reduced government expenditure and the impact of "contracting out" of local authority services to the private sector with the result that a lot of landscape planting schemes are now smaller. There is, however, a wider range of plant material generally used in these schemes than in the past. The demand for plants for the landscape sector is more likely to come now from community group schemes or commercial developments such as hotels and offices.

RETAIL MARKET

Undoubtedly one of the major developments in horticulture in the past 5 years has been the expansion and development of retail garden centres. In Northern Ireland there are now 12 relatively large garden centres with coffee shops and attractive layouts to encourage customer purchases. Some growers have moved into retailing from growing, encouraged by the demand in their area. Nurseries that have diversified into retailing still grow perhaps one or two crops, such as bedding plants, and are usually located near population centres of 20,000 to 50,000 people.

Northern Ireland consumers tend to have very favourable disposable incomes compared to counterparts in other United Kingdom regions. There is the potential for garden centre chains or groups to develop in Northern Ireland in line with trends in other areas of Great Britain. If this happens it could change the market dramatically for local growers.

The signs are that the larger sized garden centres are going to develop more rapidly and it may become more difficult for new entrants to successfully establish garden centre businesses in certain areas. There are increasing pressures on small garden centres to invest to better meet the needs of the modern consumer and thereby to compete more successfully with the larger centres. There are signs that some of the small garden centres are calling it a day and are diversifying into growing or some other aspect of the business, or possibly completely disengaging from the sector.

IMPORTS

In a recent survey of the 10 larger sized garden centres, the Department for Agriculture, Northern Ireland (DANI), found that while some garden centres buy 86% of their stock from Northern Ireland, others buy as little as 16%. Over recent years there has been a trend towards buying more stock from outside Northern Ireland. This trend has been driven by the increasing demand for a greater range and quality of plants supported with good service. Northern Ireland growers are working hard to meet this challenge but do not always have the range of stock when it is required. This survey showed that Northern Ireland growers supplied 49% of the plant material purchased by the sample group of 10 garden centres. Of the imported stock, 18% came from the Republic of Ireland and 33% from other areas, mainly Great Britain. Imports from Great Britain and the Republic of Ireland have increased while those from Holland have decreased. These figures indicate the potential for import substitution. However, the production of a wide range of high quality, competitively priced plants in line with customer requirements will be vital to ensure the success of locally based nurseries in this respect.

PRICES

Prices obtained for nursery stock in Northern Ireland have been low compared with those in Great Britain. This is perhaps because of lower labour and some raw material costs and also the size of the market. In a small market it is easy to have over production in some lines and this has occurred from time to time resulting in downward pressure on prices. There may be some signs that this is changing especially with the impact of severe losses experienced in the winter of 1995-96. It is difficult for growers to sustain these losses when they are not always receiving an adequate price for their product.

PROPAGATION

Systems are similar to those used in other areas with mist still being the main method of propagation. Quite a range of plants is propagated under polythene systems and there are a few fog systems. Some fog systems have not worked as well in small tunnels where the temperature is difficult to control in the hotter periods of the year. However, a number of the fog systems are working well where they are managed effectively.

One grower has had the novel idea of using cold water to reduce the temperature in his propagation beds in summer. The cold water is taken from a deep quarry and circulated round the base heating pipes and this cools the propagation bed down sufficiently to contribute to increased rooting. The idea came from borehole cooling which is used in the mushroom industry. The water from the quarry is approximately 5C and is circulated when the temperature exceeds 30C. This was very effective in 1995 when summer temperatures were unusually high. Each bed is fed separately with a supply of hot or cold water controlled by a motorised valve activated by a thermostat. The poles on the electronic thermostat are reversed so that once the bed temperature exceeds 30C, the motorised valve will open and allow cold water to circulate and reduce the bed temperature. This system operates between 11 AM and 4 PM. Operation of the system on a 24-h basis was found to reduce the rate of rooting through excessive cooling.

STOCK PLANTS

There is a mixed provision of stock plant material by the industry. Some growers are able to use cuttings from growing stock or liners. One system developed to propagate ×*Cupressocyparis leylandii* 'Castlewellan' is based on maintaining the juvenility of the stock plant by cutting back the mother plants severely to a flat top. A number of crops of cuttings can then be taken. Growth can be manipulated by foliar feeding. When the stock plant is initially cut back it takes some time to recover and in total it probably takes about three seasons to establish these stock plants to a reasonable level of cropping. The cuttings taken from the stock plants are juvenile and root very readily under mist.

GROWING SYSTEMS

With the increasing demand for uniform and high quality plants, the Horticulture and Crops Development Division of DANI has encouraged growers to make more use of capillary sandbeds. After building some small-scale sandbeds at Greenmount College some growers have adopted the system. The advantages of reduced water usage, more uniform plant growth, and the potential to produce higher quality plants with less labour input are now crucial. Slighter coarser sand than that specified by HRI, Efford, in the south of England, is recommended for outdoor sandbeds in Northern Ireland because of the higher rainfall here.

There is less increase in compost pH of containers grown on sandbeds, compared with overhead irrigation, where water is hard and has a high lime content.

DEVELOPMENT OF CAPILLARY SANDBED TECHNOLOGY

Two growers have investigated the use of woven polypropylene materials on top of capillary sandbeds to reduce maintenance. Provided pots have good contact with the material and the water level is kept higher, then the system works effectively. There

is a trend for growers to use woven polypropylene materials as growing surfaces for reasons of hygiene and ease of maintenance. Costs can be saved through reduced herbicide use.

At Greenmount College copper-impregnated groundcover fabric has been used on sandbeds. The copper helps prevent weed germination and prevents rooting through.

HORTICULTURE BUSINESS AND SYSTEMS DEVELOPMENT SUPPORT TO THE NURSERY STOCK INDUSTRY

The purpose of the Department of Agriculture for Northern Ireland is to promote economic growth and the development of the countryside in Northern Ireland. Horticulture and Crops Development Division (HCDD) assists with the development of a comprehensive commercial horticulture industry in line with market opportunities by developing the competencies and values of people through business and technology programmes. Technology programmes involve the development and demonstration, leading towards commercialisation and adoption, of promising new production and management technologies emerging from research programmes. These programmes involve HCDD staff using resources at Greenmount College and working closely with growers. HCDD staff also coordinate with Marketing Development Division colleagues to assist with marketing initiatives, such as the recently produced nursery stock trade directory.

SUMMARY AND CONCLUSIONS

- The retail market continues to increase in importance. Some large independents or retail groups may enter the expanding market.
- Only a small number of nurseries will be capable of investing to supply garden centres with the quantity, range, and service they need.
- Other growers are tending to change their production in one or a number of the following ways: becoming more specialist, possibly in retailing; contract growing; supplying landscape markets; supplying garden centres in niche crops.
- More nursery stock is being grown under protection to reduce winter damage and enable market requirements to be met more precisely.
- In the future more scheduling or programming of plant production to provide plants in colour when the market needs them will be required. Various techniques such as chemical treatments and cold treatments will be used to manipulate root and foliage growth as well as flowering.

This industry continues to change rapidly and will provide exciting challenges for both growers and retailers in the future. As propagators and growers it is vital to take account of changes in retail buying trends in order to constantly modify production accordingly. The increasing demand for a wider range of new and worthy plants provides growers with opportunities to lead the market.

The ready availability of land, a mild humid climate, coupled with some natural advantages such as an abundance of pure water and high quality peat, leaves growers in Northern Ireland well placed to take advantage of these opportunities.

Clonal Evaluation of *Escallonia* and *Cytisus*

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INTRODUCTION

The rapid increase in the production of container-grown hardy ornamental nursery stock in recent years has underlined the need for quality and uniformity in stock plants. As production increases, so too does the diversity of available species and their associated cultivars, leading to some taxa being misnamed in the process. This leads to confusion within the industry. For example, of eight accessions of *Escallonia* 'Peach Blossom', received by the Research Station at Loughgall, only one conformed with the true varietal description. Similarly, 50% of the accessions of *E.* 'Donard Star' were wrongly named, being in fact *E.* 'Donard Radiance'. In the remaining cultivars between 15% and 40% of the stock was incorrectly named. In the early stages of the evaluation of *Cytisus* it was discovered that all seven accessions of *Cytisus* ×*praecox* 'Albus' were wrongly named and did not match the general varietal description. Most variability recorded to date was a result of incorrect naming of plants but there were several instances of genetic variability.

CLONAL EVALUATION

Clonal evaluation may be described as the process of identifying any given species or cultivar as being true to type and to identify the features of each individual species/cultivar which best meets the demands of the consumer. This is not to be confused with the selection of a plant of any one species/cultivar over another plant of the same species/cultivar.

The clonal evaluation programme on *Escallonia* at Loughgall was started by Doug Thompson during 1988. By 1993, half of the original number of *Escallonia* species and cultivars obtained during the late 1980s had been labelled as true to type and given detailed descriptions. The remaining cultivars have, as yet, to be positively identified.

The process of evaluation begins by obtaining, from as many sources as possible, material of the genus under evaluation. Usually this includes only those species/cultivars currently under cultivation but occasionally others may be located in botanical collections, gardens, etc. All material received is then propagated and grown on to a stage where it can be set out in a randomised field trial, with a minimum of 12 plants of each clone for statistical comparison and evaluation. This process usually takes about 2 years.

Once established in the field, evaluation of each plant is undertaken for a minimum of 5 years. From the 2nd or 3rd year onwards, notes are made of the various characteristics and variations between species/cultivars from the different sources. This is carried out at least four times a year to evaluate seasonal variations within individual species or cultivars. Attention is paid to basic characteristics such as flowering, growth habit, leaf density, and ornamental value (Table 1). These notes are then compared with descriptions provided in the various texts (Bean, 1973;

Hillier and Sons, 1991, 1995; Krussman, 1984), catalogues, and journals. In some cases, descriptions from the various sources are scanty and may vary, particularly when referring to flower colour (Table 2). The most acceptable descriptions are obtained from those who have been involved in the production of new cultivars, which was the case in our assessment of *Escallonia*, where we were fortunate enough to call upon the expertise of nurserymen from the Donard nursery.

PLANT DESCRIPTIONS

The categories used to describe plants are shown in Table 1. Each plant is measured accurately and the RHS Colour Chart is used to provide a standardised description of colour. This assessment is carried out indoors in a north light. For the matching of flower colour, six blooms are taken to provide a general description of colour. Flowers are matched in bud, again at the peak of flowering and finally when starting to fade.

Table 1. Characteristics used to describe plants.

Descriptor	Characteristic
Plant height	Height of plant in metres
Plant width	Spread of plant in metres
Flowering period	Date of flowering and period over which it flowers
Flower bud	Description and colour
Flower colour and description	Where appropriate this may include number of petals or details of flower standard, wings, keel, etc. if present
Flower stalk	Length (cm) and colour
Calyx	Colour
Stem	Shape, colour, and length (cm)
Leaf	Size (cm), structure, and colour

SUMMARY OF WORK IN PROGRESS

Escallonia. The station is exchanging plant material of *Escallonia* with the Duchy College, Camborne, Cornwall, to add to the National Collection of *Escallonia* held at Loughgall. This will also be used to help confirm further cultivars of *Escallonia* which will then be released to the industry. It is also planned to survey those nurseries which originally supplied material to the programme during the late 1980s, with the intention of providing an indication of the overall effectiveness of the clonal evaluation programme within the industry.

Cytisus. A rolling programme for the evaluation and release of true-to-type taxa of *Cytisus* will be set up with the release of 6 to 8 taxa each year. Each release will be based on a theme, for example a "Heritage Collection" consisting of cultivars originating in Ireland or "Collections for the Smaller Garden" consisting of compact species or cultivars. Each release of material to the industry will be accompanied by a complete description of the plant (Table 2).

Table 2. Example of the available description for a specific cultivar.

Identification no. of clone: LG96115

Common Name	La Coquette
Bud Colour	Merging red purple 59A becoming 59D around centre fold with yellow 13A beginning to show at the edges
Flower: Standard	15 mm x 20 mm fully stretched, edges curling inward. Red purple 59D in middle becoming yellow 9A toward the side margins and join, inside red purple 65D with outer centre becoming yellow 9A/B towards side margins and inner centre with short scratches of 65D
Flower: Wings	17 mm x 9 mm yellow orange 14A with heavy flushing of orange red 34A on top half, becoming red purple 59D next join; inside yellow 9A
Flower: Keel	17 mm x 8 mm yellow 4A with faint flushing of red purple 59D
Flower Stalk	8 mm flushed grayed purple 184B
Calyx	Flushed grayed purple 187B
Leaf	Young leaves emerging yellow green 144A on underside, 143A on top, tipped grayed purple 187B
Stem	Yellow green 146A, round, and heavily ribbed
General	Quite strong unpleasant scent
Description as Given in Hillier (1991)	Standard rose red, yellow inside, wings deep orange yellow veined brick red, keel pale yellow faintly marked with rose red
Description as Given in Krussmann (1984)	Strong upright grower, tall, standard whitish carmine lilac outside, wings deep yellow with orange brown stripes, keel light yellow; F2 seedlings from *C. praecox* 'Hollandia' but with no similarity in growth habit to *C. praecox*

Database. The Station is planning to set up a computer database with photographs and complete descriptions of each species/cultivar including cultural details.

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The Production of Clean Plants in the Laboratory

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INTRODUCTION

Tissue-culture techniques complement conventional methods for the production, storage and propagation of disease-free plants. In the propagation of pathogen-free and contaminant-free plants, there are four important elements:

- The problem of detecting microorganisms in the stock plants.
- The requirement to develop an appropriate protocol to eliminate potentially harmful microorganisms.
- The problem of confirming the elimination of microorganisms.
- The requirement to maintain a good health status during multiplication and storage of the clean or elite stock.

It is increasingly the situation that elements of both the in vivo and in vitro approaches are combined in modern practice. The risks in both in vitro and in vivo techniques for the production of clean planting material will be considered here in the context of good working practice.

CONVENTIONAL STRATEGY FOR THE PRODUCTION OF CERTIFIED PLANTING MATERIAL

Potato and fruit crops, e.g. strawberry, provide models to illustrate good working practice in the production of clean planting material as both are subject to governmental certification schemes in many countries (for details of the potato scheme in The Netherlands see de Bokx and van der Went, 1987). In these crops individual plants are indexed for known crop pathogens (viruses and, where appropriate, viroids, bacterial, and bacteria-like pathogens) using proven methodology (for potato see de Bokx and van der Went (1987), Rowe, 1993; for strawberry see Mass, 1984). It is important, to emphasize that the phytopathology of these crops is relatively very well understood. Historically, test plants were used to index for pathogenic viruses but now ELISA is routinely used, especially for mass screening during field multiplication (Hill and Jackson, 1984; Fox, 1993).

Symptoms are a valuable indicator of the health status of a crop and the selection of symptomless individuals, i.e. "disease escapes", has long been the foundation of clean stock production schemes. Where disease escapes have not been available, thermotherapy has been widely used and is still used with a high level of success (Hollings and Stone, 1968). Where symptomless escapes, or symptomless individuals have been obtained after thermotherapy, these are tested as the parental material for pathogens. It is recognized, in woody species for example, that virus concentration may be low in heat-treated material and, consequently, early virus testing made give false negative results (Leonhardt et al., 1997). From the latter, it can be appreciated that confirmation of freedom from known pathogens can depend on the developmental stage of the host plant.

The multiplication of disease-free individuals by conventional vegetative propagation is slow and there is always the risk of pathogen re-entry into the crop. The risk

of re-infection is less with a protected crop such as strawberry, multiplied in vector-proof greenhouses, than in potato, a field crop. The elite stock of the latter is either multiplied in vector-free areas or vector populations are carefully monitored to minimise the risk of infection (de Bokx and van der Went, 1987). In potato certification schemes, contamination of the elite stock during successive years of field multiplication is recognised. The crop is monitored both in the field and laboratory at the end of each season and graded according to the levels of specific disease present. A mandatory down-grading of the health status occurs in each successive field generation and, depending on the extent of re-contamination, the seed may be down-graded by more than one grade.

PRODUCTION AND MULTIPLICATION OF CLEAN PLANTS IN THE LABORATORY

Meristem culture is an effective way of eliminating most microbial contaminants, whether pathogenic or not, from plant material (George, 1993). A caution is that the tissue excised from the tip of the plant should not contain any of the vascular system. Meristem culture, however, while eliminating xylem-restricted and phloem-restricted organisms (bacteria and the larger phloem-restricted viruses), cannot be guaranteed to eliminate smaller viruses and viroids that may extend into the apical region (Matthews, 1991). In the latter case, escapes can be sought or thermotherapy applied to the donor plant in vivo (Walkey, 1985), prior to further attempts at meristem culture.

Alternatively, thermotherapy may be applied in vitro, or the plant tissue may be cultured in vitro in the presence of antimicrobial compounds (Cassells, 1983; Barrett and Cassells, 1994). Thermotherapy in vitro operates on the same principle as in vivo, namely, on culturing the tissue at temperatures that are nonpermissive for virus replication and that may enhance the breakdown on pre-formed virus particles. Under these conditions virus may be eliminated or new tissue growth may be virus-free.

The strategy to eliminate bacteria from tissue cultures is usually based on incorporation of antibiotics into the medium. These may be bacteriostatic, rather than bactericidal and so new tissue is excised and subcultured. Antiviral chemotherapy of whole plants is very difficult, in principle, due to difficulties in maintaining an inhibitory concentration of the few, mainly virus-static, chemicals that have any efficacy (Cassells, 1983). The problem, as is the case with antibiotics, is reduced by their use in in vitro cultures. The most widely used plant antiviral chemical has been Ribavirin, which appears to have broad spectrum activity (Cassells, 1983; 1997a). It has been used alone or in combination with thermotherapy (Cohen, 1986).

Regardless of the method used to eliminate microbial contaminants, it remains to be confirmed that de-contamination has been achieved. While viruses have been detected in in vitro cultures, tissue-printing has shown that distribution may be uneven, leading to problems in confirming elimination at the in vitro stage without destructive sampling (Knapp et al., 1995). Plant hormones are known to influence virus replication in plants, and the hormones in in vitro culture, may suppress plant virus replication, leading to false negative results (Cassells, 1983).

A positive aspect of in vitro methods in clean plant production is that pathogen-free material is at low risk of re-infection with pathogens and thus can be stored and multiplied safely. Contamination during in vitro multiplication by cultivable envi-

ronmental microorganisms, such as fungi (including yeasts) and bacteria, is a risk but the problems are well understood and good laboratory management can minimise losses (Leifert and Waites, 1994).

INTEGRATED STRATEGIES FOR THE PRODUCTION OF CERTIFIED PLANTS

Potato and fruit crops provide good models for the integration of in vivo and in vitro methods for the production of clean planting material.

In potato and strawberry, micropropagation plays an important role in the multiplication of disease-free plants even though: (a) the starting material is certified in vivo as virus-free and (b) the progeny plants are further multiplied in the field; the certification is based on field and post harvest inspection of the crops.

In certified potato multiplication, multiplication in vitro reduces the time taken to introduce new stock by four seasons and, as a consequence, the certified seed material is likely to be less contaminated during field multiplication than that obtained from conventional (not in vitro) seed production. Similarly, micropropagation is used to produce strawberry microplants for the production of certified runners.

HEALTH STATUS OF MICROPROPAGATED PLANTS

The presence or absence of disease symptoms in the parental plant material may be the only indication to the propagator that the starting material is diseased. In many cases, symptom expression may be seasonal and latent contamination a consequence (Matthews, 1991). Even if symptoms are present, the causal agent may not be economic to detect and/or identify, especially in lesser or exotic crops where the knowledge base is limited or fragmented and diagnostics are not commercially available. Under these circumstances, micropropagators depend heavily on fortuitous elimination of pathogens in establishing their cultures. Here meristem culture, with the proviso that the minimum size explant is excised, offers a broad spectrum solution. The risk, especially where explants other than the apical tips are used, is that pathogens will be transmitted vertically and that clonally infected cultures will be multiplied. Symptom suppression in tissue cultures is common in the cases of fastidious organisms and viruses and viroids.

A further complication is the lack of broad spectrum diagnostics although this problem is being recognised and solutions developed (Bariana et al., 1994). Maintenance of test plants is expensive and modern diagnosis may be too strain-specific. Furthermore, there is uncertainty regarding both the concentration and distribution of viruses in in vitro tissue, which may result in false negative results (Knapp et al., 1995).

The strategy followed in potato and strawberry, of growing on the crop in disease-monitored fields or greenhouses is not practical for the producer who sells in vitro cultures or established microplants and where there is no legal requirement for certification. However, it can be followed by propagators who grow on microplants as mother plants for the production of cuttings (Jones, 1986).

CONCLUSIONS

A great deal is known about diseases of cultivated plants and for the major crops this information has been published in compendia (e.g., the series published by the American Phytopathological Society). In the case of minor crops, the development of computer databases makes this information readily available to the micropropagator via the Internet. In spite of this potential for greater information about crop diseases, problems of latency and the lack of availability or high cost of diagnostics, mean that in most commercial micropropagtion laboratories working practice is based on the establishment and maintenance of cultures free of cultivable bacteria. Where specified by legislation or the client, tests, usually ELISA-based, for specific pathogens of the crop may also be carried out. A scheme outlining the categories of health status of microplants is shown in Fig. 1.

The production of higher health status material via micropropagation can be achieved in the same ways as in potatoes, if the starting material is certified disease-free based on conventional procedures and if the health status of the progeny is confirmed by inspection and testing of the field progeny.

In the longer term, the prospect is that the development of highly sensitive, broad-spectrum nucleic-acid-based diagnostics will enable micropropagators to produce high health status material with confidence. In the interim, it may be in the interest of micropropagators and growers to develop nuclear stock associations through strategic links with governmental institutions and to combine the best practice elements of the potato certification scheme in the production of high health status plants.

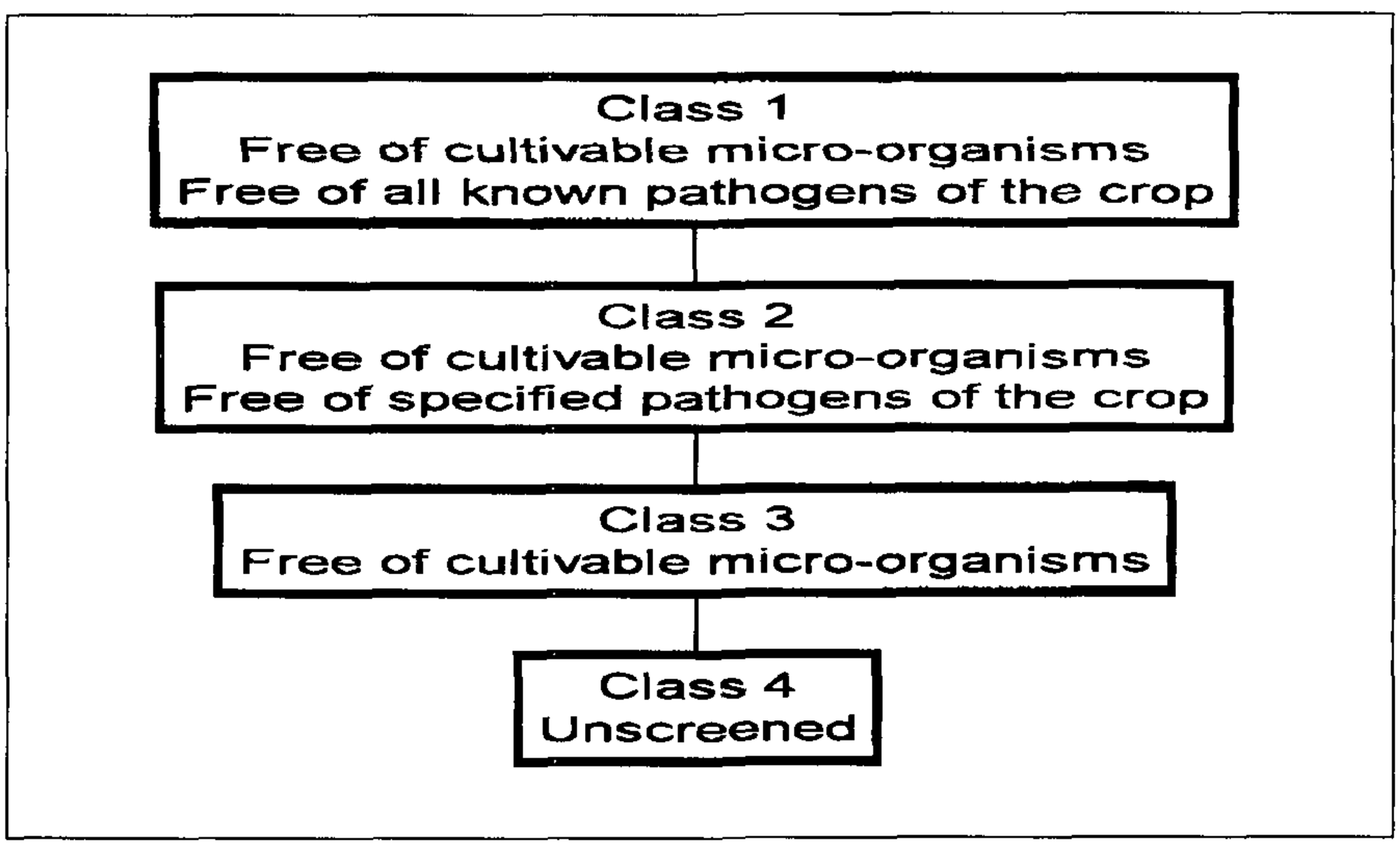

Figure 1. Catagories to describe the health status of micropropagated plants.

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A Tube Method for Grafting Small Diameter Scions of the Hardwoods *Quercus*, *Fraxinus*, *Betula*, and *Sorbus* in Summer

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In conventional grafting of oak and ash in February, the graft viability over 3 years was 15% and 97%, respectively, with 64% of oak clones responding and 100% of ash, using scions from mature trees. Using single node scions from these grafted plants, epicormic shoots, crown shoots, and a silicone tube to hold graft unions we recorded improved rates of graft viability by summer grafting. All oak and ash clones made viable grafts with efficiencies of 18% to 100%. Summer grafting of hardwoods allows several serial grafts per year and potential to rejuvenate tissues.

INTRODUCTION

Vegetative propagation of mature trees is generally difficult but it is an essential step in a programme for genetic improvement of trees such as oak and ash. Conventional grafting is usually performed once a year in the early spring (February to March) and uses 2-year-old rootstocks, elastic tying of the graft union, and waxing of the plant.

Grafting of mature scions to a seedling rootstock (primary graft) followed by re-grafting of growths from these primary grafts, with subsequent repeated re-grafting of new growths, several times, may be a way of rejuvenating material which originally came from mature trees (Huang et al., 1992; Franclet, 1983).

This study reports on results from conventional grafting as well as a new tube method, which can be applied to oak, ash, birch, and sorbus for grafting thin-stemmed scions to seedling rootstocks in summer and winter.

MATERIALS AND METHODS

Scionwood was collected from selected trees in mature forests, stored as branches at 1C for between 3 and 30 days in February to March, until grafted onto 2-year-old rootstocks. A splice (whip) graft was made using multi-budded scions, tied with elastic bands, and the union plus scion painted with molten paraffin wax.

Tube grafting was carried out using 4-month-old to 8-month-old rootstocks of, mainly, *Q. robur*. Scions were collected from 2-year-old, conventionally grafted, plants except where otherwise stated. A diagonal cut at an angle of approximately 50° was made with a scalpel in the stock and scion.

Laboratory silicone tubing (internal diameter 3.2 mm, wall thickness 1.6 mm) was cut into lengths of 2 to 3 cm and first placed halfway over the stock. A caliper

(Mututoyo, Japan) was used to determine the stem and stock positions with diameters approx. 3.3 mm where the cut was made. By viewing through the wall of the tube already on the stock, the scion was pushed into the tube so that its cut surface was guided across and matched to the cut surface of the stock. Scions generally consisted of a single lignified node 3 cm in length from which the leaf was excised. All buds on the stock were also excised using a scalpel. Grafts were tied to a small stake,covered with a plastic bag which was also tied, and placed in a plastic enclosure in a shaded greenhouse. When scion buds grew out, humidity in the bag was reduced gradually by opening the bag; the wall of the silicone tube was cut open using a scalpel when the bud grew out.

RESULTS

The viability of conventional grafts of mature scions is presented in Table 1 and show that 64% of oak clones gave at least one viable graft and 15% of all grafts were viable. Results for ash were superior.

Table 1. Viability of oak and ash grafts over 3 years using scions collected from crowns of mature trees (10 plants grafted per clone per year).

	Percent viable grafts (No. clones viable/no. grafted)			Mean % graft viability	Mean % clone viability
	1991	1992	1993		
Ash	91% (34/34)	97% (24/24)	96% (17/17)	96.6	100
Oak	17% (28/41)	10% (17/28)	17% (11/19)	14.7	63.6

First experiments with summer "tube" grafting used 4- to 8-month-old stocks and scions of oak and ash. Stocks and scions were selected with a diameter of approximately 3.3 mm to fit into a silicone tube with an internal diameter 3.2 mm (Figs. 1-5). Viable grafts were obtained using a diagonal cut, whereas horizontal cuts failed. Outgrowth of grafted buds occurred in 20 days. Scions consisting of an apical bud, with either 1, 2, or 3 axillary buds each gave 50% graft viability, whereas single and double node scions each gave 60% viability (10 to 15 grafts per treatment). Stock plants in which the growth flush had finished gave 50% graft viability, whereas those in which the flush was in progress gave 25% (12 plants per treatment).

Nonflushing stock plants and single node scions were used in further experiments. Scions from 9-month-old oak plantlets were grafted to their own rootstocks (autograft) or to another plant (heterograft) to test the effects of time delays, between collecting the scion and making the graft union. Delays of 10 sec, 1 min, 5 min, and 10 min were allowed before applying the scion to the stock. In each treatment with 15 plants, 100% of grafts were viable, indicating no adverse effects of delaying the joining of stock to scion or of rootstock type. Similarly, there was no difference in graft viability between using thicker stock and scion (within the range 3.4 to 3.5 mm).

The tube method was tested using mature clones of oak, already established from 2-year-old winter grafts. The single node scions were prepared by first removing the shoot apex between 4 and 7 days before excising the selected first node (N1) or second node (N2). Grafting was in August. Control grafts were seedling scions heterografted and viability was 68%. Unlike conventional winter grafting, all mature clones grafted were viable: two gave 100% viability while five out of the remaining six gave more than 30% (Fig. 6), (10 grafts per clone).

Eight elite trees of *Q. petraea* at Tullynally Castle, Co Westmeath provided scions from crown and epicormic shoots. Using the tube method in August 1995, crown shoots gave 55% viable grafts for one clone and 5% for another. The mean viability of grafting epicormic shoots was 7% with these eight clones (range 0 to 12%; 15,to 55 grafts per clone) and three clones failed to give viable grafts.

Scions were collected from a 20- to 25-year-old tree of *Q. coccinea* 'Splendens'. A total of 52 single node scions (3.2 mm) were grafted to *Q.robur* rootstocks in July-Aug 1995 and resulted in 29 (55%) viable grafts. This cultivar was also conventionally grafted in Feb 1996 and three grafts out of 48 were viable (B. Murphy, Pers. Comm.)

For tube grafting of ash, scionwood was collected from 2- to 3-year-old grafted stock plants of elite selections. Single nodes were selected and grafted in June-July 1995 onto 18-month-old rootstocks (Table 2).

Table 2. Viability of *Fraxinus excelsior* grafts using the tube method.

Clone	Number grafted	Number viable
Athenry 4	9	8
Athenry 7	20	15
Athenry 8	20	15
Jenkinstown 47	10	10
Shillelagh	10	9
Cong 2	13	13
Thomastown 70	14	13
Total	96	83 (86%)

The tube method was also tested during the conventional winter period of grafting in 1996, using multinodal scions and paraffin waxing. Viable grafts were obtained for *Sorbus megalocarpa, S. harrowiana*, and *S. sargentiana*. With the latter species, silicone tubing with an internal diameter of 9.8 mm was used to hold the graft union. In winter grafting of *Quercus*, the tube method was compared to elastic ties using scions from stock plants of five elite clones. All grafts were waxed and the viability averaged 38% with the tube method and was 27% with elastic ties. In grafting of *Betula jacquemontii* by the tube method and elastic ties, viability was 52% and 48%, respectively.

DISCUSSION

The skill of the grafter is especially important in aligning cambial layers and obtaining a secure graft union, especially with very thin scions. Summer scionwood

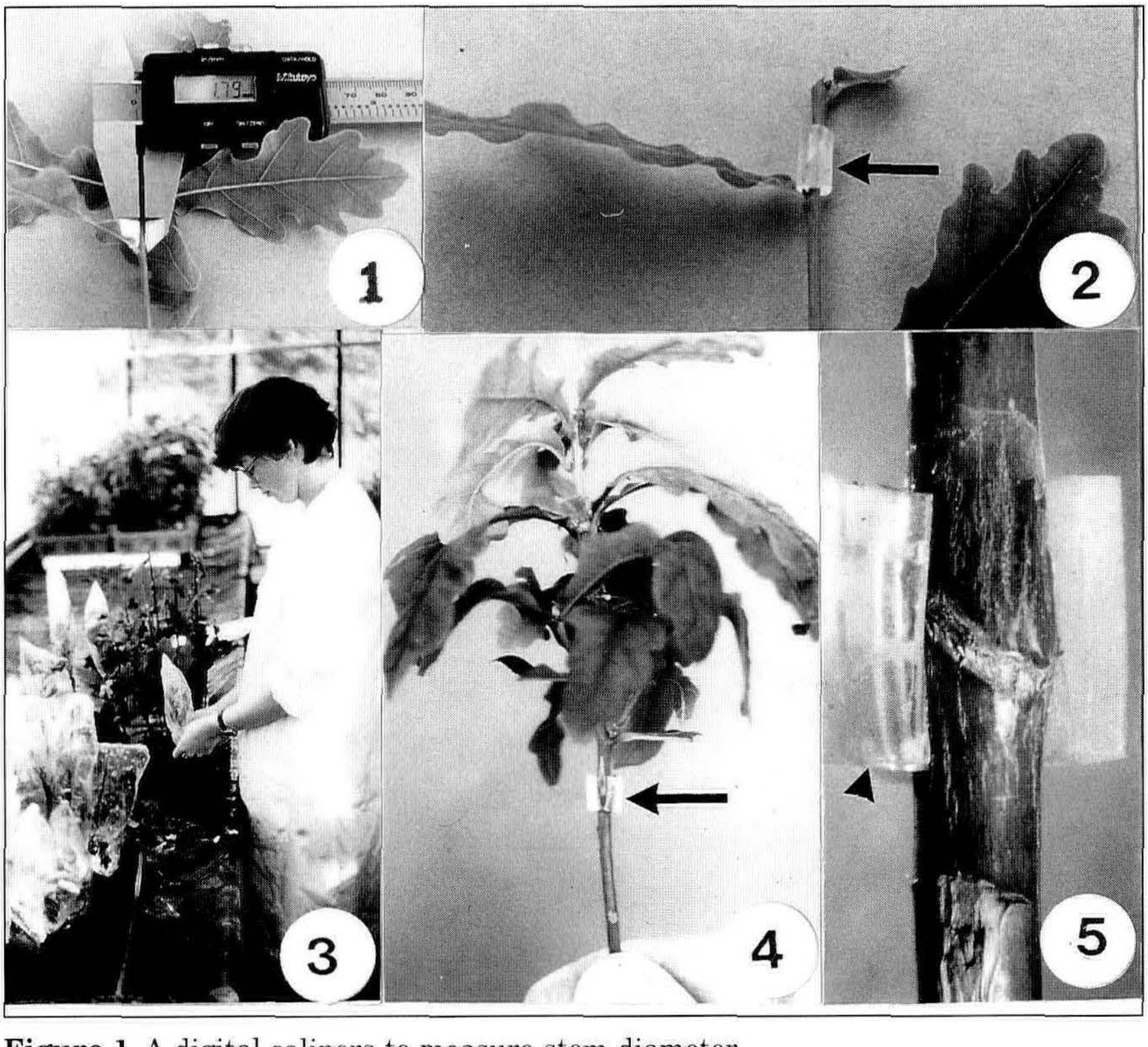

Figure 1. A digital calipers to measure stem diameter.
Figure 2. A single node of oak grafted using a silicone tube.
Figure 3. Staking and bagging after grafting.
Figure 4. Oak graft after 8 weeks.
Figure 5. Detail of an ash graft after 4 weeks (arrows show tubing).

of oak and ash is generally thin and difficult to hold with elastic ties. With in vitro grafting of stems 0.9 to 1.3 mm., Gebhardt and Goldbach (1988) first used a silicone tube with a longitudinal 'S' shaped incision in the tube wall to hold unions of *Prunus domestica* and *P. cerasus*. Olbeidy and Smith (1991) devised an aluminum coil for 4.0-mm-diameter apple and citrus.

When using intact pieces of silicone tubing, it is essential to use a caliper to select the stock and scion with the same stem diameter (or 1 to 2 mm greater) as the internal diameter of the tube and to carefully cut the tubing, once the scion bud grows out (Figs. 4, 5).

The elasticity of silicone tubes ensures an even pressure at the graft union which may facilitate cambial divisions and differentiation of vessels (Brown and Sax, 1962). The translucent silicone allows a rapid and easy alignment of the scion with the stock. Previous studies in grafting variegated clones of *Q. robur* in the dormant season gave 32% successful grafts by using an omega shaped graft union (Borzan, 1993) and 52% of *Q. robur* 'Fastigiata' scions grafted to 5- to 10-mm-root pieces (Leiss, 1988). Grafting of *Fraxinus excelsior* var. *pendula*

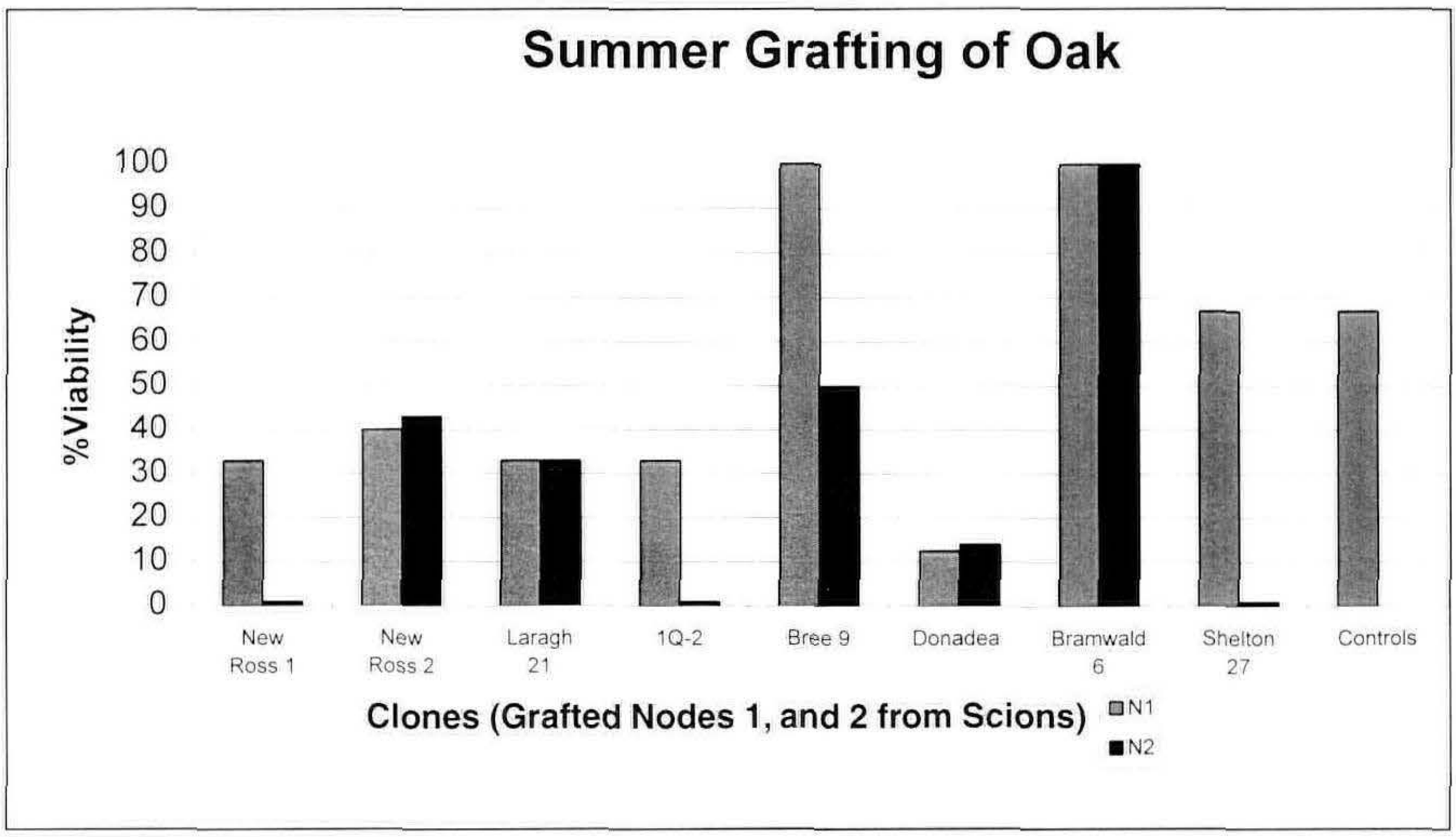

Figure 6. Summer grafting of oak by the tube method.

was 100% by pre-selection of buds using x-rays (Krsstev, 1994).

Studies on grafting *Q. palustris* 'Crownright' and 'Sovereign' suggest that virus-infected rootstocks may lead to graft failures and that *Q. rubra* scions which had isoperoxidase enzymes in common with those of the stock resulted in successful graft unions (Santamour, 1988). In the present study our average viability for oak was 15% and this contrasted with 97% for ash using scions collected directly from mature trees and conventional grafting in spring.

Summer grafting of oak in 1993 with the tube method gave consistently high graft viabilities in seven out of eight clones and with three clones, the viability was equal to or greater than the viability of control seedlings. In this experiment, scions were obtained from previously grafted stock plants and their potentially more rejuvenated condition may have contributed to increased graft viability. Good viabilities by tube grafting of crown and epicormic scions taken directly from several mature *Q. petraea* and *Q. coccinea* 'Splendens', suggest that the tube grafting in summer is a promising option for propagating oak.

Conventional winter grafting and summer tube grafting of ash gave high viabilities (86% to 100%) and with *Betula jacquemontii*, the tube method applied in winter gave similar viabilities to elastic tie grafting. Tube grafting in the growing season offers the prospects of improved rates of viability, especially for oak. However, the most important advantages of the tube method are:

- Grafting can be performed in summer when scion and rootstock vigour are high.
- Juvenile seedling rootstock can be used.
- Several successive grafts of the same plant can be made in one season.

By lengthening the season with supplementary lighting, at least three flushes of oak can be obtained and this allowed us to make three successive grafts in one season, by the tube method. Repeated grafting of new growths from mature scions to juvenile seedlings in vitro has rejuvenated *Persea americana* (Pliego-Alfaro and

Murashige, 1987), *Sequoia sempervirens* (Franclet, 1983), *Sequoiadendron giganteum* (Monteuuis, 1986), *Thuja plicata* (Misson and Giot-Wirgot, 1985), *Citrus* (Huang et al., 1992), and *Larix decidua* (Ewald and Kretzchmar, 1996).

The rootability of conventional cuttings from these grafted plants had improved in most cases as well as in material from nursery-grafted eucalyptus (Franclet, 1983), *Hevea* (Muzik and Cruzado, 1958), and *Persea* (Shafrir, 1970). In *Citrus*, repeated grafting of mature scions to germinated seedlings resulted in a progressive rejuvenation. Rooting of cuttings from grafted plants was 0%, 45%, and 70% from plants which were four, five, and seven times grafted respectively (Huang et al., 1992).

There is insufficient knowledge about the number of grafting cycles required to restore rooting competence to cuttings from mature ash and oak. However, by using the tube method of grafting, several successive grafts are possible per year and restoration of a juvenile physiology may be accelerated.

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Use of In Vitro Plants in the Irish Hardy Nursery Stock Industry

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Micropropagation has become an integral part of the horticultural industry. A survey was conducted to enquire into the usage of in vitro plants by Irish nurseries. The amount of tissue culture material used does not exceed 5%. The small size of the Irish industry means that the Irish market for tissue culture material is very small. The vast majority of users of tissue culture material recognised its great advantages but found suppliers unreliable in terms of delivery date and quantity but not quality. The unreliability was explained by the peaks inherent in hardy nursery stock production.

INTRODUCTION

Tissue-culture technology has developed over the last four decades from basic laboratory research into commercial micropropagation of plants. The structure and product mix of commercial laboratories generally reflects the market considerations from which the basic research originated. The reduced transport costs and comparative ease in meeting plant quarantine requirements has resulted in a global micropropagation market.

The 1993 Directory of European Plant Tissue Culture Laboratories lists 501 laboratories. Of these, 172 are commercial laboratories. The list shows around 1850 plant species at different stages of micropropagation protocol development. This undoubtedly underestimates the total, as a result of underreporting by commercial laboratories (O'Riordain, 1994).

Micropropagated material now plays an integral part in the horticultural industry, but accurate production statistics are unavailable for two reasons: production figures are kept as commercial secrets, and official statistics do not subcategorize micropropagated material from other propagation material (Deberegh and Reid, 1992).

In Ireland, micropropagation began as an academic research tool, for virus elimination and as a plant breeding technique. The first major commercial venture was started in 1984 by Vitroflora Ltd., which later failed, primarily due to undercapitalisation and unrealistic market expectations. It was followed by a number of others who failed for similar reasons. Plant Technology Ltd. is the only Irish general micropropagation company which has survived since its foundation in 1989. It is now the largest general micropropagation company in Ireland. The company's expansion has, however, been almost exclusively on the strength of the export market.

The costs and requirements of a very basic tissue-culture facility has been discussed from an Irish nursery's perspective by Hunter (1989). The advantages of tissue culture are also discussed in his paper (Hunter, 1989). The paper presented

here seeks to examine the use of microcuttings in the Irish Nursery Stock Industry and it is based on the results of a questionnaire survey conducted by Plant Technology Ltd.

THE MARKET

Market research conducted on behalf of An Bord Glas estimated the value of the domestic market for plants at £24.05m at retail prices. Shrubs, trees, and bulbs account for 19.4% of this, or £4.66m. (An Bord Glas, 1996). The following table summarises the area and gross value of Irish nursery production for the year 1995. A comparison between production and retail sales suggests a high level of exports.

Table 1. Size and value of the Irish nursery stock industry (Source: Dept. of Agriculture, Estimate of Gross Horticultural Output 1995)

	Area (acres)	Value (£1000)
Hardy nursery stock	1200	18,792
Bulbs	281	1112
Foliage	75	300
Total	1556	20,204
Under glass		
Cut flowers	20.4	1484
Pot plants	15.7	1564
Bedding plants	26.6	1330
Other nonfood crops	9.9	31

GROWER ATTITUDES TOWARD MICROPROPAGATED PLANTS

The questionnaire was a simple design and was distributed to most large nurseries selected from An Bord Glas listing (An Bord Trachtala/An Bord Glas, 1992). Information was requested on nursery size and structure, their major products and their views and experience with tissue-cultured material. The limited response rate made statistical analysis difficult. However, general trends are apparent as most of the largest nurseries responded.

Usage of Tissue Cultured Plants. Only half of the respondents are using tissue-cultured plants, and their usage in all cases is 5% or less. In context, this represents 40,000 units of tissue cultured material for the largest user. Users preferred to deal directly with a laboratory rather than buying generally available material.

Skills in the Handling of Microcuttings. Most current users of tissue-cultured material used weaned plugs rather than microcuttings.

All users of tissue-cultured plant material accepted that they did not have the skills to wean microcuttings. Ironically, most non-user respondents felt they had these skills. Given that both groups have the infrastructure and skills needed for handling conventional cuttings, it must be concluded that first-hand experience demonstrated the sensitivity of microcuttings. In major horticultural centres around the

world, this sensitivity has lead to the development of specialist microcutting weaners within the liner production industry.

Motivation to Use Tissue-Culture Material. The two major factors were the competitive edge that greater plant availability gives, followed by the rapid production of new material which tissue culture promises. Neither cost reduction nor improved plant quality were major motivators in the tissue-culture plant purchase decision. Cost reduction is not a major factor, perhaps because of the low volumes sold on the Irish market and cost reduction only becomes a factor at high volumes. Although not a motivating factor, the improved quality that tissue culture can deliver was recognised but only for some lines, probably where evenness of development is of importance.

Difficulties Encountered in Using Tissue-Culture Laboratories. Almost all respondents felt that tissue-culture laboratories were an unreliable source of plant material—even those who never used tissue-culture material! This is despite the fact that almost all respondents were aware of the fact that tissue culture production could not be guaranteed, that a lead period of up to 2 years was expected and tissue-culture plants should be tested before full-scale production.

The perceived source of unreliability can be summarised by one of the respondents, "They promised too much and delivered too little, if any".

This, in the view of the authors, is an unfair comment. The introduction of a new micropropagated line should be considered a major research project unless there is previous experience of similar taxa. Respondents identified the accelerated production of new plant lines as one of the major motivating factors in using tissue-culture material, hence, by definition, a major research project whose results can be slow and unpredictable thus possibly late and underproduced.

Plant specification did not appear to be a problem in comparison to the problems of volume and timing.

These opinions are not uniquely Irish but are reflected by hardy nursery stock tissue-culture users internationally.

Propagule demand peaks are an intrinsic part of hardy nursery stock production. Hence hardy nursery stock plant production is like an inverted pyramid. This results in a huge peak in demand for specialised skilled labour and inefficient usage of highly expensive laboratory and growth room space. Any slight production difficulties are magnified by the accelerated propagation rate. It is very significant that the bulk of tissue-culture plant material goes to indoor plant producers. Indoor plant production is year-round with minimal demand peaks.

CONCLUSION

There are three types of laboratory structure which can successfully produce hardy nursery stock:

- Large general laboratories where the bulk of their production is of indoor plants, thus tolerating the small peaks of hardy nursery stock.
- Small laboratories attached to very large nurseries with sales all in house. These survive by spreading management costs and sharing staff at peak production periods.

- Highly specialised laboratories. These are primarily in business to accelerate the promotion of material from their own breeding programme.

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Nursery Stock in Finland

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INTRODUCTION

Finland is on the east of northern Europe,in Scandinavia, between the 60th and 70th degree of latitude and so is as far north as Sweden, Norway, Greenland, and Alaska.

About 75% of Finland's area of 337,000 km^2 is forest and woodland, and 10% is covered by lakes. Half of the 5 million Finns live in the very south of the country.

The climate is cold temperate, potentially subarctic but comparatively mild because of the moderating influence of water (Baltic Sea, North Atlantic Current, 60,000 lakes).

THE SIGNIFICANCE OF CLIMATE FOR HORTICULTURE

The cold climate sets a limit on the range of horticultural crops which can be grown. However, a positive effect of the climate is that there are fewer pests than in warmer climates.

There are four seasons which are literally as different as day and night. The climate ranges from Atlantic maritime in the south to Arctic in the north so growers have to respect provinence of origin of the stock they are using, even when it originates in Finland.

For example in February the average temperature in the north, at -13.6C, is much colder than in the south (-6.8C); in July the average temperatures are much more similar (14.6C in the south and 14.1C in the north). In the south, the temperature occasionally drops below -20C in winter, but during warm summer days it can climb above 20C.

Hardiness is, therefore, the most important characteristic of plants. For that reason, many genera which are easily grown in more temperate climates, such as *Hedera helix*, do not survive at all. Many can only be used in the southern zones, for example *Quercus robur, Aesculus hippocastanum, Corylus avellana, Fothergilla major, Potentilla fruticosa* 'Red Ace'. Retail plant labels in Finland show the zones in which a plant is hardy.

In much of the country, soil can remain frozen after the start of the growing season (Fig. 1) which means additional difficulties are encountered if growing evergreens such as *Rhododendron, Buxus, Ilex*, and also some conifers.

THE KESKAS-PROJEKT

The word Keskas comes from the Finnish, *kestävä kasvi,* which means hardy, long-lasting plant.

The Keskas Projekt was started at the Department of Horticulture, Helsinki, in 1984 because there was an increasing need for woody ornamentals for landscape planting schemes. Imported plants often failed because they were not hardy enough while many old proven plants had been lost from general cultivation. The aim of the project was to find hardy, beautiful ornamentals in already long-established plantings in Finland, and then improve the quality of nursery stock by propagating the best clones of these plants.

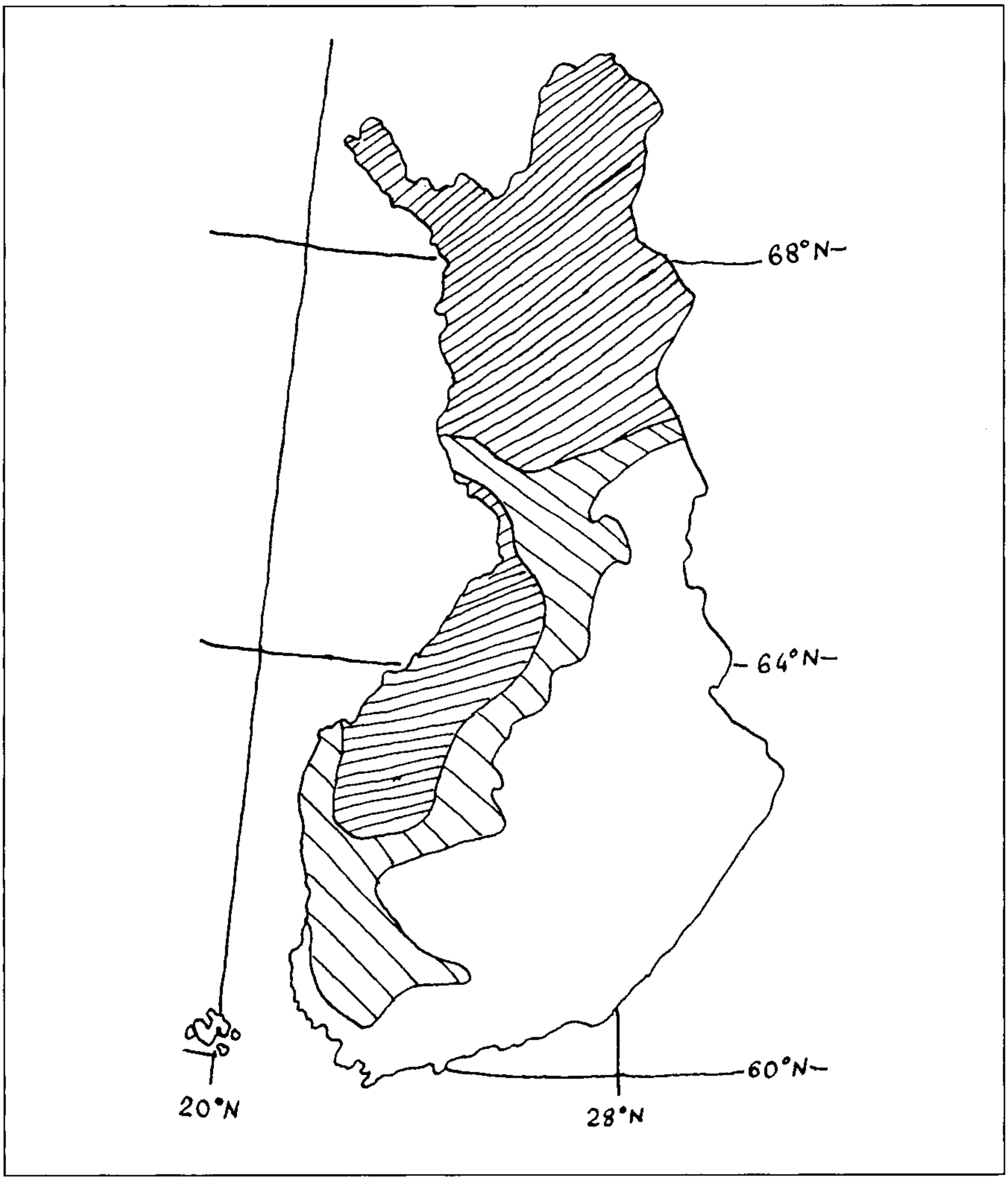

Figure 1. Finland, showing how long soil remains frozen after the start of the growing season.Key to map: [darkest shade] 5 days or longer; [medium shade] up to 4 days; [no shade] soil not frozen when growing season begins

More than 700 sources of woody ornamentals were registered, 20 of the taxa are trees, for instance *Acer, Fraxinus,* and *Taxus*; 60 are shrubs, for instance *Syringa, Cornus, Philadelphus,* and *Rosa.*

After field trials were carried out, the chosen clones were given a serial number and became stock plants for further propagation. The first of these clones are already cultivated on nurseries which plan to offer the first so called "Fine-plants" to their customers in 1997. They are likely to be sold at a price premium, since they are known to be hardy and of good quality.

NURSERIES IN FINLAND

Most of the 371 nurseries are situated in the south. Their production value is about 100 million Fin-Mark per year. Production area of nursery stock altogether is 787 ha (110 ha fruit and berries, 677 ha ornamentals) plus 40 ha perennials.

The nurseries vary considerably in size. There are about 30 nurseries that are bigger than 30 ha, but most of the others are small and, as the Finns say themselves, more like a big hobby.

Typically even the smaller nurseries grow a wide range of crops: ornamental shrubs and trees, climbers, fruit trees, and berries. Forest nurseries grow several conifer and deciduous tree species. The reason for this lack of specialisation is that Finland produces only for the home market, there is almost no export. Plants are sold direct at the nursery or sent to garden centers, public authorities, landscape designers, or other nurseries in Finland.

The main selling season is in April and May. Finnish companies produce 65% of the nursery stock requirement in the country, the rest of it is imported from Netherlands, Sweden, Denmark, Hungary, and Estonia.

Because of the short growing season (180 days in the south, 120 days in the north), cultivation times are longer. Late or early frosts can cause a lot of damage, especially during flowering of fruit trees and berries, and on new growth if not fully hardened off at the end of the season.

Propagation also begins later in the year. Nursery stock is propagated by seeds, cuttings, and grafting and in very few cases by tissue culture. Propagation material from the local area is always preferred, with propagation material from elsewhere in Finland being second choice. All grafting is by hand as it is the only way to ensure grafted plants survive the long, hard winters with heavy snow. Roses are not grafted but varieties are grown from seeds where possible.

Hard cuttings are taken in autumn and spring, soft cuttings in summer (June and July). The hard cuttings are stuck in soil, either in autumn before the ground is frozen, or in spring when the ground is soft enough. In summer, the soft cuttings are stuck either in soil, or in pots or trays in greenhouses.

Propagation staff at the nursery Puukarha Tahvoset had developed a special tool, called a Lapyske, for taking soft cuttings. It is a flat, square piece of zinc galvanised steel with one sharp edge. It fits into the user's hand, with the sharp edge opposite the thumb, and it secured there by a rubber band. The shoot is held against the blade with the thumb and the cut made with a turning motion of the hand. The tool is cheap to make, the technique easy to learn, and cuttings can be taken at a good speed. A further advantage is the reduced risk of accidents when using unskilled labour.

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Hardy Woody Plant Propagation at the Royal Botanic Gardens, Kew

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INTRODUCTION

Hardy woody plants are propagated at the Royal Botanic Gardens, Kew, in the Temperate and Arboretum Nursery. In total there are four nurseries on the site at Kew, and a further nursery at Kew's satellite garden at Wakehurst Place, Sussex. Each nursery specialises in a particular range of plants:

- Alpine and herbaceous.
- Tropical nonwoody.
- Micropropagation (concentrating mainly on endangered plant species including orchids.
- Temperate and arboretum (a merging of two nurseries in effect on one site, where mainly woody plants from sub-alpine to tropical rainforest habitats are propagated and grown).

This paper will concentrate only on the Arboretum Nursery and the propagation and cultivation of hardy woody plant species.

The nursery covers an area of 6078 m^2 of which 889 m^2 is glass, 2975 m^2 open ground area, 175 m^2 polytunnels, and 198 m^2 sandbeds.

There are three full-time members of staff: a nursery manager, responsible for the general overall running of the nursery; a senior botanical horticulturalist, specialising in the propagation and cultivation of hardy woody subjects; and a higher botanical horticulturist, responsible for propagation and cultivation of nonhardy plants in support of the Palm House and Temperate House, with assistance from the nursery manager.

PROPAGATION FACILITIES

The closed mist propagation unit is computer controlled using a sun mist programme. A light meter measures the sun's radiance. When a certain threshold is reached a mist burst is given. It is a good system, but needs regular monitoring, and does not differentiate between bright humid days and bright dry days. This system is used for a wide range of soft and semi-ripe cuttings.

Closed case is used to propagate grey foliage plants, or dry-loving Mediterranean-type species that do not like the rooting environment too moist. Subjects that do well in closed case are *Teucrium orientale* var. *puberulens*, *Artemisia*, and *Genista tinctoria*. The closed case is set up on benches in a glasshouse.

PROPAGATION AND GROWING MEDIA

Propagation medium consists of approximately one-third fine bark, one-third coir, and one-third perlite. No nutrient is added. The general compost mix for potting and pricking out seedlings consists of loam, coir, and grit (1 : 2.5 : 1, by volume). To this mix is added Osmocote Plus 15N:9P_2O_5:11K_2O + 2 Mg + traces at 1.5 kg m^{-3}.

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RATIONALE FOR PROPAGATION

Propagation is carried out in response to requests for material from the managers of the relevant parts of the Living Collections to propagate from existing plants in the collections or to produce plants from newly obtained propagation material, for example from collections made abroad. In either case, the number of plants requested is generally small.

Propagation from existing plants in the collections is usually by cuttings or grafting. Seed for propagation is rarely collected from the Gardens as so many species of trees and shrubs freely hybridise in the confines of a botanic garden. Every plant batch at Kew has a unique accession number which allows access to the history of every individual plant for curation and scientific and botanical research. It also means the propagator can locate a particular individual for propagation if requested.

About 20% of all propagation carried out in the Arboretum Nursery is in response to requests for material from existing plants in the collection. The remaining 80% is propagation to raise new material for the collection from natural-source, wild-collected seed from hardy temperate zones.

Collaborative seed collections and exchanges with overseas organisations have been increased in recent years. Wide-scale environmental degradation has resulted in greater urgency to collect seed from plants and regions not yet represented within Kew's collections, so that their scientific, economic, and amenity qualities can be evaluated.

The main criteria for seed selection are:

- Is the species required, is it already represented in the collection?
- Is it of natural source known origin?
- Is it likely that it can be collected again in the future?
- Does it have particular conservation, scientific, or economic value?

SEED PROPAGATION

Seed arrives at the nursery from exchanges with other botanic gardens or from expeditions involving Kew staff. Expeditions during the last 5 years have included Sichuan in China, Taiwan, Sakhalin Island off the coast of Russia, north-east Turkey, and Tibet.

Expeditions usually take place in September and October, which is generally the best time to collect ripened seed. Seed arrives on the nursery in November and is priority sorted according to whether it is berried or dry seeded; ripe or unripe; recalcitrant (short-lived seeds that lose their viability quickly) or orthodox (seed which can be stored before germination); sowing time (autumn or late winter, or February).

Seed cleaning is an involved and time-consuming task as many of the seeds may not yet be fully ripe and so time must be given to allow further ripening prior to cleaning. Genera which generally need further ripening are: *Ilex* (which ripen well even when harvested green), *Berberis*, *Rhamnus*, *Actinidia*, *Sorbus*, and *Viburnum*.

PRE-TREATMENTS AND SOWING.

For sowing, seed is divided into:

- Small-seeded species which do not have a dormancy requirement. For example, *Philadelphus, Rhododendron, Spiraea, Hypericum*, and *Deutzia* which are sown mid February to early March;

- Hard-seeded species that require a natural cold period to break dormancy. Hard-seeded species which require dormancy treatment are cleaned, sown, and placed into a cold seed frame outside, where they receive natural cold stratification through the winter. For many genera, including *Fraxinus, Acer, Cupressus, Picea, Betula*, and *Sorbus*, one winter of this treatment is sufficient to break dormancy followed by good germination between March and June. However, there are some species which require up to 3 years to trigger germination, species in genera such as *Tilia, Viburnum, Ilex*, and *Rhamnus* sometimes demonstrate this.

Recalcitrant genera, such as *Quercus*, do not require cold treatment and it is vital that they are sown immediately upon arrival, to prevent drying out or premature germination in transit, which may result in damage to the radicle.

Salix and *Populus* also need particular care. Experience has shown that the British native *Populus nigra* (black poplar) germinated within 12 h of being sown. The seed had been collected the previous day. For similar reasons, *Salix* seed are not usually collected on expeditions, however, a seed collecting trip to north-east Turkey, in September 1993, provided an opportunity to experiment by collecting seed from *Salix triandra* ssp. *triandra*. The seed was collected and kept in a paper envelope without being allowed to become too dry. A plastic seed bag would have caused premature germination. Regular monitoring of the seed for moisture content was essential. Seed was carried around in a rucksack for 3 weeks before arriving at Kew for sowing, and following that germination resulted just 1 week later.

This proved that with regular monitoring and good seed storage, the moisture balance could be more easily maintained. It is vitally important that collected seed is cleaned as required during the expedition to avoid loss of viability through desiccation, fermentation, or weevil damage.

Small-seeded genera, including *Rhododendron*, are cleaned, dried, packed in plastic seed bags, and cold stored at domestic fridge temperature (2 to 5C) until late winter, usually mid-February. They are then sown in 4-in. (10 cm eqv) dwarf pots and put into a glasshouse with a minimum temperature of approximately 10C and covered with a light gauge clear plastic, with bottom heat at approximately 20C. Germination takes place within 2 to 4 weeks for most of these small-seeded species.

Seed compost consists of loam, grit, and coir (1 : 1 : 2.5, by volume). Osmocote is added at 1.5 kg m^{-3} to which one part of fine grit (5-mm grade) is added to make it very free draining.

Post Emergence. When seedlings are big enough to handle they are pricked out into 3-in. (7.5 cm eqv) pots and grown on in a glasshouse with a minimum temperature of about 8C. Some genera which do not suit open-ground production, such as *Ceanothus, Cistus, Caragana, Colutea*, and *Decaisnea*, are potted on into 1-litre pots to be grown on outside or in a polythene tunnel, depending on shade requirement. The remainder are transplanted into an open-ground nursery frame, where they are grown on for 1 year. They are then moved on to the open-ground production area where they are grown for their final year, prior to being selected for planting out into the Arboretum.

To produce 10 plants of each species is the aim, in order to give choice, show natural variation, and as an insurance if any plants failed to establish in the first year of

planting. Surplus plants are gradually sent to other gardens and arboreta. This gives a wider representation of the species and performance can be measured against the specimens planted out at Kew.

PROPAGATION BY CUTTINGS

Propagation by cuttings is carried out between May and August with some hardwood cuttings in October-November or March. The majority of plants requested for propagation are in small numbers, usually about three to five plants of each, with the exception being Mediterranean plants such as *Cistus, Teucrium, Artemisia, Epilobium, Lavandula*, and *Brachyglottis*, which are propagated in batches of about 50 to 100 to give bold drifts in the area surrounding King William's Temple. These plants are stuck in May and June in a closed case within a glasshouse. A second crop is also propagated in July and August and direct stuck into a cuttings frame outside, covered with whitewashed Dutch lights. The cuttings root and are left in situ overwinter before potting in March. The early crop are potted into 3.5-in. (9 cm eqv.) pots in August and then into 1-litre pots in March and grown on for planting out by the end of May or beginning of June.

Rooting Hormone. Synergol liquid hormone (IBA and NAA) is used extensively on the Arboretum Nursery. For easy-to-root subjects a Synergol and water mixture [1 : 9, v/v (1000 ppm a.i.)] is used. For the more difficult-to-root subjects a Synergol and water mixture (1 : 3, v/v; 2500 ppm a.i.) or Synergol and water (1 : 1, v/v; 5000 ppm a.i.) are used, depending on the species in question.

GRAFTING

Grafting is only carried out on a small scale, where possible every effort is made to propagate plants on their own roots.

Hot Pipe Callus. Two years ago hot pipe callus was seen at Hadlow College and was proving to be a good facility for grafting many species of deciduous trees and shrubs. This system has been set up on the nursery at Kew.

Kew's hot pipe callus system consists of a series of lengths of 1.5-in. (4 cm eqv) diameter pipes with perpendicular side slots at set distances and extending for just less than half the diameter of the pipe. The pipe is insulated with thick foam rubber and slit at the points over the slots. A small hot water pipe runs through the larger pipe and is thermostatically controlled to maintain the correct temperature.

It has worked successfully with *Fagus sylvatica, Acer* spp., *Prunus, Crataegus, Betula cylindrostachya*, and *Magnolia*.

For the grafting of evergreens and conifers, a closed tent is used with bottom heat.

The three main types of graft used are side graft, side veneer graft, and splice graft where scion and stock are the same diameter. Elastic strips are used for tying and the union is sealed with horticultural wax which melts at a low temperature. All grafting is carried out in January and February and chipbudding of *Prunus, Pyrus, Sorbus, Crataegus,* and *Malus* is carried out in August and September.

SPECIAL PROJECTS

Collections of some genera of horticultural importance have recently been redeveloped in the light of new taxonomic research and to create displays which show visitors the relationships between the various wild species and the garden cultivars.

This requires the propagation of all the species or cultivars obtainable within a particular genus. Examples of genera that have been propagated in their entirety are *Syringa, Philadelphus*, and *Berberis*.

Syringa. The *Syringa* species are propagated by softwood cuttings, nurse grafting, and chipbudding. Seven years ago it was decided that the old collection of *Syringa* taxa would be taken out and replaced by new plantings of not only the previous species and cultivars, but new and exciting species and cultivars from Canada, U.S.A., Poland, and Russia. As a result, Kew's *Syringa* collection is now one of the best in Britain.

Softwood cuttings were taken from the end of May to about the second week in June. *Syringa* has a narrow window of rootability and so timing is critical and can vary slightly from year to year depending on the season. All of the *Syringa* taxa were rooted under a closed mist facility. *Syringa* taxa from abroad came in as hardwood material.

When stocks were not available for nurse grafting the scionwood was chipbudded onto open-ground plants of *Syringa oblata* var. *alba* with good success. When new shoots had broken in spring, cuttings were removed and propagated.

From stock plants grown under glass, propagation was carried out from about mid April. Nurse grafting was used extensively using *Syringa vulgaris* as the stock. Mother stock plants were kept for as long as required until the cuttings were on their own roots.

Rooted cuttings remained in their pots until the following March when they were potted into 3.5-in. pots. They were potted into 1-litre pots in July and 3-litre pots the following year. Their final year, prior to planting out, was in the open ground. Many of the species and cultivars propagated have been sent to other gardens and arboreta to ensure their continuation in the future.

Philadelphus. *Philadelphus* taxa are another group of plants being propagated in their entirety. The collection has also been relocated within the gardens. This project has been in progress for 3 years and is still underway. Softwood cuttings are taken in July, potted on in March into 3.5-in. pots, and are then potted into 1-litre pots outside in June. The following year they are planted out into the open ground for 1 year prior to planting out into the Arboretum. All *Philadelphus* propagated are verified upon flowering to ensure correct naming.

Berberis. *Berberis* propagation has proved the most challenging project of all. Three years ago all the evergreen berberis were successfully propagated in a closed mist facility in January.

But propagation of some 30 different deciduous species proved much more difficult. After two attempts it was decided that a stock bed might be the answer. The plants in the collection in the Gardens (Berberis Dell) were old, diseased, had suffered from drought, and overcrowding over the years and as a result had been weakened. A bed was developed on the nursery for difficult-to-root plants and, in two stages, the *Berberis* species were dug up from the Dell and brought into the nursery. Cuttings taken in July, after pruning, feeding, and watering, resulted in a 90% take, compared with complete failure 2 years previously.

CONCLUSION

The arboretum nursery is a small but complex unit with many different environments for propagating and cultivating not only plants for the Gardens but also material for scientists in Kew's Jodrell Laboratory. The great challenge is that many of the plants come to Kew at a very vulnerable stage and must be closely monitored through this stage, to growing on into an established plant. It is vitally important that skills and knowledge are passed on to fellow members of staff, to Kew Diploma students, and to international trainees, so that the work within the Arboretum Nursery and within Kew can be carried on through all the horticultural industries from botanic gardens to commercial hardy nursery stock production. The author has experience in both botanic garden and commercial nurseries and although there are many differences the same fundamentals apply—propagators in both kinds of nursery could learn much from each other.

Propagation and Plant Production in Taiwan

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INTRODUCTION

The development of Taiwan in the past 30 years has been remarkable. It has changed from an agrarian to a highly sophisticated industrial society which now has probably the highest foreign reserves of any country in the world. It is slowly adjusting to the new GATT conditions which will mean less protection for agricultural and horticultural producers.

The horticultural industry has been very strongly promoted by the Taiwanese Council of Agriculture. They have sent many people to the U.S.A. and Europe to improve their expertise so that the expansion of horticultural production has been nothing short of phenomenal. This is reflected in the figures given in Table 1.

Year	Fruit	Vegetables	Flowers	Total	% of agr. production	Value (%)
1945	18.221	35.319	-	53.539	6.4	11.5
1961	39.873	90.555	-	130.392	8	9.4
1981	138.846	224.383	1.672	364.901	26.1	57.7
1991	226.381	180.812	9.401	416.593	40.2	55.1

Table 1. Development in Horticultural Crops (increase in hectares) in Taiwan since 1945 (Source: Taiwan Agricultural Yearbook 1995).

The following are the main crops (Sources: Taiwan Agricultural Yearbook (1995), Orchid World (1996), Taiwan Flower Industry (1995), Council of Agriculture in Taiwan): Citrus (40.3 ha), *Mangifera indica* (mango) (21.1 ha), *Litchi chinensis* (litchi) and *Dimocarpus longan* (longan) (24.5 ha), Japanese apricot (10.5 ha), *Musa* (banana) (9.0 ha), *Syzygium samarangense* (wax apple) (8731 ha), plum (*Prunus*) (7.8 ha), and *Ananas* (pineapples) (7.5ha).

The main orchids produced are: *Cattleya* (48 ha), *Phalaenopsis* (37.2 ha), *Cymbidium* (16.6 ha), *Dendrobium* (10.8 ha), and *Oncidium* (7.2 ha).

Important ornamental plants are Palmae, *Pachira aquatica, Ficus, Juniperus, Azalea, Camellia, Dracaena*, *Rosa*, *Hedera, Codiaeum* (croton), *Hibiscus*, etc.

Taiwan lies on the Tropic of Cancer which means the climate is tropical and subtropical. On the higher mountains (above 2000 m) many crops requiring cold conditions at certain times of the year are grown. Many vegetable crops such as cabbages can only be successfully grown on the higher mountains in summer—near the coast it is too warm. The vernalisation of many desirable pear cultivars (Oriental or Asian pear) is not possible on the coastline. However, there is a 600 ha production of such pears which is achieved by grafting about 200 flower buds imported from Japan or from the higher hills, each year, into each individual plant!

Attempting to cultivate sweet cherries (*Prunus avium*), even at 2000 m, has been difficult because cultivars have different cold requirements. Also pollination can be a problem because different cultivars flower at different times. Attempts to grow *Forsythia* have been successful on the higher areas but unfortunately they do not flower.

Up to three crops of grapes can be harvested each year. After harvest the plants are cut back making sure to remove all leaves. They re-grow producing a further crop of grapes.

Because of the high temperature in summer many plants loose their attractive colour. *Acer palmatum* 'Atropurpureum', for example, does not look attractive in autumn and only attains a dull green colour. All the leaves are removed by hand and due to the high temperatures re-grow producing fresh red leaves.

On the other hand many foliage plants can be damaged by low temperatures. Even in the south of Taiwan, the winter temperature can decrease for a short period to as low as 15C which leads to chilling damage in, for example, *Dieffenbachia* and *Philodendron*.

Rainfall is often very heavy and can lead to leaching of nutrients. The high temperatures and humidity also encourage many plant diseases on crops grown in the open or under netting.

The day length can be a problem for propagating and producing some crops. For example, *Fragaria* ×*ananassa* (strawberry) cultivars introduced from northern Europe have not been producing runners because of the short days throughout the year. Chrysanthemums which are cultivated in the field have to be given long day treatment to produce vegetative growth. There are at least 400 ha of chrysanthemum production in Tien-wei. This area is also the main tree and shrub nursery area in Taiwan.

PROPAGATION

The propagation of plants in many horticultural enterprises is very traditional. Because of the climatic conditions mosses and liverworts can be a problem in propagation. The success rate depends entirely on the capabilities of the producer. The pressure to rationalise is very high. Labour costs have increased greatly and many migrant workers are employed. Sometimes, physiological problems, such as topophysis are not recognised. The usual method of propagation of roses involves airlayering — rootstocks are unknown. Other plants normally air-layered are lychees and rhododendron. On the other hand, cutting propagation of numerous plants is no different from standard practice in the western world. However, many growers do not grade the cuttings for evenness of product.

Micropropagation is being used, especially for orchids. Some of the most important orchid exporters in the world (e.g. Taida Nurseries) have being exporting millions of micropropagated orchids for years. In Taiwan the prices paid for orchids with special characteristics, such as stripes of different colours, can be very high—orchids appear to be almost a cult plant. In some companies guard dogs are used to protect the stock plants.

Micropropagation is also being used for papaya plant production because of a virus disease. This is the only way to get successful fruit production in Taiwan. The virus-free plants are cultivated in insect-free houses after propagation, before being put out in the fields. They survive to produce a crop for only about 1 year. Thereafter, they must be replaced.

Bonsai plant production is very important. The more gnarled a plant appears the better. Older plants are often hacked back severely. They re-grow very quickly. Sometimes plants such as *Acer* are pruned hard and using side veneer grafts attractive Bonsai plants are produced. Many such plants are exported to Japan, the U.S.A., and Europe.

Only a few growers speak a foreign language and even fewer seem to know or use botanical names. However, quietly, Taiwan has become an important source of horticultural plants which are being sold in Japan, Europe, and the U.S.A. in large numbers.

Propagation and Culture of Hebes at Lowaters Nursery

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INTRODUCTION

Lowaters Nursery is a wholesale nursery business located near Southampton on the south coast of England. It has approximately 2.3 ha of production space, 80% of this is modern heated glasshouse and nearly all production space has capillary beds.

More than 1 million cuttings are struck each year, of these 800,000 are used after grading. Half of this production is sold in rooted-cutting or 9-cm liner form with the remainder going through various stages to be sold as garden centre quality plants.

Since hebes make up more than 50% of annual sales, Lowaters is one of the largest hebe producers in the U.K. Our position requires us to have production methods designed to overcome the reputation of hebes for being difficult to grow, largely because of the susceptibility of some species and cultivars to downy mildew.

The production methods used by Lowaters Nursery described in this paper are by no means the only way of growing hebes, but they are the ones that work for this particular nursery.

PROPAGATION

Cutting material is best collected from the growing crop to ensure clean and fresh cuttings. The schedule below sets out the main propagation times for a range of popular *Hebe* cultivars.

- April: 'Autumn Glory', 'Blue Clouds', 'Mrs. Winder'
- May: 'Great Orme'
- July: 'Nicola's Blush', 'Amy' (syn. 'Purple Queen')
- September: 'Green Globe', *ochracea* 'James Stirling'
- October: 'Youngii' (syn. 'Carl Teschner'), 'Red Edge', *H. albicans*, *H. pinguifolia* 'Pagei'

Cuttings for all species and cultivars are made in much the same way—about 7 cm long from soft shoots with the lower leaves stripped and tips removed (except for whipcord types such as 'James Stirling'). These are dipped in Seradix No. 1 and inserted in PG104D cell trays. These 6-cm-deep cells produce better root systems than the conventional shallow tray. The compost used is peat and bark (1 : 1, v/v) with 2 kg m^{-3} Osmocote Mini (18N-16P_2O_5-11K_2O) 5 to 6 month formulation.

The nursery has a purpose built 300 m^2 Venlo glasshouse propagation area for hebes, with Duntech wet fog, and fan-assisted air circulation, this operates on humidity sensors control at about 85% RH. The house also has a light-controlled moveable shade-screen and underfloor heating set at 18C, ventilation is set at 28C. Under these conditions, rooting is well developed within 4 weeks, with 85% to 95% success.

WEANING

Cuttings are weaned under slight shade for approximately 4 weeks, during this time they will be pinched or mechanically trimmed at least once to encourage low breaks and improve plant structure.

LINER PRODUCTION

When ready for potting, plugs are graded for good top and root structure so that only the best material goes on to the liner stage. These are hand potted to 9-cm pots in carry trays and stood down on either sand beds (HRI Efford) or flow capillary beds (Dr. Volker Brehrens).

The liner compost mixes used for all hebes except *Hebe pinguifolia* 'Pagei' are are:

- Sphagnum peat (15 mm to 18 mm grade)
- P.G. mix fertiliser 13N-11P_2O_5-23K_2O (0.5 kg m^{-3})
- Osmocote 8 to 9 month (2.0 kg m^{-3})
- FTE 255 (0.3 kg m^{-3})
- Limestone/dolomitic limestone (3.0 kg m^{-3})
- Suscon Green (0.75 kg m^{-3})
- A.F.P. 14% to 18%
- pH 5.2 to 5.7.

For use with *H. pinguifolia* 'Pagei', 10% bark is added to the above.

Plants will spend about 6 months as liners under glass. They are kept frost free but well ventilated to 2C with air circulation fans used to keep a dry atmosphere around the plants. Liners are either hand pinched or mechanically trimmed using a specially designed machine. Trimming varies for different cultivars but the general aim is to promote a strong plant structure.

FINISHED PLANT PRODUCTION

Depending on the cultivar, final pot size and timing required for sale, some types will be put through an intermediate stage to enable plant structure to develop, minimise the time spent in final pot, and to build stocks for sales continuity.

Once ready for final potting, liners or intermediates are graded with only the best going on to the next stage in 1.5-litre, 2-litre, or 3-litre pots, depending on customer requirements. Potting is carried out using a fully mechanised potting and conveyor line with plants stood down under the same conditions described for liners.

Compost mixes used are:

Finished mix for use with all large-leaf hebes

- pH 5.5
- 95% medium sphagnum peat moss and washed grit 3 mm (95 : 5, v/v).
- Magnesian limestone (900 g m^{-3})
- PG mix fertiliser (1 kg m^{-3})
- Osmocote Plus 5 to 6 month (3 kg m^{-3})

Finished mix for use with dwarf hebes:

- pH 5.5
- Medium sphagnum peat moss : bark (9 : 1, v/v)
- Magnesian limestone (1.25 kg m^{-3})
- PG mix fertiliser (500 g m^{-3})
- Osmocote Plus 8 to 9 month (3 kg m^{-3})

PEST AND DISEASE CONTROL

Hebes present no particular problems other than downy mildew, which can wipe out entire crops if allowed to develop and in any case makes plants unsalable. The nursery routine for prevention has taken many years to achieve and involved

destroying batches of plants with the disease if it presented a danger and selecting for production only those varieties that would grow cleanly under the nursery's system. In this way clean material is ensured throughout the production cycle. One member of staff is responsible for pest and disease checking.

A minimal preventative spray regime is maintained, as too much spraying was found to aggravate the problem not cure it. The overall objective is to create growing conditions in which the disease will not develop, rather than work hard to cure a problem already developing.

SUMMARY AND CONCLUSIONS

The following key points have enabled Lowaters Nursery to produce good quality clean hebes to garden centre quality.

- Clean cutting material
- Specialised propagation facility
- Capillary sand beds or flow capillary beds
- Air circulation fans
- Glasshouse protection
- Frequent hand pinching or mechanical trimming
- Grading at every stage
- Cropping cycles adjusted for each variety
- Constant pest and disease checking
- Preventative spraying
- Destruction of problem batches
- Selection of varieties best suited to our growing conditions

All of these key points lead back to the first and most important point which is to start with clean propagation material. The rest is good nursery practice, investment in the right facilities, and attention to detail.

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Extending the Range of Plants for the Nursery Stock Industry

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The main objective of this project is to ensure that rare plants, or those of outstanding garden worthiness, are not lost. These plants will eventually be introduced into the trade thus expanding the nursery plant range.

Since it started in 1995 the project has successfully collected and propagated many woody, herbaceous, and alpine cultivars. The majority of these plants are very scarce and several have arisen as sports or by selections from existing plants. Several good garden plants are still scarce because of problems in propagation.

The first stage is location of the plants and, to this end, the project has targeted the most important gardens in Ireland. Assessment and selection of the plants then begins. Special attention is paid to disease resistance as well as any particular characteristics for which the plant is selected. Samples are then collected for propagation. Cuttings under mist is the main propagation method but grafting and micropropagation is also carried out with several woody or difficult cultivars which do not readily root under mist, e.g. *Eucalyptus* and *Daphne*. After propagation, plants are potted up and gradually hardened off. Some of the successfully propagated plants are then returned to their owners for replanting. A foundation stock is planted out at Kinsealy Research Station in several nursery beds for further evaluation, for a range of different uses and functions and as a further safeguard for preservation. Foliage plants with export potential are being evaluated in a number of foliage production areas in the south west. It is hoped that most or all of these plants can be released (with the owners permission) to the trade.

So far more than 100 scarce cultivars have been successfully collected and propagated, of which approximately 30% are woody and 70% herbaceous. In the case of woody plants several have been rescued and rejuvenated from sole existing trees which have since perished.

Because several of the most important Irish gardens, with their plant collections, have recently been sold, the priority has been to concentrate on these, as rare plants are generally more vulnerable under these circumstances, or in danger of being lost through neglect or ignorance. In some cases plant identification is incomplete.

TO DATE THE COLLECTION INCLUDES

Woody plants	Several *Crataegus, Malus* and *Pyrus* cultivars, *Philadelphus, Syringa, Betula, Quercus coccinea* 'Splendens', *Tilia, Chamaecyparis.*
Foliage plants	*Elaeagnus angustifolia,* several *Pittosporum, Leptospermum, Fuchsia, Genista, Cytisus, Eucalyptus.*
Herbaceous	Several cultivars of *Geranium, Dianthus, Erysimum, Campanula,* and a large range of alpines.

Old Roses	Climbing and shrub roses of superior constitution and resistance to black spot.
Rare Plants	Mostly of botanical interest.

PLANT CHARACTERISTICS

Trees

Acer pseudoplatanus 'Brilliantissimum'	Brilliant foliage colour, slow growing
Betula ermanii	Vigorous tree, cream-coloured bark
Chamaecyparis cultivar	Narrow tall golden conifer of exceptional beauty, not subject to sun scorch
Crataegus laevigata cultivar	Flowers, pink with white eye
Crataegus laciniata cultivar	Deeply cut grey foliage and berries
Crataegus laciniata cultivar	As above but more vigorous tree
Crataegus cultivar	Dwarf compact habit, very profuse berrying
Crataegus cultivar	Elegant shape
Malus species	Large tree 15 m to 16 m high, outstanding habit, and fruit bearing
Prunus 'Ukon'	Creamy/yellowish flowers, good habit
Pyrus species	Elegant tree 10 m high
Quercus coccinea	Brilliant autumn colour
Tilia 'Petiolaris'	Graceful large weeping tree, white-felted beneath

Foliage

Eucalyptus	Selection from *E.glaucescens* with juvenile foliage
Leptospermum cultivar	Grey foliage
Elaeagnus 'Quicksilver'	Striking silver foliage, small tree
Hedera helix 'Arborescens Variegata'	Larger-leafed variegated foliage
Pittosporum eugenioides	Foliage
Pittosporum eugenioides 'Variegatum'	Foliage
Pittosporum tobira	Variegated foliage, drought resistance

Shrubs

Fuchsia 'Corallina'	Long flowering season and dwarf habit
Genista / Cytisus	Scented flowers
Hydrangea quercifolia	Flower size and autumn colour
Hydrangea aspera Villosa Group	Lilac blue flowers
Rosa	Several cultivars of climbing and shrub
Rubus 'Benenden'	Superb hybrid for roadside or garden planting

Herbaceous and Alpine

Aethionema grandiflorum	Dark pink-flowered form
Anthyllis montana	---
Campanula	Several cultivars of lactiflora group

Dianthus	Several cultivars with long flowering season
Erysimum	Relatively long lived, long flowering season
Geranium ×riversleaianum 'Mavis Simpson'	Long flowering season, low growing
Geranium ×oxonianum	Dwarf selection from G. *endresssi* 'Wargrave Pink'
Geranium traversii	Grey foliage, long flowering
Hypericum aegypticum	Neat habit, pale lemon-coloured flowers, long flowering season
Moltkia ×intermedia	Blue flowers, long lived
Teucrium subspinosum	Round neat shape, grey leafed
Trochocarpa thymifolia	Compact form

New Methods For Germinating Orchid Seeds

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BIOLOGY OF THE ORCHID SEEDLING

Plant seedlings in their first stages are heterotrophic and depend entirely on nutrient reserves deposited during the maturation of the seed. The mother plant thus provides support until the seedling has developed a photosynthetic apparatus.

Orchid seeds are very small ("dust seeds"), being less than 1 mm long including the testa. A concentrated reserve of protein and lipids is stored in the embryo but is necessarily small. The embryo is a poorly differentiated body of at most 200 or 300 cells. During germination the reserves are mobilized but because the heterotrophic phase is extremely long and the seed reserves so limited, no orchid seedling develops far without external nutrient supplies. The seedling relies on an alternative source of nutrition, i.e. the breakdown of fungal hyphae on which the plant parasitizes. The radicle is completely specialized into a mycotrophic organ; until the seedling produces adventitious roots and leaves it cannot emerge above the substrate and begin photosynthesis. Terrestrial orchid seedlings usually live underground as heterotrophic organisms for several months after germination.

GERMINATION

Symbiosis with fungi is a necessity when orchid seeds germinate in nature. In culture the special requirements of the seedlings can be met by two means. Either they are grown asymbiotically on a nutrient substrate from which they can take up macro- and microelements, soluble carbohydrates, amino acids, vitamins, and hormones, or symbiotically in co-culture with a compatible fungus on a substrate that sustains the fungus, often based on starch or cellulose. Both methods require that germination takes place in vitro, although a procedure for symbiotic culture under nonsterile conditions could be developed.

Since the beginning of this century propagation in vitro has become a standard procedure in many genera of orchids but some groups still present considerable problems. Much emphasis has been placed on the heterotrophy of the seedlings. When symbiotic culture has been unsuccessful, lack of compatibility with the fungus in question has always been an available explanation. When on the other hand an asymbiotic culture has failed, whether sporadically germinating seeds or poorly growing seedlings, it has usually been ascribed to a lack of a crucial ingredient in the substrate. The efforts to provide an adequate substitute for the symbiosis have resulted in a multitude of complicated substrate recipes, often with undefined ingredients such as yeast extract or coconut milk.

NEW INFORMATION ON ORCHID SEED DORMANCY PATTERNS

During the last years, and partly through my work and that of my co-workers, the importance of non-nutritional factors in the germination of orchids has received more attention. Several dormancy mechanisms which resemble those of other plant

seeds have been found (Rasmussen, 1995). It is essential to distinguish between factors that influence seeds during germination and those pertaining to the subsistence of the seedlings. Components of the substrate (and properties of a co-cultured symbiont) may be irrelevant factors for the seeds if they are dormant.

Surface sterilization of seeds, usually with either sodium or calcium hypochlorite, is necessary before they are sown in vitro. Not only does that prevent contamination with microorganisms but long treatments in hypochlorite also raise germination percentages, presumably because of dissolution of lipids in the testa, thus facilitating water uptake and leaching of inhibiting substances, such as abscisic acid, from seed. In nature seeds can remain 6 to 7 months in the ground before they germinate (Rasmussen and Whigham, 1993). Other strongly alkaline solutions may have effects similar to hypochlorite. Optimum treatment varies strongly with the species (Fig. 1; Van Waes, 1984) and can be as long as 4 h in 5% NaOCl. Calcium hypochlorite is usually somewhat better than sodium hypochlorite.

In spite of the minute seed size there are no indications that orchid seed germination is stimulated by light. Many species tolerate light but some are negatively photoblastic. In *Dactylorhiza majalis* the seeds needed at least 14 days of darkness in the beginning of a 6-week incubation period, otherwise germination percentage was significantly reduced (Rasmussen et al., 1990). The reaction prevents seeds from germinating on the soil surface and is an adaptive reaction in seeds whose seedlings are mycotrophic and rootless. These seedlings depend on a stable moisture regime whereas light is an irrelevant growth factor.

The reaction of the seeds to ethylene could be another adaptation to prevent superficial germination and increase chances of a successful establishment of symbiosis. This gaseous plant hormone is developed from a host of microorganisms, amongst these the kind of fungi which are orchid symbionts. Soil ethylene concentrations can reach 10 ppm, rising with depth (Smith and Dowdell, 1974; Hanke and

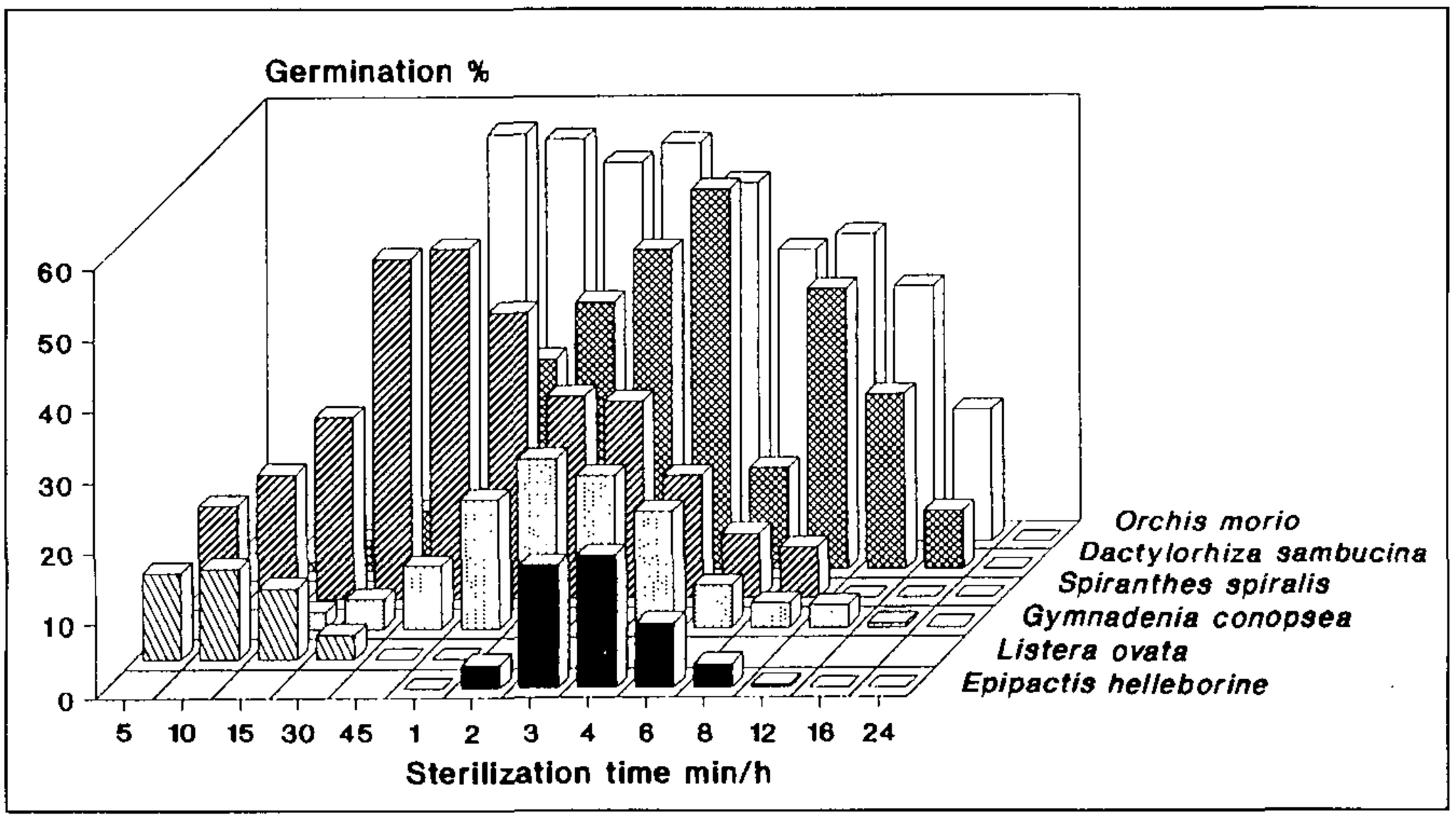

Figure 1. Optimum treatment time (scarification) for germination in a range of orchid species. The seeds were treated in 5% NaOCl with Tween 80 (1%), rinsed in sterile water, and sown on asymbiotic substrate. Data from Van Waes (1984). Figure from Rasmussen, 1995.

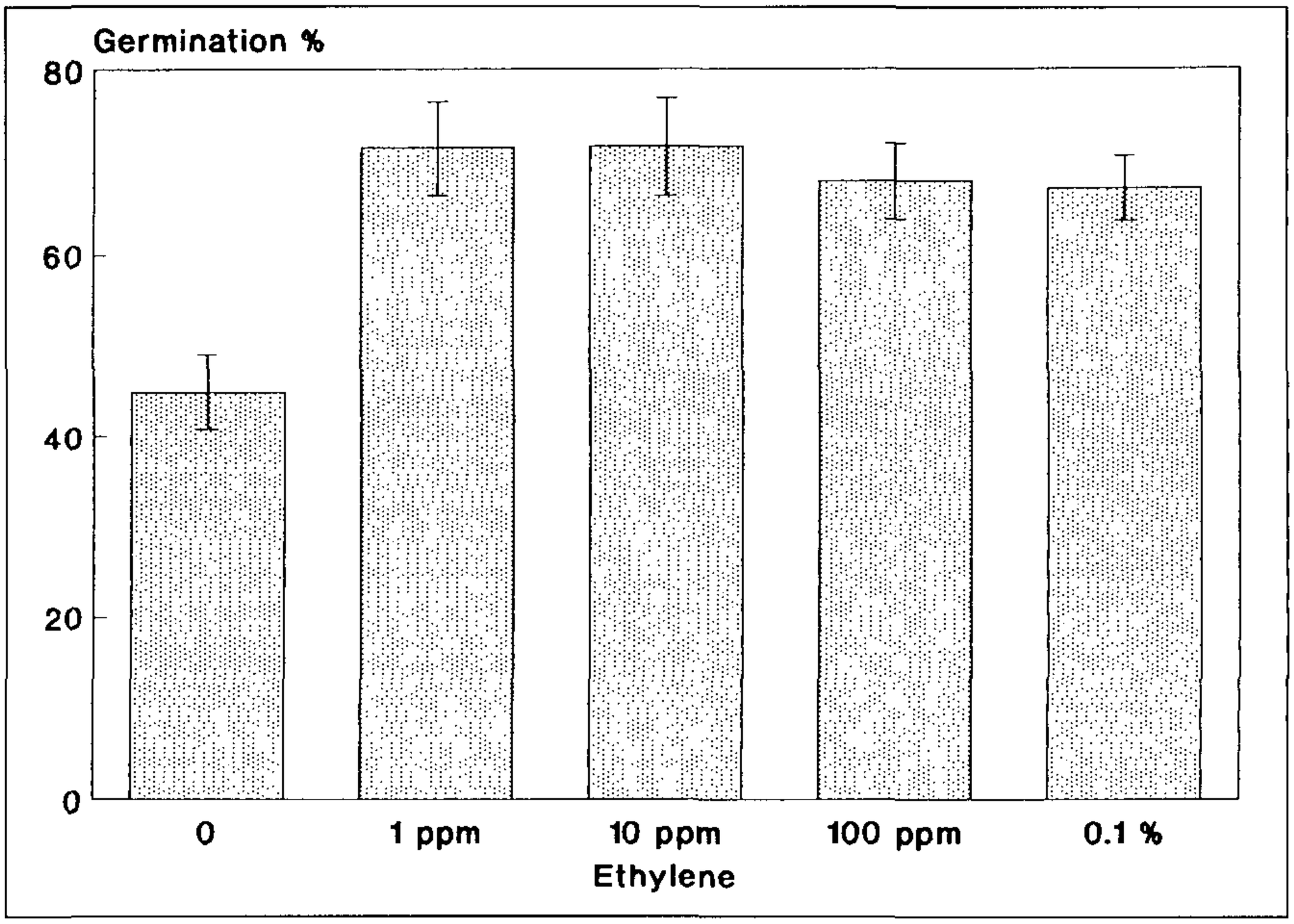

Figure 2. Effects of ethylene added to the atmosphere above ventilated Petri dishes with incubated seeds. *Dactylorhiza majalis* was sown on oat medium and inoculated with a fungal strain identified as *Tulasnella deliquescens* and incubated in darkness at 20C. Treatment began immediately after sowing and was interrupted after 21 days by ventilation with sterile ambient air. Germination was recorded after 42 days. Means of 16 to 18 samples with 95% confidence intervals. All treatments are higher than the control ($P<0.01$, arcsin transformation). Figure from Rasmussen, 1995.

Dollwet, 1976). In *D. majalis* germination percentage increased significantly in response to the addition of 1 ppm ethylene and there was a great tolerance towards high ethylene concentrations (Fig. 2).

Species differ greatly with respect to seed dormancy patterns. Cold stratification is required by some. Seeds of *Epipactis palustris* (marsh helleborine) reached the highest germination percentage when treated for 12 weeks at 6 to 8C after a warm incubation for about 6 weeks at 20C. There was an additional strong increase in the temperature reactions when the seeds were co-cultured with a compatible fungus (Rasmussen, 1992). Most likely other species, amongst these the horticulturally most interesting species of *Cypripedium* (lady's slipper orchids), need cold stratification. Although these species have been subjected to many germination trials the temperature reactions have been little studied. Such reactions may furthermore be difficult to detect since the seeds germinate sparsely without inoculation and the compatible fungi are still unknown.

Besides traditional dormancy mechanisms the seed also reacts to inoculation. A 20% germination in seeds of *Platanthera chlorantha* (greater butterfly orchid) could be increased by inoculation with a range of symbionts to levels between 20% and 80% (Fig. 3). Those fungal strains that stimulated germination most were not always those that would establish the best symbiosis with the seedlings (Rasmussen, 1995). The kind of signalling that takes place between the fungi and the seeds is still

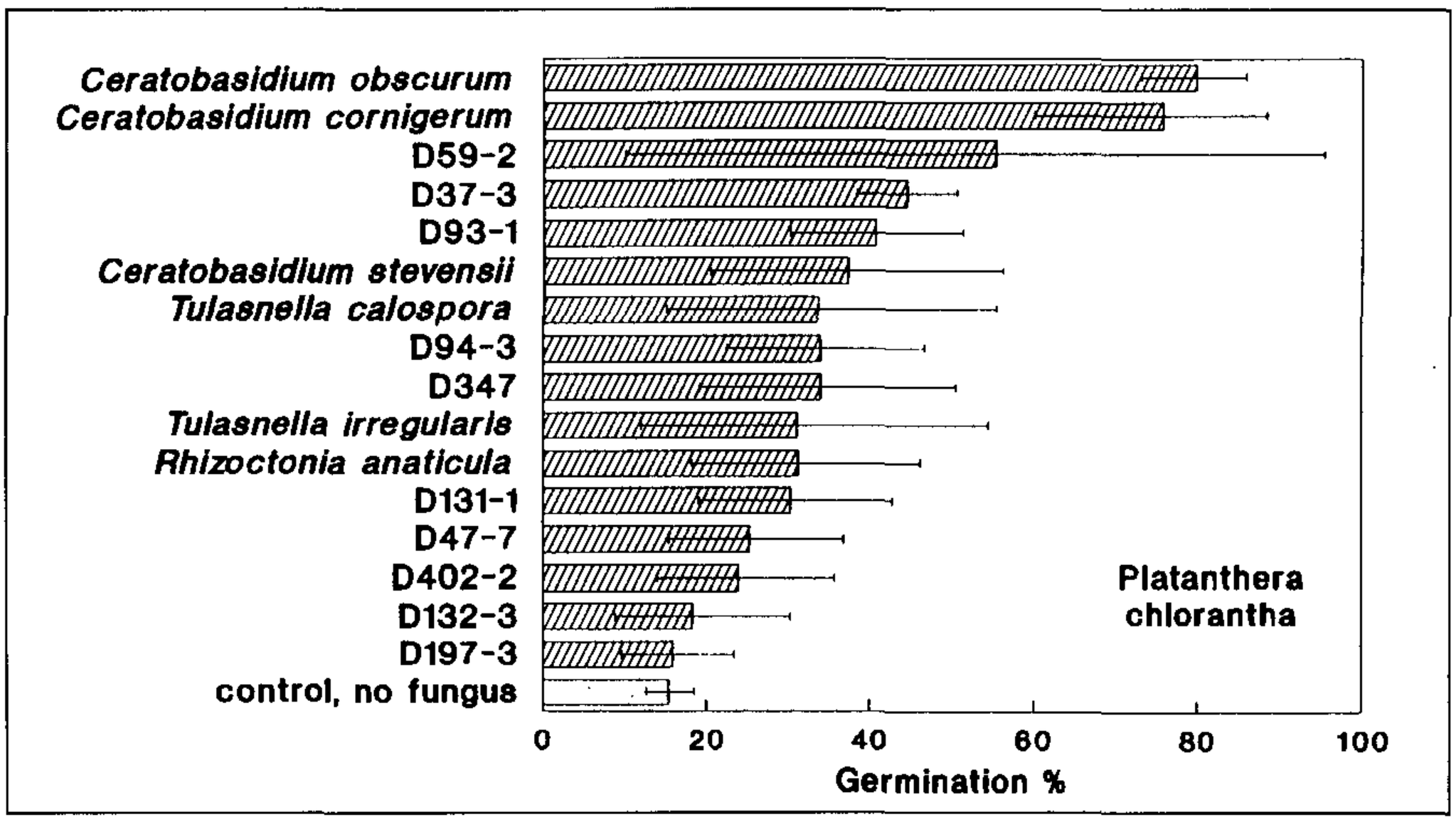

Figure 3. Germination in *Platanthera chlorantha* with a range of isolates and reference cultures of orchid symbionts. Germination percentage after 42 days in darkness at 20C on oat medium. Mean of five samples with 95% confidence intervals, arcsin transformed data. Figure from Rasmussen, 1995.

unknown; the detection of an effective stimulator of seed germination could potentially be of great practical importance.

CONCLUSION

Production of symbiotic plants presents a number of advantages. Not only germination percentage and rate but also development of the seedlings are usually improved, and a better rate of success on transfer to nonsterile conditions is achieved. Conservation of species and biological diversity are often an important consideration when orchids are concerned. Obviously, the fungal symbiont that controls the establishment of new seedlings is required if the plant species is to be preserved in natural populations. Symbiotic propagation has thus gained increasing application in the last decades.

Asymbiotic orchid culture will remain of major commercial importance for propagation of those species that respond well to this method, mainly tropical taxa. The symbiotic technique is a supplement for those species that previously have been very difficult to propagate. This technique has made it possible to reveal a number of seed dormancy mechanisms that are unrelated to the special nutritional system of the seedlings. Such mechanisms must be dealt with to obtain a rational propagation procedure. An extension of the assortment of species offered on a commercial scale is thus within reach.

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Application of Antagonistic Microorganisms to Seeds to Control Fungal Plant Pathogens

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INTRODUCTION

During the next decade biological control may become an important component of plant disease management practices. The demand for alternatives to chemical control of plant pathogens has become stronger owing to concerns about the safety and environmental impacts of chemicals. Development of fungicide resistance, lack of effective chemical solutions for specific pathogens, and the fact that pesticides are not allowed in organic farming systems has increased the need for development of biological control agents (BCAs). Biological control can be practiced in three ways:

1) By deliberate application of beneficial microorganisms which suppress plant pathogens;

2) By deliberate application of organisms which induce resistance in the host plant;

3) By cultivation practices which enhance natural disease suppression (suppressive soils).

This paper deals with the first category and focuses primarily on biocontrol obtained by application of fungal antagonists to seeds.

CRITERIA FOR COMMERCIAL BIOLOGICAL SEED TREATMENT

The first requirement for successful biological control is the selection of a superior strain of an antagonistic microorganism. This is often done by screening for antagonism using either in vitro or in vivo systems or by genetic manipulation through mutation or protoplast fusion (Ahmad and Baker, 1987; Merriman and Russel, 1990; Harman 1991). However, there are numerous examples of potentially useful biocontrol agents which have been unable to secure stable and effective biological control under natural conditions (Renwick et al., 1991; Duczek, 1994). This has been attributed to a number of soil abiotic factors, including aeration, moisture, pH, temperature, and texture as well as biotic factors such as competition from, and predation by, the indigenous soil microbiota (Shah-Smith and Burns, 1996). However, difficulties related to the production, shelf-life and formulation of the antagonist are also important factors which strongly complicate the commercialization of products based upon living organisms. Therefore, in order to develop a biological product for seed treatment, the formulated antagonistic strain must fulfil a number of requirements: (1) Appropriate fungal structures must be produced rapidly at high and reproducible levels, (2) these structures must be able to withstand drying and storage, (3) they should be activated at sowing and be able to colonize the plant roots to suppress pathogens, (4) control efficiency should be high and stable under varying environmental conditions, and (5) the antagonist should be harmless to the germinating seed and the emerging roots (Baker, 1991; Harman

et al., 1991). Finally it is important to remember that registration of the BCA is a necessity for commercialization.

SHELF-LIFE

Survival and Shelf-life of the BCA . If BCAs are to become marketable products it is essential to ensure a good yield of efficient and viable propagules which also have a long and stable shelf-life. According to Powell (1993) the ideal objective is survival of the BCA at a temperature range from -5C to 30C for 2 years. Since any decrease in viability will increase production costs, one of the main problems in the production phase of a BCA is to hold viability of propagules as close as possible to 100% of the original production. Production of *Trichoderma harzianum* in liquid fermentation resulted in conidia of which only approximately 10% germinated after drying. However, desiccation tolerance could be enhanced to 50% to 70% germination by modifying the osmotic potential in the growth media (Harman et al.,1991; Jin et al., 1991). Production of conidia of *Gliocladium roseum* (IK726) on a solid substrate gave 50% survival after drying. A comparison of freshly harvested and dried conidia showed that germination began 2 to 4 h after inoculation and that all conidia capable of germinating had germinated 24 h after inoculation on water agar. However, the speed of germination was significantly affected by the drying process since freshly harvested conidia germinated faster than the dried conidia (Jensen et al., 1996). Rapid germination may be an important factor for control efficiency of pathogens like *Pythium ultimum* which germinate rapidly and begin to infect seeds within 4 to 6 h after planting (Stasz et al., 1980). Different techniques have been used to give the antagonist a competitive advantage over the indigenous microflora by ensuring favorable conditions around the seed at the time of planting. This will be discussed below. Once a high percentage of potentially germinable propagules has been ensured, the preparation should have a long shelf-life. Most fungal preparations can be stored at 4C for 6 to 12 months without significant loss of viability, while survival has generally proved to be poor at temperatures from 20 to 25C (Papavizas et al., 1984; Lewis and Papavizas, 1985; Dandurand and Knudsen, 1993; Jensen et al., 1996; Jensen, unpublished). However, Sivan et al. (1984) found a 91% decrease in viability of *T. harzianum* conidia after 1 year at 25C and recently we have shown that conidia of *G. roseum* can survive for 1 year at 20C with less than 70% decrease in viability. Finally, it must be stressed, that high viability and good shelf-life of a preparation do not necessarily mean that the antagonist has retained its activity and ability to control the pathogen effectively and consistently under a variety of environmental conditions, this has to be tested thoroughly.

Shelf-Life on Seeds. Commercialization of a biological seed treatment product will be a more attractive alternative to chemicals if seeds coated with antagonists can be stored for several months. Survival of conidia following their application to seeds is not well documented. Cliquet and Scheffer (1996) showed that survival of conidia applied onto radish seeds through an industrial film-coating process varied according to the strain of *T. harzianum*. For two strains, a better conidial viability was observed, with a decrease of one order of magnitude after storage for 3 months at 15C and 5 months at 4C. Another strain, which had also controlled damping off (caused by *P. ultimum)* in growth chamber assays, failed to survive at both temperatures (Cliquet and Scheffer, 1996). The viability of conidia of an isolate of *G. roseum*

(IK726) applied to barley seeds and stored for more than 6 month at 4C was stable (Jensen, unpublished). The activity of germinable conidia also seemed to be intact, because sowing of kernels infected with *Bipolaris sorokiniana* and coated with conidia of the antagonist gave more than 90% control after 8 months of storage at low temperature. Conidial viability on seeds at 20C declined after 1 to 3 months depending on specific storage conditions (Jensen, unpublished). These results show the feasibility of biocontrol of seed-borne and seedling diseases by application of specific strains of antagonists to seeds. However, care should be taken since strains which have proven to be superior in disease control tests are not necessarily those with the best capacity for survival on seeds stored under commercially acceptable conditions.

SEED TREATMENT

Various strategies have been used for applying BCAs. Seed application has several advantages compared to spraying or incorporation of the BCA into soil or soilless growing mixture. Only a small amount of active ingredient (antagonist) is used especially compared to soil application and, besides this, the antagonist is placed close to the pathogen, both in time and space. In addition to protecting the plant from seed-borne infections, biological seed treatment also has the potential of protecting against attack from soil-borne pathogens as well.

Seed-borne Pathogens. In many countries seed lots of cereals are routinely treated with chemicals (Rennie and Cockerell, 1994). A Nordic project was initiated in order to screen for microorganisms antagonistic to a variety of important seed-borne diseases on cereals and adapted to the North European soil habitats and microenvironments. In Denmark, an antagonistic isolate of *G. roseum* (IK726) was isolated from the field and tested in field trails. Results showed that seed treatment with freshly harvested conidia of *G. roseum* controlled *Fusarium culmorum* as effectively as seed treatment with the fungicide Sibutol LS 280 (Knudsen et al., 1995). In another field experiment, with barley naturally infected with *Bipolaris sorokiniana,* it was demonstrated that *G. roseum* also was effective against this disease as both plant dry weight 1 month after sowing, and the thousand-grain weight at harvest, were significantly increased. In addition, control was as good as that of the fungicide Fungazil TBZ (Knudsen et al., 1995). Also a mixed natural infection of *Fusarium* spp. (including *Gerlachia nivale*) was controlled by *G. roseum* in a sand test, and a 70% reduction in the disease index was obtained (Knudsen, unpublished). In field trials, seed treatment with a dried and stored formulation of *G. roseum* conidia gave good protection against the seedborne pathogen, *Fusarium culmorum,* on winter wheat. At harvest the grain yield was as high as the yield harvested in plots which had received a chemical seed treatment with Sibutol (Jensen, unpublished). These promising results show that seed treatment with suitable formulated antagonistic preparations can become a realistic alternative to chemical seed treatment.

Soil-borne Pathogens. Most of the work on biological seed treatment has been directed towards protecting seeds and seedlings against soil-borne diseases. However, in many cases highly effective strains selected in preliminary experiments have been unable to ensure effective biological control under natural conditions. It is not sufficient to have viable propagules, the propagules also have to be properly

formulated to give effective and consistent results. In this connection the composition of coating material (binder, solid carrier) plays an important role. Harman and Taylor (1988) showed that using a carrier with pH 4.1, seed treatment with *T. harzianum* gave better protection against soil-borne pathogens than a formulation with a more alkaline carrier. This was mainly because the acidic environment favored growth of *Trichodema* compared to most other microorganisms (Harman and Taylor, 1988). A conducive environment for the bioprotectant can also be created through a physical barrier. Taylor et al. (1991) used a liquid-coating system consisting of *T. harzianum*, a solid carrier, and a binder. The application technique resulted in the formation of a continuous, uninterrupted, <0.1-mm-thick coating around the seed, which was sufficient to slow down the infection of the seed by *P.ultimum* by 5 to 6 h (Harman, 1991). The creation of such a physical barrier between the antagonist and pathogen also favored the utilisation of exudates from the seed by the antagonist rather than the pathogen during initial seed germination. McQuilken et al. (1990), showed that modern seed technologies like pelleting and film-coating are compatible with the use of BCAs. Cliquet and Scheffer (1996) have demonstrated the same with film-coating.

Combining Seed Priming and Biological Control. Various physiological seed conditioning treatments have been reported to enhance and stabilize the efficacy of biological control agents. One of the most promising is seed priming, in which controlled hydration initiates the physiological processes of germination, without radicle emergence. Treatment of cucumber seeds with *T. harzianum* was not sufficient to control *P. ultimum*. When seeds were coated and primed, however, control efficacy was strongly increased (Taylor et al., 1991). Priming favored the antagonist as it could colonize and take possession of substrates including exudates from the germinating seed before either the competing microflora or plant-pathogenic fungi (Taylor et al., 1991).Treating seeds of sweet corn with an antagonistic isolate of *Pseudomonas aureofaciens* effectively controlled seed decay induced by *P. ultimum* in soils with low to medium water content. However, when the water content of the soils was high coating was unable to control the disease but if seed coating was combined with priming, control was obtained (Mathre et al., 1994). They concluded that a combination of preplant seed hydration and the use of a BCA provided the most consistent protection against seed decay. Although priming is a promising technology for enhancement of biological control, technical problems concerning storage of primed seeds without loss of seed germinability and variability of the antagonist have to be solved.

RHIZOSPHERE COMPETENCE

Rhizosphere competence of antagonistic strains is a very important trait since not only the seed but also the root need to be protected from attack by soil-borne plant pathogens. Rhizosphere competence may be defined as the ability of a microorganism, applied by seed treatment, to colonize the rhizosphere of developing roots (Baker, 1991). In general, bacteria apparently have greater root colonization capabilities than fungal antagonists (Rovira and Campbell, 1974). One of the fungal genera — *Trichoderma* — which has been extensively used for biocontrol of soil-borne diseases has seldom been reported to be rhizosphere competent (Ahmed and Baker, 1987). However, Sivan and Chet (1989) did demonstrate rhizosphere competence in a wild strain of *T. harzianum*. An antagonistic isolate of *G. roseum*

(IK726) was able to colonize young barley roots in sand (Knudsen et al., 1996) and in field soil *G. roseum* was reisolated 4 months after sowing in a significantly higher number from roots of plants derived from seeds coated with the antagonist than from roots derived from noncoated seeds (Knudsen et al., 1996). In preliminary greenhouse tests, seed treatment with this isolate has shown good ability to control *P. ultimum* on sugar beet (Jensen, unpublished). Rhizosphere competence has been demonstrated in *T. harzianum* following protoplast fusion (Sivan and Harman, 1991) and by mutation (Ahmed and Baker, 1987) and these strains were shown to exhibit a significant improvement in the control of *P. ultimum* compared to the original strains (Harman et al., 1989; Baker, 1991). The trait of rhizosphere competence cannot be generalized from one plant-antagonist combination to another. Sivan and Harman (1991) showed that the rhizosphere competent isolate of *T. harzianum* colonized roots of maize and roots of cotton differently. The responses of two plant species to root colonization by *Streptomyces griseoviridis* were also different (Kortemaa et al., 1994). Therefore, rhizosphere competence has to be investigated for each combination of host plant and antagonist.

CONCLUDING REMARKS

The prospects for successful biological seed treatments to control seed-borne diseases are very promising. A storable formulation of *G. roseum* has proven highly efficient under field conditions when applied as a seed treatment. Furthermore, seeds coated with this antagonistic isolate can be stored for several months. Biocontrol of soil-borne diseases have also been achieved by coating seeds with antagonistic fungi. In this context rhizosphere competence of the BCA seems to be a very important trait in order to obtain or improve control efficacy. On the basis of the good results achieved with biological seed treatment in small-scale experiments the commercialization of biological control agents for seed treatment is now becoming a realistic possibility. However, the resources of commercial companies and foundations are required for large-scale production, wide-scale field testing, and registration including risk assessment and marketing.

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Production and Storage of Perennial Seed

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The great majority of perennial seed are specially raised for our company in regions that are particularly well suited for that particular species. Thus, we control and inspect a cultivation network that stretches from north of the arctic circle through the whole of Europe to northern Italy and the northern part of the U.S.A. as well as Chile. Altogether, we have people producing seed for us in 23 different countries. We have no production in tropical or subtropical regions, since we specialize in hardy perennials. With these plants the source (origin) of the seed plays a major role in determining the "hardiness" of the plants.

Sometimes, however, we really do have to seek and find particular seeds. This can be very difficult and may take years — particularly when we need original material from the natural location. Just one example: For many years there was a certain *Campanula raineri* on the market, which actually was not *C. raineri*, but *C. carpatica* var. *turbinata*. A botanist friend of mine from Switzerland searched for the real *C. raineri* in the Dolomites of northeastern Italy and finally found it above 6500 ft on Monte Baldo near Lake Garda. He propagated this species for us in his acclimatization garden at an altitude of some 3000 ft. Thus we've been able to offer seeds of the true *C. raineri* now for the past 14 years. An acclimatization garden is an intermediate station where high alpine plants (that is — those occurring at 6500 ft or higher) can become adjusted to lower altitudes gradually to prepare them for life in the lowlands.

The seed cultivation network that I operate is in the hands of specialists and plant experts — some of them are internationally known. Some parts of the seed harvest arrive to us already well cleaned by the growers. But the main parts of the harvest are still in the seed capsule, and often still with the stems attached. Two and often three of our employees do nothing but clean seeds year round. The dry seed is stored in large bags made of absorbent paper or in paper sacks. These bags are very practical and they are also used to transport the seed during harvesting.

Until the seeds are cleaned, they are kept in these paper bags and stored in a special wooden structure with temperature-controlled air circulation. This system is very efficient and keeps the seeds dry. The seeds are cleaned by specially made machines as well as by hand.

We are often working with small volumes of small seeds such as *Cypripedium reginae, Eritichium nanum, C. portenschlagiana, Haberlea, Ramonda, Primula juliae* (true), and others. With such seeds one can't use big machines. After the final cleaning the seed batches are weighed and registered. At this stage, samples are taken for analysis — one for the germination laboratory and one for determining the water content of the seed. These control samples are very important for determining the storage life of the seed as well as determining other necessary treatments that may be needed in the processing of the seed. If the water content is too high we have a simple but effective way for reducing it quickly. A very low water content is essential if the seed is destined for freeze storage. This is a very dependable method for long-term storage, when the seed has been properly treated. One could say that

this is our own "gene bank". For this type of storage the seeds are vacuum-packed and then frozen at -10 to -20C. This is a shock-freezing that takes place within seconds; something that never occurs in nature. Since water expands when it freezes, this would burst the cell walls and kill the seed. In nature, the freezing procedure takes place much more slowly, so that the expanding water has time to diffuse through the porous cell walls, thereby establishing a pressure equilibrium. Due to this osmotic pressure within the seed cells, the seed doesn't freeze until the outside temperature is down to about -5C. Chemical processes in the seed continue until they reach the critical freezing point. Thus, the temperature for germinators can be reduced to -4C. The Ranunculaceae typically have a higher osmotic pressure in the seed, and therefore, need a somewhat lower temperature during the cold period. But if the seed is frozen at -8C, then it is in a preserved state that no longer has any effect on the germination of the cold germinator! We store the seeds of certain species in a refrigerator at 3C. These are mostly seeds that have a naturally high water content that cannot be reduced without damaging the seed. Yet other seeds are stored in water in a refrigerator and are delivered moist (or wet) to our customers. These are mostly the seeds of water plants. All seed not stored in the freezing-storage or refrigerator are stored in a special climatically controlled chamber with constant humidity and temperature. After the cleaned batches have been checked for germination ability and water content, they are stored.

From the storage room we have a continual supply of seed for the weighing room. In the weighing room some species are kept in special jars. These jars guarantee that the seeds remain dry, despite repeated opening of the jars. There is a compartment built into the stopper, which contains silica gel — sometimes called "blue gel". The compartment has a porous bottom that allows the silica gel to immediately absorb moisture that enters when the jar is opened. When the silica gel has become saturated with moisture, it loses its blue color, and it is then replaced.

Keeping the seeds uniformly dry is very important for their viability and later germination energy. When the humidity is continually changing, the seed must repeatedly absorb water and then evaporate it again through its membranes when the air becomes drier again. This causes "stress" for the seed. Stress affects the seed just like it affects us — it weakens the constitution and shortens life expectancy.

Seed Production in Horticulture

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THE DEVELOPMENT OF DANISH HORTICULTURAL SEED PRODUCTION

Danish seed production has existed for several hundred years. At first all growers supplied their own or were at least partly self-sufficient, then in the later part of the last century it changed. Commercial production started.

Market gardeners were the first to turn to commercial seed production, but production moved to agriculture at the start of this century. This occurred mainly because of growing competition.

Around Wold War I cabbage seed production was substantial. In 1919 the total seed production area was 2873 ha of this 1738 ha was used for cabbage seed. Most seed was exported to the U.S.A. and Germany. This seed production continued until the 1960s with shifts in the species produced. Some species were grown because they were traditionally grown rather than because of the favourable growing conditions. As vegetable production became more specialized the demand rose for more efficient seed production in the developed countries of the world. There was a demand for seeds with better physical and genetic properties. Machines for precision sowing and the establishment of special nursery units enhanced this development.

Carrot seed, for example, used to be produced in this country. Production has ceased, not because of low yields or production costs but because seed quality was too poor. Seed lots with 75% to 80% germination rates just can't be sold. Carrot seeds are now mainly produced in the U.S.A. and France.

When Denmark joined the EEC, the seed production industry received unfair competition. Suddenly, all agricultural crops were financially supported. This meant seed companies had a difficult time getting contracts for vegetable seeds. Because of this, seed production area was reduced by more than half. During the 1970s some production returned partly because of the dollar's exchange rate but also because Dutch seed companies chose Denmark as the production country for their new spinach hybrids.

SEED PRODUCTION TODAY

Today the global vegetable breeding is concentrated with a few firms. Production, however, is carried out in many countries and by both large or small production firms.

There are a number of reasons for this spreading of production, mainly risk minimizing, harvest time (northern or southern hemisphere), climates, grower's know-how, security, labour force, price, etc.

In Denmark seed production covers 2000 ha of which 2/3 is used for *Spinacia oleracea* (spinach) seeds and the production of hybrids, spinach accounts for 80% of this.

Other important seeds are *Brassica rapa* Pekinensis Group, *Chrysanthemum coronarium, Scorzonera hispanica, Allium schoenoprasum, Anthriscus cerefolium,* and *Thymus vulgaris.* All these species produce high quality seed at a competitive

price. In addition, a number of annual flower seed crops are grown in Denmark.

Since the first production of hybrid spinach in the early 1970s, hybrid production has expanded to *B. oleracea* Botrytis Group, *B. rapa*, *Raphanus sativus*, *B.* rapa Pekniensis Group, and other oriental annual cabbage species.

THE ORGANIZATION OF SEED PRODUCTION

Seed production is on a contract basis between seed companies and growers. The seed company provides the basic/variety seed for the specific contracted production, acreage, and production price are greed to in the same contract along with quality specifications such as:

- Minimum germination
- Maximum water content
- Minimum purity
- Maximum amount of weed or other seeds
- Minimum spacing for seed areas with the same crop.

Planning is essential if good results are to be achieved by the grower. Because seed production is an exclusive agreement between grower and seed company, supervision is provided by seed company advisers.

HORTICULTURAL SEED PRODUCTION IN THE FUTURE

We are continually striving to produce better quality seeds, how far we can get is impossible to say but the ultimate goal is a seed lot with 100% germination, physical and genetic purity at 100%, and 100% soundness and uniformity.

We will probably never achieve the above goals with all species but with some we are getting close, i.e., lettuce.

A great challenge facing us is seed production in greenhouses. This type of production isn't something new but the amount is rapidly increasing.

An advantage of greenhouse production is the ability to provide optimum climatic conditions. In this environment seeds free of fungal problems can be produced and unwanted crossing can be eliminated. In addition, the seed can be harvested when the water content and the stage of development are at there best possible levels.

Vegetable seed production won't disappear from the fields, but the growing practice will change. More species will be established from transplants instead of sown directly. When handled this way, the annual *Brassica* species start flowering earlier and more uniformly.

However, a dilemma for the producers of seed will be balancing the restricted use of herbicides with the demand for cleaner seed lots. Such challenges will stimulate the development of new ways to grow plants.

Handling of Recalcitrant Tropical Tree Seeds

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INTRODUCTION

A large number of tropical tree species have recalcitrant or intermediate seeds, i.e., seeds that are intrinsically short-lived, as they do not tolerate drying to the same extent as orthodox seeds and can not be stored at low temperatures. For most species the optimal conditions during seed handling and storage have not yet been established. This presents serious problems with regard to the short-term utilization of the species and the long-term conservation of the genetic material.

This is the background for a recently started project, funded by Danida, with the objective of determining desiccation tolerance and storage conditions for 20 to 25 important tropical tree seed species. The project is coordinated by IPGRI (International Plant Genetic Resources Institute). DFSC (Danida Forest Seed Centre) provides technical backstopping and a large number of seed centres and research institutes in Africa, Asia, Central, South, and North America, as well as Europe, participate in the project.

RECALCITRANT AND NONRECALCITRANT SEEDS

Most agricultural and horticultural seeds can be dried down and stored for a long time without losing viability. When the seed moisture content is reduced below a certain level, respiration becomes minimal, and the seed is quiescent. The metabolic processes will not start again until the seed has re-imbibed water. The relationship between survival and moisture content and temperature is quite simple. For general guidance, a reduction of the moisture content by 1% and a reduction of the temperature by 5C will respectively double the lifespan of the seed. However, not all seeds tolerate drying and seeds with a high moisture content are metabolically active. They use oxygen and energy and germinate if the conditions are favorable. The metabolic rate can be reduced by lowering the temperature, but many tropical, desiccation-sensitive seeds do not favour low temperatures. High moisture content in combination with high temperature additionally makes the seed more prone to fungal attacks. Consequently, there are internal and external factors that make the storage of recalcitrant tropical tree seeds difficult.

For want of better words, seeds that tolerate drying and storage at low temperatures are called "orthodox". Seeds that hardly tolerate drying are "recalcitrant" and seeds that tolerate drying to some extent, but not low temperatures are called "intermediate".

Many tree seeds, especially from the tropics, are recalcitrant. They are often large fleshy seeds from tree species growing in a humid climate, and it takes controlled experiments to establish in which group the seeds belong. There are recalcitrant seeds in the temperate part of the world too, e.g. acorns and sycamore seeds. Both are desiccation sensitive but can be stored at 4C.

SEED OR PLANT ?

Recalcitrant seeds are not "designed" for long-term storage. As they often originate from climates where water is not a limiting factor, there is no risk associated with the lack of desiccation tolerance. When they drop from the tree they germinate and grow. Problems first arise when we want to collect, transport, and store the seeds.

There is controversy as to whether the storage categories are separate or if there exists a continuum from orthodox to recalcitrant. This discussion is, however, academic as it is necessary to determine the storage physiology separately for each species anyway. Further it is not possible to apply the result from one seed source of a species to the whole species, as different provenances can have different behaviours, e.g. neem (*Azadirachta indica*), an important multipurpose species in the tropics, which is recalcitrant or intermediate depending on the seed source.

The desiccation tolerance that develops during the maturation phase of the orthodox seeds fails to develop in recalcitrant seeds. Therefore, they perhaps should be considered more as plants than as seeds. Their physiological and biochemical background is not yet known. Proteins, sugars, and hormones are being investigated, but there is probably no simple explanation.

Desiccation tolerance also depends on seed maturity and the drying method. Immature orthodox seed can also be damaged by desiccation. Beechnuts demand relatively low drying temperatures if they are to tolerate drying, but they are orthodox. An investigation of desiccation tolerance comprises a number of factors: maturity, temperature and relative humidity during drying, and temperature and moisture content during storage.

SCREENING OF 25 SPECIES

For many, especially tropical tree species, there is very little information on seed handling methods. In developing countries it can be difficult to reach seed sources because of weak infrastructure and almost impossible to time the collection. Procurement is expensive and demand often low. In order to secure both the present utilization of as many species as possible and their future survival, it is essential to determine the optimal seed handling procedures for them.

This is why a project was initiated in Dec. 1995, funded by Danida (The Danish International Development Assistance) and coordinated by IPGRI (International Plant Genetic Resources Institute), with the purpose of determining desiccation tolerance and storage conditions for approximately 25 tropical tree species.

It is primarily seed centres in the tropics which will do this screening, but European research institutes also participate. DFSC (Danida Forest Seed Centre) takes part in the screening and supports the project with technical backup. Each determination is made by at least two institutes to obtain a reproducible result, as many things can go wrong with recalcitrant seeds. The project runs for 3 years, thereafter it is planned to continue with a more strategic project on desiccation tolerance.

The first project will result in directly applicable guidelines for the handling of the investigated species, but equally important is that a protocol for the experiments is being prepared and tested. It will be easy, especially for the institutes participating in the project, to continue with species that can not be covered by the project. The protocol is for everybody to use and hopefully it will be used as there are many species we know very little about.

The experiments are meant to be simple and demand as few resources as possible. The screening starts at collection, as maturity is an important factor. There is also a focus on transportation and seed extraction to keep the seed alive and in good condition at least until desiccation. The seeds are desiccated with silica gel to 5% moisture content. During the desiccation, samples are removed for germination testing at intervals of approximately 3%. If the germination test shows that the seed has been damaged at a moisture content above 15% to 20%, the seed is recalcitrant. If it tolerates down to 8% to 9% before it is damaged, it is probably intermediate; and if 5% to 6% can be reached without damage, it is probably orthodox. After the desiccation trial, the recalcitrant seeds are stored at different, relatively high temperatures (minimum 15C) at the lowest possible moisture content. Orthodox and intermediate seeds are stored in the same way but at lower temperatures (e.g., -20 and 5C).

The species chosen for the project are expected to be recalcitrant or intermediate. But some of them will probably turn out to be more desiccation tolerant than expected. The whole procedure from collection to storage, and especially desiccation, will in some cases be monitored more carefully than normally which will prevent some damage from occurring.

CATIE (Centro Agronomico Tropical de Investigacion y Ensenanza, Costa Rica) and DFSC studied the desiccation tolerance of *Vochysia guatemalensis* seeds. CATIE has not had experience with the species itself, but were told by local seed centres that it was difficult, probably recalcitrant. Both CATIE and DFSC obtained germination percentages of 95% to 100% after desiccation to 5% to 6% moisture content. So it is definitely not recalcitrant. Additional storage experiments will show whether it is orthodox or intermediate. It has, however, been demonstrated that the seeds can germinate at a high percentage, so it is not necessarily the seed that is difficult to germinate but it appears that its treatment is wrong.

A newsletter is issued twice annually. It can be ordered at Danida Forest Seed Centre.: IPGRI/DFSC Newsletter; The Project on Handling and Storage of Recalcitrant and Intermediate Tropical Forest Tree Seed. No 1, July 1996.

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Precision Drills and Vacuum Seeders for Vegetable Seeding

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Haarby forge at Southwest Fyn has been in existence for 30 years and has, among other things, specialized in machinery for vegetable production. They manufacture the Stanhay sowing equipment — the most widely used type in Denmark. In vegetable seed sowing two techniques are mainly used — precision drills and vacuum seeding. Stanhay manufactures both types which are built on a parallel chassis that rides on two pressure rollers. In this way even sowing depths are maintained.

When using the Stanhay 870 or 985 precision drill you have a reliable machine for sowing a range of vegetable seeds both natural (no coatings) or pelleted. You can maximise the profitability of your seed-produced crops by selecting the proper choke, base, and seed belt (ribbed, plain, or plastic) for the metering unit; getting the right hole seize; and deciding whether to use single, double, or triple rows.

The seed hopper contains a choke which regulates the amount of seeds in the chamber; the seed belt then moves the seed to the repeller wheel. This procedure agitates seed in the chamber and rolls excess seed away from the holes in the belt, thus allowing only the required amount of seed to drop through at the end of the base. Since the seed is released in the opposite direction to the movement of the drill and the drop is only 25 mm, bounce and roll are prevented, and accurate seed spacing is assured.

When using the Stanhay 785 vacuum seeder even the smallest uncoated seeds are no problem. The metering unit has a vacuum chamber which is divided into three galleries. When in operation with a seed disc fitted over the central drive turntable, the vacuum created in the chamber, sucks seeds from the base of the seed hopper onto a series of holes in the disc. To ensure each hole retains only a single seed, a singulator device removes any excess seed from the holes. This is very finely controlled by a large calibration wheel which is simply set by hand to the required position for spacing accuracy. After the seeds are released the holes are cleaned by jets of air. The discs used are thin and flexible to ensure an airtight seal when in operation.

Additional optional equipment including different types of counters — single, doubles, or triples — are available for both types of seeders. The pressure rollers can be changed depending on the soil type the machines are used for.

Maintenance is important for the best seeding results. Although the above mentioned factors influence the end result, it is important to test and clean the system before the season starts. The better maintenance your machinery receives the better will be your seeding results. The vacuum seeder type additionally must be cleaned after each working day.

From Seed Technology to Seed Products

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Research developments over the past 20 years in the areas of precision sowing, crop protection, and germination performance as they relate to the vegetable and flower seed industry are discussed. It will be shown that technology oriented research in these fields has led to innovative, value-added seed products. The marketing of these seed products is targeted at the needs of growers. Products that are discussed include "100% usable plant seed" based on pregermination technology, "high vigor seed" based on priming technology, and "seed plus shield" based on coating technology.

INTRODUCTION

The goal of seed technology is to improve the quality of seed. Thirty years ago seed batches were processed to remove impurities, but no efforts were made to further improve quality. Research in this field with vegetable and flower seeds started in the 1970s. In this paper three areas are highlighted: precision sowing, crop protection and germination performance. All activities related to seed-borne diseases, and to the production of a standard seed quality, are excluded because the starting point of this paper is seed with a standard germination performance and freedom from pathogens.

PRECISION SOWING

The first concern of the grower is how to get the seed planted into the soil or plugs. With improvements in the quality of seeds and the quality of precision planters, the concept of precision sowing was introduced some 15 years ago in the horticultural industry.

Two types of planting machines have been developed for sowing: mechanical and pneumatic. Pneumatic sowing machines use vacuum to suck the seeds onto perforated drums or disks, while mechanical sowing machines use plates or bands with holes that exactly fit the seeds.

For sowing machines to work there best, the seeds have to be sized into diameter classes, the seeds must be as smooth as possible, and the seed must be perfectly clean. To provide dust-free and smooth seeds the seed industry applies film coatings. This means that the seed is provided with a coating made of a polymer with a thickness of between 1-5 μm.

Seed coatings started to become popular in the 1980s. The technology is now generally available, not only by the seed suppliers but also by custom coating companies like SeedCote Systems (UK), Ceres (France), SUET (Germany), and Incotec (U.S.A., Netherlands).

The use of colors to visualize sowing performance has been integrated into the concept. Thus, a seed coating improves sowing precision and it helps performance checking of the equipment.

Sizing of seeds has become a standard procedure for most seed types to improve the sowing performance. This processing step has great consequences for the stock management in seed-processing operations. One seed lot may be split up into four or five sizes. Each of these sizes must be treated as separate lots in further processing and quality control. Although people assume that large seeds perform better than small seeds, the literature is not conclusive (Villeneuve et al., 1993). However, a clear advantage of the calibration is uniformity in plant size.

A very important breakthrough in applied seed technology was the invention of the seed pellet in the 1960s by Royal Sluis. The pellet made automated sowing in plugs possible and thereby changed the plant-raising industry. Over the years the number of crops that could be bought with a pellet increased. Noteworthy was the Celery QuickPil by Royal Sluis in the early 1980s and some years later the Celery Prestinun pellet by Nunhems that caused a significant change in celery growing. For several open-field vegetables like carrot (*Daucus carota*) and onion (*Allium repa*) pellets are also available. For these crops the higher speed of sowing is an important reason to buy pelleted seed.

A typical lettuce pellet is made of natural materials. In recent years new types of pellets are being developed on the basis of synthetic polymers. On top of improved germination performance the new generation of pellets is more suitable for combinations with agrochemicals used for crop protection.

COATING TECHNOLOGY

Treatments to protect the seed against diseases are the oldest type of seed treatments. Over the years a number of effective chemicals have come on the market that may be used as seed treatments. The first generation treatments, now called "traditional treatments" consisted of the addition of a small amount of chemical to a batch of seed. These treatments made a lot of dust during seed handling and sowing, and were therefore replaced by slurry treatments with a mixture of the chemical and a sticker. This second generation of treatments is called "dustfree", and that is exactly what they are meant for. However, this type of treatment is becoming obsolete because the distribution of the chemical over one seed and between seeds cannot be controlled. A dustfree treatment also does not give the flexibility that is required for different combinations of seed treatments.

The third generation of seed treatments are called "film coatings" or "polymer coatings". The bases of these coatings are polymers — the type being dependent on the producer and the application purpose — that hold the chemical or a combination of chemicals and a dye. The color that is added to the coating makes the seed very recognizable, can be used to identify seed from a typical originator, and is useful to check sowing performance.

Typical equipment used to apply these coatings comes from the pharmaceutical industry, but adapted versions have been designed over the years to fit the particular needs of the seed industry.

CROP PROTECTION

In recent years the agrochemical industry has shown a renewed interest in the application of agrochemicals in seed coatings. This new interest is based on the decreasing public acceptance of agrochemicals and the bigger influence of retailers on the way vegetables are produced.

The seed industry has become aware of the unique opportunities. While in the past seed treatments were provided to protect the seed during emergence, the seed houses are now in a position to use the seed as a vehicle to bring agrochemicals into the soil, as close as possible to the plant. Because the chemical is placed exactly were it should be and nowhere else, the reduction in the amount required for good protection is enormous.

To have an effective and long-lasting coating, the chemical must either remain active in the soil for a number of weeks when targeted for soil-borne diseases, or must be taken up by the plant and have systemic action against air-borne diseases. An example of the latter is the use of Metalaxyl as a seed coating against downy mildew in brassicas (Fig. 1).

Seed coatings that protect the young plant against insects have also been developed. S&G Seeds was the first seed company to introduce such a coating for brassicas: the Gigant coating, protecting the plants against cabbage root fly (Fig. 2).

This development is leading towards a coating that protects the young plant against all the main diseases and pests that may occur during the first weeks after sowing, and in some crops even close till harvest. The convenience and cost reduction of such crop protection is of interest to the grower, and at the same time the amount of chemicals needed for crop protection is reduced.

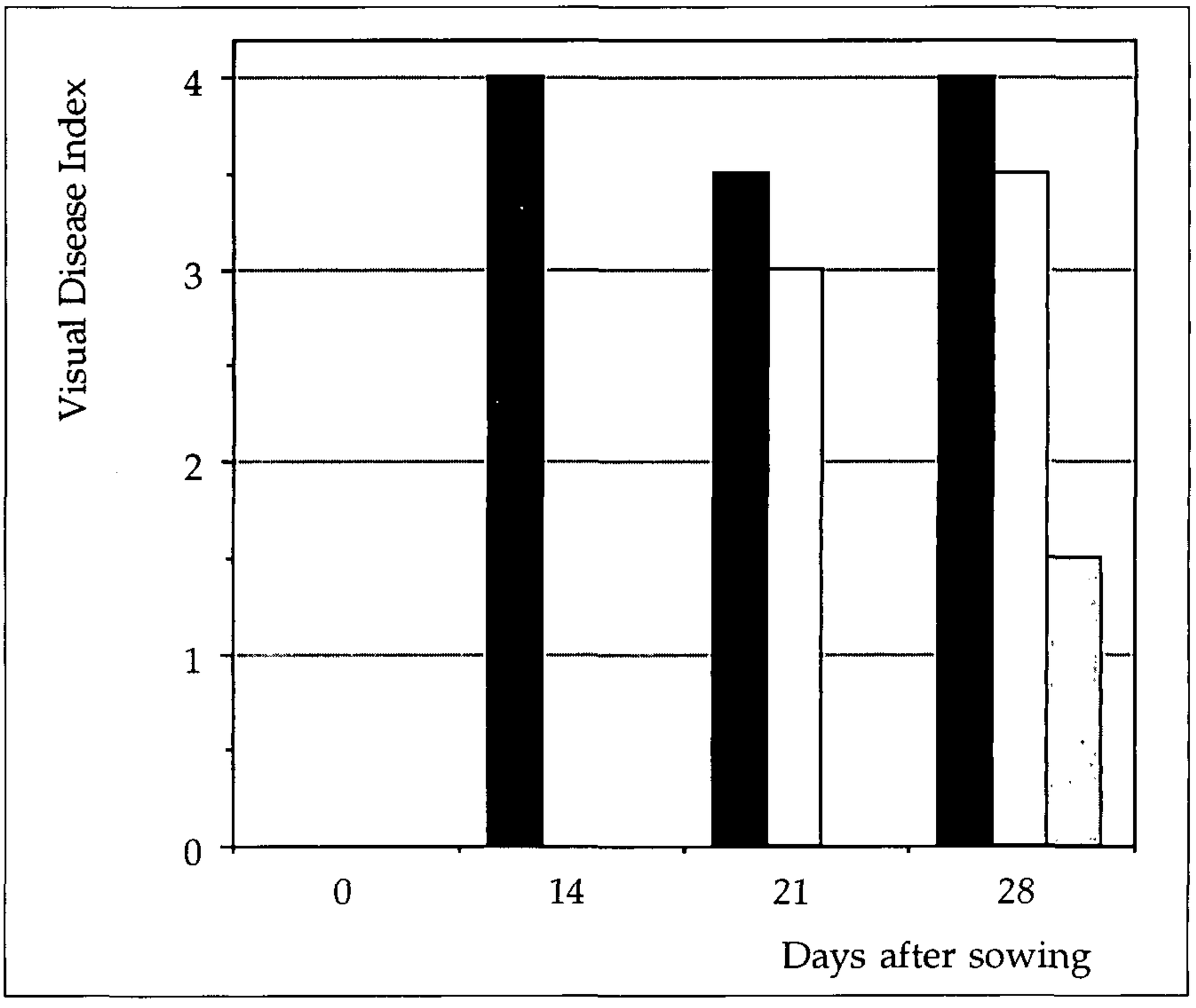

Figure 1. Effect of a seed coating with metalaxyl [0.70 g a.i kg^{-1} (□) and 1.05 g a.i. kg^{-1} (□)] on the infection of cabbage seedlings with downy mildew. The control (■) seed coating did not contain metalaxyl, and no other protection agents were used. (Hofstede, S&G Seeds, unpublished results).

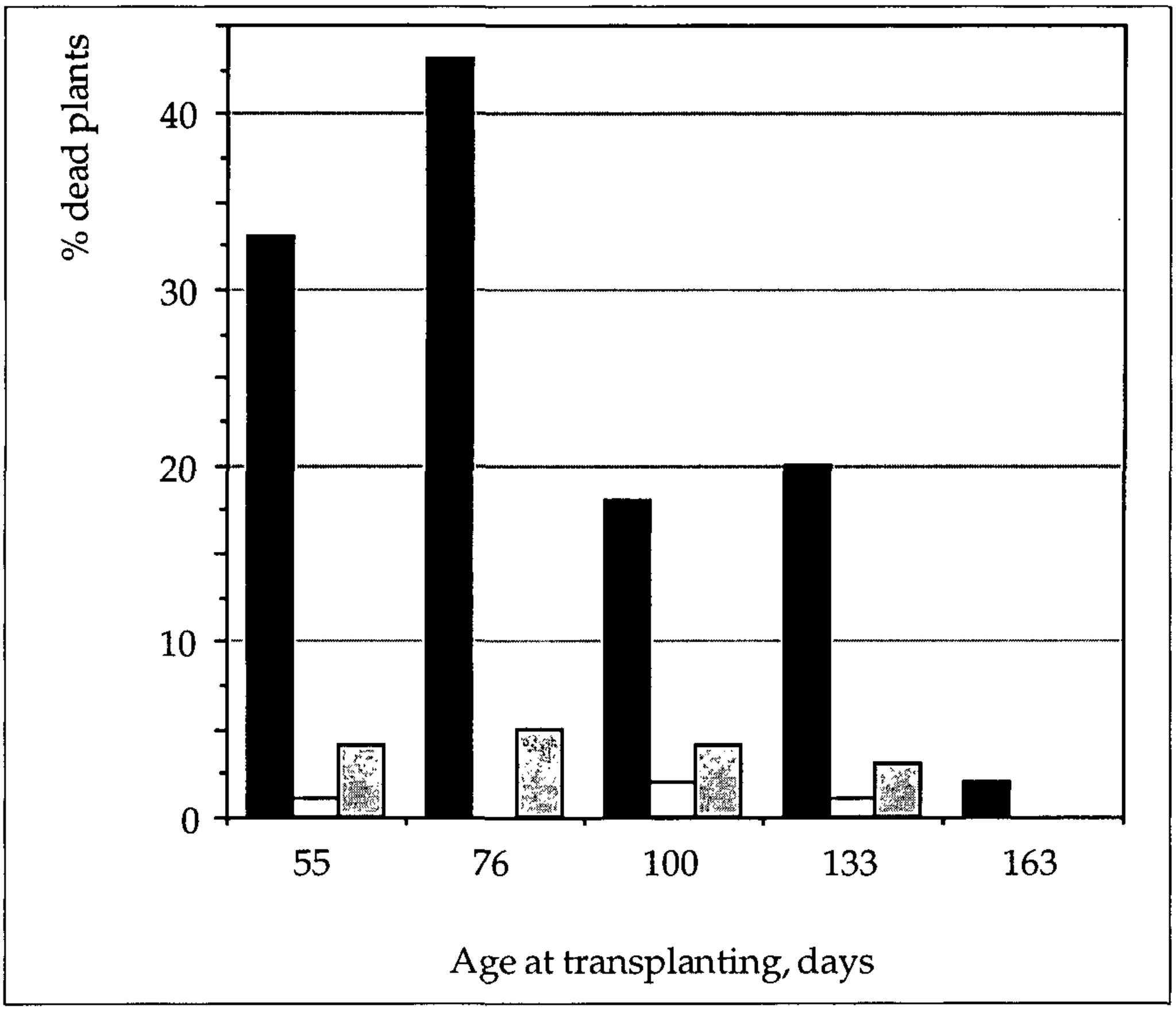

Figure 2. Percentage dead cauliflower plants from cabbage root fly 48 days after planting. At time of transplanting (April 15) plants had a different age as indicated on the X axis. Seeds were coated with fungicides only (■) or with fungicides and chlorpyrifos (□). A second control included a chlorpyrifos granulate treatment after transplanting in combination with fungicide coated seeds (▩) (After Kosters and Hofstede, 1994).

BIOCONTROL

Over the last 10 years a new line of seed treatments— biological seed treatments— has been introduced on the market. The research into suppression of diseases in the soil by the use of natural enemies, called antagonists, has driven the application on seeds, as they are a natural carrier to bring these antagonists into the soil. In a number of crop-disease combinations the same level of protection can be reached as with agrochemicals. The continuous work on selection of more effective strains, and the use of genetically modified antagonists have resulted in even more effective protection.

S&G Seeds started the research into biologicals in 1989, and in 1994 BioCoat for radish seeds was introduced in the Netherlands. This coating is highly effective against *Fusarium* species, a disease that cannot be controlled except with expensive soil steaming or environmentally undesired Metamnatrium treatment. Experiments have shown that by using biocoated seed the population of the microorganism, *Pseudomonas fluorescens*, builds up during the season resulting in improved protection (Fig. 3).

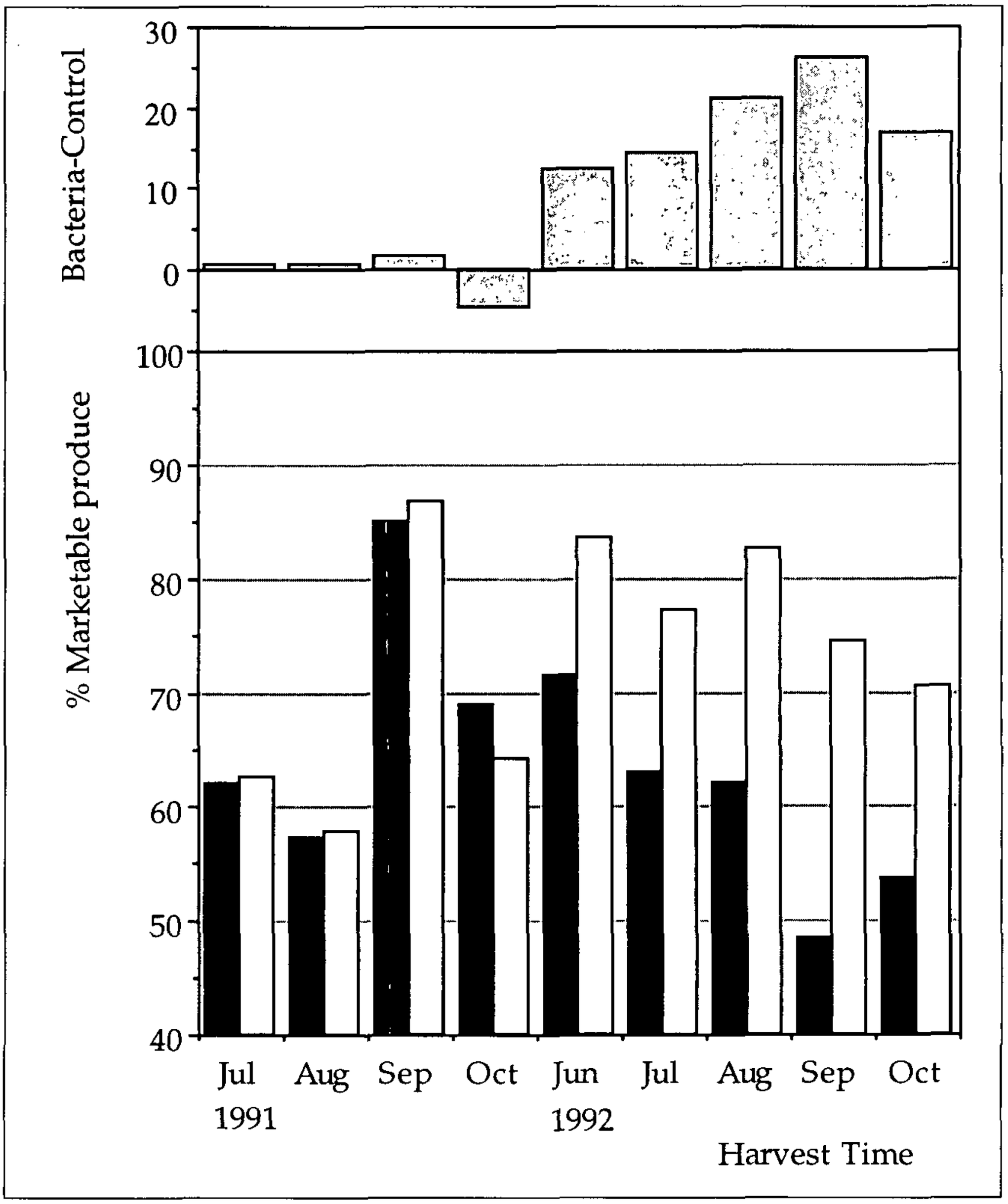

Figure 3. The effect of BioCoat on percent marketable produce of radish grown in a greenhouse. During subsequent sowings the yield of coated seeds (□) was compared with control seeds (■). In the upper section the difference in percent marketable yield is indicated (After Leeman et al., 1995).

Although the market is increasingly aware of the importance of reduction of the use of agrochemicals, and biological seed coatings offer a good alternative for chemical seed treatments, it is not expected that many more examples of biological seed treatments will come on the market soon. This is due to the higher costs of the coating compared to conventional treatments and the strong trend in the industry for cost reduction. Once again the public opinion on the use of chemicals in crop protection will play a decisive role in the future.

SEED QUALITY

The standard approach to test seed quality is a "paper test" — germination on water-saturated filter paper. The methods used for the different crops are described in the official rules of the International Seed Testing Association (1985).

The important advantage of these tests is that they supply a reproducible indication of the potential quality of a seed batch. That is, within the statistical variation that is normally expected in a test of 4× 50 or 2× 100 seeds it gives the percentage normal seedlings germinated under optimal conditions. The international seed trade has agreed upon germination standards used for different classes of seeds.

However, it is well known that the paper test is less useful when it comes to predicting germination under practical conditions. The often variable conditions of open-field-sown crops — but also for crops sown in the greenhouse — make a paper test an unreliable indicator for field emergence. Research in this field has led to standardized tests for usable plants on soil. Such a test comprises 2× 100 seeds sown in soil blocks and germinated under standardized conditions. Again, within the statistical variation it is a reliable assessment of the percentage of usable plants. A

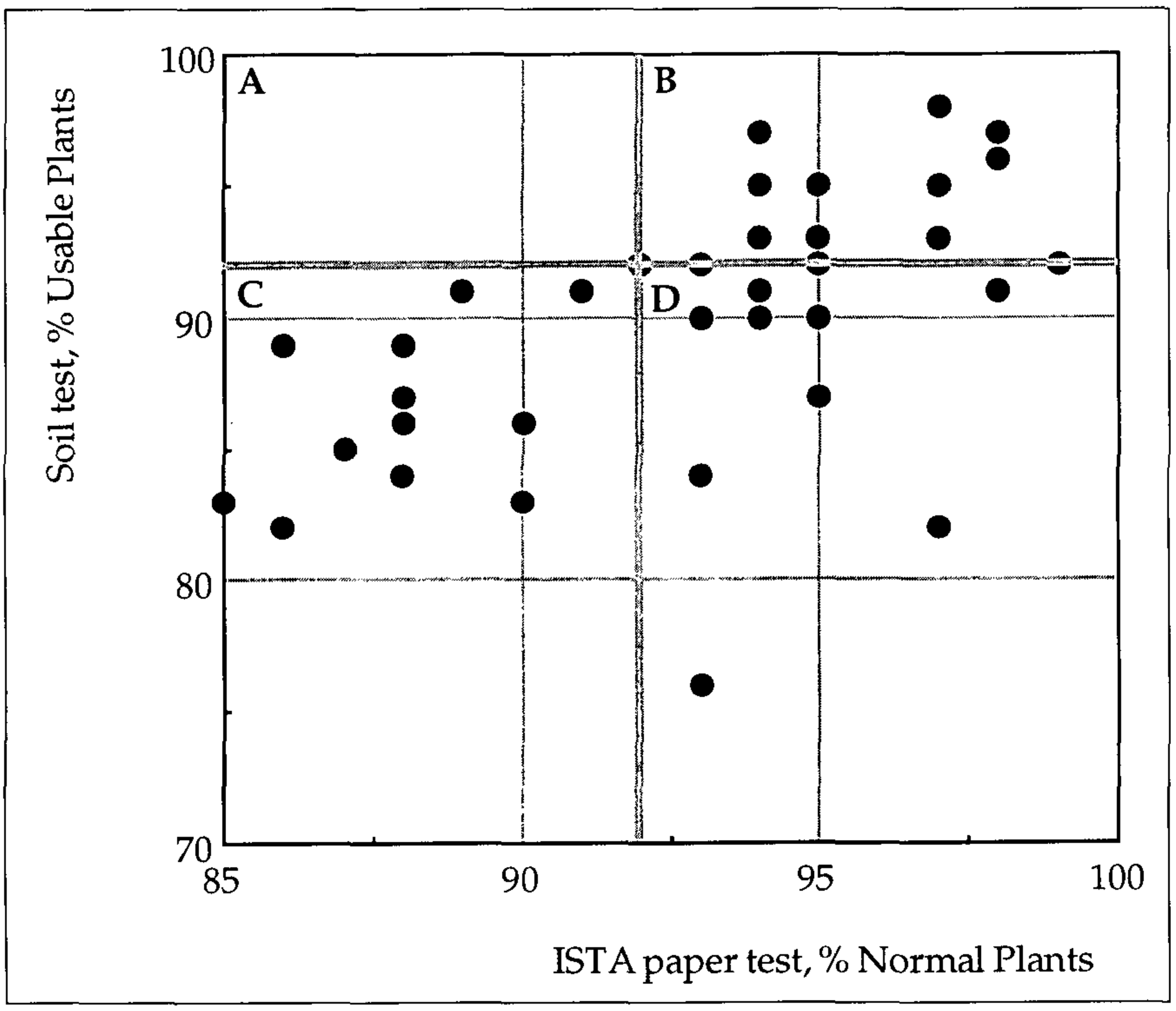

Figure 4. A comparison of the germination performance in an ISTA paper test and a percent usable plants-soil test. Each data point represents one seed lot. Note a significant number of seed lots in quadrant D, indicating 92% or more usable plants in the ISTA test but less than 92% usable plants in the soil test. Note also that no seed lots are present in quadrant A (Bruggink, S&G Seeds, unpublished results).

comparison between the paper test and the soil test shows that the soil test can be more discriminating and can better identify the high quality seed lots (Fig. 4).

A soil test quantifies usable plants, looks at uniformity and, to a lesser extent, speed of germination. Speed of germination, or germination rate, is the critical factor that translates into "vigor"; the characteristic that makes a seed less sensitive to adverse germination conditions like low temperature. Speed of germination can best be measured by daily counting of germinated seeds incubated on paper. Formulas (Orchard, 1977) have been developed to calculate the germination rate of a seed lot using the daily countings.

In conclusion, the most valuable information a grower can have is the percentage usable plants obtained in soil under specified conditions, and information related to the germination rate, expressed in a vigor index. This kind of information is as yet not typically available for growers who buy seed, but it will be in a few years. Special product forms like Sterling® seed, introduced in Europe for open-field vegetables by S&G Seeds, makes the need for such information greater. In Sterling® seed the vigor index is on average twice that of standard seed. Due to the higher vigor index Sterling® seed results in much better plant stands in early season sowings of field crops like carrot and chicory (Huygens, 1996).

IMPROVING VIGOR

Sterling® seeds have been primed to improve the vigor. The idea to prime seeds was originally proposed by Heydecker (1973), a scientist from Nottingham University. Heydecker introduced the concept as the incubation of seed in an osmoticum, preferably polyethylene glycol 8000, a high-weight inert molecule, to control the seed water content. This technology has been used for a number of years but in the 1980s innovations in the technology were published. Taylor (1988) described a method to control the water content by means of a matrix made of vermiculite, perlite, or similar materials. Rowse (1988) published an even simpler method called drum priming. In this system the seed is put into a drum and a calculated amount of water is slowly added by means of nozzles. Recently Rowse (1996) published still another method, a combination of PEG and drum priming. The drum comprises an outer layer that contains a PEG solution, and an inner drum that is made of semipermeable material, such that the seed in the inner drum can take up water from the PEG solution without coming into contact with the solution itself.

All methods are based on the principle that the water potential of the seed during the incubation is strictly controlled. This is important because the rate of metabolism preparing the seed for radicle protrusion — the germination per se — depends on the moisture content in the seed and the temperature during the incubation. The best results of a priming treatment are obtained when the progression of pre-germination development is allowed to proceed as far as possible without the occurrence of radicle protrusion. Radicle protrusion is a critical step in the process because the seed then becomes prone to desiccation damage.

The typical result of a priming treatment is a 100% increase in seed vigor (Van der Toorn, 1990). However, an important drawback of primed seed is the limited shelf life of these seeds. Therefore S&G Seeds has developed a method to increase shelf life in primed seeds (Schipper et al., 1995). With this method the seeds can be easily stored, not only longer than conventionally primed seeds, but also under conditions similar to untreated seeds (Fig. 5).

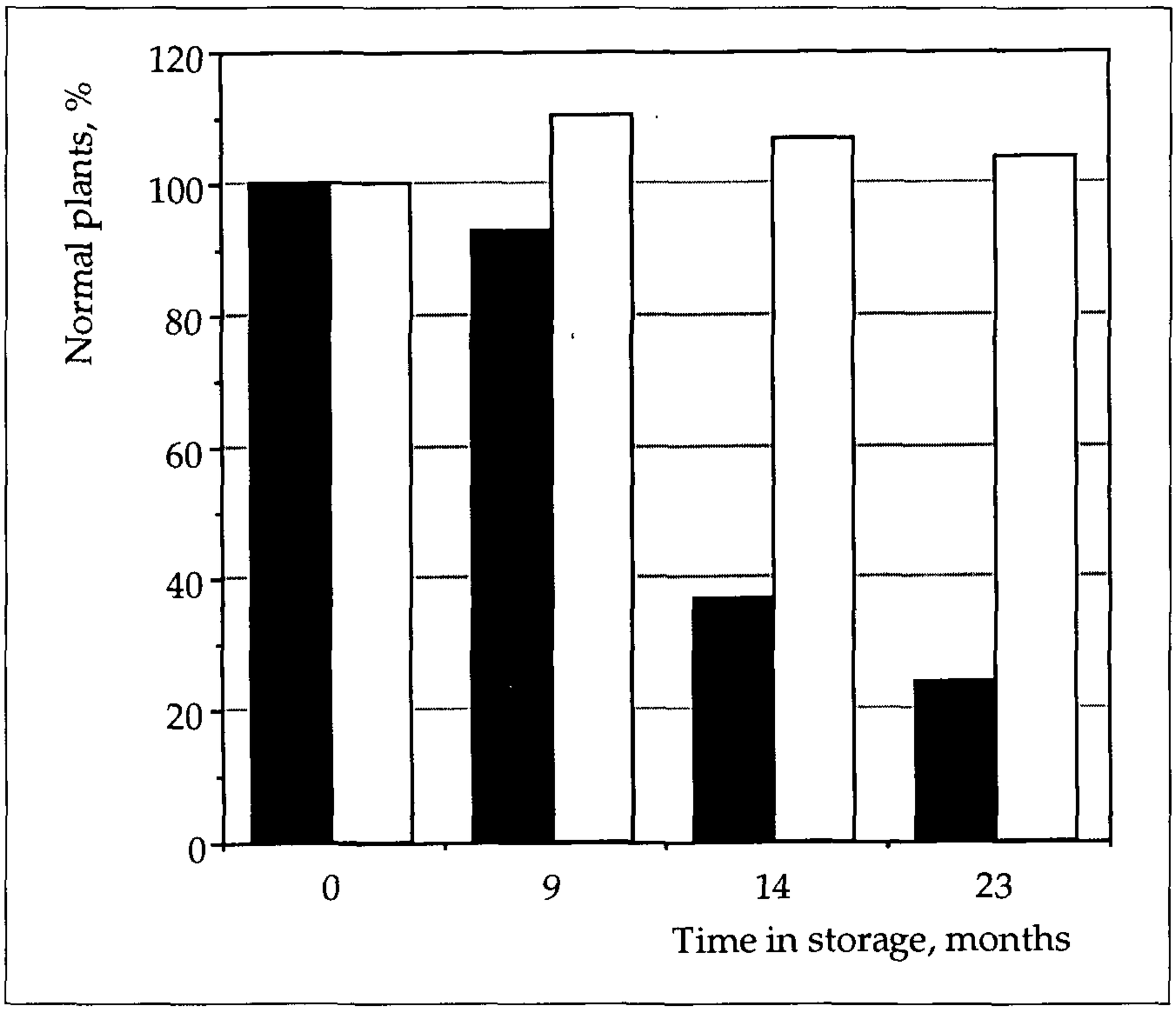

Figure 5. The effect of a shelf-life induction treatment on primed Pansy seeds. The seeds were primed at t=0 and either dried back immediately (■) or treated to induce shelf life (□) and subsequently dried. Seeds were stored at 18C in sealed packets. Normal plants are expressed as percentage of germination at t=0 (After Schipper et al., 1995).

The technology used to restore the shelf life of primed seeds is related to the induction of desiccation tolerance in germinated seeds. Primed seeds are held under conditions that confer a stress, preferably a combination of temperature and moisture stress. When a primed seed batch contains 35% (f.w.) moisture content at the end of the priming period, it may then be incubated at 30% moisture content and at a temperature of 32C to increase shelf life.

IMPROVING PERCENTAGE USABLE PLANTS

Priming does not necessarily improve the percentage usable plants obtained under standard optimal soil conditions. Therefore, next to physiological enhancement a lot of research and development is allocated to seed separation methods. The goal of this research is to develop methods to separate viable seeds from less viable or nonviable seeds, so that seed batches can be obtained with 100% usable plants.

The efficiency of a separation method (SE) may be expressed by the formula:

$$SE = (Qo-Qi)/W$$

where Qo = % usable plants of outlot, Qi = % usable plants of inlot, and W = % of lot that is rejected during processing. For example, a seed lot with a germination of 80% is processed and gives a seed batch which is 60% of the original seed lot and has a

germination of 85%. The efficiency of the separation process was (85-80)/(40) = 0.125. A typical seed-cleaning method, like calibration or graduation, has an efficiency of 0.1.

The reason for low efficiencies of conventional seed separation equipment is the absence of a causal relationship between physical seed characteristics used for the separation and the physiological quality.

The parameter with the highest correlation with the quality is the density of seeds. To address the potential of density separation, Taylor et al. (1982) developed a separation in mixtures of chloroform and hexane. A typical density separation has an efficiency of 0.3, meaning a 10% increase in percentage usable plants and a seed loss of about 30% (Fig. 6). The method has been commercialized by Franken, a seed-processing company in the Netherlands.

For some years the Dutch seed industry has been working at the use of X-ray imaging as a seed separation method. The idea is based on the relationship between specific embryo morphology characteristics and the resulting young plant quality (Van der Burg et al., 1994). This type of relationship has been worked out in detail, and the required hardware and software has also been designed. The bottleneck in the application of this technology is in the complicated equipment that has to be designed for the singulation and positioning of large numbers of seeds in the vision system, the limited capacity, and the selection hardware.

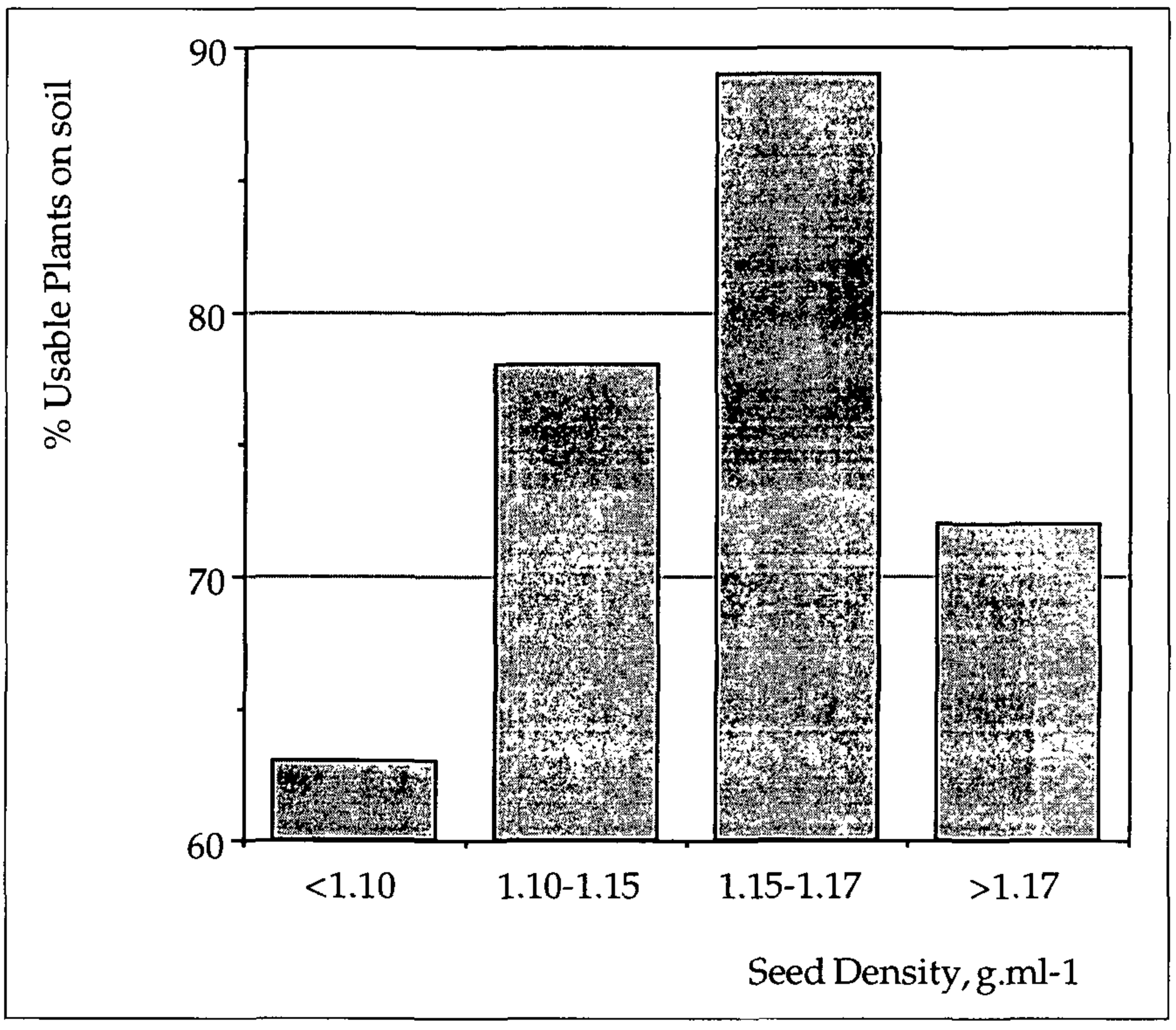

Figure 6. The effect of separation of a tomato seed lot in mixtures of hexane and chloroform. The separation solutions were prepared according to Taylor et al. (1982) (Van der Toorn, S&G Seeds, unpublished results).

PREGERMINATION

Finch-Savage (1989) chose a completely different approach for the development of high-efficiency separation methods. He reasoned that since seeds in their original form cannot be separated into viable and nonviable seeds, the difference had to be induced in the seeds: that is, the viable seeds must be germinated. Subsequently, germinated seeds can be separated from nongerminated seeds.

The idea to obtain 100% usable plants by selection of germinated seeds brings up several problems. The first problem is to control the germination process. As radicle protrusion occurs, the radicle, freed from the surrounding barriers, accelerates into a very high rate of elongation and water uptake. Therefore, the window that is available for selection of an individual seed is very short. In a seed batch the actual time of radicle protrusion of the individual seeds is spread over a longer period, in most species several days. Those two factors lead to the conclusion that to obtain a uniform seed batch of germinated seeds, the separation step must be carried out frequently and without disturbing the germination process.

To shorten the period needed for separation, pretreatments like priming can be used. In addition to these pretreatments the manipulation of temperature and light can be used to control the germination process.

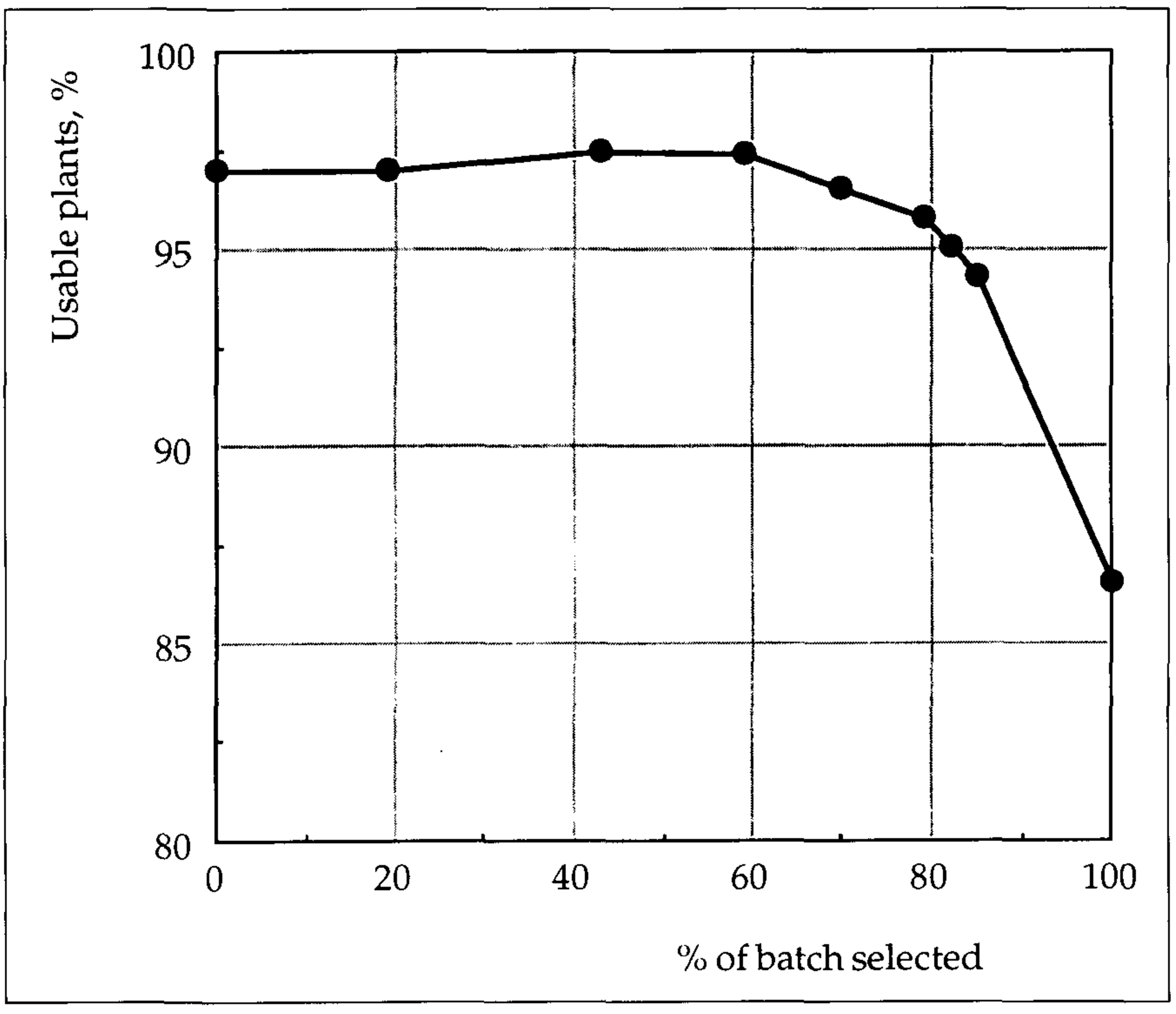

Figure 7. The relationship between the time of radicle protrusion and the young plant quality of Impatiens seeds. A seed lot was incubated in aerated water. Germinated seeds were removed periodically and tested for resulting young plant quality. The graph indicates that the last 30% of the seed lot is of a lower quality (Bruggink, S&G Seeds, unpublished results.)

The second problem that has to be addressed is how to separate the germinated from the nongerminated seeds. A very powerful method appeared to be the use of image analysis systems in combination with the germination systems, in such a way that seeds are permanently monitored and germinated seeds are removed and further processed.

The efficiency of separation of germinated seeds should be 1.0, but is as a rule between 0.7 to 0.8 because not all germinating seeds are used. For most crops, a relationship exists between the germination rate and the quality of the young plant (Fig. 7). The early germinators are the seeds that give the highest quality of young plants. The seeds that germinate slowly are not selected.

The third problem is the instant loss of desiccation tolerance at the moment of germination. S&G Seeds has developed a method to reinstate desiccation tolerance in the germinated seed (Bruggink and Van der Toorn, 1996). The method is based on an incubation treatment at a slightly lower water content than at the moment of radicle protrusion. The effect of the water withdrawal is a complete inhibition of radicle growth. But during this period of suspended radicle growth the breakdown of food reserves continues. As a result sucrose is concentrated in the radicle. Figure 8 shows the relationship between the sucrose content in the seed and the survival after desiccation. Next to these processes we have shown that also a group of proteins that are called Late Embryogenesis Abundant (LEA) proteins are being synthesized during the incubation (Bruggink and Van der Toorn, 1995).

The products that are based on pregermination technology are sold under the name PreMagic®. Reports from the plant raisers indicate that "it is possible to get 100 usable seedlings routinely without a lot of effort" (Shaw, 1996).

FROM TECHNOLOGY TO PRODUCTS

The developments covered in this paper lead to a reassessment of the added value of seed technology. Seed treatments are changing into "crop protection add-ons". Priming treatments are used to provide the customer with seeds fit for suboptimal sowing conditions. New separation technology is brought into the trade to create totally new classes of seed quality. In other words, treatments are translated into products and these products are targeted to markets. This paper shows that it is possible to define five seed types with distinct features of benefit to different market segments:

- **Standard Seed.** This is the starting point of the product line, seed with a known quality, based on the market standard, and coated with agrochemicals that protect the germinating seed. Standard seed is of interest to growers that rely on a "value for money" concept and grow their crop under controlled conditions.
- **High Vigor Seed.** This seed is targeted towards high risk sowing environments, like early season sowings in Northwest Europe or greenhouse conditions in summer South-East United States. The product offers a higher reliability in emergence compared to standard seed under such conditions. The Sterling® seed marketed by S&G Seeds for open-field crops is an example of this type of seed.
- **High Percent Usable Plant Seed.** This seed is targeted to professional growers which can control the germination conditions and want to optimize the operation as much as possible. The

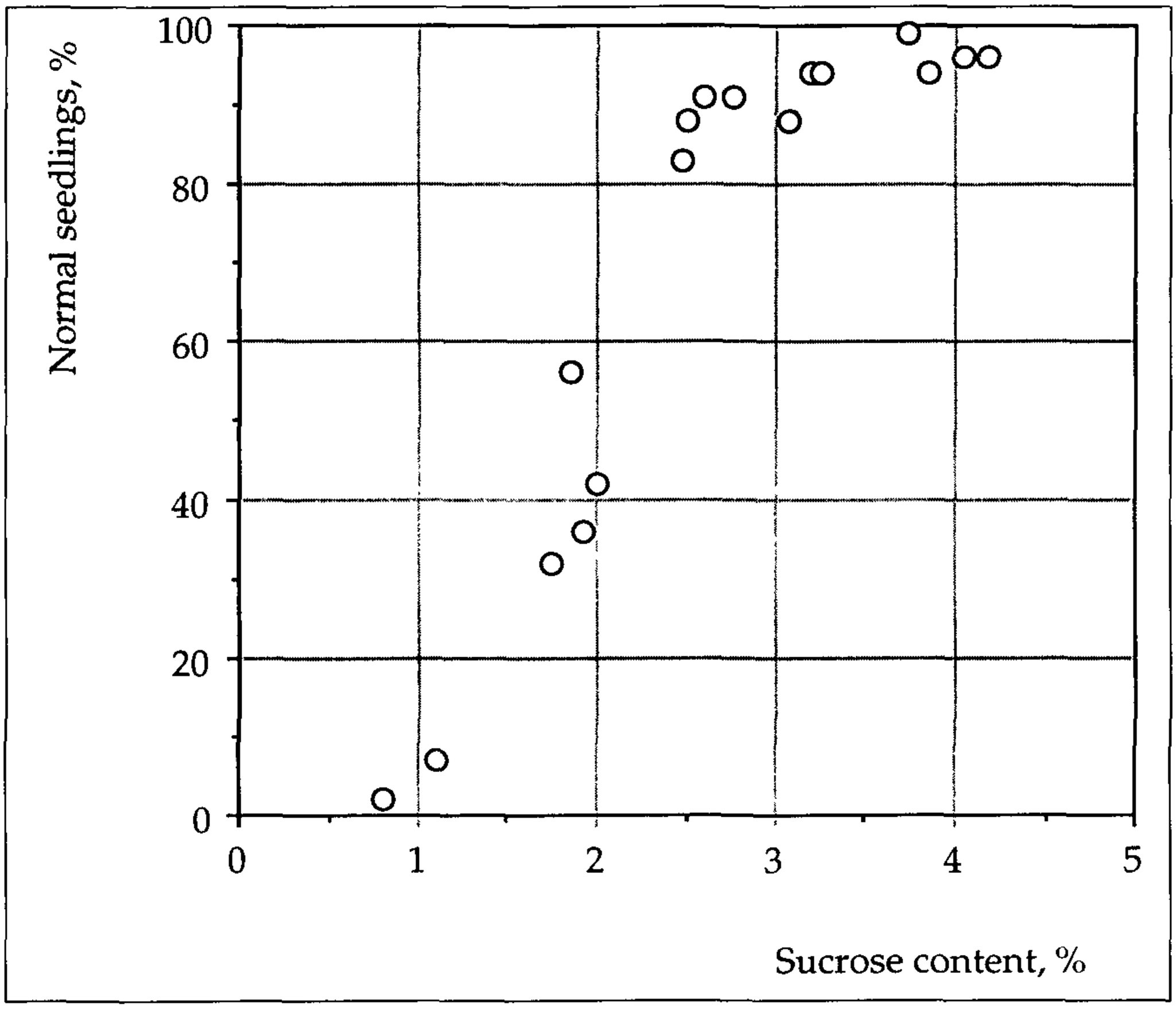

Figure 8. The relationship between the sucrose content and the survival of germinated Impatiens seeds after desiccation. Each data point represents a batch of germinated seeds that was treated at different moisture contents and for different periods to induce desiccation tolerance (Bruggink, S&G Seeds, unpublished results).

concept of 100% usable plants brings automated transplanting in the picture, it eliminates patching of trays before delivery, and it enables the plant raiser to make more efficient use of the greenhouse. The PreMagic® seed for bedding plants in the U.S.A. marketed by Vaughans is an *example of this type of seed.*

- **Pelleted Seed.** This seed facilitates high speed precision sowing. For some crops it is an absolute requirement, for others it is an extra that makes a more profitable operation possible. Example of this type of seed is Lettuce Splitkote marketed by Incotec.
- **Seed Plus Shield.** This seed is combined with a crop protection package that protects the young plant until several weeks after sowing. This seed type is of interest to growers who face a high disease and/or pest pressure. For these markets it offers a convenient alternative to conventional crop protection methods. Examples of this seed type include Brassica Triocoat seeds marketed by SeedCote Systems in the UK.

The different types of seed products may be combined to meet the specific grower demands. The complete transfer of technology into products yields the full potential of seed technology and creates added value both for the grower and for the seed industry.

Acknowledgments. I would like to thank several people from the S&G Seeds Department of Technology: Bernadette Kroon, Sietske Hofstede, and Frank de Rooij for their help on biologicals and coatings; Tonko Bruggink for his help on seed quality and pregermination, and Ruud Scheffer for his peer review of the manuscript.

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Vigour Test In Oil Seed Rape And Peas

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INTRODUCTION

A vigour testing experiment with spring oil seed rape (*Brassica napus*) and pea (*Pisum sativum*) was performed. The aim of the study was to subject seeds of the two species to "controlled deterioration" and then compare the results of a vigour test with field observations.

There is interest in examining if there is a correlation between the results of a vigour test and the field performance of the seeds to better predict seed quality. In order to test this, a vigour test was applied to a number of seed lots, and the test results were compared to results of field trials, i.e. trials where the development of plants of the different seed lots was followed during the growing season.

If the vigour test is to be considered as applicable there must be a close correlation between its results and results of the field trial, i.e. seed lots with the best test results should have the best field performance. Thus, on the basis of the vigour test it should

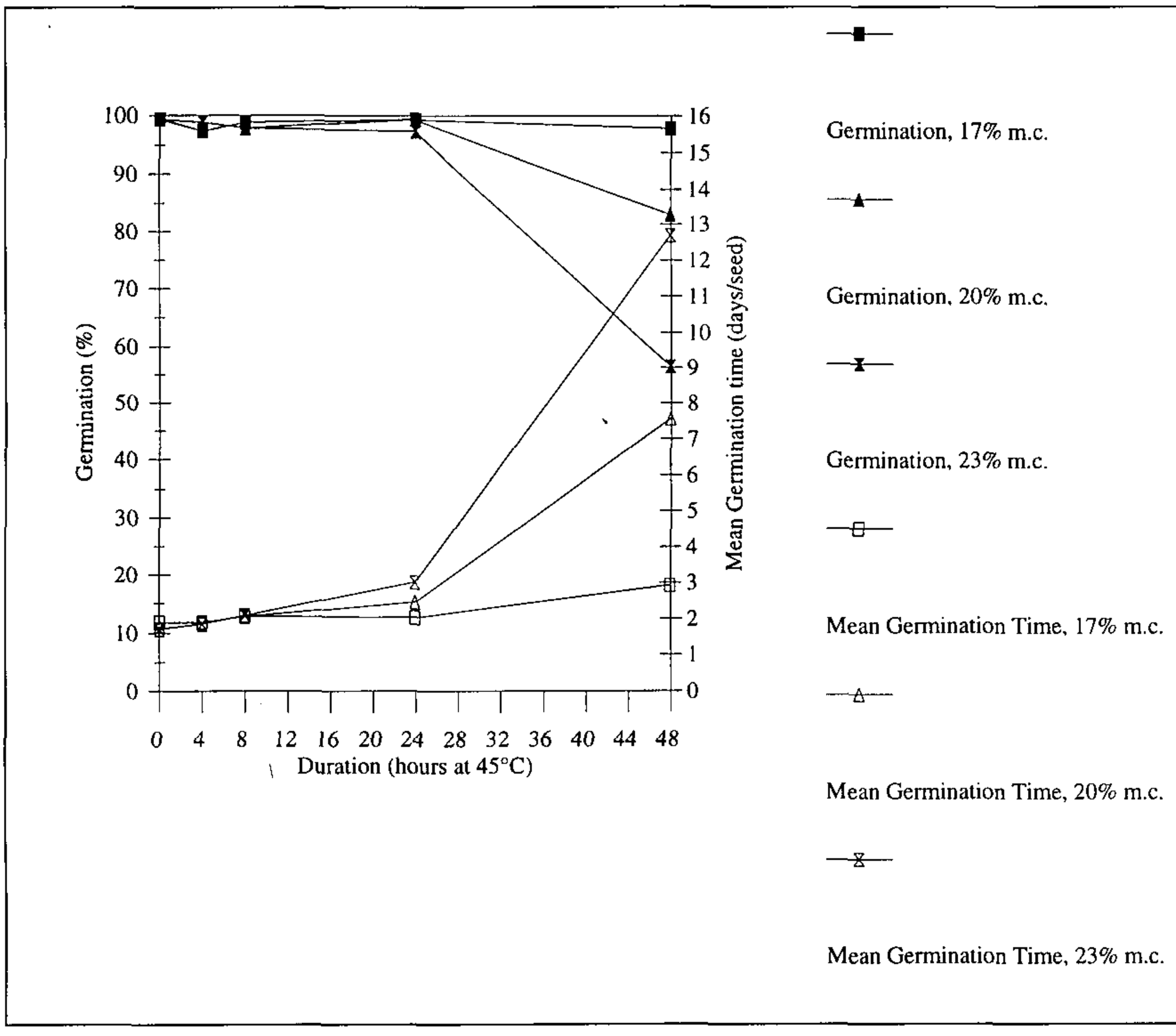

Figure 1. Relationship between germination, moisture content, and storage at 45C in oil seed rape. Germination percentage and mean germination time vs. duration of controlled deterioration.

be possible to rank the seed lots according to the expected field performance.

This project is, therefore, based on laboratory and field experiments.

MATERIALS AND METHODS

In the laboratory a preliminary experiment was carried out in order to select an appropriate stress treatment for the two seed species.

As temperature and seed moisture content during seed storage are very important factors controlling the speed of seed aging, these two factors and the duration of the treatments where factors used to accelerate aging of the seed lots. An appropriate level of stress would be where germination capacity is reduced considerably — without killing all seeds — in seed lots of low vigour, while germination capacity of seed lots of higher vigour would be less affected by the treatment.

With this testing procedure it will be possible to obtain distinct differences in germination percentage in a subsequent germination test. The germination percentage of the seed lots after the stress treatment will be used as a basis for ranking the seed lots according to vigour.

In order to find appropriate levels of temperature, moisture content (MC), and duration of the treatment an experiment was carried out with a seed lot of oil seed rape and peas, both seed lots were presumed to be of high vigour.

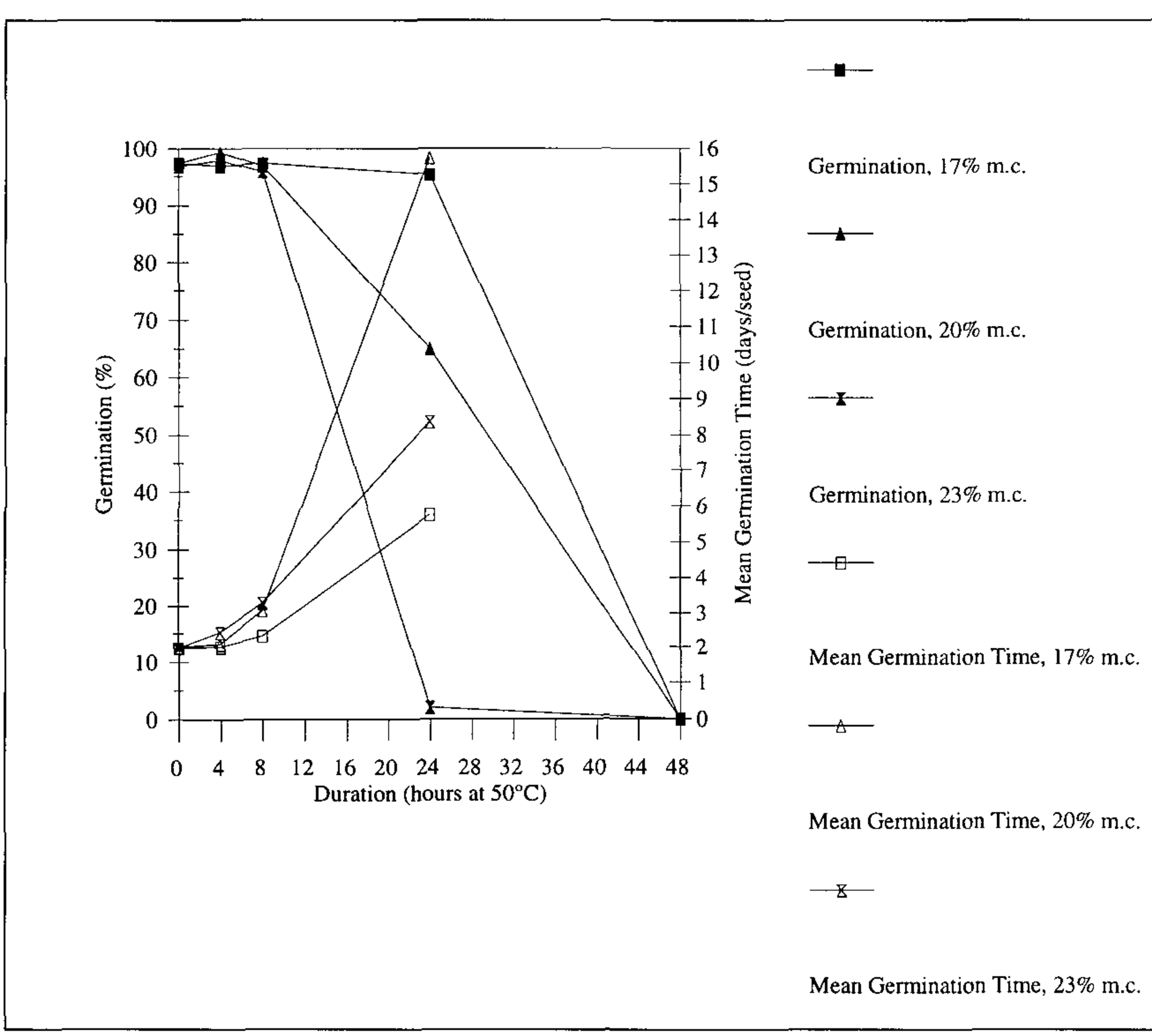

Figure 2. Relationship between germination, moisture content, and storage at 50C in oil seed rape. Germination percentage and mean germination time vs. duration of controlled deterioration.

Samples were treated with factorial combinations of three moisture contents (17%, 20%, 23%), three temperatures (40, 45, 50C) and five durations (0 to 48 h).

Even small changes in temperature as well as in moisture content had a marked effect, as increased temperature and increased moisture content both gave reduced germination percentages and reduced germination speeds, as shown for oil seed rape in Figs. 1 and 2. It is, therefore, important to be accurate when raising the moisture content to the target level, as well as using an accurate temperature in order to give the samples the same level of stress and hence the same degree of deterioration.

On the basis of the preliminary results from various combinations of temperature and moisture content the standard treatment chosen for the vigour test was 20% MC and 45C for both oil seed rape and peas with a 0 to 48 h treatment for oil seed rape

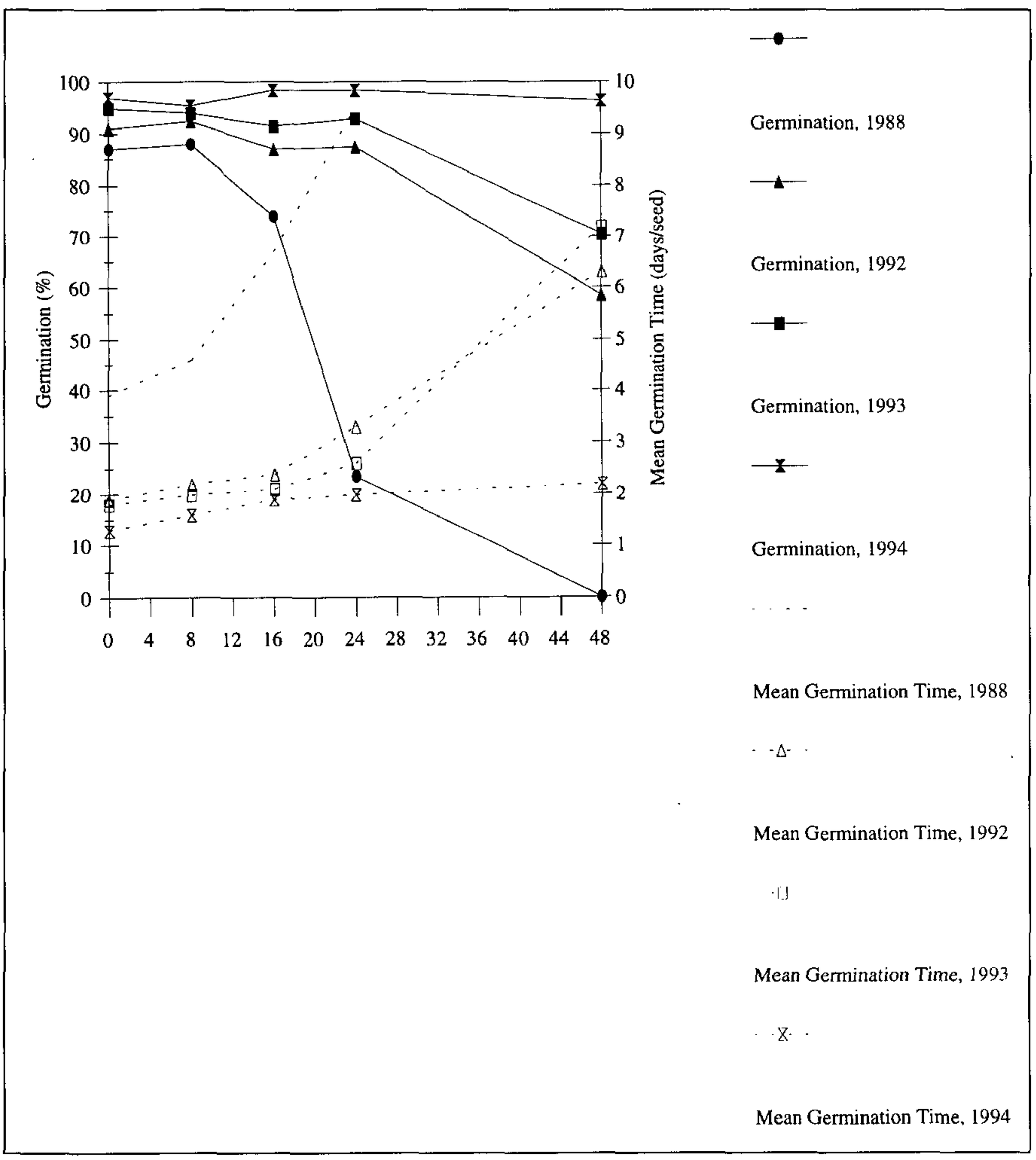

Figure 3. Controlled deterioration of oil seed rape — four seed lots of one cultivar, four different harvest years. Germination and mean germination time vs. duration of controlled deterioration at 45C, 20% MC.

and 0 to 96 h for peas. This standard treatment was applied to seed lots of different cultivars and within the cultivars to seed lots of different ages (naturally aged seeds with expected differences in seed vigour).

All the tested seed lots were sown in the field trials. During the growing season the following factors were evaluated:

- Date of seedling emergence
- Germination percentage
- Development stage
- Plant height
- Date of flowering
- Seed yield

RESULTS

The analysis of the results at present is not finished, but some results for four seed lots of one cultivar of oil seed rape will be presented.

The results of the vigour test of the four seed lots (laboratory results) are shown in Fig. 3. As expected the germination capacity and germination speed after the stress treatment were reduced more for the older seed lots.

Table 1 presents a comparison of results of the vigour test and the field trials for the four seed lots. There was a clear tendency for the oldest seed lot (from 1988) to perform more poorly in the field.

Table 1. Results of the vigour test and the field trials for four seed lots of different ages. All seeds are from one cultivar.

Seed lot (year of harvest)	1988	1992	1993	1994
Germination, standard laboratory test (%)	76	93	97	96
Germination after 24 h of controlled deterioration (%)	23.5	87.5	93	98.5
Field seedling emergence (days from sowing)	20.0	11.75	11.5	10.5
Field germination (% of total number of seeds)	67	76	89	84
Field germination (% of viable seeds)	89	81	91	87
Developmental stage 48 days from sowing (leaves/plant)	3.8	6.0	5.9	6.2
Developmental stage 62 days from sowing (leaves/plant)	6.2	8.2	8.5	8.4
Plant height 62 days from sowing (cm)	32.8	62.9	64.8	64.8

Germination as percentage of viable seeds, i.e. the number of seeds that would be expected to germinate according to the standard germination test, does not show any

obvious difference between the four seed lots. However, when looking at the development of the plants there is an obvious difference. Seeds of the oldest lot germinate more slowly, and even 2 months after sowing, plants of the oldest lot are still smaller and less developed than plants of younger seed lots. The difference is of such a magnitude that a difference in seed yield would appear likely.

These results for oil seed rape show that there may be considerable differences in seed vigour, and that seed vigour is of importance not only for initial plant growth but also for plant development later in the growing season. The results for peas did not show any clear tendencies, possibly because the selected seed lots did not differ markedly in seed vigour.

Since the results of the vigour test showed similar tendencies to the field trials in the ranking of the seed lots, it would appear that the vigour test in combination with controlled deterioration is of use for detecting differences in seed vigour in seed lots of oil seed rape. An analysis of the results, including results for seed yield in the field trials, may confirm this.

Germination and Priming

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The following paper will present some of the basic physiological mechanisms underlying the germination of orthodox seeds. The same mechanisms will be invoked in an attempt to explain "seed priming".

The most important physical/chemical factors influencing the germination process are the availability of water and oxygen and the influence of temperature. The following discussion will make reference to Fig. 1.

When dry seeds come in contact with a sufficiently humid substrate the seed will imbibe water very quickly if the seed coat permits it — this is called Phase 1. Phase 1 is a passive process and will happen also in dead seeds. The seed swells and the water content will level at a plateau. During the next phase, Phase 2 or lag period, the water content will only increase marginally. The duration of Phase 2 varies widely and is dependent on plant species. To a lesser degree it varies by seed lot within a species, however, it is differences in the length of this period between seeds within a lot that determines the uniformity of emergence of a particular lot. After this genetically and environmentally determined Phase 2 the water uptake enters the third and final phase, Phase 3. A sudden increase in water content is seen, which is timed exactly with the perforation of the seed coat by the radical. The consumption of oxygen takes more or less the same course as the water uptake. In Phase 3, after the protrusion of the radical, the consumption of food reserves raises dramatically as a consequence of the strong increase in general metabolism. In seed physiological

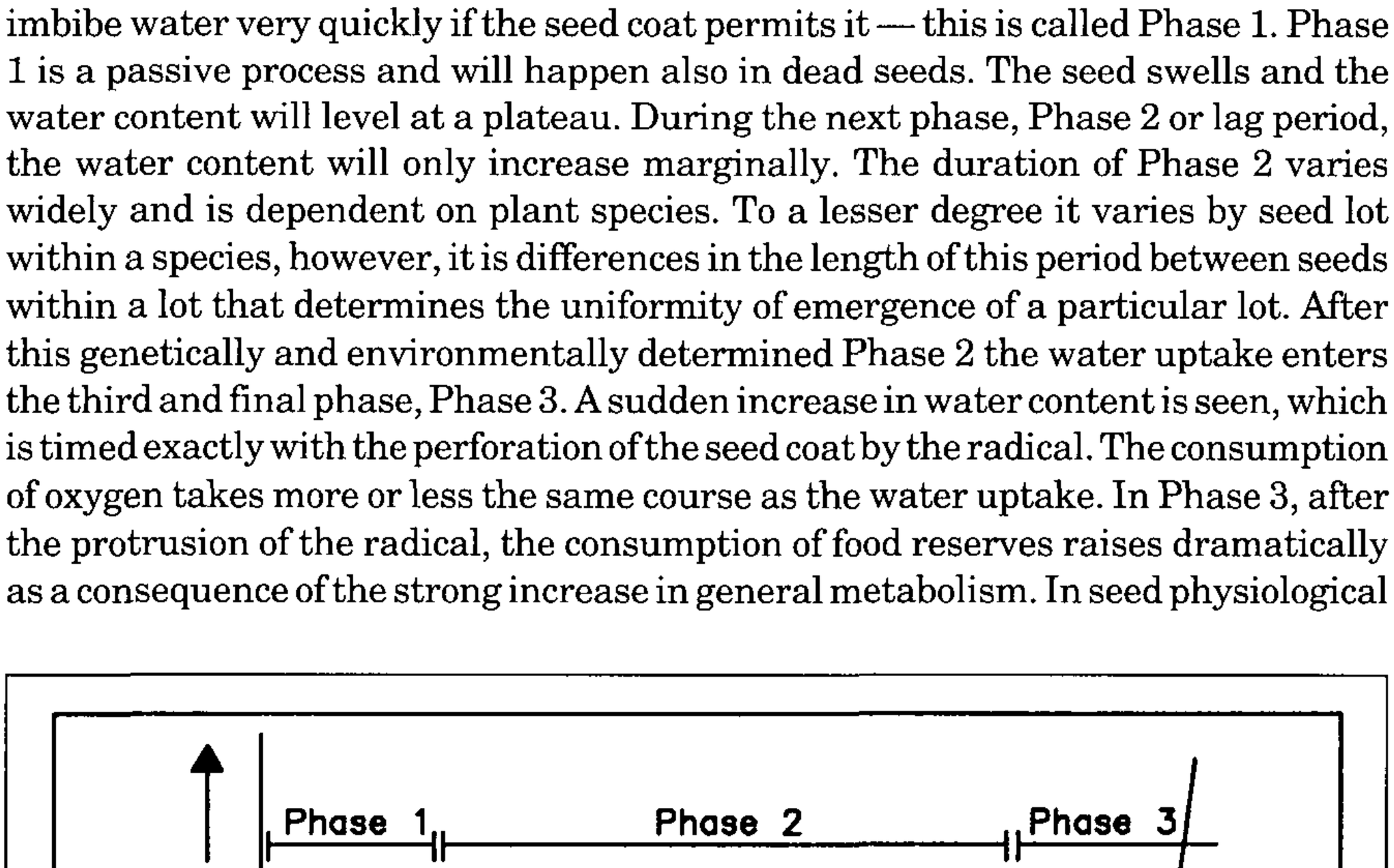

Figure 1. The germination process.

terms, Phase 2 is considered the germination per se, whereas Phase 3 is regarded as a post germination growth phase. This is not in accordance with commonly accepted nomenclature.

In Phase 2 all the cellular processes which are a prerequisite for successful plantlet establishment are initiated and completed. As the water content raises in the seed, the cellular membrane structures are reestablished and repair mechanisms can take place on damage incurred earlier as a consequence of poor seed management or just deterioration as the seeds age. Respiration is initiated, new proteins (enzymes) are formed and the osmotic pressure rises during Phase 2 as a consequence of the formation of simple sugars from more complex structures. To a larger extent, the degradation of the endosperm or other reserve materials takes place only in Phase 3. In the last part of Phase 2 a noticeable amount of DNA is formed, this is a prerequisite for cell division. No such division takes place before Phase 3, all growth, including the growth of the radical at "germination" is accounted for by cell enlargement only. It is the building up of the osmotic pressure within the radical cells which is the direct reason for the raise in turgor pressure which eventually culminates in the protrusion of the radical. In some species a concomitant relaxation of intercellular binding forces in the structures covering the radical (endosperm) is also seen.

It is a well known fact that there are large differences in the time from sowing to emergence between plant species. Likewise, differences can exist between single seeds in a lot. It is also known that temperature is influencing the germination/ emergence rate as is the water relations of the substrate. As mentioned they are all factors influencing Phase 2 of the germination process. The relations with respect to temperature and water relations has been quantified in the following equations:

1) $\Theta g = (T - Tb) tg$

where: Θg is the temperature sum / day degrees necessary for g%, germination
T is the actual temperature
Tb is the minimum temperature for germination
tg is number of days to g% germination

and

2) $\Theta h = (\Psi - \Psi bg) tg$

where: Θh is the so-called hydro time constant
Ψ is the water potential of the substrate
Ψbg is the minimum water potential that allows for g% to germinate
tg is the number of days to g% germination

This brings us now to a discussion of seed priming. The purpose of priming is to enhance the emergence of the seeds in a more uniform way under more diverse environmental conditions such as high or low temperatures and/or suboptimal substrate water conditions. The priming process influences all the mentioned cellular processes in the seed during Phase 2. In a physiological way you can say that the seed has germinated. Phase 2 takes place under controlled conditions in a time sufficient to allow the germination processes to come more or less to an end. At the same time the seed water content is kept low enough to hinder radical protrusion. This allows for an extended priming period, which should result in a more uniform

emergence. It has been shown that priming does not lower the basic temperature for a certain species for germination. The effect is rather seen in a decrease in the need for day degrees or heat sum after priming as the seeds in effect have "used" a certain amount of the needed "temperature time" during the priming process. The same effect is seen with respect to "hydro time". The seeds have "used" some of the necessary hydro time sum during priming. It is less often seen that primed seed has obtained a lower minimum water potential for germination, in fact, primed seed cannot in general be said to be able to germinate under drier conditions than unprimed seed.

THE MECHANICS OF PRIMING

To have the maximum benefit of the treatment it is necessary to find the combination of water content, treatment time, and treatment temperature that best achieves your goal. There are at least three possible methods to achieve the desired seed water content:

Osmotic Priming. The seeds are held in an osmotic solution under constant agitation during which a predetermined amount of water is taken up by the seeds. The correct osmotic potential is determined experimentally; temperature and time are important variables. After treatment the seeds are washed and dried back to their normal storage water content. This method is the oldest but is not convenient for large quantities of seed because of oxygenation problems and the large amounts of osmoticum which must be discarded.

Matrix Priming. The seed is mixed with a suitable carrier of fine consistency and water in such a way that the seed imbibes a predetermined amount of water. The technique is quite simple and is in fact analogous to what happens when seeds are sown in a medium too dry for germination — the water uptake is limited. The method is rather new and patented in a number of countries by Kamterter Products in Nebraska, U.S.A.

Drum Priming. This is the newest and best method for the treatment of seed in large quantities. This method is also patented in some European countries and U.S.A.

Due to the above mentioned patent we at Dæhnfeldt have developed our own method which is based on the same principles which hold for all the above methods: To add to the seed a predetermined amount of water (this allows cellular germination processes to take place without radical protrusion), hold the seed at this water content for a specific time period at a specific temperature, and then dry the seed back to normal water storage content.

Storage of Orthodox Seeds

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Seeds have an unique position in the world of plant propagation because they can be dried down and stored for long periods of time. This makes seeds ideally suitable for long-term storage (gene bank preservation) and the shipping of plant materials. The oldest recorded living seed is about 240 years old. This seed is from the species *Nelumbo nucifera,* however, there is doubt about the dating of this seed. In addition, we have other reports of germinable seeds about 100 to 150 years old. For tree seeds, companies are not interested in storing for more 10 to 20 years.

Seeds suitable for storage can be divided into two groups. One group, orthodox seeds, is desiccation tolerant and suitable for storage. The second group is desiccation sensitive and therefore very difficult or impossible to store. The desiccation sensitive seeds are called recalcitrant seeds.The largest group is the orthodox seeds and the following paper will only address these kinds of seeds.

Many different conditions influence the storage of seeds, but two issues are of great importance — seed moisture content (MC) and storage temperature.

MOISTURE CONTENT IN SEEDS

Seeds are hygroscopic, and as such there water content will be a balance between there MC and the relative humidity (RH) in the air. Interactions between seed MC and RH in the air are normally presented as graphs called sorption isotherms. Investigations of MC at different RH have shown that all water in seeds is not bound with the same strength. The water in seeds can normally be divided into three types.

1) Bound water (about 3% to 8% MC in seeds)
2) Less tightly bound water (about 8% to 14% MC in seeds)
3) Mobile or free water (about 14% to 40% MC in seeds)

In order to remove bound water it is necessary to have a RH close to 0% and still it will be difficult and occur very slowly or not at all. The less tightly bound water can exist over a broad range of RH (about 20% to 60%) and it is in this MC that seeds have to be dried down for long-term storage. The mobile/free water is much more loosely bound and little change in RH can result in important changes in the seed MC.

DIFFERENT RELATIONS FOR WATER IN SEEDS

- MC in seeds is always measured on a fresh-weight basis
- MC in matured seeds is in the range of 10% to 30%
- MC in fully imbibed seeds is between 35% and 45%
- Orthodox seeds can be dried down to a very low MC (2% to 6%) without loosing germinability
- At a MC lower than 8% to 9% their will normally be no insect activity
- At MC lower than 10% to 12% their will normally be no fungal activity
- At MC lower than 8% to 10% the respiration will be very low
- At MC of about 14% to 16% heating can occur

From the U.S.A. we have the following "rule of thumb". For each 1% decrease in MC in seeds between 5% to 14% MC, the life of the seed is doubled. The optimal moisture content for seeds in airtight full containers for long-term storage is about 4% to 8%.

THE TEMPERATURE AT STORAGE OF SEEDS

Temperature is another important factor in the storage of seeds. There is a relationship between MC of seeds and temperature in the long-term storage of seeds. Seeds with a high MC are much more sensitive to high and low temperatures

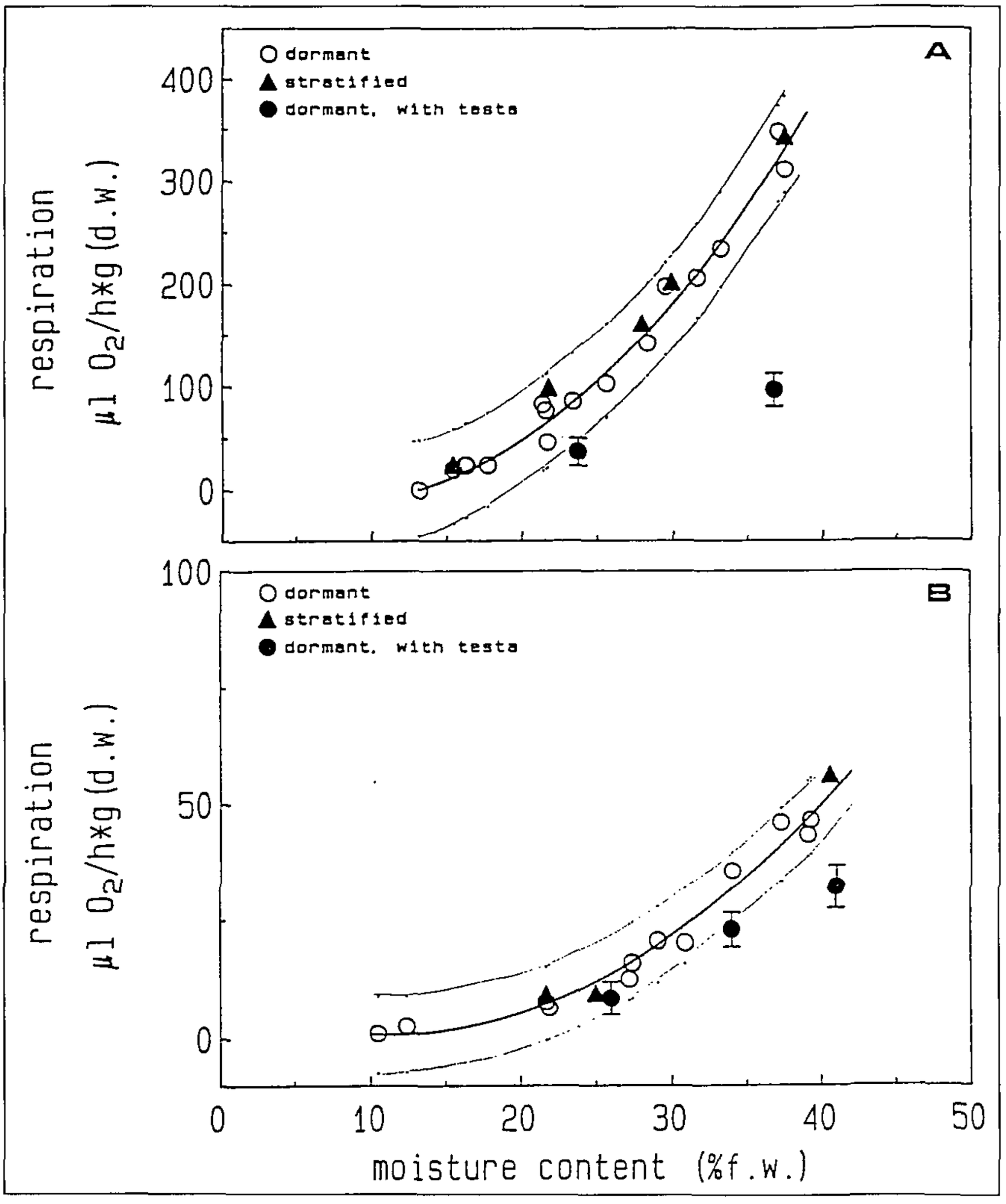

Figure 1. Relation between respiration and mosture content of embryos or seeds from beech nuts. Curves delimited by 95% confidence limits for prediction. Bars represent 95% confidence limits. Respiration at 25C and 4C in A and B respectively. (Poulsen, 1992)

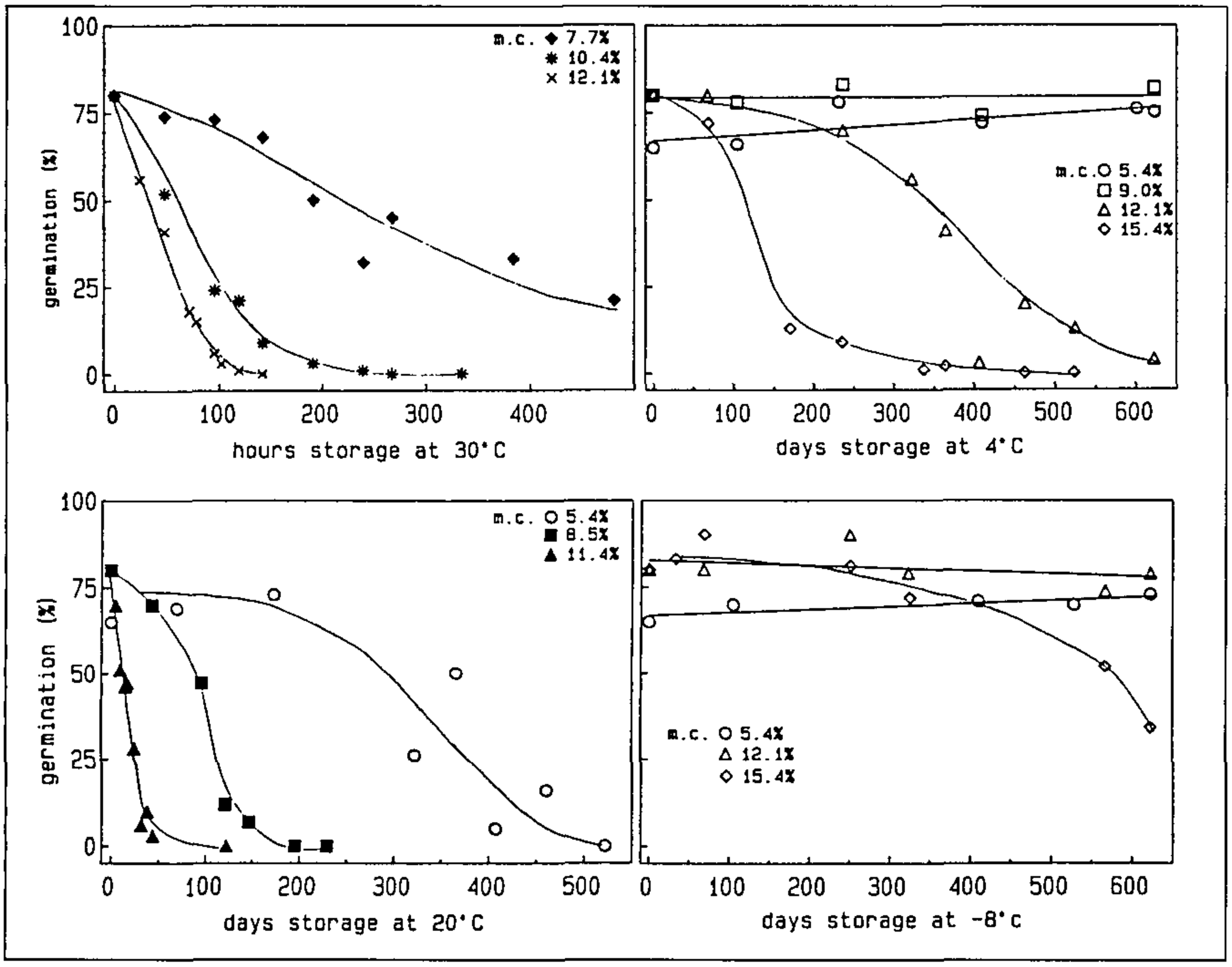

Figure 2. Survival curves for beech nuts (limited amount of the total data set shown). Seeds dried to 5.4% suffered a 'drying shock,' the initial germination percentage was reduced, consequently the survival increases. Lines fitted by linear regression, curves fitted by eye. (Poulsen, 1993)

than seeds with low MC. For example, seeds stored for a few days with a MC of about 30% will be damaged at temperatures above 25C during the drying process and at temperatures below -4C there will occur freezing damage. On the other hand, for seeds with a low MC, such as 10%, the same temperatures will not be injurious to the seeds.

Respiration in seeds is very sensitive to both high temperature and high MC. For seeds of *Fagus sylvatica* with a MC of 35% the respiration about doubles for about every 10C increase for temperatures between 4 to 25C (Fig. 1). Figure 2 shows a good example of how fast seeds can be destroyed when stored at high MC and at high temperature. Note that seeds stored at 30C only survive for hours.The danger of fungi attack also increases at higher temperatures and higher MC in the seeds. The optimal storage temperature for orthodox seeds is 0±2C in a container at low RH.

OTHER CONDITIONS INFLUENCING STORAGE OF SEEDS

Seed Quality and Viability. A seed sample with a low germinability and low vigour is not suitable for long-term storage, as dead seeds and low vigour seeds are much more sensitive to attack by fungi than high vigour seeds. Similarly seeds harvested at an immature stage or seeds damaged during grading and cleaning are also poor candidates for storage.

Genetic Conditions. Most orthodox seeds of tree species are suitable for long-term storage — normally for 5 to 10 years or more. Seeds with hard seed coats are particularly well suited for long term storage. These seeds are also called impermeable seeds and they are mainly seeds from plants belonging to the Fabaceae, i.e., *Acacia, Caragana, Cytisus,* and *Robinia.*

Another group, even though they are not recalcitrant seeds, are by nature not suitable for long-term storage. This group is characterized as having small seeds, which matured early in the growing season and the seeds are able to germinate immediately or only have a short dormancy. Examples of seeds in this group are *Betula, Populus, Salix,* and *Ulmus.*

Atmospheric Conditions. Long-term storage of seeds can not take place in the open, but must always be in closed containers. The use of inactive gasses to improve the seed longevity has been examined. The idea behind this treatment is to reduce respiration and thereby delay the breakdown of the seeds. The inactive gasses carbon dioxide (CO_2) nitrogen (N), Helium (He), Argon (Ar) plus vacuum have been tried.

In seeds with a low MC and storage at low temperature it is possible to obtain a minor promotive effect by using inactive gasses. If low MC and low temperature conditions are not used the inactive gasses can have a negative effect because they can induce anaerobic respiration in the seeds. Normally it will not be necessary to use inactive gasses for long-term storage of seeds.

Seed Size. Variation in seed size within a seed sample can influence long-term storage. Their is a clear interaction between seed density and suitability for storage. Seed with high density, e.g. well-filled seed, survives longer than light seeds. If storage is only for a few years there will hardly be any difference between small and large seeds. If the storage period is to the limit of survival, the small seeds often will die first.

Seed Chemical Composition. Food reserves in seeds are mainly starches, lipids, and proteins and the content can vary from a low percentage up to 40% to 60%. Tests with a large number of species did not show a correlation between long storage and high protein content. For starch it seems clear that increasing starch content prolongs the storage period. For lipids the correlation is not very clear, but there seems to be a tendency to decreasing storability. These correlations are based on a large number of species and it will be easy to find taxa which do not fit this pattern.

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Breaking of Tree Seed Dormancy at Controlled Moisture Content

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INTRODUCTION

In nature it is very common for seeds to have mechanisms that delay germination for shorter or longer periods. This delay or temporary inhibition of germination is often termed seed dormancy, and covers a range of different physical, chemical, and biological conditions in the seeds. More than 60% of Danish tree and shrub seeds have some kind of dormancy. In commercial production seed dormancy constitutes a major problem, causing losses of viable seed resources and reducing possibilities for optimizing the size of the production to the demand of the market.

In breaking physiological dormancy by a prechilling or cold stratification treatment, the seed has traditionally been fully hydrated and kept at a near maximum moisture content (MC), sometimes mixed with peat moss or sand, and prechilled at 2 to 5C for a time period required for the seed to initiate germination at the storage temperature. The duration of the prechilling treatment depends on the species and the seed lot involved and varies from a few weeks to many months.

The prechilling treatment is usually carried on until 5% to 10% of the viable seed has visible radicles and at this point the seed lot is either sown directly or stored for a short period at -2C to stop further germination of the lot.

A careful management of seeds prechilled by this method can provide good germination results.

WHAT IS THE PROBLEM?

The traditional method described above is based on a compromise and is quite sensitive to incorrect management. This means that the dormancy release of the seed lot cannot be fully optimized and even minor errors in management can produce major reductions in the potential of the seed lot to produce a good seedling stand.

Three factors in the behavior of tree seeds should be mentioned to understand this.

1) Many northern temperate tree and shrub seeds can germinate at temperatures close to 0C or even below this, and will germinate well at a prechill temperature of 3 to 5C.
2) Traditionally seeds are prechilled at full hydration, i.e. at a MC that allows germination of nondormant seeds.
3) The prechilling demand of individual seeds within a seed lot are not the same but can vary up to ± 4 to 6 weeks from the average prechilling demand.

The consequence of this is that both dormancy release and germination can occur simultaneously at the temperature and moisture content seeds are exposed to during the prechilling treatment. During the dormancy breaking treatment an increasing fraction of nondormant seeds will accumulate, which in turn will begin to germinate during the treatment. Germinated seeds with protruding radicles are

very susceptible to damage during seed handling and sowing, with great risk of killing the seed or producing poor seedling stands of inferior plant quality.

Storage of fully hydrated seeds with protruding radicles is very difficult for even short periods, and accordingly any radicle protrusion during prechilling should be avoided.

If prechilling is stopped too early, the prechilling demand of seeds with the deepest dormancy might not be satisfied and consequently these seeds will not germinate after sowing. A compromise of prechilling long enough to release as many seeds as possible from dormancy but ended early enough so that only a few seeds will germinate during the treatment is the goal.

European scientists have suggested that up to 30% of viable tree and shrub seeds are lost in production due to nonoptimal methods of breaking seed dormancy. To eliminate the above compromise in the dormancy breaking method, it is necessary to allow dormancy release to occur but eliminate the ability of the nondormant seeds to germinate during prechilling. This would provide a possibility of prolonging the prechilling treatment until all seeds were released from dormancy without any seeds being lost due to early germination.

One method of inhibiting radicle growth is to lower the seed MC to a level which just inhibits the elongation of root cells. This critical MC will allow most physiological and biochemical processes in seeds, such as prechilling or priming, to go on although sometimes at a lower rate than at full hydration.

HISTORICAL DEVELOPMENT

The effect of reducing the MC in seeds during prechilling has been known for some years. In 1973 the English scientist Blundell described prechilling of *Rosa corymbifera* 'Laxa' seeds at a controlled MC that inhibited germination but allowed dormancy release (Blundell, 1973). In 1975 the Polish scientist Suszka described a method of prechilling at controlled MC in *Fagus sylvatica* (Suszka, 1975). With conifers the effect of holding seeds at different MC during cold storage was studied in the 1960s and 1970s, but was first adopted into a practical usable method in the beginning of the 1980s (Edwards, 1982; 1986).

In Europe significant research on prechilling of tree seeds at a controlled moisture content (CMC) occurred in the 1990s (Jones and Gosling, 1994; Suszka et al., 1994). An EU (European Union) research project running from 1993 to 1996 investigated and developed this method on a number of tree species. The method is now used commercially on a large scale with a few species in a number of European countries.

PRECHILLING AT CONTROLLED MOISTURE CONTENT IN NEW SPECIES

To establish this method in a new species it is critical to obtain knowledge about the critical MC for germination — or rather radicle protrusion — in the species. This can be obtained easiest by testing the germination ability of prechilled, non-dormant seeds kept at different constant levels of MC and at the prechilling temperature for different periods. At the higher MC the seeds will germinate and the critical MC will be at the highest MC where germination is completely restricted.

The critical MC for germination often lies between 3% and 8% below full hydration and generally only varies a little between seed lots. The critical MC for germination describes the upper limit of MC where you can safely prechill your seeds without having premature germination.

It is then necessary to investigate at what MC you will have the optimal rate and most efficient release of dormancy given the above moisture limit. The MC interval just below the critical MC for germination is relevant to investigate. It is further important to compare the rate of dormancy release at full hydration to the method at reduced MC to be able to transfer the new method into application, with regard to the duration of the prechilling.

The optimal MC for prechilling by CMC is found by cold stratifying seeds at different MCs and durations. Samples are withdrawn at intervals, imbibed to full hydration, and tested for germination capacity and speed of germination at a temperature that clearly shows if the seeds are dormant or not. Depending on the species both high, intermediate, or low temperatures could be used in these tests. After having calculated germination capacity (GC) and mean germination time (MGT) or another parameter describing the speed of germination, the efficacy of the treatments can be evaluated as an improvement in GC or a reduction in MGT. The optimal CMC for prechilling can then be defined as the MC giving the fastest improvement in GC and MGT. The optimal CMC for prechilling often lies just below the critical MC for germination.

The critical MC for prechilling describes the lowest MC where you can obtain a positive effect of a prechilling treatment. This lower MC limit and the critical MC for germination delimits the "treatment window" for a CMC prechill. The theoretical effect of MC on prechilling and germination in tree seeds based on experience with a number of species is shown in Fig. 1. The shown moisture scale is arbitrary and actual values would depend on the species. It cannot, however, be ruled out that some species can show other types of reaction patterns with regard to the effect of MC during prechilling.

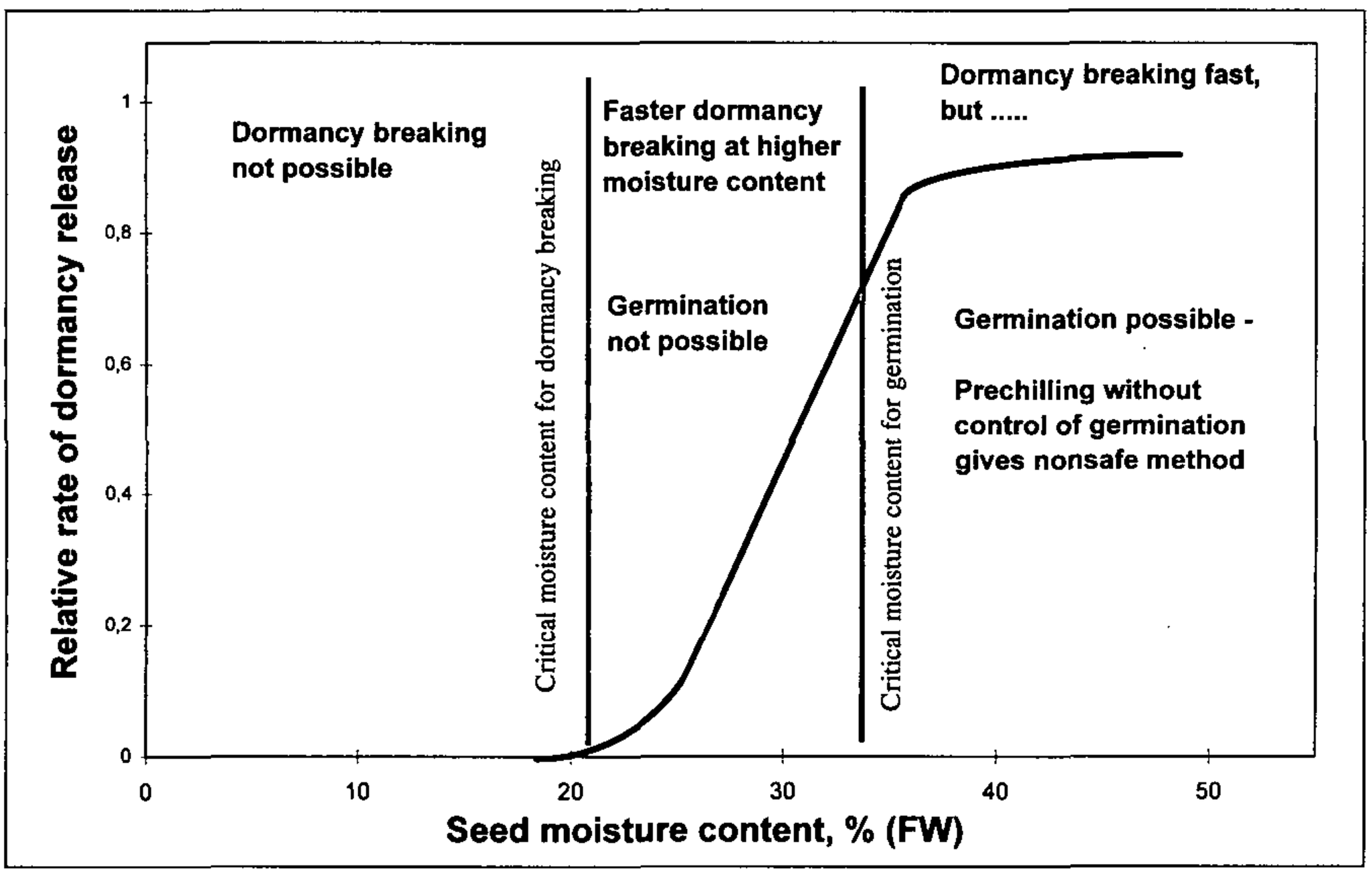

Figure 1. Theoretical effect of different controlled moisture content values during prechilling of seeds. The moisture interval between the two critical m.c. levels is the "treatment window", where dormancy can be released without having premature germination during the prechill. Critical moisture content levels vary between species.

HOW LONG CAN THE TREATMENT DURATION BE PROLONGED WITHOUT HARMING THE SEEDS?

Studies with a number of conifer species suggest that the CMC prechill can be prolonged significantly without reducing the quality of the seed, i.e. with no reduction in GC or MGT at optimal conditions (Derkx and Joustra, 1996; Jensen 1996; Jones and Gosling, 1994). Experiments with *F. sylvatica* and *Abies nordmanniana* showed that the duration of the CMC prechill should be almost doubled to obtain maximal benefit of the treatment. Other experiments show that prolonging the CMC prechill significantly longer than traditional treatment durations will reduce both GC and MGT (Suszka, 1994). The prechill period should therefore only be continued until no further improvements in GC or MGT is seen. At this point the seeds should either be sown or kept at -2C for short-term storage. If it has been shown that seeds of a species can be dried back and stored after being prechilled at CMC, this could be a third option.

The optimal duration of the prechill treatment is related partly to the level of dormancy in the seeds, which varies according to the seed lot, year of harvest, and processing method, and partly to the rate of dormancy release which is affected mainly by the prechilling temperature and seed moisture content. A low quality seed lot usually has a shorter optimal duration of the prechill period than a high quality seed lot. Therefore, a general treatment duration can not be listed for individual species. The theoretical effect of the duration of the prechill period on the speed of germination (MGT) is shown in Fig. 2. The average optimal prechill duration at optimal MC will often be a few weeks longer than the duration of a traditional prechill of fully hydrated seeds. It is recommended that a small sample of the seed lot be tested for the optimal duration of the treatment before scaling up. Individual

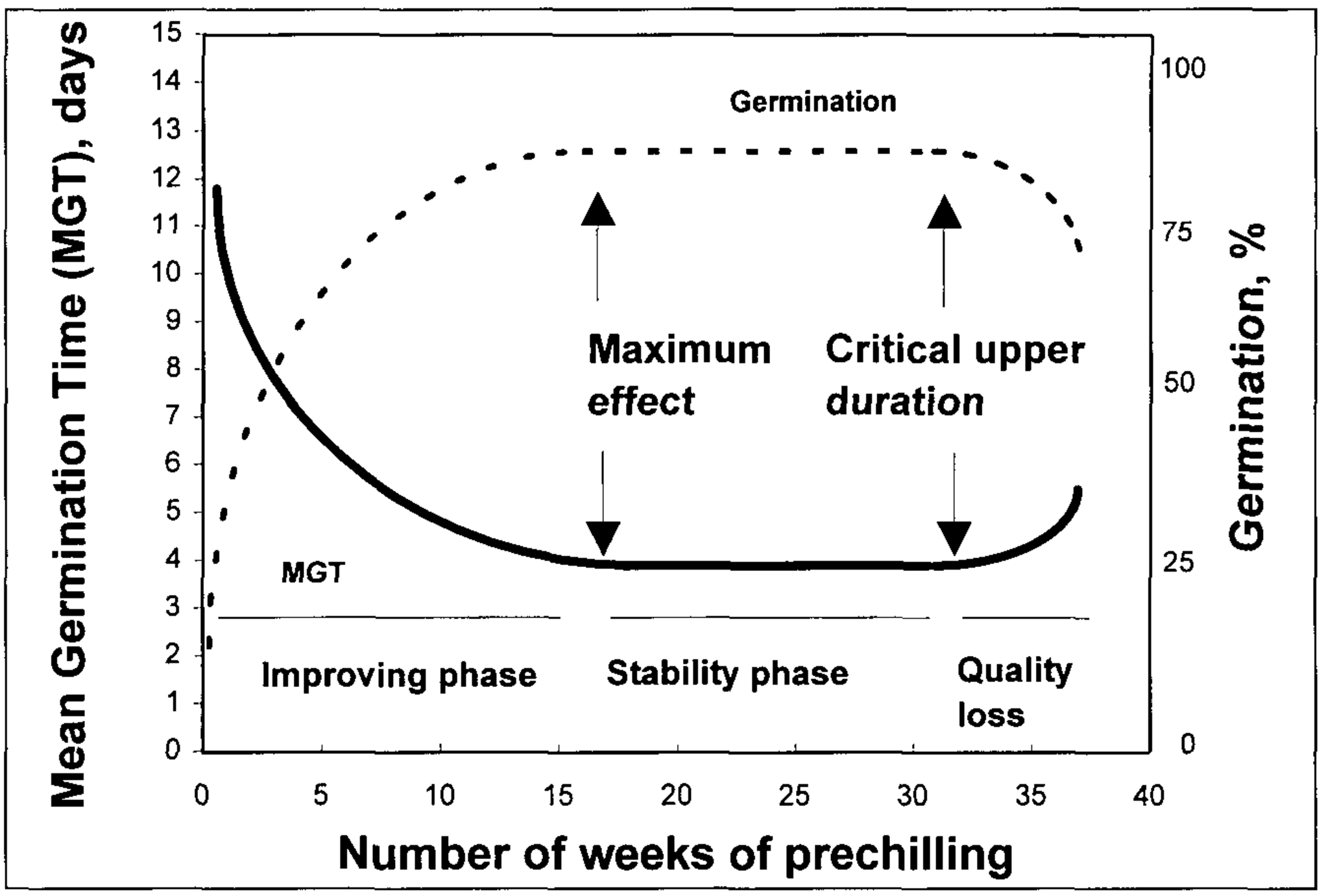

Figure 2. Theoretical effect of a prolonged prechill at controlled moisture content on the germination capacity and mean germination time. Absolute levels of GC, MGT, and prechilling duration varies between species.

growers should also test this method on the specific seed lots they use in order to develop a standard procedure adjusted to their seed provenances and nursery practice.

In summary, the basic knowledge necessary to develop a controlled moisture content prechill for a new species requires the following three tasks:

1) Establishment of the critical MC for germination (radicle protrusion) by investigating the effect of different levels of MC on the germination ability of seeds at 2 to 5C.
2) Establishment of the optimal MC for CMC prechilling by investigating the effect of different MC levels just below the critical MC for germination on the rate of and final level of improvement in GC and MGT.
3) Establishment of the optimal duration of the CMC prechill by investigating the effect of different prechill durations at the optimal MC on the level of improvement in GC and MGT.

The primary advantage of using CMC prechill is that seeds will not be able to initiate radicle protrusion during the prechill treatment. This means that the duration is not as critical as in the traditional method, thereby reducing the need for intensive monitoring during the last weeks of prechill and reducing or eliminating the risk of loosing seeds due to premature germination. The method provides an opportunity to obtain optimal germination capacity by prolonging the prechill treatment until all seeds have been released from dormancy.

A prolonged prechill treatment also enhances the speed of germination and the synchronization of germination of individual seeds in a seed lot which provides a much better starting point in production. Seeds which are sensitive to induction into secondary dormancy by high temperatures, e.g. *Prunus* spp., become less sensitive to high temperatures when the prechilling treatment is extended. The CMC prechill

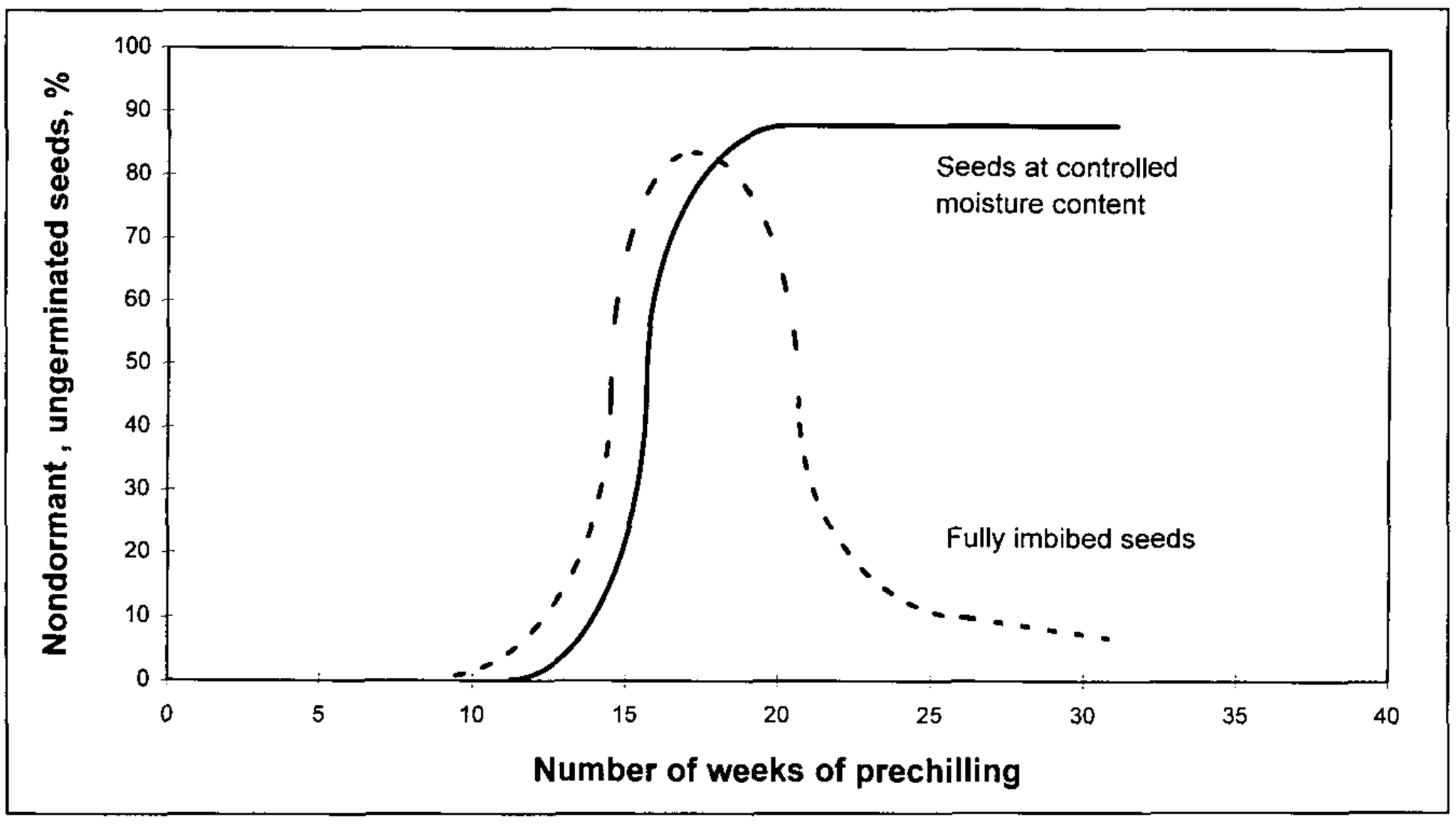

Figure 3. Theoretical changes in the number of nondormant but ungerminated seeds during a controlled moisture content prechill or a traditional prechill at full hydration. At full hydration seeds begin to germinate during the prechill. Germinated seeds are often damaged during sowing and retain little ability to produce normal seedlings.

method accordingly provides a unique possibility for reducing the risk of induction of seeds into secondary dormancy.

The method also adds flexibility to the sowing time as the CMC prechill can be extended without reducing germination potential of the seed lot. Seeds are generally surface dry and free-flowing during a CMC prechill. This means that the rate of growth of fungal hypha at least on the surface of the seeds is reduced significantly. The relatively high MC in the seeds may, however, provide opportunity for fungi to proliferate within the seeds.

The CMC method is superior to the traditional method mainly because it provides much better control of biological processes during the prechill treatment which in turn improves our ability to optimise the dormancy release process. The theoretical difference in dormancy release and premature germination during a prechill treatment of CMC prechilled seeds and traditionally prechilled seeds at full MC is shown in Fig. 3.

CONTROLLED MOISTURE CONTENT PRECHILL IN INDIVIDUAL SPECIES

As the critical MC for germination and the optimal CMC for prechilling varies with the species, it is necessary to investigate and develop the method for each new species.

Literature that describes the effect of seed MC on the biological activity of the seeds including the ability to germinate would provide a sound basis for choosing relevant moisture content levels for investigations on CMC prechill in new species. Table 1 provides a summary of MC levels or intervals reported in the literature to restrict germination but allow dormancy release to occur. The results are from investigations on either prechilling or priming/invigoration of tree and shrub seeds. As minor variations in optimal MC would be expected due to differences in provenances, etc., the data should only be used as a guideline when developing protocols for any particular seed lot.

WHAT WILL FUTURE RESEARCH AND DEVELOPMENT BRING?

Only a small number of species have been investigated so far and the method is only used commercially with a few species in Europe. However, in those species there are still a number of problems remaining that need to be studied in future research.

As the development of the CMC prechill method in a new species, using the above described scientific approach, is costly and time consuming it will be difficult to adapt the CMC prechill concept to all tree and shrub species propagated by seed. It is, therefore, of great interest to develop a fast, easy, and less expensive protocol for establishing the optimal CMC prechill in new species.

Potential similarities in reaction patterns and optimal moisture contents for prechilling of closely related species should be used as a basis for predicting CMC values in new species. In addition to this a general understanding of the relations between the biochemical composition of the seed, barriers to water transport, and MC or water potential of the seed would significantly improve the ability to predict optimal MC. With knowledge on the content and character of the main biochemical compounds (e.g. lipids, proteins, carbohydrates) and the distribution of these and water within the principal seed tissues controlling germination and dormancy release, it should be possible from moisture sorption/desorption references to predict more precisely the critical MC of interest.

Table 1. Seed moisture content or moisture intervals found to restrict germination but allow dormancy release or priming to occur.

Species	Critical moisture content %FW	Reference
Abies amabilis	30	Leadem, 1986
A. amabilis, grandis, lasiocarpa	30-35	Edwards, 1982; 1986
A. lasiocarpa	30	Leadem, 1989
A. nordmanniana	33-34	Jensen, 1997
A. nordmanniana	28-35	Poulsen, 1996
A. procera	30-34	Poulsen, 1996
A. procera	25-30	Tanaka and Edwards, 1986
Picea abies	30	Bergsten, 1987; 1989; 1991
P. glauca	30	Downie et al., 1993
P. glauca	22-30	Edwards, 1986
P. mariana	30	Downie et al., 1993
P. sitchensis	24-27	Poulsen, 1996
P. sitchensis	31	Jones and Gosling, 1994
P. sitchensis	27-30	Jones et al., 1991
P. sitchensis	25-30	Gosling and Rigg, 1990
P. sitchensis	25	Edwards, 1986
Pinus banksiana	30	Downie et al., 1993
P. contorta	35	Jones and Gosling, 1994
P. contorta	25	Edwards, 1986
P. strobus	30	Downie and Bergsten, 1991
P. sylvestris	30	Bergsten, 1987; 1989; 1991
Pseudotsuga menziesii	35-37	Derkx, 1996a
P. menziesii	32-34	Muller, 1996 (pers. comm.)
P. menziesii	35-36	Poulsen, 1996
P. menziesii	36-37	Jones and Gosling, 1994
P. menziesii	35	Edwards, 1986
Acer palmatum (fruit)	36-40	Derkx, 1996 (pers. comm.)
A. platanoides (fruit)	36-38	Derkx, 1996a
A. platanoides (fruit)	35-40	Suszka et al., 1994
A. pseudoplatanus (fruit)	44-50	Knudsen, 1996
A. pseudoplatanus (fruit)	48	Derkx, 1996a
A. pseudoplatanus (fruit)	44-50	Suszka et al., 1994
Berberis thunbergii	40	Derkx, 1996b
Fagus sylvatica (before storage)	30-32	Muller, 1996 (pers. comm.)
F. sylvatica (after storage)	32-34	Muller, 1996 (pers. comm.)
F. sylvatica	30	Derkx and Joustra, 1996
F. sylvatica	30-33	Knudsen, 1996
F. sylvatica	30-32	Suszka et al., 1994
F. sylvatica (before storage)	28	Suszka, 1975
Fraxinus excelsior (fruit)	55-60	Muller, 1996 (pers. comm.)
F. excelsior (fruit)	45	Derkx, 1996a
F. excelsior (fruit)	55-60	Suszka et al., 1994
Prunus avium (incl. stone)	27-29	Muller, 1996 (pers. comm.)
P. avium (incl. stone)	26-28	Knudsen, 1996
P. avium (incl. stone)	28-30	Suszka et al., 1994
Syringa vulgaris	40-45	Derkx, 1996 (pers. comm.)
Tilia cordata	40	Derkx, 1996 (pers. comm.)

In order to be able to provide growers with pretreated, nondormant seed it is important to be able to redry and store prechilled seeds. Shipment of pretreated seeds over great distances is largely dependent on this ability, since hydrated seeds are very sensitive to conditions during transport.

In a number of species, mainly conifers, drying of pretreated seeds can be done without damaging the seeds. In other species drying has been shown to reduce speed of germination or even partly reinduce dormancy in pretreated seeds. Some species seem to have lost their desiccation tolerance and storage ability after a prechill and will not survive drying. The loss of tolerance to drying could be caused at least partly by the pretreatment conditions. A prolonged treatment and especially too high MC during prechilling will potentially allow the seed to initiate the early phase of radicle protrusion, which is often associated with a loss of desiccation tolerance and storage ability. Indeed, prechilling at slightly reduced CMC values has in some species been found to conserve the desiccation tolerance and make drying possible (Muller, pers. comm.). At the moment practical experience on the optimal duration of a CMC prechill or the use of a reference sample CMC prechill test are the only methods to assess the optimal treatment duration in a seed lot. A quick, easy and nonexpensive biochemical or immunological test for assessing the level of dormancy in a seed lot or its potential for fast and complete germination would be of great advantage in future optimization of prechilling. Even if significant progress in prechilling of tree seeds has been made many important questions still remain to be answered in future research.

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Controlled Moisture Content During Release of Dormancy in Tree Seeds — Large Scale Handling

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The Tree Improvement Station (TIS) is part of the National Forest and Nature Agency under the Ministry of Environment and Energy. TIS has three main objects:

- Seed supply to the Danish forestry, both state and private nurseries and forest districts;
- Nursery production of plants to the Danish state forest districts;
- Tree improvement in order to secure seed supply of the best genetic material in the future by establishing seed orchards and seed stands in a great variety of forest tree species. Furthermore TIS has a close cooperation with Danida Forest Seed Centre in seed testing of tropical tree species and in projects in developing countries.

The release of dormancy is in many tree species necessary in order to achieve germination. In nature this is taking place during the winter under the cold and humid conditions on the forest floor. This has been copied and improved by nurserymen over the years. Seeds have been collected and placed in cold storage where dormancy is released at low temperature and high moisture content. The problem with this method is that the seeds sometimes begin to germinate at an awkward time (normally before sowing is possible). In addition, the seeds will be sown when 5% to 10% of the seeds have started to germinate; this means that perhaps only 30% of the seeds have been released from dormancy.

TIS has since 1992 been breaking dormancy in beechnuts (*Fagus sylvatica*) on a large scale and in addition has been working with *Prunus avium, Acer pseudoplatanus* (in commercial seed lots), and *Abies nordmanniana* (in large-scale tests).

In all species, seeds have been placed in net trays (seed layer 5 to 8 cm) and the moisture content has been raised from storage moisture content to the moisture contents given in the table below by spraying the seeds with water and mixing the seeds manually. This was repeated three to four times to reach the target moisture content. During pretreatments seed were mixed manually every 2 weeks to keep a uniform moisture content in all the seeds and to avoid spread of fungal attacks. The moisture content was measured weekly.

This pretreatment has been carried out successfully yearly since Spring 1993 with *F. sylvatica*. The average quantity of seed was 3500 kg per year.

For *A. pseudoplatanus* and *P. avium* we have found big differences in the germination capacity after pretreatment depending on the seed lot. Poor results in some seed lots were due to pretreatment periods that were too short. The quantities of seed pretreated were 200 kg (*Acer*) and 100 kg (*Prunus*) per year.

Abies nordmanniana has been tested on two seed lots of 40 kg each. The standard pretreatment is 6-weeks cold-wet stratification. For both seed lots we found no difference in germination capacity and speed of germination between the standard method and the method using reduced moisture content. Furthermore we found no effect from increasing the pretreatment with reduced moisture content to 10 weeks.

The next step will be to try to minimize the hard physical labour in connection with the manual mixing of the seeds.

The results so far has encouraged us to continue using this pretreatment with controlled moisture content on other species. We are at the moment testing this method on several broadleaf and conifer species.

Table 1. Pretreatment using controlled moisture content.

Species	Moisture content (target) (% FW)	Duration
Abies nordmanniana	30 - 33	6 - 10 weeks
Acer pseudoplatanus	44 - 50 (50-58 in seed)	x[y] + 2 weeks (10 - 12)
Fagus sylvatica	30 - 32	x + 2 weeks (8 - 18)
Prunus avium	27 - 30	18 - 26 weeks[z]

[y]The factor x is the number of weeks of prechilling of a reference sample kept at full hydration until 10% of the seed is germinated.

[z]2 weeks 25C + 2 weeks 3C + 2 weeks 25C + 12-20 weeks 3C.

Machine Grafting of Grapevines using the Spinks Grafting Machine

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INTRODUCTION

Sunridge Nurseries, Inc. is a wholesale grower of grapevines for the fresh market and primarily for wine grape production. Our production includes:

- Bench-grafted vines grown in the nursery in 2 in. × 2 in. × 10 in. deep tubes and sold as green plants for transplanting in spring and summer.
- Bench-grafted vines grown in the nursery, transplanted into an outdoor field nursery row, and dug in winter for sales as dormant vines for early spring transplanting.
- Rootstock rootings that are stuck directly into outdoor field nursery rows in late winter, grown for one season, and dug in winter for sales as dormant vines for early spring transplanting. These vines are field grafted 1 year after transplanting into the vineyard.
- Softwood mist-propagated varietals and rootstocks grown in 4-in. pots or 2 in. × 2 in. × 10 in. deep tubes for sales as green plants for transplanting in spring and summer.
- Hardwood propagated varietals and rootstocks grown in 4-in. pots or 2 in. × 2 in. × 10 in. deep tubes for sales as green plants for transplanting in spring and summer.

PURPOSE

This presentation of machine bench-grafting of grapevines demonstrates how the Spinks grafting machine can produce a very tight graft union with a very large surface area of cambium mating between the rootstock and scion. The demonstration shows how each side is cut and how fast this machine can produce a consistent, high-quality graft.

METHODS AND PROCEDURES

Wood to be used for grafting is harvested while dormant in December. Wood is selected that is straight and within a size tolerance of 5/16 to 7/16 in. When harvested, the wood is cut to 14 to 16 in. long and bundled in groups of 100. The wood is dipped in 1% Hasa-chlor solution, then packed in moist fir shavings in bins for cold storage until needed.

Prior to grafting, machine blades are checked for sharpness and adjusted so the cuts for the scionwood and rootstock wood mate perfectly. The rootstock wood is disbudded. The scionwood and rootstock wood is warmed (if necessary for the variety) and soaked in water for 24 h. All materials, supplies, equipment, surfaces, and hands are sterilized prior to grafting. All wood is inspected at each of the following steps for damage and/or abnormality:

1) Rootstock
   - The base is recut 1/2 in. below a bud.
   - The distal end is cut "straight and square" to the proper length in the internode zone.
   - The distal end is cut in the machine level and straight with any flat side of the stem horizontal.

2) Scion
   - The base is cut 1-1/2 in. below a viable bud "straight and square".
   - The distal end is cut on a diagonal 1/4 in. above the bud.
   - The basal end is cut in the machine level and straight with any flat side of the stem horizontal.

3) Assembly
   - All wood is resoaked.
   - Since the machine cut leaves a frayed side, both the scion and rootstock sections must have the frayed side mated when assembled.
   - The scion and rootstock wood is mated based on caliper so maximum cambial contact is made.
   - The "fit" is checked so the scion and rootstock graft holds itself together (no taping is done).
   - The wood is resoaked again for a few minutes after assembly.
   - The bench-grafts are then laid in a bed of moist, sterile peat moss for callusing. After 18 to 24 days at 85F, the grapevines are ready for planting.

Rose Budding with T-Bud Technique

Bruce Frost
Bear Creek Production Co., P.O. Box 280, Wasco, California 93280

PRE-BUDDING CARE

A pre-plant fertilizer (8-8-8 at 30 gal per acre) is shanked (drilled) in on both sides of where the hardwood cuttings are planted in November. The cuttings are kept watered on a weekly basis until budding time in early April. By then we have 12 in. or more shoot growth and good root development.

BUDDING

The budwood is cut in November and stored at 30F until spring. We use the T-bud technique with a rubber strip 5 in. × 9/32 in. × 0.016 in. tied two wraps below the bud and three above. The bud is cut with a small portion of wood left behind it. The budders and tiers use 4-wheeled carts to position themselves for budding 2 in. above the ground. The budder/tier teams can bud and tie approximately 4000 plants per 8-h day.

POST-BUDDING CARE

The rootstock is kept actively growing before, during, and after budding to keep the bark slipping and to facilitate healing of the callus. Within 10 days the bud is well connected. Thirty days after budding we fertilize with 8N-8P_2O_5-8K_2O at 85 gal per acre. Forty days after budding we break the top over by cutting partially through the cane 1 in. above the bud and pushing the top over. The top acts as a nurse limb while the bud shoot is forced to start growing. The bud shoot is called a maiden and is allowed to grow along with the broken top, until January when the top is removed and the maiden is cut back to 1/2 in. The bush is grown for another year.

Giant Sequoia in the Sierra Nevada

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The ecology of giant sequoias has been a subject of intense interest for the last three decades. Fire, mycorrhizal fungi, squirrels, and insects have essential roles in the survival of the sequoia forest. Managers must implement strategies to create natural conditions in areas overprotected from naturally occurring processes. Pre-Euroamerican forest species and natural processes are the management goals of restoration.

HISTORY

Giant sequoias (*Sequoiadendron giganteum*) have evoked a sense of awe and wonder since the time of their discovery by Euroamericans in 1933 and again in 1952, when their "discovery" was more widely publicized (Harvey et al., 1980). Giant sequoias have been in the Sierra Nevada for thousands of years increasing in abundance since approximately 4500 years ago. After thousands of years of evolving in the microclimates of 75 disjunct groves the big trees faced a century of differing views on their ecology and management. Most of the 75 naturally occurring sequoia groves occur in the southern Sierra Nevada, south of the Kings River (Rundel, 1972). The "big trees" created visions of utilitarian usage in some groves and preservation enclaves to others. Approximately 92% of the sequoia grove area is in some form of public ownership primarily managed by the U.S. Forest Service and the National Park Service.

PUBLIC VALUES

The use and preservation of these forests has always been an arena in which public values are discussed and played out in implementation of specific management plans. The "big trees" are perceived differently by the public than other trees in the forest. *Members of the public tend to perceive sequoias as unchanging, sacred objects, not as* dynamic members of evolving ecosystems. The sequoias had the power to motivate American citizens to reject the political norms of the mid-19th century, which was at the height of the expansionist-pioneer era selling government lands for a minimal price and direct Congress to set aside the Mariposa Grove and give it to the State of California to be managed in perpetuity for preservation and recreation (Tweed, 1994). In the mid-1980s, timber managers on the Sequoia National Forest decided it was time to log within the uncut groves of giant sequoia, but after public outcry the Forest Service concluded a mediated settlement that insured there will be no commercial logging within the groves and the Forest Service will prepare a management plan for each grove aimed at restoration and regeneration.

SEQUOIA MANAGEMENT

Sequoia, Yosemite, and Grant Grove (now Kings Canyon) National Parks were preserved in 1890 as part of the efforts of the American public to protect giant

sequoias. During this era of protection, logging and naturally ignited fires were suppressed. Throughout the early 1960s no significant fires, human or lightning-caused, had burned in any of the groves of the three parks (Parsons, 1990). In a 1963 report to the Secretary of Interior, a Special Advisory Commission on National Parks warned that continued fire suppression would cause an increase in hazardous fuels and change plant and animal communities in the conifer forests of the Sierra Nevada (Leopold et al., 1963). This committee stressed the ecological complexity of the national parks and implied that a more thorough understanding of each area was necessary in order to effectively manage them. Beginning in the early 1960s, the National Park Service began to move away from its founding philosophy of preserving objects to a management strategy based on preserving ecosystems. Yet significant portions of the general public, who have been taught that giant sequoias are sacred objects which transcend the normal limits of life, continue to haunt and to confuse the current world of giant sequoia management (Tweed, 1994).

SEQUOIA ECOLOGY

Viewing the giant sequoias from an ecosystem perspective, mycologists, entomologists, and mammalogists found sequoias to be closely associated with mycorrhizal fungi, various insect species, and a Douglas squirrel (*Tamiasciurus douglasi*). Giant sequoia forms associations with vesicular-arbuscular (VA) mycorrhizae. These mycorrhizae increase the uptake of phosphorus and nitrogen and protect sequoia roots from soil pathogens. Under laboratory and nursery conditions sequoia seedlings inoculated with mycorrhizae were two to three times larger than noninoculated seedlings (Molina, 1994). Burrowing of insect larvae severs vascular connections which results in drying of the cones and seed release from high up in the tree canopy dispersing over wide areas of the forest floor (Harvey et al., 1980). Douglas squirrels cut large numbers of giant sequoias from the canopy and create caches from which they chew the cones and release, but do not eat the seeds, which they leave behind on the surface of the soil. One squirrel was observed to cut 538 cones in 30 minutes (Harvey et al., 1980).

Studies carried out in the l960s and early 1970s documented the importance of periodic fire in maintaining the giant sequoia mixed-conifer forests of the Sierra Nevada. In 1968 the National Park Service reversed its official resource management policy of fire exclusion and recognized that the "presence or absence of natural fire within a given habitat is recognized as one of the ecological factors contributing to the perpetuation of plants and animals native to that habitat. Prescribed burning to achieve approved vegetation and/or wildlife management objectives may be employed as a substitute for natural fires" (Biswell, 1989). For thousands of years fire has reduced flammable surface fuels, thinned forest trees, stimulated sprouting of shrubs and other hardwoods, released seeds and prepared seedbeds favorable for germination of giant sequoia, efficiently recycled nutrients, and influenced insect and disease populations (Kilgore, 1972). It was clear the practice of fire suppression was in conflict with what researchers were discovering about the need for fire in the survival of young sequoias. In the late 1960s the National Park Service began a program of prescribed burning in the sequoia groves.

FIRE AND GIANT SEQUOIAS

The challenge of returning to more "natural" conditions with the use of fire is subject

to different interpretations and values. What is natural? Should grove conditions be recreated to what existed prior to Euroamerican expansion? For at least the last 2 or 3 thousand years preceding Euroamerican settlement, predominantly low- to moderate-intensity surface fires burned within individual sequoia groves on the order of every 2 to 10 years. Because of the suppression of natural fires most groves have experienced a 100- to 130-year period without significant fire. Giant sequoia reproduction has effectively ceased in groves protected from fire and dead material has accumulated. Shade tolerant species such as white fir have increased creating "ladder" fuels capable of conducting fire into the crowns of mature trees. Because of this increase in fuel load and ladder fuels, high severity fire conditions are created which threaten even mature monarch giant sequoias. Fire is important in creating conditions for the release and germination of the small and delicate giant sequoia seeds. In addition fire-created forest gaps are the site of abundant sequoia seedling establishment (seed germination, rooting, and survival for the first few summers) and recruitment (growth of the seedling into a mature, seed-producing tree). Not just any fire will result in successful giant sequoia seedling establishment and recruitment. Giant sequoia is what is known as a "pioneer species," requiring canopy-destroying disturbance to complete its life cycle. "Patch dynamics" driven by canopy-destroying disturbance is the rule in the giant sequoia forest community, not the exception (Stephenson, 1994).

For better or worse, people are now a part of the Sierra Nevada ecosystem. Forests surrounding some groves have been logged which results in hydrological changes, air quality from human activities respects no ecosystem boundaries, and groves are managed by different land-use agencies each with different management philosophies and objectives.

The literature on giant sequoia research, different management philosophies from land resource agencies and research universities, and current field studies have been reviewed by Nathan Stephenson of the National Biological Survey for the Sierra Nevada Ecosystem Project (Stephenson, 1996).

While most researchers agree for the need to return fire to the sequoia forest there is disagreement over the methods used to restore sequoia groves. Structural restorationists argue that grove structure and species composition must be restored, by whatever means possible, before natural processes (particularly fire) are allowed to run a more natural course in determining grove dynamics. Process restorationists argue that the goal of restoration is to restore the major processes (particularly fire) that shaped sequoia ecosystems in pre-Euroamerican times. Fire becomes a tool of choice in determining future grove structure and composition (Stephenson, 1996). The practicality of these two approaches is currently debated with economic, political, philosophical, and ecological issues influencing specific management plans.

Giant sequoias have a special place in the hearts and minds of many people. They are an international attraction and play a role in the identity of our local community including my college, College of the Sequoias. For many years giant sequoias were thought to be self-perpetuating and by taking action in the 1890s to preserve these trees in National Parks, it was thought the sequoia forests were safe. One hundred years later we know that the giant sequoia needs to be viewed as part of an ecosystem that requires the natural processes of fire, as well as invertebrate and vertebrate interactions to maintain viable mixed-age forests.

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"The San Joaquin Valley" Question-Answer Period

Jim Booman: I have a question about the redwoods (*Sequoiadendron giganteum*). I was up in the groves yesterday and every three seconds there was a cone falling, ricocheting off the branches, and coming quite close. Was that the squirrel? Secondly, unlike the coastal redwoods (*Sequoia sempervirens*), the redwoods here are only in small groves in very isolated pockets. Was it ever an extensive forest or was it always in isolated pockets?

Jim Sellers: The cones are falling after being cut down by the squirrel. The squirrel is so high in the canopy you can't see it. This is the time of year they are most active. To answer your question about the disjunct groves, it's an interesting genetic story. The giant sequoias were much more widespread previous to 4500 years ago and if you go back 10 to 100 thousand years ago, there's a fossil record showing them in Florida and all across North America. As climates changed and the Sierra Nevada continued uplifting what apparently happened is the populations were relatively continuous on the east side, but as they came across they came across as disjunct groves through the canyons. So as we look at the genetics, they are not continuous as we go from the southern-most to the northern-most coast. The reference in my paper most appropriate for this question is the one by Harvey, a monograph put out by the Department of Interior that focuses on paleoecology history.

Greg Kirkpatrick: I just wanted to add one thing to that...if you look at drillers logs in Hanford, at about 140 ft. down they often encounter, as wells are being drilled, "tea colored" water and chunks of redwood. The flooding that occurred when the redwood forest was much more extensive carried those redwoods all the way out into the Tulare Lake.

Bruce Briggs: We have a problem up north of people being able to get together. We have water, power, people, and plants. Some people want to go back and tear out the dams; they want to go the other direction and they're not very sold on research, because native plants don't have to be watered as much and they'll grow without fertilizer. How do we get all these people in one room and solve our problems piece by piece? Have you found the solution for this?

Greg Kirkpatrick: I guess I'm the most activist in this group. We try all the time to bring people together, especially American Farmland Trust, but it's difficult. There are many opinions and it's difficult to get people to come together and agree. Certainly, we can't go back to the situation with no dams, no farmland, and no irrigation of the San Joaquin Valley, but we do need to take a look and try to preserve some of the best examples of remaining natural areas.

Curtis Lynn: It's difficult. I've been involved for the last 25 years rather extensively in developing water policy that satisfies the urban interests, the agricultural interests, and the environmental interests. If you look at the long stairway to solving all the problems, we're almost to step one after 25 years. But, things are beginning to happen. Right now I am involved in developing a memorandum of understanding that will be mailed out in about 3 weeks to all water districts in California, to all agricultural water suppliers, to environmental organizations, and to other interest groups for signature. People will then agree to what water conservation or water

efficiency practices will be used by agricultural water suppliers. This is the kind of activity that is starting to take place. People after a while do get together and agree, but they have to go through a lot of stumbling to get there, it seems to me.

Howard Brown: A question for Mr. Kirkpatrick... you showed us evidence of browsing by cattle on removing young oak trees, what about the deer population? What effect does deer population have on growth of new oaks?

Greg Kirkpatrick: I've seen evidence that it is significant especially in the blue oak woodland you find in the foothills. We have very little deer population left on the valley floor.

Foundation Clonal Systems of Source Selection

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INTRODUCTION

Plant breeding and plant propagation can be considered mirror images of one another. Plant breeding depends upon increased genetic variation to provide the chances of producing new cultivars. Plant propagation, on the other hand, depends upon decreasing, or at least controlling, genetic variation in order to maintain the genotype of specific cultivars produced by breeding. Maintaining plants that are true-to-variety and true-to-type is accomplished through selection of propagation sources. One of the primary methods of accomplishing this goal is through vegetative propagation and the selection of a clone. A further refinement of clonal selection and propagation is the selection of individual plants within that clone and will be *referred to as foundation clones.*

The purpose of this workshop is to describe the types of clonal variants that need to be controlled and the process utilized to achieve this control through "Foundation Clone" selection. These procedures are embodied in the California Registration and Certification programs.

KINDS OF VARIATION

Propagation sources in horticulture are either seedling or clonal. Seedling populations exhibit both genetic variation and nongenetic variation. Seedling sources are populations of individual plants, each of which have different genotypes.

Genetic Variation. This type occurs among individual seedlings resulting from segregation of chromosomal DNA during sexual reproduction. DNA controls the genetic codes that determine plant characteristics. Variation among individual seedlings within a population is controlled by managing gene frequencies through plant breeding techniques.

Nongenetic Variation. This type develops within individual plants as the seedling grows and completes its life cycle. The process is controlled by the transcription and translation of the specific genetic codes in the DNA in relation to age, season, and pattern of growth. This type of variation is defined by biologists as *epigenetic* and in horticulture includes the phenomenon known as phase change which utilizes the terms juvenile, transitional, and mature (adult) to different phases in the life cycle. Variations can be expressed in: (a) the age of flowering, (b), growth and foliage characteristics, and (c) the ability to regenerate adventitious roots.

Vegetative propagation can be used to control both genetic and non-genetic variation within seedling plants. The process of vegetative propagation, also referred to as *cloning*, creates a unique kind of plant population which is known biologically as a *clone,* all plants of which have the same genotype.

Origin of Clones. Most horticulturally important clones originate by the selection from a seedling population of a single individual. This process can result in a very large genetic advance in one step and the resulting genotype can theoretically be

maintained indefinitely through clonal propagation. In practical horticulture, this statement is not historically true. As horticultural industries have evolved and expanded, specific kinds of clonal variation, including both disease and genetic modifications, have also emerged that may create serious problems of trueness-to-type, involving plant modification or change in performance. The need to control such problems has led to revolutionary changes in the traditional methods of source selection.

Variation patterns within clones can be conveniently designated by the consecutive generation's vertical propagation. The original seedling plant is designated as S_0, the first scion generation as S_1, the second scion generation as S_2, etc. Horizontal propagation is multiple propagations from the same plant or from the same vertical generation. Plants of the same horizontal generation can be designated by lower case letters, as S_{1a}, S_{1b}, S_{1c}, etc.

PHASE CHANGE AND VEGETATIVE PROPAGATION

Although usually restricted to the first few generations of vertical propagation, S_0, S_1 and sometimes later, juvenility and maturation provide important examples of *non-genetic variation which can have profound effects on trueness-to-type of many* plants. As seedlings, many perennial plant species, i.e., trees, bulbs, tubers, orchids, etc., require many years to come into flowering, show striking morphological differences between the juvenile and mature parts of the same plant and lose their ability to reproduce vegetatively as they age. Vegetative propagation of buds from different parts of the S_0 plant may result in horizontal variation among S_1 plants depending upon the location of the meristem on the original seedling plant source.

Proper selection and maintenance of source material from juvenile parts of the clone are necessary to maintain ease of rooting and specific growth forms in clonal forestry, for instance, or for growing clonal rootstocks.

Most clonal cultivars grown for their fruits and flowers, however, become stabilized to the mature (adult) phase with repeated vertical and horizontal propagation. These characteristics include the more desirable horticultural characteristics (precocious bearing, somewhat less vigor, good fruit quality, thornlessness) whereas the juvenile form is often highly vigorous, thorny, produces poor quality fruit, and has a tendency toward upright growth. Loss of rooting ability requires that many of these clones be propagated by budding and grafting.

PATHOGENS, INFECTION, AND DISEASE WITHIN CLONES

The most serious problem of clonal variation in long-term established cultivars after repeated horizontal and vertical propagation is systemic infection by pathogens. Historically, many if not most clones eventually show declines in yield or may actually die out, a phenomenon referred to in fruit growing as "running out". The cause was attributed initially to old age of the clone which had to be rejuvenated by creating a new cultivar by seed propagation.

Eventually scientists discovered that most of these problems were caused by pathogens. Bacteria, fungi, and other organisms were identified which adversely affected both seedlings and vegetatively propagated plants. This led to the concept of pathogen-free stock controlled through a variety of sanitation, heat treatments, and chemical techniques. However, other plants, primarily woody plants, and including most fruit and nut trees, small fruits, strawberries, grapes, potatoes, and

other clonally propagated cultivars, became almost systematically infected with submicroscopic organisms as viruses, viroids, phytoplasma, etc. These pathogens literally became part of the genetic system of the host in some cases. These were propagated along with the cultivar, transmitted across graft unions and transmitted by insect vectors (particularly aphids) and pollen. By the mid-1950s certain fruit industries in California, for example cherry in coastal valleys and peaches in southern California, were being decimated by serious viruses. Subsequently, various fruit and nut crops became affected by a series of virus-induced disasters, including citrus decline, walnut blackline, and pear decline.

FOUNDATION CLONE SELECTION

Research by plant pathologists discovered indexing methods of detection for most viruses through transmission to susceptible indicator plants. These tools led directly to the method of control which is called here Foundation Clone Selection based on the identification of single plants which tested free of significant pathogens. Reinfection was prevented by growing the Foundation Trees in a Foundation Orchard followed by multiplication (horizontal propagation) in nursery source orchards (mother blocks, scion orchards, or nursery increase blocks) for limited numbers of vertical propagation generations. These procedures were embodied in the California Registration and Certification system based upon the well established Registration and Seed Certification System. The source plant and its progeny were referred to as a clone which is biologically correct, but fails to distinguish this category of plant from the original clone of which it was a part. It is not a new cultivar. For this reason, it would be better to refer to it by another term as Foundation Clone although other terms have been used, including source-clone and nuclear stock.

Three methods can be used to identify foundation clones. One is already described and involves screening of available plants. A second method utilizes plants in which the virus has been eliminated from infected plants, primarily through thermotherapy and meristem culture. This advance makes possible the selection of genetically superior material as the primary step and the removal of the virus as the second. A third method is used in citrus with the selection of virus-free apomictic seedlings of established cultivars followed by vertical propagation to establish the horticulturally desirable mature form.

GENETIC NATURE OF FOUNDATION CLONE SELECTION

Events occurred in the early stages of program development that reinforced the concept that Foundation Clone selection is not just for disease control, but is also a genetic process. A single plant is chosen within the entire clone to represent the entire cultivar. It is essential that this plant be verified as true to variety. As it happened, a Foundation Clone of a red-fruited cherry cultivar selected for the program turned out to produce white fruit, evidently due to an error in selection at some stage. Although momentarily embarrassing, the event emphasized the importance of this verification step. This event led to the practical rule to collect propagation material only from a plant whose genetic identity had been verified at the fruiting stage by visual inspection.

Trueness-to-Type. This term is sometimes used synonymously with trueness-to-variety. A distinction should be made in that the plants to be used as a propagation

source may actually be the correct cultivar but deviate in some fundamental way from the standard for that cultivar. When propagated, off-type individual progeny result, a fact not necessarily predicted from visual inspection of the source plant. This distinction brings up an important concept:

Phenotypic Selection. Selection based on visual inspection of the source plant.

Genotypic Selection. Selection based upon visual inspection of the progeny plants. The procedure requires propagations be made and the progeny plants grown in appropriate test sites. Plant breeders use this procedure to evaluate a new cultivar but plant propagators often may not utilize it in evaluating sources.

NONPATHOGEN VARIANTS IN CLONES

Mutations are produced by genetic changes in the basic structure of DNA which results in a new genotype. These events occur at random within clones and can be an important source of new cultivars. Equally probable is that mutations can produce permanent changes that are adverse (reduced yield, reduced quality, inferior growth). These changes are not necessarily identified in the source plant, but may only appear later in the progeny plants (often in the customers orchard).

New mutations occur in single cells which are located in specific layers of the growing point and invariably become unstable chimeras. Genotypic selection can identify unstable plants because new plants arise invariably from single buds.

Mutation breeders generally utilize one or more generations of vertical and horizontal propagation to identify new mutants. A late-blooming budsport was discovered in almond in the early 1950s , not in one tree but as single limbs or whole trees in several separate trees, all apparently arising as nursery trees from single buds taken from a single tree where the mutation had occurred. It was a single factor mutation. Later on, a type of variant began to appear in commercial orchards, characterized by low production, vigorous growth, abnormal fruit, and extreme variability within and among tree. It appeared to be a multiple factor mutation which was eventually traced through two major nursery propagation source lines, apparently arising from some event in the environment some years previously. Foundation Clones can control these problems providing that the Foundation Clones were previously subjected to genotypic selection.

Hereditary Disorders. Noninfectious bud failure (BF) is a unique disorder that develops in specific propagation lines of particular almond cultivars. It produces a "witches-broom" type of phenotype (also known as "crazy-top"). Vegetative buds are killed in late summer and fall, resulting in bud-failure, dieback, and vigorous growth from surviving buds in the spring. The disorder is not pathologic, but the potential for BF is inherited during breeding and develops over time in clonal source material of individual cultivars. Enhancement of the potential increases during vegetative growth, the rate directly proportional to accumulated exposure to temperatures over 32C (80F). In the traditional nursery propagation orchard selection systems used in the past, the potential for BF increases during consecutive vertical propagations and variation increases with horizontal propagation. Control has been achieved through pinpointing specific Foundation Clones whose potential for BF has been previously progeny tested by genotypic selection.

Genotype × Environmental Interactions. This phrase means that the expression of specific genotypes sometimes results from interactions among genotype, environment, and (or) management. Visual inspection of source plants for trueness-to-type can sometimes be misleading since a specific variant may be due to an environmental interaction. Commercial fruit quality of such plants as apples, peaches, plums etc. depend upon restricting the crop load on the tree by thinning and maintaining vigor and other characteristics. Time of bloom may depend upon the amount of chilling in the winter as well as warm temperature patterns in spring. Time to harvest may depend upon the temperature accumulation during development or the amount irrigation, etc.

When we were studying the so-called "bull" problem in almond, observations were made of Foundation Clone trees in scion orchards which had been severely pruned for budwood, and showed bull characteristics. Questions were raised if these specific Foundation trees were off-type. Accompanying studies showed that these plants were not off-type and the symptoms were due to management conditions. Similarly, young nonbearing trees in orchards may show off-type fruit symptoms. This phenomenon can be a problem in Foundation Clone selection and management because maintenance of trees for production of propagating material is radically different than optimum for fruit or nut production. This potential problem further emphasizes the importance of genotypic selection in the kind of Source Selection system described here.

SUMMARY

Clonal propagation through vegetative propagation is the dominant method of producing woody and herbaceous perennials in horticulture. Although a powerful tool for selecting superior cultivars and maintaining their genotype in propagation, their use requires special methods of source selection to maintain their trueness to type and freedom from disease. It is evident that coevolution of pathological organisms and clonal cultivars has been a fact of horticultural development and specific programs of source selection has become a fact of modern propagation systems. The principles of Foundation Clone selection and maintenance have become a necessity. This workshop described the specific application to orchard and vine crops in California.

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Foundation Plant Materials Service: Production and Distribution of Virus-tested Propagation Materials

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INTRODUCTION

Foundation Plant Materials Service (FPMS), a unit of the University of California at Davis, was created to provide virus-tested plant materials for research and commercial use. Field- and greenhouse-grown plants of new varieties developed at the University, as well as plants from several unique collections from other sources, are maintained by FPMS on the Davis campus. Propagation material in the form of seed, buds, cuttings, rooted plants, and tissue-culture plantlets are supplied to the public. This service is in keeping with the University's policy to release healthy plant material whenever possible. Crops included in the FPMS programs include grapevines, deciduous fruit, and nut trees, roses, strawberries, and sweet potatoes.

Most of the material maintained and distributed by FPMS is propagated vegetatively. Although vegetative propagation has the advantage of creating progeny plants that are genetically identical to the mother, it also has the potential to transmit diseases caused by viruses or other plant pathogens. It is important to avoid propagation of infected material. Virus infection can have various adverse affects on plant growth that can be manifested as reduced vigor, reduced uniformity, shortened productive life, reduced cold hardiness, a lower rate of survival when transplanting, reduced crop yields, and inferior crop quality.

In addition to the distribution of virus-indexed plant materials, FPMS provides custom disease detection and elimination services on a fee-for-service basis and operates a National Grapevine Importation Program for growers who wish to import foreign grape materials into the United States. To meet these missions FPMS must follow the regulations and policies of the California Department of Food and Agriculture, the U.S. Department of Agriculture Animal and Plant Health Inspection Service, and the University of California.

TECHNIQUES FOR VIRUS DETECTION

Disease testing procedures, commonly referred to as indexing, are proscribed by California state regulation and are used to determine the presence or absence of virus diseases before release of plant material. Although foundation materials supplied by FPMS are apparently free of potentially harmful viruses, it is not possible to guarantee that materials are healthy due to limitations of testing methods available.

Detection of plant viruses can currently be accomplished using four distinct methodologies: serological screening, bioassay using *Prunus* 'Shiro-fugen' (syn. *P. serrulata* 'Shirofugen') flowering cherry, graft transmission, and mechanical transmission. For the purposes of this text the plant material that undergoes indexing procedures will be referred to as the "candidate selection" or the "candidate", a description defining the selection's potential for inclusion in a certification program.

Serological testing, using Enzyme-Linked Immunosorbent Assay or ELISA, is a laboratory test that can be performed in as little as one day. To detect a specific virus in a plant, the wells of an ELISA plate are coated with the antibody specific to the virus. The antibody has been produced by the immune system of a warm-blooded animal previously injected with the virus particles purified from infected plant tissue. Sap derived from macerated tissue from the candidate is then added to the coated well and incubated. During the incubation time any virus particles present in the candidate sample will bind to its specific antibody. After washing the plate, an enzyme-conjugated antibody (the same antibody initially used for coating the plate, but conjugated to an enzyme) is added to each well of the plate and incubated. After another wash, a substrate specific to the enzyme is added to the plate and any resultant yellow color development in the wells indicates the presence of virus in the candidate sample. This technology is extremely sensitive and can be used to identify specific viruses in a variety of plant types. However, its scope is somewhat limited as not all viruses present in plants have been successfully purified and characterized.

A second method of indexing involves the flowering cherry *Prunus* 'Shirofugen' which displays a hypersensitive reaction when inoculated with virus-infected buds. Buds from the candidate are inoculated onto the Shirofugen cherry by T-budding to a branch of the cherry tree. Thirty days after budding, the entire branch of the cherry tree is removed from the tree and the bark on either side of the inoculated buds is removed to expose the cambial tissue layer. A distinctive gumming and necrosis around the inoculated site is indicative of the presence of virus. Shirofugen cherry indexing is used primarily for testing of roses and fruit and nut trees in the species *Prunus*.

Virus indexing through graft transmission is a third method of disease detection. For each candidate plant type, a series of indicator varieties of the same genus is selected based on the relatively rapid, distinct disease symptoms they display when infected. Examples of such indicator varieties are as follows.

- *Prunus*: Bing cherry (*Prunus avium* 'Bing'), kwanzan cherry (*P.* 'Kwanzan'), tomentosa cherry (*P. tomentosa*), Tilton apricot (*P. armeniaca* 'Tilton'), Elberta peach (*P. persica* 'Elberta'), Shiro plum (*P.* 'Shiro')
- *Pyrus*: Bartlett pear (*P. communis* 'Williams' Bon Chrétien'), Beurre Bosc pear (*P. communis* 'Beurre Bosc'), Nouveau Poiteau pear (*P. communis* 'Nouveau Poiteau'), Passe Crassane pear (*P. communis* 'Passe Crassane')
- *Rosa*: Burr multiflora, 'Madame Butterfly'
- Strawberry: *Fragaria vesca*, *F. virginiana*
- Grape: *Vitis rupestris* 'Saint George', Cabernet Franc (*V.* 'Cabernet Franc'), LN33, Kober 5BB, Richter 110

Indicator plants are inoculated with buds or leaves of the candidate plants and are observed for disease symptoms over a period of time varying from 6 weeks in strawberry to two entire growing seasons needed to complete the field index for *Prunus*. Symptom expression can consist of the balling, rosetted growth, and veinal chlorosis as occurs in rose spring dwarf, to the extremely serrate leaf margins and widely splayed petiolar sinus found in grape leaves infected with fanleaf virus.

Another method used for virus detection is referred to as mechanical transmission. Herbaceous host indicator plants such as lambsquarter (*Chenopodium*), tobacco (*Nicotiana tabacum*), and cucumber (*Cucumis sativus*) are grown from seed in the greenhouse. For infection to occur, the virus must enter the tissues of the herbaceous indicator through a sublethal wound. This is normally accomplished by the application of a mild abrasive such as carborundum powder, which damages the cuticle and epidermis of the herbaceous indicator as sap extracted from the candidate plant is rubbed on the leaf surface. The virus enters cells of the herbaceous indicator through these wounds. The plants continue to grow in the greenhouse and in 4 to 6 weeks, under proper conditions, symptoms will develop on the hosts inoculated with a positive sample.

VIRUS ELIMINATION

Upon completion of one or more of the indexing tests, results are compiled and a determination of the virus status is made. For those plants infected with virus, disease elimination work becomes an option. The feasibility of virus elimination will depend upon the particular virus present, the importance of the variety to the individual or industry, the possibility of locating another potentially healthy selection of the variety, and availability of funds to perform the work, often running into the thousands of dollars.

Virus disease elimination can be accomplished in two ways. Inactivating or killing the virus particles through thermotherapy can be used for elimination of many viruses that are sensitive to high temperatures. Using this method entire plants, or simply buds of the diseased material budded to a healthy rootstock, are placed in a heat chamber and are held at 100F for a minimum of 60 days or until the plant begins to decline beyond the point from which viable buds can be removed. New plants are propagated from the heat-treated material either through further budding to a rootstock or by rooting the green growing heat-treated material under mist in the greenhouse.

A second method used for virus elimination is tissue culture. In this procedure the apical meristem and the first few leaves below it are excised from the shoot tip and placed in conditions such that roots form at the base to produce a small plantlet. This technique is used to produce a pathogen-free stem cutting, since the tip is usually free of bacteria, fungi, and viruses.

MAINTENANCE OF VIRUS-TESTED PLANTING STOCK

The value of virus-tested stock is widely recognized by the establishment of certification programs in many states and countries. In California, various certification programs are administered by the Department of Food and Agriculture (CDFA). CDFA has designated FPMS as a source of propagation materials for its grapevine, deciduous fruit and nut tree, and strawberry certification programs.

Plant material produced and tested by FPMS is called foundation stock. Prior to its inclusion in the collections at FPMS, prospective foundation level plant material is tested using one or more of the indexing procedures described above. In addition, each plant is checked by experts for trueness-to-type and to variety, confirming that it is correctly identified and labeled. All of the plants are visually inspected by state, county, and university personnel each spring and fall and are subject to annual ELISA testing to monitor disease status.

Foundation-level plant material is used to produce planting stock at the registered level by private nurseries that are participating in the certification program. A third level, certified nursery stock, is produced from the registered increase blocks. It is certified stock that is sold to growers for production purposes. Each level of plant material is identified with a different color tag issued by CDFA—white for foundation stock, purple for registered stock, and blue for certified stock. This source and disease testing information, maintained by FPMS and CDFA, can be used to assure growers of the quality of the plant material they are purchasing, to track the source history of the plants, and to inform growers of any changes in the disease status of the plants. Complete regulations, describing growing conditions, inspection and testing procedures required to produce foundation, registered and certified stock are available from CDFA.

Propagation materials are sold by FPMS to the public in accordance with an allocation policy that ensures that materials are distributed as widely as possible to industry, researchers, repositories, and others. Amounts suitable for establishing increase plantings are distributed as first priority to participants in the California Registration and Certification programs. Remaining materials are sold first to domestic and then to foreign customers.

Nursery Propagation by Hardwood Cuttings: *Prunus*

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Several tests were conducted to look at the rooting of *Prunus* hardwood cuttings in the commercial nursery. The commercial propagation of plum rootstocks ('Marianna 2624' and 'Myrobaln 29C') was used as a comparison with the more difficult-to-propagate rootstocks, 'Hansen 536' and 1-82, peach/almond hybrids. A comparison between the size of the cuttings, the time of year they were cut, and the different environments in which they were grown was analyzed for two growing seasons (1994-95 and 1995-96).

Hardwood cuttings of 'Hansen 536' and 1-82 were cut in Nov. 1994 and Nov. through Feb. 1996 and either planted directly in the field or rooted in a greenhouse and then transplanted to the field. In 1995, plastic sleeves to cover the cuttings planted directly in the field greatly enhanced the survivability of the cuttings. Ninety-eight percent of the 'Hansen 536' cuttings that were covered with plastic sleeves rooted and survived in the field.

Hardwood cuttings of 'Hansen 536' were taken to the greenhouse in Feb. 1995. An overall rooting of 19% and a overall field survival of 75% was achieved that year.

In 1996, rooting of 10.2%, 4.1%, 11.1%, and 9.2% occurred with hardwood 'Hansen 536' cuttings taken in Nov., Dec., Jan., and Feb., respectively. Different planting dates affected the survivability of the rooted cuttings, the later in the winter the cuttings were planted, the better the survival. For example, only 10% of the cuttings planted in Jan. 1996 survived, whereas 20% of the cuttings planted in April 1996 survived. This was also true in 1995 when 75% of the cuttings planted in April survived and grew well.

INTRODUCTION

Propagation of *Prunus* rootstocks in the commercial nursery has long been required to maintain certain desirable characteristics of rootstocks. Seed propagation has been the propagation method of choice, but more recently the demand for specialized rootstocks that are adapted to certain soil conditions have been in high demand. The good news is that nurserymen have at their disposal several different rootstocks for problem soils. The bad news is that propagating these rootstocks, other than from seed, has presented some challenges.

Rootstocks such as the 'Marianna 2624' and the 'Myrobaln 29C' plums are easily propagated by hardwood cuttings. Plum rootstocks are propagated in November, dipped in a rooting hormone and planted to the field. A 90% to 95% rooting in the field is consistently achieved with this method (Hartmann and Kester, 1983).

Two new rootstocks developed by the University of California at Davis are the 'Hansen 536' and Hansen 2168. Both of these rootstocks are peach/almond hybrids that are very vigorous and resistant to some soil nematodes as described in Kester and Asay (1986). Commercial nurseries recognized the importance of these charac-

teristics and the benefit of propagating true-to-type rootstocks.

'Hansen 536' was released from U.C., Davis and propagation began in 1989. Several methods were used to propagate this rootstock. In 1995 and 1996, experiments with the 'Hansen 536' and a newer experimental hybrid were conducted. Cuttings of each clone were either planted directly in the field, after a basal dip of rooting hormone, or placed in the greenhouse for rooting. The objective of this study was to obtain commercial levels of production of 'Hansen 536' and 1-82 peach/almond hybrids equal to or greater than that of the commercially propagated plum rootstocks, 'Marianna 2624' and 'Myrobaln 29C'.

Several problems were encountered when 'Hansen 536' and the 1-82 hybrid were placed in the standard plum propagation system. First, the cuttings that did not root in the field rotted and died. Second, by planting a field of 'Hansen 536' and having several die, there was suddenly an inefficient use of space. The solution to these problems is the main thrust of this project.

Propagation of plum rootstocks ('Marianna 2624' and 'Myrobaln 29C') consisted of taking 16-in.-long cuttings from mother plants maintained in a "bush" form. The reason for this form of mother plant was for ease of collection and the ability to make a close planting similar to a hedge row. These cuttings are taken in November right at or after leaf fall. If necessary, the leaves were removed and the cuttings were bundled in units of 100. The base of the bundles were cut off with a band saw to make a fresh, uniform cut. The bundles were then placed in a 1-in.-deep solution of 1H-indole-3-butyric acid (IBA) at about 100 ppm. Each bundle of plum rootstocks was held in the solution for 24 h. At the end of the 24-h soak, the bundles were placed upside down in a 3 ft^3 wooden bin and filled with moist sawdust so all of the bundles were covered. The bundles of cuttings were stored this way until the field was ready for planting. The bundles were then taken to the field in mid- November and the individual cuttings were planted in raised beds at a spacing of 5 to 7 in. apart and about 6 to 8 in. deep. The cuttings were firmly packed into the raised beds and watered in. Usually, winter rains provide sufficient moisture for the cuttings but occasional irrigation applications may be necessary if the winter is unusually dry. The cuttings will stay dormant in the field until early spring, about mid-February, when the buds swell and the cuttings begin to grow.

Following this same procedure for the 'Hansen 536' peach/almond hybrid, 23,145 16-in.-long cuttings were cut from 'Hansen 536' mother plants on 14 Nov. 1994. These mother plants were maintained in much the same way as the plum mother plants (bush type). The source of 'Hansen 536' mother plants came from trees that were budded onto certified 'Nemaguard' peach in the spring of 1993. The 'Hansen 536' budwood that was used in 1993 came from the Foundation Plant Material Service in Davis as certified budwood.

The 'Hansen 536' cuttings were divided into small-, medium-, and large-caliper sizes. All of the cuttings were dipped in 4000 ppm IBA for 10 sec. The cuttings were planted in the field on 19 Nov. 1994. The cuttings were not callused when they were planted. The soil was a very light, sandy loam with good drainage.

On 20 Dec. 1994, one month after planting, several 'Hansen 536' cuttings had callused. Two months after planting, over 80% of the cuttings had callused. By the Spring of 1995, very few cuttings leafed out and less than half survived (Table 1).

Table 1. Propagation of hardwood 'Hansen 536' cuttings in 1994-95. Direct planting in nursery row.

'Hansen 536'	Number cut	IBA in ppm	Date cut	Date planted	Survival	Survival (%)
Small	18,610	4000	11/14/94	11/19/94	6141	33
Medium	2838	4000	11/14/94	11/19/94	1050	37
Large	1697	4000	11/14/94	11/19/94	670	39
Total	23,145				7861	34

During that same time, 100 1-82 peach/almond hybrids and 500 'Marianna 2624' were planted in the same field. The 1-82 hybrids and the 'Marianna 2624' were treated the same as the 'Hansen 536'. The 1-82 hybrids and the 'Marianna 2624' were planted on 19 Nov. 1994 and carefully watched during the winter and the following spring.

On 23 Jan. 1995, 67,200 'Hansen 536' were cut from the same mother plants as before. These Hansen were cut to 8 in. long and dipped for 10 sec in 4000 ppm IBA in 50% alcohol. The cuttings were then taken to a greenhouse on 4 Feb. 1995 where they were put into small, individual plugs measuring about 2 in. wide and 4 in. deep. These plugs were then placed in styrofoam trays of 200 cuttings per tray and placed on a bench with bottom heat and overhead mist. The mist came on for 5 sec every 15 min and the bottom heat was maintained between 75 to 78F. After about 10 days, callusing was noted around the base of the cuttings.

On 3 April 1995, 13,070 cuttings had rooted. These cuttings were then taken to the field on 16 April 1995 and planted. Out of the original 13,070 cuttings that had rooted, 9862 survived in the field (Table 2).

Table 2. Propagation 1994-95 greenhouse grown 'Hansen 536' peach/almond hybrid.

Date cut	Number cut	Date to green-house	Date rooted	Number rooted	Rooted (%)	Date planted	Number survived	Survived (%)
1/23/95	67,200	2/4/95	4/3/95	13,070	19.4	4/6/95	9862	75

In Nov. 1995 another test was conducted with 'Hansen 536' and 1-82 hybrid. Sixteen-inch-long cuttings were taken from mother trees of 'Hansen 536' and 1-82. A total of 250 'Hansen 536' and 500 1-82 were cut on 1 Dec. and dipped in 4000 ppm IBA for 10 sec. The cuttings were then planted in the field on 9 Dec. along with plum cuttings of 'Marianna 2624'. Small plastic "jackets" were placed around 150 of the 'Hansen 536' cuttings. These jackets were a white, thin sleeve of plastic about 2 in. in diameter and 12 in. long. The jackets were open on both ends so they were able to be slipped over the top of the cuttings. The cuttings remained in the field all winter and were scored for survival in the spring.

On 28 Nov. 1995, 106,800 8-in.-long cuttings of 'Hansen 536' were cut from the

same 'Hansen 536' mother plants as in 1994. The cuttings were bundled into bunches of 100 and then dipped for ten sec. into a 4000 ppm IBA solution. These cuttings were placed upside-down in a 3 ft^3 wooden bin and covered with moist sawdust. The wooden bins of cuttings were then taken to a greenhouse on 1 Dec. At the greenhouse, the bundles were cut open and each cutting was placed in an individual growing plug. The plugs were then placed in a styrofoam tray that held 200 plugs per tray. These were the same plugs and trays that were used the previous year. The trays were placed under a mist system in the greenhouse and misted for 5 sec every 15 min. The trays of cuttings were on benches that had bottom heat supplied to them by hot water pipes. The temperature of the benches measured between 75 to 78 F. After 30 days, rooting was noted in the growing plugs on the base of the cuttings.

On 16 Jan. 1996, 10,890 of the 106,800 cuttings (10.2%) had rooted and were taken to the field and planted. This same procedure was repeated for 'Hansen 536' cuttings on 28 Dec., 15 Jan., and 1 Feb. The layout and results of the experiment are detailed in Table 3.

Table 3. Layout and results of 1995-96 hardwood propagation of two peach/almond hybrid rootstocks.

Rootstock	Date cut	IBA	Number cut	Date to greenhouse	Date to field	No. Planted	Planted (%)
'Hansen 536'	11/28/95	4000 ppm	106800	12/1/95	1/16/96	10890	10.2
1-82 Hybrid	11/28/95	4000 ppm	1400	12/1/95	1/16/96	186	13.3
'Hansen 536'	12/28/95	4000 ppm	99250	1/2/96	4/10/96	2142	2.2
'Hansen 536'	12/28/95	4000 ppm	2100	1/9/96	4/10/96	203	9.7
'Hansen 536'	1/15/96	4000 ppm	65000	1/16/96	4/10/96	7200	11.1
'Hansen 536'	2/1/96	4000 ppm	53000	2/26/96	4/10/96	4898	9.2

A comparison between the two propagation tests in 1994 revealed that 7861 (34%) of the 'Hansen 536' cuttings had survived out of 23,145 original cuttings that were planted directly to the field in November of 1994. The results of the 'Hansen 536' that were rooted in the greenhouse before planting revealed 13,070 (20%) of the cuttings rooted out of the 67,200 originally cut.

Out of the 100 1-82 hybrids that were planted directly to the field in November of 1994, 20 cuttings (20%) survived.

In 1995, of the 500 1-82 hybrid cuttings that were directly planted in the field on 9 Dec. 246 survived (49.2%). Of the 250 'Hansen 536' cuttings that were directly planted in the field on 9 Dec. 1995, 148 survived (59.2%). Of the 150 'Hansen 536' cuttings that were planted with the plastic sleeve, 148 survived (98%).

In 1995-96, 326,150 'Hansen 536' cuttings were taken to the greenhouse to root. Out of that, 27,130 cuttings rooted (8.3%) (Table 4).

Table 4. Results of the 1995-96 'Hansen 536' hardwood rooting trial in a greenhouse.

Date cut	Number cut	Number planted	Percent planted
11/28/95	106,800	10,890	10.2
12/28/95	101,350	4142	4.1
1/15/96	65,000	7200	11.1
2/1/96	53,000	4898	9.2
Total	326,150	27,130	8.3

Reighard et al. (1990) suggested that hardwood cuttings are a potential means to propagate *Prunus* selections. The commercial availabilities of 'Marianna 2624' and 'Myrobaln 29C' plum are examples of successful hardwood propagation in a commercial nursery.

This was the first greenhouse propagation test on a large commercial scale of peach/almond hybrid rootstocks. It is possible to achieve at least 30% rooting by directly planting peach/almond hybrids in the field (Hansen and Hartmann, 1968). For commercial purposes and cost of production in a commercial nursery, 30% survival is not adequate. Thus, cuttings of 'Hansen 536' were taken to the greenhouse to root before they were planted in the field. In 1994-95, 19.4% of the cuttings taken to the greenhouse rooted. Out of that, 9,862 cuttings (75%) were planted to the field. This might sound like a very low number, but the benefit to transplanting only rooted cuttings is that the nursery field is 75% utilized compared to 30% utilization of the field that is directly planted in the fall. The loss of cuttings occurs in the greenhouse before they are planted, not in the field.

Table 5. Percent survival of 1995-96 'Hansen 536' cut on different dates and rooted in the greenhouse.

Date cut	Percent survival
11/28/95	10.2
12/28/95	4.1
1/15/96	11.1
2/1/96	9.2

Greenhouse grown 'Hansen 536' in 1995-96 produced 27,130 rooted cuttings out of 326,150 (8.3%). It didn't seem to matter when the cuttings were taken to the greenhouse.

When the rooted cuttings of 'Hansen 536' were planted in the field in April 1995, 75% of the cuttings survived. In 1996, cuttings were planted on Jan. 16 and only 10% of them survived. 'Hansen 536' cuttings planted in April of 1996 had over a 20% survival in the field.

It was noted that the rooting and survival percentages for 'Hansen 536' grown in

the greenhouse in 1996 were lower than that of field grown 'Hansen 536' the same year (8.3% rooting in the greenhouse compared to 59% rooting for those directly planted in the field). However, many environmental factors need to be taken into consideration when working with hardwood cuttings of *Prunus* in the field. The goal of this continuing research is to help eliminate some of the variables encountered in this preliminary study and to create a propagation system for difficult-to-root *Prunus* species that would be as successful as the system used for commercially propagated plum rootstock.

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"Single Plant Selection as the Basis for Foundation Clones" Question-Answer Period

Devin Cooper: Could you comment on the differences between the 'Shirofugen' and ELISA tests?

Mike Cunningham: The 'Shirofugen' index only works with *Prunus* necrotic ringspot and prune dwarf. ELISA will diagnose those, but it will also detect a whole range of leaf roll and fan leaf viruses in grapevines that 'Shirofugen' is not sensitive to. 'Shirofugen' is not as specific as ELISA. When ELISA shows a positive result it indicates the presence of a specific antibody that is specific to a particular virus. ELISA is a 1- to 2-day project while 'Shirofugen' cherry is a 30-day project.

John Dixon: Why 'Shirofugen' over other cherries?

Mike Cunningham: I don't know. The 'Shirofugen' test was established by George Nyland several years ago. Apparently, there is something unique to 'Shirofugen' that is missing in other cherry genotypes.

Don Dillon: Do insect or other vectors pose a risk to reintroduction of viruses in your foundation planting and, if so, what can you do about it?

Mike Cunningham: They do. Each crop is different. Strawberries have to be kept indoors because aphids can carry viruses of strawberry very readily. For grapevines, current work at the Foundation Plant Materials Lab indicates that mealybugs can carry leafroll viruses, but it's not known to what extent it happens in nature. In the grapevine certification program, there is an isolation distance of 100 ft to prevent the spread of diseases by nematodes. Fruit and nut tree species are a different story because prune dwarf and necrotic ringspot are pollen-transmitted viruses vectored by bees. The current isolation distance is 1/2 mile since ELISA testing can effectively and easily monitor the occurrence of viruses on an annual basis.

Phil Barker: Is this program being done in other parts of the country? And, do you envision this program eventually being adopted for landscape trees?

Dale Kester: This is a unique program to California. However, the same basic program and procedures are being used all over the country and elsewhere around the world. You need to make a distinction between a specific registration and certification program and a virus-control program. It can be done without necessarily having regulations; it can be left up to the individual state and/or individual nurseries. The principles would basically be the same. Now, with shade trees, as more trees have been clonally propagated these problems have occurred and as they do you must respond to them. Eventually, as shade trees are clonally propagated especially with the use of rootstocks, you can expect that sooner or later something is going to come along and cause serious problems.

Recently Introduced Plants from Saratoga Horticultural Research Foundation and Techniques for Their Propagation

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PLANT DESCRIPTIONS

Agapanthus 'Storm Cloud'

The umbels, about 7 in. in diameter have tubular very deep blue-violet flowers that bloom mid-summer to early-fall and are borne on stalks 3 to 4 ft. high. The growth habit is similar to that of *Agapanthus africanus*, forming circular clumps 2 ft tall by 3 ft wide.

It is evergreen to 28F and in warmer areas can be used in mass plantings; in colder areas as color accents. 'Storm Cloud' does well in full sun to part shade although the flower stalks may be taller in sun and umbels larger in full sun. In hot environments 'Storm Cloud' should be placed where it is lightly shaded during the hottest part of the day.

It is an adaptable, easy care plant, preferring rich, moist, well drained soil although once established it is tolerant of drier conditions.

The original specimen of this plant was a seedling produced by Barrie Coate from the cultivar 'Mood Indigo', a hybrid developed by the Los Angeles State and County Arboretum by hybridizing *A. africanus* with *A. pendulus*, a very dark purple species.

Arbutus 'Marina'

A sun-loving, highly ornamental, evergreen flowering tree noted for deep green foliage, pendulous clusters of deep pink flowers, strawberry-like fruit, and gorgeous, peeling, cinnamon-red bark. Its mature height is up to 40 ft with equal spread. It grows fast when young and moderately with age. It blooms from December through February, and occasionally again in the summer. It produced much less fruit than the *A. unedo*.

It will tolerate typical gardening conditions and regular watering as long as the soil is well drained, but it does well in heavy soil if not over watered. Once established, it may be treated as drought tolerant.

The cultivar name commemorates the location of Western Nursery in San Francisco's Marina District (where the first propagation was done from a specimen that arrived for the 1917 Exposition). *Arbutus* 'Marina' is a tribute to the owner of this nursery and one of California's early nurserymen, Charles Abrahams.

Laurus 'Saratoga'

A vigorous and versatile evergreen tree with fragrant foliage and clusters of small yellow spring flowers. *Laurus* 'Saratoga' does well in full sun to part shade, is drought tolerant, and grows to 25 ft tall with the same spread. Leaves are elliptic, 3 to 5 in. long, shiny, dark green on top and lighter below, and aromatic when crushed.

The flowers are male, so no fruit is produced from the flower clusters produced in the leaf axils.

Laurus 'Saratoga' is a robust plant with all the vigor associated with hybrids. It has the capacity to produce a single-trunked specimen tree with a dominant leader that will continue in the development of the crown or it can be grown to produce an open, multi-stemmed tree by pruning the leader at an early stage of development. It is easier to grow as a tree and suckers less than *L. nobilis*. It can also be used as a dense and strongly growing hedge if sheared.

Lonicera nitida 'Maigrun'

This tough and vigorous compact groundcover or low hedge has small round leaves with glossy leaves of medium green color which remains consistent. Its yellow flowers are insignificant and bloom in spring. It can been pruned as a formal border, as a boxwood would be used, or used as an informal border with a graceful and solid effect.

It will grow to 2 to 3 ft in height and spread 6 ft wide. *Lonicera nitida* 'Maigrun' leaves are long lasting. 'Maigrun' is drought tolerant and pest resistant, an easy-care plant that grows in most soils, in sun or shade.

This *Lonicera* is currently one of the top groundcovers used in France. It has been replacing *Cotoneaster*, that is prone to fire-blight disease.

Sequoia sempervirens 'Simpson's Silver'

A rapidly growing redwood tree with silver-blue foliage and a dense pyramidal shape. It produces a definite vertical leader forming a moderately tapered trunk and a rather dense crown. It produced no cones and will reach a height of 60 to 70 ft in 20 years, spreading to 20 to 30 ft.

Sequoia sempervirens 'Simpson's Silver' has a horizontal and whorling branching habit with the tips of the branches growing upward, highlighting its silver-blue color.

The tree maintains juvenile foliage through the 1-gal stage and does not begin to show both its true form and color until the plant is well along in the 5-gal can stage.

The original tree of this introduction was found growing near Eureka at an elevation of 800 ft in July 1975. It was about 45 years old and 127 ft tall with a trunk diameter of 17.5 in.

It is insect and disease free and is frost hardy in most California areas.

It responds to summer water if planted away from the coast.

Tristaniopsis laurina 'Elegant'

This is a small to medium-sized Australian evergreen tree notable for its elegant bark, fragrant flowers, semiformal appearance and red-tinged new growth. The profuse flowers are 3/8-in. lemon-yellow blossoms in cluster of 4 or 5 near the stems, blooming in spring. Its mahogany-colored bark peels to expose a satiny-white under surface. The graceful evergreen foliage of 'Elegant' is twice as large as the standard species and has wine-red colored new growth. It is insect and disease resistant.

Tristaniopsis laurina 'Elegant' is frost hardy and can be grown as single-trunk or multi-stemmed tree, as a specimen plant, or as screen or background planting. It can also be used as a dense and strongly growing hedge if sheared.

'Elegant' is tolerant of most soil conditions and will even flourish in heavy soils. Although seasonably drought tolerant, it grows best with supplemental summer

watering.

PROPAGATION TECHNIQUES

Environment in San Martin, California.

- Winter temperatures as low as 22 to 25F.
- Summer ranges up to 95 to 110F; often a strong afternoon wind.
- All of our propagation media is perlite and peat (4 : 1, v/v).

Agapanthus 'Stormcloud'

We do this one from tissue culture through Briggs Nursery of Olympia Washington.

Plant material is initiated from floral buds using (initiation process takes about one month): MS salts, 50 mg liter^{-1} 2iP, 0.02 mg liter^{-1} NAA, 30 g liter^{-1} sucrose, 5 g liter^{-1} agar, pH maintained at 5.7

Multiplication of the tissue takes place on the same medium. Subculturing is repeated every 6 weeks for as long as is necessary to produce the desired number of plants.

Plant material is then rooted in vitro using: MS salts, 1.0 mg liter^{-1} NAA, 600 mg liter^{-1} activated charcoal, pH maintains at 5.7, 30 g liter^{-1} sucrose, 5 g liter^{-1} agar

Plantlets transplanted into plug trays (72) for growing on.

Comments: Divisions can be made in the early spring or late fall. Keep divisions on the dry side to avoid rot.

Tissue culture liners to 1-gal size take approximately 4 months in the winter under plastic cover.

Arbutus 'Marina'

We do this one from tissue culture though Briggs Nursery of Olympia Washington.

Plant material is initiated from vegetative stems using (initiation process takes about 2 months): WPM Salts, 2.0 mg liter^{-1} Zeatin, 20 g liter^{-1} sucrose, pH maintained at 4.5, 5 g liter^{-1} agar

Multiplication of the tissue takes place on the same medium. Subculturing is repeated every 8 to 10 weeks for as long as is necessary to produce the desired number of plants.

Plant material is then rooted ex-vitro in a peat and perlite (1 :1, v/v) mix.

Rooting occurs within 3 weeks with no need for auxin pretreatment.

Plantlets are transplanted into plug trays (128) for growing on.

Comments: Cuttings taken from mature plants, that were not propagated from tissue culture do not tend to root very readily. Some growers are taking cuttings from plants that were propagated through tissue culture and the rooting percentages are slightly higher. We are trying this now with IBA at 5000 ppm.

Liner to finished 1 gal takes 6 months.

Laurus 'Saratoga'

Type of wood: Semi-hardened cuttings of summer growth, tips and seconds used.

A) Date initiated:	10 Jan 96
Number of cuttings	2304
Number rooted	1044
Percent rooted	45.3
Date rooted:	7 Apr 96

B) Date initiated:	13 Mar 96
Number of cuttings	4961
Number rooted	3714
Percent rooted	74.8
Date rooted:	12 Jun 96

Preparation of cuttings: Washed in a mild soap.
Rooting compound: Hormex #8
Environment: Bottom heat at 70F; mist 8 sec in summer, 15 in winter every 20 min.

Comments: We can take cuttings into winter depending on the condition of the wood. For example, this past year, with a mild winter, we took cuttings through February.

***Lonicera nitida* 'Maigrun'**
Type of wood: Slightly hardened wood from new growth year-round, tips and seconds used.

Date initiated:	2 May 96
Number of cuttings	1014
Number rooted	998
Percent rooted	98
Date rooted:	9 Aug 96

Preparation of cuttings: Washed in a mild soap.
Rooting compound: Hormex #3
Environment: Bottom heat at 70F; mist 8 sec in summer, 15 in winter every 20 min.

Comments: Rooted cuttings to finished liner takes 2 months. Liner to finished gallon takes about 3 to 4 months.

***Sequoia sempervirens* 'Simpson's Silver'**
Type of wood: Tip cuttings

A) Date initiated:	23 Jan 96
Number of cuttings	1221
Number rooted	448
Percent rooted	36
Date rooted:	2 Aug 96
B) Date initiated:	27 November 95
Number of cuttings	1296
Number rooted	777
Percent rooted	59
Date rooted:	1 Aug 96

Preparation of cuttings: Washed in a mild soap.
Rooting compound: IBA 5000 to 10,000 ppm.
Environment: Bottom heat at 70F to speed rooting in the first 2 months, after which they remain on a cool bench in greenhouse; Mist is only once per hour, if necessary.

Comments: Rooted cutting to a finished liner takes 2 to 3 months. Liner to finished gallon takes 8 to 9 months. We have found patience to be the key to rooting Sequoias.

***Tristaniopsis laurina* 'Elegant'**
Type of wood: In fall, hardened-off summer's growth—tips and seconds used.

A) Date initiated:	20 Apr 96
Number of cuttings	1011
Number rooted	262
Percent rooted	26
Date rooted:	2 Mar 96
B) Date initiate:	2 Mar 96
Number of cuttings	1802
Number rooted	515
Percent rooted	29
Date rooted:	7 July 96

Preparation of cuttings: Washed in a mild soap.

Rooting compound: Hormex #8

Environment: Bottom heat at 70F; mist 8 sec in summer, 15 in winter, every 20 min.

Potential Causes of Graft Incompatibility

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There is probably no universal cause of graft incompatibility in woody plants. Anatomical, physiological, and biochemical factors may all play a part in this phenomenon. Scientific explanations of incompatibility in certain stock-scion combinations may have no relevance to other combinations. While intergeneric and interspecific graft incompatibilities may be more common and suggest that major differences based on phylogenetic evolution (and subsequent taxonomic classification) may be operable, graft incompatibilities between individual plants of the same species indicate that there are also more subtle forces at work. In this paper, the author presents and discusses some experimental data bearing on graft incompatibility as well as some suggestions for future research in this field.

INTRODUCTION

There may not be a definition of graft incompatibility that is widely accepted by scientists working on such problems. However, I rather subscribe to the thoughts expressed by Barbara Mosse (1962). She has written that "the only certain criterion of incompatibility is the characteristic interruption in cambial and vascular continuity which leads to the spectacular smooth breaks at the point of union", and further that "at the point of union no normal vascular tissue develops. The gap thus formed is filled in by proliferating ray tissue which does not lignify normally". I am interested in long-term graft compatibility that will allow a landscape tree to flourish for 50 years or more.

ENZYMES AND LIGNIFICATION

My own research over the past decade or so has concentrated on intraspecific graft incompatibilities as they may be influenced by variation in the peroxidase isozymes in the cambial tissue of stock and scion. The theory underlying this work was first fully explained by Santamour (1988a) and this was followed by several papers (Santamour 1988b, 1988c, 1989) to "prove" the theory in Chinese chestnut (*Castanea mollissima* Blume), red oak (*Quercus rubra* L.), and red maple (*Acer rubrum* L.). The reason for selecting these three species for intensive research was that nurserymen had reported significant incompatibility problems even when selected cultivars were grafted on seedlings of the same species.

What is the function of peroxidase enzymes and how do they relate to graft compatibility? Peroxidases are the only enzymes involved in the polymerization of p-coumaryl alcohols to form lignin. Lignin is the second most common organic compound in the world (cellulose is the most common) and most botanically oriented scientists may think of lignin as only the material deposited as (or in) secondary cell walls to give them "strength". Indeed, the evolution of lignin formation allowed the development of large, exceedingly long-lived, perennial plants called trees. It must

be stressed here, however, that lignin is not a single compound and no chemical formula exists. Actually, there may be several different types of lignin in the same plant or even in the same cell (Santamour, 1988a).

Lignins are also a major component in the middle lamella between cells. It would then follow that the middle lamella in cells of trees that had different cambial isoperoxidase enzymes might produce structurally different lignins and perhaps different bonding patterns between lignins and carbohydrates. Thus, in a graft, adjacent cells of the stock and scion might function in their genetically prescribed biochemical mode and produce different kinds of lignin. Such activity could interfere with the production of matching pits and primary pit fields, perforation plates of xylem vessel members, and sieve plates of sieve-tube members in the phloem. There would then be a disruption in normal cell-to-cell connections, a breakdown in cell development, and a failure to re-establish a functional vascular system across the graft union.

In our work with the chestnut, oak, and maple species mentioned earlier, we found at least two, and sometimes three anodal peroxidase isozymes that appeared to be involved in lignification and graft incompatibility. These enzyme bands, separated by starch-gel electrophoresis and visualized by specific stains, were, for convenience, labeled "A", "B", and "C", with band "A" moving the furthest from the origin toward the positive pole. Basically, we found that trees which differed in their cambial isoperoxidase patterns could not form a lasting union and no vascular continuity was established across the graft interface. Thus, trees having only the "A" band did not successfully graft with "B" trees, and neither "A" nor "B" trees formed successful unions with trees having an "AB" constitution. Our conclusion was that long-lasting graft unions could be achieved only when both stock and scion contained identical isoperoxidase isozymes. It is of some interest that we never found any variation in anodal peroxidases in *Acer platanoides* L. or *A. saccharum* Marsh. and nurserymen have not reported any problems with intraspecific grafting in these species.

Could this theory be a universal explanation of graft incompatibility? I doubt it. In our studies of presumed graft incompatibility between *Cornus florida* L. and *C. kousa* F. Buerger ex Hance, we found that neither species produced any strong and consistent anodal isoperoxidase bands. This work was not entirely in vain however, since we were able to utilize the cathodal isoperoxidases (that moved toward the negative pole) to show that a new evergreen species from China was not a variety of *C. kousa* but a distinct and separate species (Dudley and Santamour, 1994).

WOUND COMPARTMENTALIZATION

All forms of grafting involve wounding of both stock and scion, ranging from complete severance of both members to mere removal of some bark tissues. When woody plants are subjected to wounds that expose xylem tissue, at least one of the responses is the production of chemical compounds that are inhibitory to the growth and spread of microorganisms, thus walling off the injury and preventing wood discoloration and decay. This process has been termed "compartmentalization", and a model system, CODIT (compartmentalization of decay in trees) has been developed (Shigo and Marx, 1977). This model is not overly complicated, but it must be understood to be appreciated and a full exposition here is not possible. But it is important to know that the potential for any tree to successfully wall off or compartmentalize the cells killed by injury is under moderate to strong genetic control (Shigo et al., 1977; Santamour, 1979).

Of the four walls produced by the trees in response to wounding, the easiest to reproduce, the simplest to understand and possibly the most biologically meaningful is Wall 2. Wall 2 is formed interior to any incursion into the xylem and the amount and quite possibly the rate of production of various chemicals in the Wall 2 zone determines whether that tree is a "weak" or "strong" compartmentalizer. The formation of a strong Wall 2 prevents the inward spread of microorganism-caused discoloration toward the center of the tree. In trees that form only a weak Wall 2, such discoloration may extend even to the pith. The chemicals that form Wall 2 may be water-soluble or water-insoluble and are probably synthesized through the breakdown of carbohydrate reserves in ray parenchyma (Santamour, 1987). There are still many unknowns regarding the compartmentalization phenomenon, but some understanding may be achieved through reading some of the references cited in this paper.

What does wound compartmentalization have to do with graft compatibility? I'm not sure, but I can say that **every** cultivar I have tested, those that have traditionally been propagated by budding or grafting, has proved to be a strong compartmentalizer in that they produced a strong Wall 2 in response to a chisel driven into their trunk. These trees have included 33 cultivars of such genera as *Acer*, *Fraxinus*, *Ginkgo*, *Gleditsia*, and *Tilia*, (Santamour, 1984 a., 1986). When we tested some hybrid poplar (*Populus*) cultivars, traditionally reproduced by rooted cuttings, both strong and weak compartmentalizers were found (Santamour, 1986). Tests for the ability to compartmentalize trunk wounds can be made easily even on young trees (Santamour, 1984b). Both strong- and weak-compartmentalizing trees have been found in virtually all tree species we have studied, and it would be interesting to determine whether a weak-compartmentalizing tree could even be grafted to itself.

GIRDLING

Girdling may be defined as the disruption of vertical continuity of phloem around the total circumference of a woody stem. In most forms of grafting, especially those involving complete severance of stock and scion, the resultant two-parted plant is girdled. The interruption of normal phloem activity may result in drastic alterations in cambial physiology (or in the formation of a new cambium) and these alterations may be dependent on the time of grafting and the distribution of vessels (ring porous vs. diffuse porous) in the species being grafted. There is little I can add to the brief discussion of this subject in Santamour (1988a), but it is apparent that investigations of the effects of girdling would require extremely detailed anatomical study.

COUMARINS

Up to the present time, little attention has been given to the presence of coumarin compounds in the stem bark of woody plants. Yu and Carlson (1975) postulated that coumarins may play an important role in tree growth and (graft) compatibility. In their work, they were dealing only with seedlings of *Prunus avium* L. And *P. mahaleb* L., of which only the latter species contained the coumarin herniarin (7-methoxycoumarin). More recent work in our laboratory (Santamour and Riedel, 1994) found both scopoletin (6-methoxy-7-hydroxy coumarin) and its 7-glucoside (scopolin) in the bark of mature grafted trees of several *P. avium* cultivars. Strangely, no coumarins were found in *P. avium* seedlings. (Is there an effect of aging?). The distribution of scopolin and scopoletin varied both within and between

the *Prunus* taxa we studied and the inheritance patterns were highly erratic. Scopolin and scopoletin may also occur in the stem bark of other woody genera (unpublished data). While it has not yet been determined whether these coumarins actually could be related to certain graft incompatibility problems, their influence on IAA oxidase activity has been well documented (Andreae, 1952; Schaeffer el al., 1967). In fact, Imbert and Wilson (1970) considered scopoletin to be "the most potent, naturally occurring stimulator of IAA oxidase activity so far reported". The destruction and/or activity of IAA must have profound effects on the growth and development of tissues at the graft interface and the study of coumarins and graft incompatibility may prove to be a fertile field of endeavor.

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Citrus Rootstock-Scion Compatibility and Characteristics

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HISTORY

The genus *Citrus* originated on the Asia continent, with tales of early movement from China, Burma, Malaysia, and Vietnam area to Mesopotamia and Palestine, sometime between the 9th and 6th Century B.C. The Biblical reference "hadar" suggests the citron to be the first citrus used, moved, and cultivated in new regions and by the Second Century the "Persian apple" was extensively distributed around the Mediterranean. During Constantine the Great (274-337 AD) mosaics of lemons and oranges were found. Albertus Magnus (1193-1280) described the sour orange with the name Arangus, the first description of *C. aurantium*, and later the term became the word orange.

Sometime in July 1518 citrus was planted in the Americas and it was during this time of expansion many new varieties were transported via seed.

Descriptions from travelers in Florida during the mid 1700s tell of citrus fruits growing spontaneously over the countryside. The majority of these trees were of the sour orange type. By the 1830s a topworking technique was introduced on the D.D. Dummitt grove in order to change the old sour wild groves to new selections which were now being commercially grown. With many markets being made available during a population growth, there was now a reason to develop a citrus industry. During this time budding replaced seed propagation as the primary form of propagation.

Also during this era the California citrus industry was halted for a short time as the Missions maintain control over all citrus propagation. In 1834 Jean Louis Vignes planted 35 sweet orange trees at his residence and through his cooperation eventually citrus was spread to new orchards. Today citrus is produced in over 100 countries on six continents with current world production exceeding the total volume of deciduous tree fruits.

Cultivated citrus in the 1990s has evolved from the experience of the past scientific and horticultural responses observed and consequently adjusted. The combining of a rootstock and scion, through the predominately used T-bud process, has changed very little, while the actual cultivar has remained the quandary of even the present. The scientists want to produce the ultimate plant tissue for horticultural expediency and the market wants the ultimate in fruit quality. Consequently, many new *Citrus* varieties are constantly being developed and introduced. Unfortunately, the process in developing new varieties is slow due to a number of years required for adequate testing and evaluation.

In any case the citrus nursery tree is the foundation of the citrus industry. The proper beginning will reward the orchardist in their efforts to supply a quality commodity with energetic public acceptance.

The responsibility of the nursery manager is to maintain the two most important rules of plant propagation:

- Observe the characteristics of propagation material and obtain only true-to-type budwood and seed source.
- Select budwood and seed from disease-free and tested material, preferably from one of the many foundation and budwood certification programs.

Citrus rootstocks are primarily grown from seed due to the highly predictable nucellar embryo germination. *Citrus* produces both polyembryonic and monoembryonic seeds. All non-pollinated embryos are from maternal genetic material and are asexual. The genetically identical nucellar embryo germinates predominantly in the most often used rootstocks of choice. A rouging of zygotic seedlings still is important to keep seedling uniformity.

There are six commercial species of *Citrus* and within these species hundreds of cultivars and budlines are used around the world. Some of these varieties have been created from either natural hybridization or human selection; many are products of spontaneous mutations. Presently, citrus mutations can also be artificially induced by irradiating seed.

CLONAL PROPAGATION

Taking advantage of a single, superior plant by asexual reproduction is most easily done by selecting a cultivar and budding onto a nucellar seedling. Because of genetic uniformity, predictable results may be obtained in orchard conditions.

There are three main purposes for using a rootstock while propagating *Citrus:*

- Mitigating juvenile characteristics. Trees grown from seedlings tend to be upright in growth pattern, vigorous, and thorny. When selecting budwood from scion trees there is a reduction in these effects.
- Environmental adjustments. Rootstocks have the ability to differ in tolerances to various pathological, soil, and climatic conditions. These limitations may directly affect the growing location of citrus.
- Horticultural traits. The relationship of rootstock on the scion has many direct effects on the quality of the fruit, the growth and precociousness of the tree, and productivity.

CONCLUSION

In selecting a scion/rootstock combination, research the conditions in which the tree will ultimately be grown and use the current information gathered by the cooperation of growers and scientists. The combination of many years of experience will help in making the correct choice. It takes many years to benefit from the fruition of your choice so do it wisely.

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"Graft Union and Incompatibility" Question-Answer Period

Jon LaForge: Steve, you mentioned a fungicide dip used in the field for Marianna. Could you explain that in more detail?

Steve Veyna: Sometimes we use Captan or Physan 20. We follow label directions to determine concentrations.

Frank Santamour: I forgot one word: predict. We can predict the incompatibilities without having made the graft on the basis of the isozymes for those species I was talking about. Our predictions were 80% correct with the oaks.

Phil Barker: If a nursery wanted to identify the peroxidases in their material they are grafting, who could work with them?

Frank Santamour: *Beautiful question, Phil. I investigated a nursery friendly* home-design kit a number of years ago and it worked pretty well. But, this was done for human and animal blood work. When I tried to stain for peroxidases with this gel kit, it didn't work. For the price of postage, if it's real interesting, get in touch with me.

Jim Conner: A question for Steve Veyna... I had an opportunity to visit Bailey Nursery and Sherman Nursery in Iowa and I noticed when they are digging, their material is almost always put back into cold storage so it can be graded later. I noticed you laid your trees out in sunlight. Is there a limit to how long you leave it out? Second part... I noticed last year buying trees from Oregon, Minnesota, or California, there seems to be a difference in grading. Is there a standard that is acceptable?

Don Kleim: I'll make an easy comment. Didn't you notice all that fog during his digging operation? Most of the digging that's done on the Valley floor occurs when the relative humidity is high due to fog.

Steve Veyna: *Those other nurseries ship to the colder areas and the reason they* have to use cold storage is because they have to wait until those areas thaw out before they can ship to them. We grade three fingers from the bud union. That's way above the union.

Charley Hess: How did you choose peroxidase to use to correlate to incompatibility and did you look at other substances that might correlate to degree of incompatibility?

Frank Santamour: Actually, we got into the use of isozymes for clonal identification. There are sometimes 10 isozyme patterns you have to run to zero in on one clone. *Peroxidases were easy to work with and they did something. They make lignin.* We don't know what the other enzymes do. Peroxidases stain easily and there is plenty of variability.

Bill Burchell: Frank, interested in your comment on rot in grafting areas, can you expand on that and are we losing something in sanitation?

Frank Santamour: The discoloration you saw that proceeded down from the cut surface of the understock should stay just about there. As far as the wound

compartmentalization and its relationship, I just can't say, but I would suspect that if you had many weak wound compartmentalizers as your understocks and we don't know that your take of budding might be a lot lower than if they were strong. This is highly theoretical at this point and I don't think that sanitizing, applying fungicides, will do any good.

John Nitta: What is the availability of the pistache, Keith Davey? Can you explain your propagation technique for it?

Don Kleim: I am more than delighted to explain the technique. Here are a few important things to keep in mind. Experiment with various seed sources for your understock. Eventually, you will find a source that will be more effective than others. *Pistacia chinensis* is a fast-growing tree that "bleeds" when cut. The bleeding prevents callus formation and can flood the bud out. To overcome this you can use a bottom cut or an inverted T-bud and a balance wrap. Wait until the bud pushes before you unwrap it. During the winter months, let the trees go dormant, then bring them into a cold house (no heat) and let them start to swell (may take 3-6 weeks). If they are brought in in December they are ready to work with in late January. When they start to swell gather scion wood from terminal shoots. Use an English approach graft or a side-veneer graft, as some people call it. Once the graft is made, use a sealant called Tree Doc. We put the grafted plants on a bench with bottom heat (60 F). In three to six weeks, growth should be apparent.

Phil Barker: Up around the Sacramento area, almost all the pistache trees produce nonviable seeds because of an insect that infests almost all the fruit. Is that a problem elsewhere and does anyone have a solution to this problem?

Don Kleim: Trees in our area form seeds readily.

Antibiotics in Sphagnum Moss

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Horticulturists have used sphagnum moss as a seed germination medium for years. It has a high moisture-holding capacity and provides good aeration. In addition to the favorable physical features, seedlings germinated in sphagnum moss have a lower incidence of "damping off," a term used to describe the rapid death of seedlings caused by several fungi including *Pythium, Rhizoctonia,* and *Fusarium* spp. Substances have been extracted from sphagnum which inhibit the growth of fungi associated with damping off. One source of the fungistatic substances is bacteria in the genus *Pseudomonas* which grow in association with sphagnum moss. The species of *Pseudomonas* producing inhibitory substances varied in sphagnum collected from different geographical areas. One of the substances is tropolone.

INTRODUCTION

Understanding natural biological control systems which have evolved over long periods of time may provide information basic to environmentally friendly pest management systems of the future. Many synthetic substances used for the control of fungi have or are in the process of being removed from commercial use because of environmental or human health concerns. Knowledge from studying natural biological control systems can help in the development of alternative pest management strategies which would contribute to the long range improvement and sustainability of U.S. agriculture.

Horticulturists have used shredded or screened sphagnum moss as a germination medium for years. It may be used alone or as a layer over another germination medium. Sphagnum moss has a high moisture-holding capacity because the leaves and stems are comprised of groups of large water-holding cells. It also provides good aeration. However, the primary reason for its use is that seedlings germinated in sphagnum moss have a much lower incidence of "damping off," a term used to describe the rapid death of young seedlings caused by a number of phytopathogenic fungi in the genera *Pythium, Rhizoctonia,* and *Fusarium*. Hope et al. (1941) measured germination percentages on a wide range of plant material with and without the presence of sphagnum moss. In all cases, the use of sphagnum moss enhanced the percentage germination and survival of the seedlings. They also showed that live sphagnum moss and dried sphagnum moss were equally effective in preventing damping off.

Sphagnum moss should not be confused with sphagnum peat, the decomposed residue produced from moss in bogs. Sphagnum peat also may be suppressive to diseases caused by soil-borne plant pathogens. The suppressiveness to damping off and root rots caused by *Pythium ultimum* is related to the decomposition level of the peat (Boehm and Hoitink, 1992). The least decomposed, light peat has the greatest suppressiveness.

Fleming and Hess (1964) reported that a substance could be extracted from sphagnum moss which inhibited the growth of the damping off organisms, *Pythium, Rhizoctonia,* and *Fusarium.* They also suggested that a source of the inhibitory substance may be a bacterium growing in association with sphagnum moss. Granhall and Hofsten (1976) have shown through electron microscopic studies that intracellular organisms such as blue green algae and bacteria are found in the large hyaline cells of sphagnum. Many bacteria were found embedded in the mucilaginous material lining the insides of the hyaline cells. Dal Vesco (1974-75) observed that samples from sphagnum-dominated vegetation were poor in fungal species diversity. He suggested that the inhibiting properties of sphagnum moss make plant residues less degradable.

Hess and Hess (1982) isolated two fungistatic substances from sphagnum moss and from pure cultures of sphagnum-associated bacteria grown in potato dextrose broth. Preliminary thin layer chromatography and chromogenic reagent data indicated that the fungistatic substances may be phenolic acids.

Thus, a number of researchers over a long period of time has demonstrated or observed the presence of inhibitory substances associated with sphagnum moss. On the basis of the literature and our own research, there clearly are substances in sphagnum moss which inhibit the growth of other organisms.

CURRENT RESEARCH

In the current research, scanning electron microscopy has shown a high population of bacteria on the surface of freshly harvested sphagnum shoots and electron microscopy confirmed the presence of bacteria embedded in the mucilaginous material lining the insides of the hyaline cells. The bacteria producing the fungistatic substances are gram negative and rod shaped with polar flagella. Based on metabolism on differential media, the genus of the bacteria is *Pseudomonas.* The species of the bacteria differed depending on where the sphagnum moss was collected.

There are three fungistatic inhibitors found in extracts of sphagnum moss or bacterial cultures. The R_f values of the inhibitors from sphagnum and bacterial cultures are the same in thin layer chromatography (TLC). The R_f values on a silica gel plate using a benzene : methanol : glacial acetic acid (180 : 32 : 16, by volume) solvent system were 0.2, 0.4, and 0.7. Attempts to identify the inhibitor at R_f 0.7 were made because it was present in the largest amounts in extracts from sphagnum moss and bacterial cultures. This inhibitor reacted to chromogenic reagents as follows: diazotised sulfanilic acid - orange red to red; ferric chloride/ferric cyanide - blue; and bromocresol green - yellow. The reactions with the first two reagents indicated the presence of a phenolic functional group and the bromocresol green reaction indicated a carboxylic acid group.

Bacteria isolated from sphagnum moss collected in Millston, Wisconsin produced large quantities of the inhibitor found at R_f 0.7. A sufficient quantity of the inhibitory substance was extracted to permit crystallization. X-ray crystallography was used to identify the inhibitor as tropolone. Tropolone is a non-benzenoid, aromatic compound with a seven-membered ring. It is a weakly acidic compound with a hydroxyl group at position seven and a carboxyl group at position one accounting for the phenolic-acid-like reactions to the chromogenic reagents described above.

One of the early reports of the antibiotic activity of tropolone was made by Pauson (1955) who investigated why western red cedar (*Thuja plicata*) was so resistant to decay and attributed the presence of a derivative of tropolone to its durability. Lindberg et al. (1980) and Lindberg (1981) reported the isolation of a tropolone producing *Pseudomonas* sp. from Bermuda grass (*Cynodon dactylon*) and demonstrated that tropolone was toxic to *Pythium* and other fungi.

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New Applications in Clonal Forestry

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DEFINITION

For many folks, clonal forestry simply means planting cloned trees in forests. However, it is increasingly coming to imply much more than that (Libby and Ahuja, 1993a). In brief, full clonal forestry means that a relatively few, tested, well-understood clones are deployed to the forest. Furthermore, it means that not only is the value of the forest increased because the clones have outstanding value, but also that the efficiency of management is increased because management can adapt to the strengths and requirements of each well-known clone.

HISTORY

The history of clonal forestry extends back at least 1000 years and that of cloning trees even longer (Libby and Ahuja, 1993b). Yet it is a recent development in mainstream forestry, and most of the so-called new applications discussed below are pretty early in this developing field.

The oldest continuous program of clonal forestry is from south-central China, with Chinese-fir (*Cunninghamia lanceolata*), a near relative of our coast redwood. That story is being developed for publication by Professor Minghe Li, of Huazhong (Central China) Agricultural University in Wuhan, Hubei Province, collaborating with Weyerhaeuser's Gary Ritchie. For 10 centuries, Chinese farmers and foresters have rooted shoots of good Chinese-firs, and thus developed locally adapted clones with excellent properties.

A better-known program of clonal forestry, also with one of redwood's relatives, has long been operational in Japan with sugi (*Cryptomeria japonica*). Increasingly well-known cultivars, often a mixture of several similar clones, have been grown in Japanese forests for over 500 years. Recent production of sugi cloned as rooted cuttings has varied between about 20 million and 50 million plants per year (Ohba, 1993).

Poplars and willows have also been clonally produced for millenia (Zsuffa et al., 1993), and the well-known Lombardy poplar and weeping willow clones both originated and became widespread over 300 years ago (Kleinschmit et al., 1993). During the past century, some of the most advanced strategies for using clones in forestry have been developed with clones of these two genera, and particularly with hybrids between the American *Populus deltoides* and the European *Populus nigra* (Zsuffa et al., 1993).

Some of the greatest excitement lately has been generated by recent successes of clonal forestry with eucalypts. In the Aracruz Florestal program in Brazil, for example, average productivity was quickly jumped from 33 $m^3 ha^{-1}$ of wood per year in seedling plantations to 70, by selecting healthy well-formed clones from those seedling plantations. This increase in wood-volume growth was accompanied by an increase in the average basic density of the harvested wood, and thus a decrease of 19% in the cubic meters of wood consumed per ton of pulp produced (Zobel, 1993). Some clones now in test grow over 100 $m^3 ha^{-1}$ of wood per year (average wood productivity of commercial American forests is about 4 $m^3 ha^{-1}$ per year).

Finally, and perhaps why I'm here, the company I work with in New Zealand produces about 8 million Monterey pine stecklings and plantlings (the rooted-cutting and tissue-culture stocktypes) per year, at our nursery at Te Teko. It has been over 4 years since we've planted a Monterey pine seedling on our North Island forests, except a few for research purposes.

RATIONALE

There are at least three reasons to be involved in clonal forestry: (1) We will need more wood from less land. (2) Raising wood clonally is more profitable. (3) Clonal forestry is, in several ways, a better way to professionally grow new forests.

Will We Really Need More Wood from Less Land? We've heard cries of timber famine before, and yet, timber gluts have been more common than timber famines during the recent century. However, in his presentation to the Portland Oregon Meeting on planted forests last year, Dr. Wink Sutton reviewed not only the upward trend in human population worldwide, he also reviewed the continuing rise in per-capita use of wood and wood products in both developed and undeveloped economies. He calculated that the combination of these two trends will, in the near future, require an increase in world wood supplies about every 6 months that is equivalent to all the wood produced annually by New Zealand plantations. Or, closer to home, about every 6 years Earth's forests will need to add an increment to annual forest harvest that is equal to the recent annual wood harvest in British Columbia.

In most countries today, forest land is being converted to agricultural and urban purposes, and/or forest land is being withdrawn from timber production for watershed, wildlife, recreation and aesthetic purposes. With few exceptions, these withdrawals are larger than the new forests that are being created on unforested lands. Growing wood more effectively in timber-producing forests is at least a good way to delay a possible timber famine. Perhaps that timber famine can thus continue to be avoided until we achieve a sustainable human population in tune with sustainable forest harvests.

Is Raising Wood Clonally More Profitable? This is not a guarantee that it always is. I'll give you two case examples drawn from New Zealand experience. Both will be given in New Zealand dollars (currently about 70% of the U.S. dollar), but I think the principles will be clear.

The first is how, in the mid 1980s, John Gleed (1993) convinced corporate management to raise and plant expensive cloned propagules rather than much cheaper seedlings. A series of arguments is given in his cited paper, but two of them carried the day. They are both focused on reducing early costs, rather than the more traditional argument that good clones increase later returns.

When New Zealand foresters planted unselected Monterey pine seedlings, they were planted at a density of about 2500 stems per ha, and then thinned in several stages to a harvest density of about 250 trees. Large amounts of time and money were devoted to deciding which trees to prune, and to thinning out the 9 poorer trees in each 10-tree neighborhood. Using reliable clones, the initial planting density can be about 600 stems per ha, with lower per-hectare planting costs as well as much lower subsequent thinning costs to achieve the same 250 (probably higher quality) stems per ha to grow on to harvest.

Because the clones are at a somewhat greater maturation state than seedlings, their branch architecture allows more effective and cheaper pruning than does that

of the typical seedling. That, plus the fact there are fewer trees per hectare that need be pruned, leads to additional pruning cost savings.

The combination of planting fewer trees, pruning fewer trees, thinning out fewer trees, and spending less time pruning each pruned tree, added up to substantial cost savings per hectare. These savings were recovered within the first decade after planting. Never mind that the trees will be worth more at harvest as well. The early net cost savings alone convinced management to accept the higher cost per planted propagule.

Our clonal program began in earnest in 1987. Managers of other organizations were still requiring that nursery-cost-per-propagule be equal to or less than nursery-cost-per-seedling in order to consider cloning. (This requirement, by the way, is generally satisfied for Chinese-fir, sugi, poplars, and willows.) Then, during the following 4 years, another financial element came into play.

In the late 1980s, Monterey pine seeds cost less than $1000 per kg. It cost between $1300 and $1700 to raise rooted cuttings that would equal the number of seedlings that could be raised from a kilogram of seeds. But, because others were doing benefit/cost analyses similar to John Gleed's, managers were increasingly willing to pay more for seeds from proven families. The demand for seeds of the better proven families drove their price over $2000 per kilo, and it has recently been between $6000 and $10,000 per kilo for seeds from the very best families. This sharp upward shift in price for genetically reliable planting stock of many tree species became clear during a 1992 symposium (Bey et al., 1992). It doesn't take a very sophisticated analysis to figure out that buying relatively few seeds at $8000 per kilo, and then vegetatively propagating them at $1500 per-kilo-equivalent, is a sensible thing to do. Several other organizations in New Zealand and Australia have joined the one I work for, which by the way is now called Fletcher Challenge Forestry, in planting 100% vegetative propagules in their wood-production forests.

It is well established with fruit-tree species that reliable clones produce a more profitable harvest than genetically variable seedlings. The same principle should hold for forest trees, although we don't yet have much harvest data to back up that principle.

Finally, many smaller forest owners don't have, and probably can't afford to have, their own clonal propagating nurseries. So, for some of you who DO have the capability to clonally propagate trees, there may be a fine opportunity to make your own profits in that niche.

How is Clonal Forestry Better Professionally? Before answering this question, it is perhaps useful to indicate that wood is an important and environmentally sound natural resource. This has been well done in two recent articles (Koch, 1992; Postel and Heise, 1988). Postel and Heise reviewed the needs of many of Earth's peoples, and the availability of wood to satisfy those needs. Koch calculated the costs of wood and of various substitutes such as plastic, steel, aluminum, and cement. Rather than monetary costs, he calculated the energy costs of production, manufacture and delivery, the fossil carbon dioxide thereby released, and the toxic pollutants released incidental to that production and manufacture. With very few exceptions, wood has much lower environmental costs than do these and other substitutes considered.

In brief, clonal forestry allows the forester much greater control. Knowing the requirements and performance of the deployed clones allows management activities such as pesticide application, fertilization, thinning, and pruning to be scheduled

and executed more efficiently. It probably means less pesticide and fertilizer over-applied, or inappropriately applied. It also allows more precise control of deployed diversity and, perhaps surprisingly, more effective deployment of genetic diversity than does the planting of sexually-recombined and thus individually-unknown seedlings. In short, it allows us to grow forests that are less at risk of environmental damage, and are less at risk of disease or insect epidemics, than were previous plantations of seedlings, or even naturally-regenerated forests. That sounds pretty egotistical. We think we can do it (Libby, 1982).

NEW APPLICATIONS

Well, finally to the topic requested. I can be brief, partly because you already know about most of these approaches to cloning.

We are developing better ways to root cuttings, both to lower costs and to produce propagules that, upon outplanting, grow better than seedlings (Bey et al., 1992).

Tissue culture and somatic embryogenesis are both moving from research projects to operational forestry much faster than many of us had anticipated (Talbert et al., 1993). Some of you may have noticed the 8000 acres of eucalypts west of I-5 near Corning. In recent years, new plantings in that Simpson Timber Company plantation are almost exclusively of tissue-culture origin. In New Zealand, Fletcher Challenge Forestry is now operationally putting about 2,000,000 tissue-cultured Monterey pines out the nursery gate annually at Te Teko. Emblings (plants of somatic-embryo origin) of yellow-poplar (*Liriodendron tulipifera*) and of several pine and spruce species are now growing by the thousands in early tests of this stocktype. (As yet, no somatic embryos of forest-tree species have been operationally encapsulated in artificial seeds.)

Although grafting was tried and rejected for production plantations in the first half of this century (Larsen, 1956), values of individual trees are now becoming high enough so that this is again being considered.

Maturation of a clone is a problem for both propagation and subsequent growth (Frampton and Foster, 1993; Greenwood and Hutchison, 1993). It is also an opportunity. For example, compared to juvenile clones or seedlings of Monterey pine, mid-adolescent clones grow straighter, have fewer and smaller branches, and are more resistant to juvenile diseases such as western gall rust.

Finally, ecosystem restoration is an increasingly important activity, and it is often done counterproductively (Millar and Libby, 1989). One problem is that nonlocal plants of native species are often planted into the ecosystem being restored. They can then cross pollinate with the remaining local plants of that species, thus probably reducing the adaptedness of the offspring to the site. One solution is to clonally propagate some of the remaining local plants, thus increasing numbers and keeping the gene pool truly local.

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Breeding Miniature and Other Roses

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Breeding miniature and other roses: To get to where you want to go, it's best to know where you are and where you have been.

BEGINNING

First of all, most of us who breed roses and other plants usually begin with what we have and where we are. We may have no long-term plans or projects in mind. We learn the simple basics of pollination, seed harvesting and planting. We anxiously wait to see what comes up. But the serious breeder of roses (and other plants) will learn about different cultivars being grown now and in the past, the different rose types or classes, species, etc. He or she will study what has been done and keenly observe not only his/her own work, but that of other breeders.

In my own case, it was the little roses - Cecile Brunner, some of the polyanthas and rambler roses of the day plus certain old tea, china and other roses, that grew in my mother's and my grandmother's gardens that caught my interest. First, I grew self set (bee pollinated) seeds from a large plant of 'Climbing Cecile Brunner' and also seeds of several other roses to see what would happen. Thus, I got an introduction to rose seed harvesting, planting and propagation at the early age of 14! So I have been at this rose breeding a long time. But I really got started in serious rose breeding about 60 years ago (in the mid-1930s) Through the years I have studied and observed the work of Luther Burbank, Dr. Walter Lammerts, Kordes, Jack Harkness and others.

"IMAGINEERING"

Several years ago Dr. Howland of the University of Nevada used a word which I think describes the breeding of roses. That word was "imagineering". In any creative endeavor we must imagine or dream of what is desired and then devise or discover ways to achieve that end. Along the way always be ready for surprises. Little things, variations in plant habit, flowers color, size and shape may be observed. Disease resistance, ease of propagation, tolerance of heat and cold and other factors all enter into any successful long term breeding project. In short, this is what rose breeding is all about.

ROULETII

Now, for some specifics from my own work and observations over the years. The story usually told is that a little rose called Rouletii (*Rosa* 'Rouletii'), discovered in Switzerland in 1918 is the cultivar from which all present day miniatures are descended. This is only partially true as there is another "found" rose, named 'Oakington Ruby', which was introduced by Robinson (England) in 1933. I did not use Rouletii directly in my breeding, but used one of its offspring named 'Tom Thumb' (Peon in Europe). When 'Carolyn Dean' (a seedling from 'Etoile Luisante'

[polyantha]), a small cluster flowered climber was crossed with 'Tom Thumb' the tiny miniature 'Zee' was produced. When 'Zee' was crossed to other roses I got a whole array of miniatures and larger roses. From the seedlings, several were selected and introduced, among them a very fine yellow named 'Yellow Doll'.

In the meantime I had acquired another dwarf polyantha rose of European origin called 'Éblouissant'. When 'Éblouissant' was crossed with 'Zee' two cultivars of importance resulted. 'Fairy Princess', a mini climber to about 3 ft., was used on crosses to produce my well-known 'Mary Marshall' and by Dr. Onodera in Japan to produce his 'Nozomi'.

The other selection, a medium-red mini-climber, was named 'Magic Wand' and its "magic" helped to develop many of today's miniatures, among them 'Sheri Anne', a popular orange-red that has been used by many breeders.

Another one of Magic Wand's crosses produced a very bushy, compact pink miniature we named 'Little Chief'. And 'Little Chief' became the seed parent of the first striped miniature named 'Stars 'n Stripes'. This one has also been grown worldwide and used by numerous breeders to produce, directly and indirectly, several of the striped roses in commerce today.

OAKINGTON RUBY

The other side of the story is about 'Oakington Ruby'. Among some of my earlier crosses were two which would prove to be of great importance. One, a cross of the species, *Rosa wichuraiana* × 'Floradora' [a very new cultivar of the time and later used by Dr. Walter Lammerts at Germain Nurseries in Los Angeles, CA to produce his famous Queen Elizabeth® rose ('The Queen Elizabeth Rose')] was selected for further breeding. Several plants of this rose, #O-47-19, were grown and over the years thousands of pollinations were made of many different combinations.

At about the same time I crossed 'Oakington Ruby' with 'Floradora', one plant of this cross with very double 1-1/2 in. red flowers produced pollen that was then used on our 0-47-19 seedling. From this cross we got several new miniatures that were named and introduced. Among them were 'Little Buckaroo', 'Dian', 'Westmont', 'Red Germain' and others.

But, it was 'Westmont' and 'Red Germain' that would prove the "value" of this cross and parentage. Crosses of 'Little Darling' × 'Westmont' produced two important miniatures, 'Over the Rainbow' and Magic Carrousel® ('Moorcar'). When I made the cross of 'Little Darling' × 'Red Germain' three seedlings were selected and named. They were 'Windy City' (pink), 'Janna' [pink and white bi-color, similar to Magic Carrousel® miniature rose ('Moorcar')] and 'Peachy White' (a lovely white, blended with soft pink and an 'Award of Excellence' winner from the American Rose Society Miniature Trials). When 'Peachy White' was crossed to 'Golden Glow', (a Brownell sub-zero yellow climber) four good yellow miniatures were produced, 'Yellow Magic', 'Yellow Jewel', 'Golden Angel' and 'Calgold'. All these roses have been used by me and others.

'Little Darling' × 'Yellow Magic' gave two selections, # 1-72-1 (a yellow mini Climber) and 'Rise 'n Shine', an Award of Excellence miniature. # 1-72-1 ('Little Darling' × 'Yellow Magic') × Gold Badge™ ('Meigronuri') produced Golden Gardens miniature rose ('Morgogard') and the award (AOE) winning Cal Poly miniature rose ('Morpoly'). More recently we have introduced a tiny yellow offspring of Cal Poly named *Cinderella Gold miniature rose* ('Morcingold') (1996). *So all these roses, and*

more, owe their miniaturization to 'Oakington Ruby' and not 'Rouletii'.

RUGOSA AND OTHER ROSES

But there is more. I firmly believe the miniature rose of today will be employed more and more in the breeding of roses of all types. Species and other crosses, difficult or not ordinarily possible, will be successful when some of the miniatures are involved in the breeding. Also, I have learned that it is not difficult to move up and down the scale from large to small or small to large.

A few cases in point. I have made many crosses of rugosas on miniatures. Topaz Jewel rose ('Moryelrug') is a cross of 'Golden Angel' × 'Belle Poitevine', and is the first repeat flowering yellow rugosa. Linda Campbell ('Morten') is a cross of 'Anytime' (miniature) × *R.* 'Rugosa Magnifica'. Both are full-size shrub roses even though the seed parent was a miniature. And we have many more roses of unusual crosses being developed and tested here at Sequoia.

Out of my work with miniature roses has come an array of miniature, floribunda, climbing, striped, mossed and groundcover roses. The latest is my new line of HALO™ roses. These mimic the difficult *Hulthemia* (*Rosa*) *persica*. Near the base of each petal is a red to lavender area giving the flower a halo effect.

There is so much more to be done with roses, so many untapped possibilities. We need more "imagineering". I have been at this for many years and am still excited about the possibilities!

"General Propagation Topics" Question-Answer Period

No recording.

Hardwood Cuttings as a Nursery Practice: *Prunus*, Developmental Aspects

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Hardwood cuttings are made of 1-year-old, dormant, leafless cuttings of deciduous plant species. For clones with a capacity to initiate adventitious roots easily, the procedure is simple, economical, and readily adapted to commercial applications. The development, introduction, and commercial success of a new nursery product, such as a clonal rootstock, is a long-term project which does not end in the research plot, but continues until the product is accepted by both the propagation nursery and the production industry. This paper describes a case history of one such product and ongoing stages in its development.

Rooting Parameters. Biological and horticultural parameters for rooting, nursery handling, and site establishment are the following: (1) genetic potential, (2) propagation source selection and management, (3) cutting selection and treatment, and (4) environmental management and survival.

Prunus Rootstocks. The stone fruit (*Prunus*) and nut industries and nurseries of California prefer seedlings as rootstocks. 'Nemaguard' is the most often used rootstock for commercial peach orchards. Nevertheless, clonal rootstocks are being introduced for specific uses. 'Marianna 2624' plum is a major success story in rootstock development and is a model system in California for clonal rootstock propagation. The original 'Marianna' rootstock originated as a seedling of myrobalan (*P. cerasifera*) plum in Texas, believed to be from a cross with *P. munsoniana*. Trees of this hybrid were in the collection at the Dept. of Pomology, U.C., Davis. Leonard Day (1953) planted seeds from the hybrid and tested a range of seedlings for ease of propagation and as clonal rootstocks for stone fruits. Two clones were selected as 'Marianna 2623' and 'Marianna 2624'. The latter showed some tolerance to *Armillaria* (oak root fungus) and was introduced to California nurseries where propagation began in the 1950s. Early experiments (Hartmann and Hansen, 1958) with hormones and methods of handling showed a useful procedure to make cuttings in the fall (mid-November in California), treat with IBA , preferably quick dip in 50% alcohol, and store in moist peat moss at 60F for 6 weeks. Root initiation started, but shoots did not grow because of their dormancy. Shifting to 36F overcame the rest in buds and, when planted in the nursery row in the spring, the previously formed roots emerged promptly. Burchell (1996) describes the general procedure that is now widely used in California nurseries.

ROOTSTOCK BREEDING AT U.C, DAVIS

Rootstock breeding and selection programs continued to test nematode resistance genes in peach germplasm (Sharp et.al., 1969) utilizing controlled-greenhouse screens. Ultimately, breeding lines and individuals resulted which were immune to the two major species of root knot nematode (*Meloidogyne incognita* and *M. javanica*) in California (Hansen, et al., 1956). One of these known as Pch Sel. 1-8-2, although itself immune, was heterozygous, segregated genes as seedlings, and could only be utilized as a clone. A second line of research was hybridization between peach and almond which included its use as a rootstock (Kester and Hansen, 1966), inheritance of root initiation (Kester and Sartori, 1966) and transmission of nematode resistance (Kester et al., 1970). Peach rooted easily while almond was very difficult and the hybrids showed a range from easy to difficult. Testing individuals from seedling populations of hybrids produced selections that combined nematode immunity, high vigor, ease of rooting, and what was thought to be some tolerance to *Phytophthora* (Kester and Asay, 1986). Hansen and Hartmann (1968) published a procedure for clonal propagation of peach (Pch sel. 1-8-2) and PA hybrid 2-16-8-63 clones which included fall collection of firm basal hardwood cuttings, and treatment with a relatively high concentration of IBA (quick dip; 50% alcohol) in conjunction with a fungicide [Captan and talc, 1 : 1, (v/v)]. Cuttings were immediately planted in the nursery row and left overwinter to grow out in the spring. Pch Sel. 1-8-2 was not introduced because it showed low initial survival in the orchard.

Hansen Hybrids. Eventually two hybrid rootstocks 'Hansen 2168' and 'Hansen 536' were released (Kester and Asay, 1986). Only 'Hansen 536' was attempted by nurseries and the initial reaction with the direct sticking procedure described (Method No. 1) was unfavorable and nurseries reported that rooting percentages were low. In the late 1980s, the Plant Research Laboratory (Driver, pers. comm.) in cooperation with The Burchell Nursery, Inc. found 'Hansen 536' to be well adapted to tissue-culture propagation and subsequent transfer to the field (Method No. 2). Relatively large numbers of almond trees propagated to 'Hansen 536' under the trademark name TrueClone™ began to be distributed by Burchell Nursery with some commercial success. The argument was made that 'Hansen 536' had lost rooting potential due to reduction in juvenility whereas micropropagated material enhanced rooting potential.

Two problems arose with the tissue-culture procedure, however. First, root systems produced were unique, being slender, spindly, and elongated, possibly due to juvenile influence. Although not seeming to create an establishment problem, they were not always viewed favorably as nursery plants. Secondly, the procedure was expensive. Procedures were then initiated utilizing the nursery-grown tissue-cultured plants as sources of cuttings that were grown by direct nursery rooting with some modification of timing and handling of source material (Method No. 3.). Eventually Burchell Nursery returned to the direct method.

Three other commercial nurseries were able to adapt the direct method of rooting to commercial production although all reported that the percentage was less than desired (averaged about 50%) and production was erratic both in the nursery row and in different years. In addition, some trees in specific lots sometimes failed to survive transplanting, particularly if stored or if planting was delayed. 'Hansen' has a short chilling requirement and (as stated by one nurseryman), has a short "window" for nursery handling (digging and transplanting).

New Rootstock Selection. In 1993, test plot information from a range of rootstocks indicated potential superiority of another experimental peach × almond hybrid with different parents as "Hansen 536" but from the same program. Cutting material was provided to three commercial nurseries and to Foundation Plant Materials Service, U.C., Davis (FPMS) to be planted in the same nursery rows as 'Hansen 536' a range of rooting percentages (27% to 61%) resulted for the experimental hybrid and a comparable range of 33% to 65% for 'Hansen 536'. Rooted cuttings of both rootstocks were budded to 'Nonpareil' almond and produced under standard production procedures of the three participating nurseries. Trees were dug, handled according to individual practice, and delivered to Department of Pomology, U.C., Davis. Trees of the two rootstocks were alternately planted in close planted rows at the Nickels Research Farm, Arbuckle, CA, each nursery source being kept separate from the others.

Tree survival counts made in mid summer showed differences both between rootstocks and among nurseries indicating genotype × environment (management) interactions. Trees produced by one nursery showed essentially complete survival (97% vs. 100% survival of the two rootstocks). Trees produced by Nursery 2 had been delivered in a timely fashion to U.C., Davis and were heeled in at a sawdust holding bin under a shelter, but in the open. Because of extensive rain in February, planting was delayed until after trees had leafed out. Only 4% of the trees on 'Hansen 536' survived, but 49% of the experimental hybrid had survived and grew well. Trees from Nursery 3 had been in cold storage where they remained until planting. Examination of the root systems in storage showed rotting and deterioration on essentially all roots of 'Hansen 536'; in contrast roots of the experimental hybrid were healthy with little or no rotting. Planting took place in March, of which 90% of the experimental hybrid survived whereas only 16 percent of trees on 'Hansen 536' survivied. All surviving trees on both rootstocks were growing well at the end of the year.

DISCUSSION

Rooting response and adaptation to nursery propagation may result from interactions among parameters listed in the early part of this paper. Genetic factors determine if a particular clone is easy-to-root as with 'Marianna 2624' . 'Hansen 536',which falls into an intermediate rooting category, may be vulnerable to other rooting and survival parameters. Short chilling of 'Hansen 536' narrows the dormancy window and may make this clone more susceptible to adverse storage and handling conditions. Changing to a higher chilling genotype may overcome some of the handling problems, but not improve rooting. Hormone treatments, timing of collection, type of cutting material, and source of cutting material need to be investigated. Protecting the exposed cutting from drying out in the fall and winter in the nursery row may help to increase survival (Burchell 1996). Thinner cutting material of plum produced higher rooting percentages than thicker material. However, unless the cuttings were well protected they were less capable of surviving in the nursery row. Thicker cuttings survived better under field conditions (Howard, 1994).

Selection and handling of stock material for hardwood cuttings of intermediate rooting clones as 'Hansen 536' have brought into question the possibility of loss of rooting potential occurring during the initial distribution of the clone and during

subsequent maintenance. Tissue-culture propagation, although expensive, was apparently effective initially in developing a supply of nursery plants to establish a market and possibly restoring some rooting potential which was beneficial in the next propagation generation when used in combination with other modifications of stock plant handling and timing. In the longer term, micropropagated plants did not result in significantly improved production, and the commercial nurseries involved returned to conventional propagation procedures, which had problems of inadequate and somewhat erratic rooting. Key biological questions concerning the importance of juvenility status of source plants and other procedural parameters could not be answered because of trade secret aspects of the operation.

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Rooting Walnut Hardwood Cuttings

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INTRODUCTION

The use of hardwood cuttings is often the most economical method of producing clonal rootstocks or own-rooted varieties of temperate deciduous fruit trees (Hartmann, et al., 1990). Because leaves are absent and the material is dormant, hardwood cuttings are not as vulnerable to desiccation nor are they as cumbersome to handle as leafy semihardwood cuttings. These attributes make hardwood cuttings desirable for commercial nursery production.

Since walnut is difficult to root and genotypic variation in rooting ability exists, results derived from one clone may not be applicable to other clones. Significant differences in rooting ability among *Juglans regia* (Persian or English walnut), *J. hindsii* (northern California black walnut), and their F_1 hybrid (*J. hindsii* × *J. regia)* known as Paradox have been noted (Hartmann 1978). Paradox hybrids appear to have higher rooting percentages than either parent species. In addition, F_1 hybrids differ markedly from BC_1 (Paradox × *J. regia*) hybrids in rooting ability (Sutter and McKenna, 1995). Although rooting percentages and number of roots/cutting are highest in semihardwood 'Paradox' cuttings compared to hardwood cuttings, hardwood cuttings remain an attractive method of clonal propagation for walnut because of their ease of handling.

The use of bottom heat ranging from 72 to 80F (Burger and Sutter, 1994; Lynn 1957; Sutter and McKenna, 1995) is an important factor required for optimum rooting of hardwood walnut cuttings. This requirement for bottom heat explains the poor results (only 10% to 30% rooting) obtained when one tries to root hardwood walnut cuttings directly in the nursery. When hardwood cuttings are rooted in propagation structures with bottom heat as much as 80% rooting has been achieved (Lynn, 1957; Sutter and McKenna, 1996). The difficulty in using bottom heat, however, is that it dries the lower portion of the propagation medium while the upper portion remains wet making it difficult to maintain an optimum moisture content in the medium surrounding the basal portion of the cuttings where roots form. Kester, working with several *Prunus* species determined that the optimum moisture content when using peat moss as a rooting medium is obtained by mixing peat moss and water (2 : 1, w/w) (pers. comm.). We found in preliminary experiments that this moisture content is useful for walnut cuttings as well.

The objective of our research was to determine factors other than moisture content of the rooting medium that were significant in the rooting of hardwood walnut cuttings. We investigated the effects of factors such as the method of application of auxin as well as auxin synergists on rooting of hardwood walnut cuttings.

The following is a summary of research conducted between 1993 and 1996 designed to determine the rooting potential of hardwood cuttings from a diverse collection of Paradox selections in the Walnut Improvement Program (WIP) at U.C., Davis, and an F_1 Paradox clone known for its relatively high rooting potential, Paradox Bowman Kuhn (BK).

METHODS

All plant material was collected from experimental orchards at UC Davis. Most selections, including BK, were grafted onto seedling Paradox in 1988. The trees were a diverse collection of Paradox selections obtained from the WIP at U.C., Davis. Most of these Paradox genotypes had not been screened for rooting potential. The harvest of cuttings followed a specific protocol. Shoots ranging from 2 to 5 ft were harvested in the morning from current-year shoots. They were placed upright in 5-gal pails and transported to a workroom for immediate treatment and sticking. Three node cuttings were used, 8 in. long on average, with the length largely a function of the number of nodes. Basal cuts were made 1/2 in. below a node. Stem diameters varied from 5/16 to 3/4 of an in. and terminal and subterminal cuttings were handled together. The tops of cuttings were waxed with paraffin to prevent desiccation. All cuttings were soaked for a minimum of 1 min in a 1500 ppm citric acid solution prior to auxin treatment.

Auxin was applied as an aqueous solution of the potassium salt of indole butyric acid (K-IBA) either as a quick dip or by using a KIBA-saturated toothpick. For quick dips, cuttings were soaked in 8000 ppm K-IBA to a depth of 1/2 in. for 30 sec and, allowed to dry for several min, bundled in groups of 15 cuttings with a rubber band, and placed in 5-gal pots containing peat moss moistened by using peat moss and water (2 : 1, w/w). In 1995 and 1996, cuttings were placed in individual plugs, positioned in specially designed Styrofoam® trays that allowed periodic flow-through watering. The trays were placed outdoors over bottom heat in a specially fabricated propagation structure.

Toothpick treatments consisted of soaking common round white spruce toothpicks in a 4000 ppm K-IBA solution for 18 to 24 h in an aluminum foil-wrapped vial prior to use. Pilot holes were drilled perpendicular through the entire width of each cutting in the vicinity of a node using a 3/32-in. wood drill bit and a hand-held electric drill. Toothpicks were removed from the solution using forceps, inserted into the pilot hole, and one blunt end was formed using anvil pruners. The toothpick was hammered through the pilot hole using a block of wood, and was clipped nearly flush on both sides. Cuttings were put into bundles and placed in damp peat moss or plugs as described above for quick dip treatments.

Potential auxin-synergists tested in combination with 4000 ppm K-IBA included the following: 20 ppm abscisic acid, 12 ppm o-coumaric acid, 12 ppm ferulic acid, and both 400 ppm and 2000 ppm spermine (Sigma Chemical Corp. St. Louis, Mo.). Other auxin combinations tested included 100 ppm 2-4-D + 1000 ppm NAA + 2000 K-IBA ppm; and 1500 ppm citric acid + 4000 ppm K-IBA.

RESULTS AND DISCUSSION

Rooting studies the first year resulted in low rooting percentages among the few selections that rooted. The most promising results were obtained with selections 84-121 and 84-128, but great variability was noted among replicates (Table 1). One difficulty that affected results was that the peat moss dried out in the bottom of several containers and we assumed that rooting was decreased as a result. Another important factor was the date the cuttings were collected. The greatest percentage of rooting was obtained in cuttings collected on 3 Dec 1993 (Table 1). Very little rooting was obtained in cuttings collected on 15 Dec 1993 and 11 Jan 1994 and no rooting was obtained in cuttings collected on 4 Feb 1994. In addition all selections

that rooted from the Dec. 3 collection date were treated with toothpicks, not quick dips. Of the two selections in the Dec. 15 collection date that rooted, one rooted best with the quick dip and one with the toothpick application. From this data it was impossible to determine the relative effectiveness of the two methods of auxin application. It was clear, though, there was an effect of time of collection of plant material on the rooting of the cuttings. We could not verify reports by Serr (1950) who found that hardwood cuttings rooted well when collected immediately prior to bud break since, we did not collect cuttings at that time.

Table 1. Rooting percentages of hardwood cuttings of selections in the Walnut Improvement Program subjected to different methods of auxin application. Observations were taken 50 days after cuttings were treated and placed in the propagation medium[1].

	Dec.3, 1993[2]		Dec.15, 1993[2]		Jan.11, 1994[2]	
Selection	TP[3]	QD[4]	TP[3]	QD[4]	TP[3]	QD[4]
84-121-1	53[5]	0	0	0	0	0
84-121-2	15	0	0	0	0	0
84-128-1	3	0	8	0	0	0
84-128-2	15	0	0	13	0	0
85-117-19	5	0	0	0	-	-
87-050-1	-	-	0	0	4	0

[1]Note: only those selections that produced roots are included. 11 selections did not produce any roots: 85-117-20,85-117-21,87-026-2,87-027-4,87-032-1,87-112-12,87-117-16,87-117-2,Hagus-8, Sibbett, VK110-6.
[2]Date cuttings were collected
[3]Toothpick application, using 4000 ppm potassium IBA
[4]Quick dip application, using 8000 ppm potassium IBA
[5]Numbers of cuttings in each treatment ranged from 9 to 40 depending on their availability. The experiment was run one time

In order to reduce confounding of results due to genotypic variability and low numbers of available cuttings, we conducted much of the remaining research with one clone, Paradox Bowman Kuhn (BK). This 50-year-old clone, BK, is known for its relatively high rooting potential which was demonstrated in our 1994 and 1995 rooting trials. Results of rooting trials with BK in 1993-1994 indicated that application of auxin by using toothpicks was more effective than that using a quick dip (Table 2). Moisture control of the propagating medium was handled by spraying the peat moss with a hand pump sprayer with a fine spray nozzle. The peat moss became too wet in several containers resulting in rot in the bases of cuttings.

We were not able to replicate results of Lynn (1957) in which he obtained rooting percentages as high as 80% in hardwood cuttings. Perhaps one reason for the difference in results is that the methods of auxin application were different in the two studies. Lynn (1957) treated BK cuttings with a 24-h soak in 200 to 300 ppm IBA concentrations. Another reason for the differences in the two studies may have been

that the BK clone was only 10 years old at the time of Lynn's studies. Our work used BK but it was a 50-year-old clone. An aging process, known to occur in clones, may have caused the reduced rooting that we obtained compared to that obtained by Lynn.

Table 2. Effect of harvest date and treatment on percent rooting of hardwood cuttings of Paradox Bowman Kuhn[1].

	Date	
Treatment	Dec. 3, 1994	Dec. 14, 1994
Quick dip	7.0%	9.0%
Toothpick application	8.0%	13.2%

[1]For each treatment 4 replicates of 15 cuttings each were used.

In the next series of experiments we applied several compounds together with K-IBA in order to improve the rooting percentages we had obtained with BK cuttings. Of the different chemicals tried, spermine, o-coumaric acid, ferulic acid, and abscisic acid all increased the percentage of rooting over that of K-IBA alone (Table 3). None of the other treatments had an effect on rooting percentages. Ortho-coumaric acid, ferulic acid, and spermine also caused a marked increase in the number of roots per rooted cutting (Table 3). The use of citric acid resulted in a greater proportion of rooted cuttings having roots originating on at least two opposite sides of the base of the cutting compared to other treatments in which a majority of rooted cuttings had roots emerging primarily from one side.

The experiment using 400 ppm spermine in addition to K-IBA was repeated in Dec. 1995 using a completely randomized complete block design with four blocks of 24 cuttings per treatment. The results confirmed the efficacy of spermine, although its effect was not as marked as in the previous year (Table 4). The addition of spermine to the rooting hormone solution using a quick dip produced rooting percentages three times as great as that obtained using the toothpick method of application. The combination of spermine and K-IBA resulted in rooting percentages three times that of K-IBA alone applied as a quick dip and 1.2 times greater than when K-IBA was applied alone using toothpicks (Table 4). There were fewer roots per rooted cutting than obtained the previous year. In addition, cuttings in which compounds were applied using toothpicks had an average of 4.6 roots per cutting compared to using a quick dip which produced an average of 2.8 roots per cutting. The use of a plug system in this experiment, which allowed more precise control of moisture in the rooting medium during the propagation period, made accurate root counts impossible.

Ultimately, successful clonal propagation of walnut by hardwood stem cuttings will depend on integrating methods of rooting cuttings and handling and transplanting newly rooted cuttings to yield high survival rates. Survival of rooted hardwood cuttings in our experiments has ranged between 21% and 27%. More research is necessary to enable production of own-rooted walnut trees to be commercially viable.

Table 3. Effect of various chemicals on the rooting of hardwood cuttings of Paradox Bowman Kuhn walnut cuttings, collected 20 Dec. 1994.

Treatment	Percent rooted/ (no. cuttings in treatment)	Mean number of roots per rooted cutting	Percentage of rooted cuttings having "2-sided" roots[2]
citric acid[1] 1500 ppm	13/(30)	4	0.7
o-coumaric acid[1] 12 ppm	61/(37)	8.2	0.4
ferulic acid[1] 12 ppm	77/(30)	10.1	0.3
spermine[1] 400 ppm	82/(28)	7.9	0.4
spermine[1] 2000 ppm	39/(28)	5.6	0.4
abscisic acid[1] 20 ppm	43/(30)	3	0.3
2,4-D 100 ppm + NAA 1000 ppm + K-IBA 2000 ppm	10/(30)	4.7	0

[1]In addition to the chemical indicated, 4000 ppm K-IBA was added. The resultant solution was applied using toothpicks soaked in the solutions.

[2]Origin of roots were scored depending on whether they originated from one side or from two opposite sides (two-sided) of the stem base.

Table 4. The effect of spermine with and without potassium indole butyric acid on rooting of hardwood Paradox Bowman Kuhn walnut cuttings. Cuttings collected 19 Dec 1995.

Chemical	Application method	Percent rooting mean	Mean number roots per cutting	Percent two-sided[3]
K-IBA 4000 ppm + spermine 400 ppm	TP[1]	75 ± 12.2	4.4 ±0.6	0.5 ±0.1
K-IBA 4000 ppm	TP	63 ± 0	4.8 ± 1.5	0.4 ± 0.1
Spermine 400 ppm	TP	1 ± 2.1	4.0 ± 8.0	0.3 ± 0.5
K-IBA 8000 ppm + spermine 800 ppm	QD[2]	54 ± 12.3	2.5 ± 0.5	0.3 ± 0.2
K-IBA 8000 ppm	QD	18 ± 8.6	3.0 ± 0.3	0.5 ± 0.4
Spermine 800 ppm	QD	0	0	-

[1] Toothpick application, using 4000 ppm potassium IBA
[2] Quick dip application, using 8000 ppm potassium IBA
[3] Origin of roots were scored depending on whether they originated from one side or from two opposite sides (two-sided) of the stem base.

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Propagation of Rose Rootstock 'Doctor Huey' from Hardwood Cuttings

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Bear Creek grows Jackson & Perkins and Armstrong brand cultivars of roses. We are located 20 miles north of Bakersfield, CA, near the southern end of the San Joaquin Valley. Most of our plants are budded onto one rootstock which we grow from hardwood cuttings. We plant approximately 17,000,000 hardwood cuttings each year and average 97% live cuttings stands. Our main rootstock is 'Doctor Huey', and we bud the selected cultivars onto that.

We start by fumigating our fields with methyl bromide in July or August and then prepare them for planting. The cuttings are collected from the 180 acres of stool blocks we maintain for cuttings source. We select cuttings that are mature enough that they won't bend easily, and are 1/4 to 7/16 in. in diameter. Five crews made up of 10 people each, who follow a tractor and trailer through the stool block, gather canes 30 in. long and place them on the trailer where they are grouped into bunches of 50 and placed in a tube that has slots that allow for installing three rubber bands on each bundle. The location of the rubber bands is located to fit the saw operation so that when the bundle is cut into three sections, 9 in. long, there is a rubber band around each bundle. Once the rubber bands are in place, the long bundle is removed from the tube and placed in a water barrel to get it wet, then stacked under wet burlap on pallet racks until they have a load ready to truck into the saw shed.

When they arrive at the shed the pallets are set into a water dip tank for 5 min to get thoroughly wet. They are then placed into a 0.5% solution of Bactichlor and water for 5 min to surface sterilize the canes.

The canes are then taken to the saw, where the bundles are placed on a conveyor that has semicircular trays that hold the long bundle as it goes into the saw and holds the 3 shorter bundles as it comes out of the saw. The saw has 4 circular blades that cut both ends of the 3 sections. Once through the saw, the 9-in. bundles are placed on a conveyor that runs in a long loop to the crew that "de-eyes" them (removal of lower buds).

These "de-eyers" cut the buds off the bottom 6 in. of the 9-in. cutting, leaving 1 or 2 buds on the top, to leaf out and grow. By removing the lower buds we decrease the problem of sucker growth. Once de-eyed the cuttings are bundled in 50s with a rubber band and then their bases are powdered with 0.3% (3000 ppm) Hormodin powder by tapping them into ˚ in. of powder in the bottom of shallow tub.

The cuttings are then placed in a plastic bag, 5 bundles per bag, and stored in a cool place for 1 to 2 days, until they are taken to the field for planting.

We plant the cuttings in a water furrow on a spacing of 6 in. with a row spacing of 42 in. The cuttings are stuck into the ground 3 in., and watered within a few hours. The plants are watered 3 times a week for the first week, and then twice a week until the foggy season begins. Then we water once a week until they are well rooted and ready for budding.

When the weather is warm in November we'll have a ring of callus on the base of the cutting within 14 days of planting. Roots usually start in late December. By late

January leaves appear and by the first week in April the plants are ready for budding.

We handle the long cane Tree Roses in a similar fashion with a few exceptions. One exception is that the canes are longer, i.e. 27 in., 33 in., and 47 in. We also put an opaque white plastic sleeve over the cane and we tie the canes to a bamboo stake. The plastic sleeve is 2 in. wide, perforated on 2 sides, and 3 in. longer than the cane when stuck into the soil. This keeps the cane from drying by acting as a miniature greenhouse keeping the cane warmer and more moist. Once the leaves emerge we open the top part of the sleeve to help keep the leaves dry and prevent *Botrytis*. When the plant is rooted well enough to hold the cane (early March), we remove the sleeve and tie the cane securely to the bamboo stake.

"Nursery Propagation by Hardwood Cuttings" Question-Answer Period

No recording.

Embryo Rescue and Genetic Transformation

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INTRODUCTION

A part of the plant breeding program at the USDA's Agricultural Research Service in Fresno is to develop early-ripening fresh market stone fruit and seedless grapes for the table and raisin industry. The California stone fruit industry needs earlier ripening cultivars which have fruit with good size, color, and eating qualities (i.e., high sugar and firm texture). For California's table and raisin grape industry early-, mid- and late-ripening seedless cultivars are needed with good fruit characteristics. Using conventional breeding the presence of immature embryos in early-ripening stone fruit and seedless grapes only allows their use as male parents. Therefore, in stone fruit, mid-season selections that develop mature seeds are used as female parents. For grapes, seeded females are used and only about 15% of the hybrid offspring are seedless. These small hybrid populations of early-ripening stone fruit and seedless grapes make the development of new cultivars slow and inefficient.

The immature embryos found in early-ripening stone fruit are due to the flesh ripening before the embryo has had sufficient time to mature within the seed. During the ripening process embryo abortion will occur. In stenospermy seedless grapes pollination and fertilization occurs but embryo and seed development becomes arrested during the early stages of development. The use of embryo rescue would allow the maturation of immature embryos found in early-ripening stone fruit and seedless grapes. This would permit the use of selections from these crops as female parents. When both parents are early-ripening and/or seedless a greater number of the hybrid population will possess these desired characteristics. This increased efficiency in a breeding program would allow the rapid development of early-ripening stone fruit and seedless grapes.

In addition, grape embryo rescue has opened another strategy of genetic improvement via genetic transformation of somatic embryos derived from zygotic embryos. If these somatic embryos develop into stable transgenic plants they could be used as parents to transmit inserted beneficial genes by traditional or nontraditional breeding methods. This approach will allow a breeder to enhance germplasm with beneficial genes previously not present in that germplasm.

EMBRYO RESCUE PROTOCOLS

Stone Fruit. The stone fruit embryo rescue program at Fresno was started in 1975. Over the years it has developed into a two-part procedure. The first part involves in-ovulo embryo rescue of our earliest-ripening selections. These ovules contain embryos ranging in length from 0.5 - 3.0 mm. Fruit is harvested before the ripening process begins and surface sterilized with 70% ethyl alcohol for 1 min then 5 min with 10% bleach. Ovules are removed aseptically and cultured in vitro on liquid Stewart and Hsu medium (Stewart, 1979) plus 6.0% sucrose from 2 to 4 weeks at 27C in the dark. During this time embryos will enlarge to lengths of 5.0 to 10.0 mm. To further develop these embryos they are excised from their ovules and placed into test

tubes containing Woody Plant Medium (WPM) (Llyod and McCown, 1981) plus 3% sucrose. These embryos are transferred to a dark cold room for 60 days of chilling at 1C. The second part of embryo rescue consists of culturing embryos that are 5.0 mm in length or larger directly from immature seeds of female parent selections. Fruit is opened and the seed is removed and placed into Petri dishes. These are then taken to an aseptic environment where each seed is surface sterilized by dipping into 95% ethyl alcohol and flamed using an alcohol lamp. Once the flame is out the seed coat is slit open and the embryo is removed and placed into a test tube. Embryos that are 10.0 mm or less in length are cultured in test tubes containing WPM with 3.0% sucrose. Embryo lengths larger than 10.0 mm are cultured on Smith, Bailey, and Hough medium (Smith et al., 1969) plus 2.0% sucrose. Upon culture these embryos are placed in a dark cold room and chilled for 60 days at 1C. On the completion of chilling embryos are germinated at 20C under fluorescent cool-white lights with a 12-h photoperiod. When shoots are the length of the cotyledons the tubes are transferred to a temperature setting of 24-25C with the same lighting regime. Once shoot lengths are from 50 to 60 mm, plants are transplanted to soil.

Using the above embryo rescue protocols the USDA has released five early-ripening stone fruit cultivars (Table 1). Depending on the early-ripening parentage used, fruit ripening dates have been advanced 10 to 30 days (Table 2).

Table 1. Cultivars developed by the USDA's peach (*Prunus persica*) embryo rescue program.

Cultivar	Fruit type	Year released
Goldcrest	Peach	1983
Mayfire	Nectarine	1983
Spring Gem	Peach (freestone)	1995
Spring Baby	Peach	1996
Crimson Baby	Nectarine	1996

Grape. The USDA's Fresno laboratory reported on the first plants produced from a stenospermic seedless grape (Emershad and Ramming, 1982) via in-ovulo embryo rescue. This pioneering research has evolved into a protocol which is used exclusively for the breeding of table and raisin grapes at our facility. Fruit is harvested 6 weeks after cross pollinations have occurred. The berries are surface sterilized with 70% ethyl alcohol for 1 min then 5 min with 50% bleach followed by three rinses with sterile water. Seed traces are removed aseptically and cultured onto Emershad/Ramming medium (Emershad and Ramming, 1994) with 6.0% sucrose for two months at 25C under fluorescent cool-white lights with a 12-h. photoperiod. After 2 months of culture, embryos are excised aseptically from seed traces and placed into test tubes containing WPM plus 1.5% sucrose plus 1.0 μM BAP to germinate and grow into plants. Test tubes are placed inside a chamber set at 26C under fluorescent cool white lights with a 12 h photoperiod. Once 4-5 true leaves have formed, plants are transplanted to soil.

Table 2. Fruit ripening dates of parents and the earliest-ripening peach selections from their progeny

Parentage	Ripening dates: Parents	Ripening dates: Earliest-ripening selection
Maybelle × OP	5/19/87	4/29/93
Junegold × Maycrest	6/4/87 × 5/18/87	4/28/92
P34-147 × P83-48	5/28/95 × 5.26.95	4/29/92
P57-56 × P107-78	6/1/87 × 5/28/83	5/9/94
P46-74 × P30-129	5/24/96 × 5/8/96	5/2/96
P45-142 × P45-141	5/15/96 × 5/3/96	5/6/96

Table 3. Summary of embryo production from 336 seedless × seedless crosses from 1989 to 1992.

No. female genotypes	108
No. *male genotypes*	128
No. ovules cultured	112,903
No. zygotic embryos found	21,567
No. zygotic embryos forming somatic embryos	2589
% zygotic embryos forming somatic embryos	12
% female parents forming somatic embryos	89

GRAPE GENETIC TRANSFORMATION

Occasionally when a seed trace is opened the zygotic embryo will have proliferated somatic embryos (Emershad and Ramming, 1984) (Table 3). Similar observations of somatic embryogenesis from zygotic embryos have been reported by others (Gray, 1992; Stamp and Meredith, 1988). Somatic embryogenesis from zygotic embryos found in cultured stenospermic grape seed have been shown to proliferate from epidermal cells of larger embryos (Margosan et al., 1994). The successful transformation of somatic embryos of walnut (McGranahan et al., 1988) and soybean (Finer and McMullen, 1991) by *Agrobacterium* and particle bombardment, respectively, suggest that these transformation/regeneration systems may also be feasible in transforming these epidermal cells. Transformed cells could then develop into embryos and eventually stable transgenic plants. A highly proliferative somatic embryogenic and plant development system was developed from our zygotic embryos (Emershad and Ramming, 1994). Using this system in cooperation with another USDA research facility we were successful in the transformation of somatic embryos and their regeneration into transgenic grape plants (Scorza et al., 1995). From the success of this research another collaborative project produced transgenic *Vitis vinifera* 'Sultana' (syn. 'Thompson Seedless') grape plants (Scorza et al., 1996). The source of somatic embryos used in this research were derived from in-vitro-grown leaves. The genes transferred include a viral coat protein gene and a lytic peptide gene. Briefly the steps followed by the researchers were: 1) microprojectile bombardment wounding of somatic embryos with gold particles using the Biolistic

PDS-1000/He device (Bio-Rad laboratories); 2) cocultivate wounded somatic embryos with *A. tumefaciens* / plasmid for 15 to 20 min (wounding allows for easier entry of *Agrobacterium* into cells); 3) rinse; 4) transfer of somatic embryos to cocultivation medium (proliferation medium containing 100 µM acetosyringone) for 2 days; 5) wash and transfer to proliferation medium for two passages (3 weeks each); and 6) transfer embryos for selection on proliferation medium containing kanamycin.

SUMMARY

In the development of improved selections and cultivars for early-ripening stone fruit and seedless grapes embryo rescue has been a successful tool. Genetic transformation is a relatively new technology, but rapid advances are being made in this field. In either case plant breeders are having more and more new breeding tools made available for crop improvement.

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"Nursery Propagation by Hardwood Cuttings" Question-Answer Period

No recording.

Biology and Management of Crown Gall Disease in the Nursery

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Crown gall disease occurs on over 390 genera of plants (Bradbury, 1986). It is most significant on plants grown for the nursery trade because galled plants are culled and discarded. Annual losses can run in the millions of dollars (Kennedy, 1980). The disease is particularly damaging to plants that become infected the first year after out-planting. Severely galled young plants are weakened, stunted, unproductive, and occasionally die. Contradictions abound, however, regarding the injurious effects of crown gall. Regardless, current nursery practices of culling galled plants is highly recommended as a means of providing clean planting stock.

Crown gall is a tumor disease of plants caused primarily by three pathogenic species of *Agrobacterium: A. tumefaciens, A. rhizogenes*, and *A. vitis* (Bouzar, 1994). Although this "new" classification is more correct than earlier classifications, it is confusing due to historical usage of *A. tumefaciens* to designate pathogens and *A. radiobacter* to designate nonpathogens. For sake of clarity, I will use the descriptors "pathogenic" and "nonpathogenic" *Agrobacterium* throughout this paper, with the exception of *A. vitis,* the crown gall pathogen of grape vines.

Emphasis of this paper is on management practices to reduce the incidence of disease to an economically tolerable level. Rarely will 100% control of the disease be achieved by any single method due to the interaction of multiple environmental factors, genetic variability among the pathogenic strains, host susceptibility, and cultural practices.

BIOLOGY AND ECOLOGY

Learning basic elements about the biology of *Agrobacterium* and its disease cycle is important to understanding why various management procedures are effective, and, conversely, why some methods fail. Briefly, pathogenic strains of *Agrobacterium* are considered present in most agricultural soils or on infested plants. The pathogen is disseminated by splashing rain, irrigation water, drainage water, tools, wind, insects, and plant parts used for propagation. Plant wounds are required for infection. Wounds occur during pruning and cultivation, natural emergence of lateral roots, frost injury, and insect and nematode feeding. The pathogen colonizes the wound and transfers part of its DNA into the chromosome of a plant cell. This event initiates gall development. Small galls appear in 10 to 14 days at temperatures above 72F; infection is inhibited above 92 to 97F and below 50F. Latent infections occur (Moore, 1976), but long latent infections are not common in our experience.

The gall is a rich source of nutrients for the *Agrobacterium* which proliferate and escape the gall to begin the infection cycle anew or survive as nonparasitic epiphytes on the surfaces of host and nonhost plants, particularly roots. Pathogenic *Agrobacterium* also survive saprophytically as endophytes in the xylem tissues of some plants (e.g. grape vines) and reportedly up to 2 years in soil. Lelliott (1971) observed that crown gall occurrence in apple rootstocks beds in England could not be related to soil type (e.g., type of loam or silt loam), kind of bed, age of bed, nor soil pH.

Diversity: There is wide diversity among *Agrobacterium* isolates from different plant hosts, planting sites, and even the same gall. Failure to recognize this diversity leads to unwarranted assumptions and generalizations, whereas recognition of the diversity can aid in making disease management decisions.

DISEASE MANAGEMENT

Prevention: Think prevention! Avoid exposing plants to pathogenic *Agrobacterium* at all stages of plant production. Once infection has occurred, there is little that can be done to stop the disease. Factors important to prevention include the following.

Planting Stock: Pathogen-free plants grown in uninfested soil do not develop crown gall, which emphasizes the importance of planting clean propagating material to clean soil. Dispersal of agrobacteria to other geographical areas is readily accomplished through shipment of diseased and infested planting materials. However, it is difficult to prove whether infectious inoculum was present in the soil at planting, introduced into the planting site by water, or carried on or in the transplant propagule.

Cultural Practices: Suppliers and growers alike should use good sanitation and cultural practices as deterrents to crown gall disease. Upon harvest, discard all nursery stock showing gall symptoms to avoid contamination of healthy plants. (Despite careful sorting and culling of diseased plants, latent infections and symptomless plant carriers of pathogenic *Agrobacterium* go undetected. Unfortunately, we have no practical way to detect latent infections or symptomless plant carriers.) Surface sterilize benches and tools used in propagation and storage. Keep graft and bud unions above the soil line. Avoid: wounding plants during cultivation, use of high nitrogen and irrigation late in the season, and storing diseased plants with healthy plants. Irrigate with deep-well water or sanitized pond water.

Planting Sites: Previous cropping history can affect gall incidence. A general recommendation is to avoid planting sites where galled plants were grown within the last 4 to 5 years and rotate with nonhost crops such as grains. Avoid planting to heavy, poorly drained soils and those with nematode infestations or insect vectors.

Vectors: Nematodes (Dhanvantari et al., 1975; Vrain and Copeman, 1987), grubs and other chewing insects (Tawfik et al., 1983), and whiteflies (Zeidan and Czosnek, 1994) have been implicated in providing wounds and being passive carriers *of A. tumefaciens*. Nematode feeding also increased the susceptibility of resistant raspberry (*Rubus idaeus*) plants to *Agrobacterium* pathogens (Vrain and Copeman, 1987).

Disease Resistance: Although genetic resistance to crown gall is the ideal method of control, reports of plant resistance to crown gall are limited and variable.

Differential host susceptibility has been reported among grape and raspberry cultivars. In Britain, Malling Jewel was considerably more resistant than Malling Delight. Malling 7 is considered the most susceptible apple rootstock to crown gall in Italy and the Pacific Northwest, followed by *Malus* 'Jaune de Metz' (syn. Malling 9) and Malling 26. Malling 9, however, is reportedly the most susceptible rootstock in Switzerland. This variability is probably due to strains of the pathogen being better adapted to one nursery site than another. Because of this variability, use more than one pathogenic strain when screening plant selections for resistance to *Agrobacterium* pathogens.

Chemical controls are very limited. Traditional bactericides have included copper and streptomycin formulations. Neither of these groups have been particularly effective as preplant dips or sprays to control crown gall, especially on apple and pear rootstocks (Mirow, 1985). Terramycin as a preplanting treatment of apples and pears has given relatively good control of crown gall in Oregon and Washington tests, but it is not registered with EPA for commercial use (Canfield and Moore, 1992).

Soil fumigation with Vorlex was reportedly effective against some strains of *A. vitis* (Pu and Goodman, 1993), but not against crown gall pathogens of peach (Dhanvantari, 1975). Soil treatments with Metam-sodium and formaldehyde also failed to control crown gall (Utkhede and Smith, 1990). Methyl bromide has generally been ineffective against *Agrobacterium* (Cooksey and Moore, unpublished), while soil fumigation with a variety of fumigants reportedly increased the incidence of crown gall on mazzard cherry seedlings (Deep and Young, 1965).

Physical Heating: Physical heating of root-pruned, dormant *Prunus* rootstocks to encourage wound healing greatly reduced the incidence of crown gall (Moore and Allen, 1986). Careful heating of grape cuttings reduced populations of *A. vitis* in vascular fluids of grape vine cuttings (Ophel et al., 1990).

Biological Control: *Agrobacterium radiobacter* K84 has given excellent control of crown gall disease on a variety of host plants, particularly *Prunus* spp., but it is generally ineffective against crown gall disease of apple and pear rootstocks (Utkhede and Smith, 1990) and *A. vitis* on grape vines. Best control is observed when pathogenic strains are sensitive to K84. Strain K1026, an improved genetically engineered mutant of K84, is safer than K84 and is poised to enter the commercial market (Vicedo et al., 1993).

Microorganisms other than K84 have been investigated for biocontrol of crown gall. These include fungi, other *Agrobacterium* and non-*Agrobacterium* isolates (Cooksey and Moore, 1980; Pu and Goodman 1993). Utkhede's (1992) research with *B. subtilis* shows promise for biological control of crown gall on apple trees.

An integrated pest management strategy has been in test at Oregon State University for the past few years to investigate the effect, individually and in combination, of soil solarization, cover crops, and Metam-sodium fumigation on survival of *A. tumefaciens* and *A. rhizogenes, Pratylenchus penetrans, Verticillium dahliae*, *Phytophthora cinnamomi*, and weed seeds in different-textured soils. Soil solarization eliminated or greatly reduced the population of pathogenic *Agrobacterium* in sandy loam and clay loam soils, respectively (Raio, et al. 1996). No galls developed on mazzard cherry seedlings planted to solarized soils.

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METHYL BROMIDE ALTERNATIVES FOR FIELD-GROWN NURSERY STOCK

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INTRODUCTION

It is through the purchase of contaminated nursery stock that new and different soil pests, diseases, nematodes, and viruses are most readily and widely distributed to farmers' lands. For California growers the nurseries have provided nematode-free field-grown nursery stock through the combination treatments of fallowing/soil fumigation. Today, California farmlands remain free of reniform nematode and burrowing nematode. The same cannot be said for growers in Florida, Texas or northern Mexico. Of the 300,000 ha of California stone fruits and almonds, some of which have now been replanted three or four times, only 33% are infested with *Pratylenchus vulnus*, the root lesion nematode. As new biotypes of root knot nematodes have broken the resistance mechanisms in Harmony and Freedom grape rootstocks that problem is clearly an in-field occurrence rather than a problem being transported along with nursery stock. The same can be said about biotypes of phylloxera on A.×R.#1 (syn. *Vitis* Ganzin Number One) rootstock. Additionally, the fallowing/soil fumigation treatment has by its existence reduced the spread of soil pathogens other than nematodes.

The soil fumigants that formed the backbone of the nursery treatment have been methyl bromide and Telone, and alternatives to these two are currently the subject of much investigation. This paper provides an overview of our effort to evaluate potential alternatives and lists the four most practical alternatives which are now ready for fine tuning under field conditions. One should be careful to note that there are soil pests other than nematodes which influence the eventual worth of nursery stock.

FIVE POTENTIAL ALTERNATIVES

The first potential alternative to the current treatment of fallowing/soil fumigation would be to double or triple the length of the fallowing period, thus increasing the land needed by the nurseryman. Certain advocates suggest that a rotation might help to shorten the fallowing period. For example, if one nursery crop has resistance to root lesion while another has resistance to root knot nematode one could still take advantage of the resistance they do have by rotating their planting through the nursery lands. Of course, nursery crops are grown for their demand by farmers, not for their utility as a rotation crop, but a bigger shortcoming is that no nursery crops are resistant to all nematodes and there are more than a dozen nematode species that can occur in California crops. Additionally, acceptance by nurseries of a lengthy clean fallow treatment, which can generate dust, may become a problem as the California PM_{10} requirements evolve. Also, tree and vine roots remaining in soil can survive at least a year after undercutting for harvest and the nematodes without available food should be expected to persist a year and a half beyond as an egg stage. This lengthy fallow approach will have potential until the land once becomes contaminated with endoparasitic nematodes. We recently learned that peach and

plum roots that had been dead for 2 full years remain a protective refuge for root lesion eggs within.

A second potential alternative involves the increased use of container-grown plants using steam-treated soils or soil mixes that are nematode-free. This approach has been taken in other areas of the world as well as in California. Factors to consider include the farmer's expectations for a large root system, the need for recycling of potting containers and many additional benefits or constraints associated with container-grown stock.

A third potential alternative involves the use of biocides or nematicides other than methyl bromide (MB). On the top of the list is a shanked Telone application. After 6 years without Telone the current California requirement is that no more than 65 ha/9400 ha of land can receive a Telone treatment each year. Given the size of California nurseries they would need to have a priority for the use of Telone within their township. For a better perspective, California's irrigated farmland is only about 350 townships in size. This California EPA requirement is based on the need for public protection from a Type B carcinogen as it is volatilized above the surface of a treated field.

It is clear that any new technologies which reduce Telone volatilization would be helpful for increasing the total hectares treated with Telone each year. In this regard, we now have data to show that Telone applied as a drench within 15 cm water is just as efficacious against nematodes as the same amount of Telone shank applied (McKenry, 1995). Telone drenches will probably never be applied by sprinkler or as a basin application. A portable drenching device like the one we have built would be necessary but it would also need to be covered by a plastic tarpaulin capable of moving across the field with the dripper lines (McKenry et al., 1994). Water is a very useful tool for reducing biocide volatilization once the biocide is beneath the soil surface.

A fourth potential alternative involves methyl-isothiocyanate (MIT)-liberating compounds such as Vapam or Soil Prep and others. For nursery settings requiring 1 and 2 years of nematode protection (tree or vine crops) MIT-liberating compounds can become an alternative, but we have identified serious shortcomings to the use of the product. First, MIT delivery can be effective when uniformly mixed into a solution of 10 to 15 cm of water, but it will not be effective when applied via shank where 99.9% nematode control is a requirement. The reason is that MIT is a poor fumigant even when delivery nozzles along each shank are spaced only 12 cm apart. A second problem is that there are many soils which cannot be effectively drenched. Soils having good internal drainage and usually classified as a sand, loamy sand, or coarse sandy loam are suitable for drenching if the 15 cm of water can be delivered with no puddles remaining after 8 h. A third shortcoming of MIT is that MIT delivered at 500 ppm (200 gal per acre in 15 cm water) can reduce growth of trees or vines planted within 6 months after a treatment. This problem disappears after a full year of clean fallowing. A fourth problem is that MIT is a poor penetrant. Roots that are pencil-sized and larger, tubers, corms, or even the nutlets of nutgrass need to be penetrated. A dosage of 250 ppm is adequate only if these plant tissues are all located within the surface 60 cm of soil. There must be no surviving pest-infected roots in the top 120 cm of soil to be planted to tree or vine nurseries. A fifth shortcoming with MIT is the need for a well-mixed addition of the MIT into the water so that in theory, every drop of water has some MIT within. On a positive note, MIT

deliveries by sprinkler or basin can be effective if they meet the requirement of infiltration of 15 cm water within 8 h.

A fifth potential alternative to the fallowing/soil fumigation treatment involves the use of reduced rates of fumigants applied deeply followed within days by 4 to 5 cm of 250 ppm MIT solution. For example, 224 kg ha^{-1} MB applied at 60 cm soil depth followed by a ring roller and then 24 h after treatment apply 1.2 cm of 250 ppm MIT each day for the next 4 days. This would mean the addition of approximately 120 kg ha^{-1} of MIT as a sprinkler application. If 325 to 400 kg ha^{-1} Telone is the shanked biocide at 45 cm soil depth; follow at 48 h, 72 h, 96 h, and 120 h with 1.2 cm of 250 ppm MIT solution. Treatments such as these will greatly reduce volatilization by plugging air pore spaces while delivering biocide to the surface 30 cm of soil where it is needed most.

POTENTIAL ALTERNATIVES THAT HAVE SERIOUS LIMITATIONS

Other suggested alternatives specifically including hot water, steam, solarization, or antagonistic rotation crops have serious limitations where endoparasitic nematodes are the pests of concern. Biocides incapable of penetrating roots such as Enzone, Clorox, urea, and plant extracts also have major limitations where endoparasitic nematodes are present.

FOUR ALTERNATIVES HAVING THE GREATEST CHANCE FOR FIELD SUCCESS

Based on the previously listed information, there are four alternatives worthy of field evaluation. Two are for situations where endoparasitic nematodes along with other soil pests (except oak root fungus, *Armillaria mellea*) are known to be present:

Alternative #1. Shank 390 kg ha^{-1} Telone at a 45 cm depth. Connect manifold lines to existing sprinkler pipe and then 48 hours after treatment deliver 3 to 5 cm water containing 250 ppm MIT over a protracted period of up to 4 days.

Alternative #2. Drench 500 ppm MIT (200 gal per acre) in 15 cm water. Drenching may be by sprinkler or portable soil drenching device (McKenry, 1994) but the soil must take all the 15 cm water in 8 h or less. Then, clean fallow for one full year before planting.

For situations with ectoparasitic nematodes as the only pests present or where remnant roots are fully decayed, two additional alternatives are worthy of field testing.

Alternative #3. Drench 250 ppm MIT by some type of portable drenching device in 10 to 15 cm water that infiltrates in 5 to 8 h, respectively. Water may also be delivered by sprinkler if the application is uniform. A basin irrigation may have value in soils that infiltrate the water in 3 h or less.

Alternative #4. Drench 1000 ppm Enzone in 10 to 15 cm water. Water may be delivered by various means that provide uniformity of treatment.

This is not a final report but actually the first of a 3-year study now underway as we evaluate these four alternatives and many others.

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Growing with a Cravo Retract-a-Roof Greenhouse

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At Woodburn Nursery and Azaleas the decision to build a retractable roof structure was easy once we had all the facts and costs. The number one thing we looked at was the cost of producing the plant. The question was asked how could we produce plants quicker and less expensively. We grow certain plants inside plastic covered houses, out in the full sun, under a shade or lathe house. Certain plants performed better under different conditions. The biggest problem we had was when Mother Nature prevented us from doing things when necessary thus creating production problems. This increased our expenses and jeopardized crop quality. Flexibility was an issue that was high on the priority list. The greenhouse had to be flexible for several different crops, with easy accessibility for moving product in and out of the structure. Labor that was needed to cover and uncover the greenhouse in the winter months was a big consideration. We needed a structure that required minimal labor because we were maxed out already when cold weather approached. Cold protection was another consideration. We needed something to protect the crop similar to a cold frame covered with polyethylene. Shade in the summertime was something I considered, but was not concerned about at the time. After growing under the Retract-a-roof for two seasons, Ihave changed my mind considerably. It now ranks very high on the priority list. I was very surprised how well the plants performed using this system.

The retractable roof concept is very new to the industry, having the first commercial installation in 1993. I knew when we first looked at it there was going to be a learning curve for us to become proficient at growing with this technology. We have always looked for challenges so we thought we would give it a shot. I guess I saw the potential to produce a better crop. I looked at one in Oregon prior to purchasing it, but had made up my mind already.

Plants really benefit from growing in this system. During a nice warm sunny day the roof is open exposing plants to direct sunlight and wind. Plants are more compact and tend to be more disease resistant, just as if they had been grown outdoors. When temperatures get too warm the roof moves to the shading position (about 15% open) to shade the plants and protect them from excessive temperatures. In the winter when a cold front approaches the roof is completely closed, blocking excessive dehydration. All this is under the automated control of an Argus computer to avoid human error.

The grower benefits also from fewer diseases to contend with, since plants are grown hardier. There is greater flexibility in chemical applications because the roof can be open or closed depending on the weather. Irrigation costs are also reduced because the plants are not exposed to the hot sun.

In closing, we are very pleased with the performance of our Cravo and plan to add addition covered acreage in the future.

"Nursery Propagation by Hardwood Cuttings" Question-Answer Period

No recording.

Seed Collection and Cleaning Revisited

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The seed is sown. Adequate water is imbibed. Temperature is modulated. Soil- and water-born pathogens are controlled. Appropriate lighting is applied. Germination can then be expected to occur. These conditions assume one crucial element; the propagator has acquired and sown viable seed with adequate vigor. Increased mechanization, cost-consciousness, and competition in the nursery require the propagator to obtain quality viable seed. Seed must be, true to type, and free from waste, pathogens, and contaminates. As a seedsman, who has been involved in the collection and distribution of ornamental tree, shrub and palm seeds for over 23 years, I have acquired some practical expertise. The skill for this trade is learned through practice, education, apprenticeship, and trial and error. From where and how the seed travels from plant to propagator is the subject for discussion.

Collection Sources for seed stock are varied and numerous. Seed orchards are reliable yet costly. Field or container nurseries provide a uniform collection site. Regionally required seeds may be located in native fields, parks, schools, commercial centers, street plantings, and private residences. Best time to scout site location is prior to need. Many parent plants are easily spotted in their conspicuous bloom (*Chorisia, Fremontodendron, Grevillea*). Record locations on maps and file cards. A hand tape recorder is effective while traveling.

Ultimate growing habitat is important in site selection. Not a great problem in the woody ornamental trade, elevation and habitat are crucial for native restoration plantings. Seedlings introduced into locations foreign to their parental climate may lack adequate vigor and form (*Liquidambar styraciflua*). Collection sites should be monitored so cross-pollinating species have adequate isolation (*Agapanthus, Asparagus, Eucalyptus, Prunus*).

Timing of the seed collection is a crucial element. Maturation of the seed is the single most elemental component for quality seeds. Maturation can be stated as the point where the seed has reached its maximum fresh weight. Maturity provides the seed with adequate carbohydrate reserves, stored proteins and fats, and adequate nutrients translocated from the parent plant tissues (Bewley and Black, 1978). Additional hormonal changes provide proper germination triggers.

Determining maturity requires familiarity with the plant. Fruit color, texture, and physical condition are clues to adequate maturation. Avoid immature fruit or "green seed". A cut test is essential. Cutting longitudinal exposes the endosperm and

embryo. Fully developed embryos or embryos surrounded by an endosperm of uniform creamy color are desired. The endosperm should be smooth, uniform in color and texture, and not excrete when pressed upon—"hard dough stage" (Young et al., 1986). Avoid hollow, discolored, deformed, and insect-ridden seeds and fruit. Make several tests to validate a collection decision. A horizontal cut of cones or pods gives an estimate of seed count, an important economic consideration (*Cedrus, Hypericum, Liriodendron*).

Access to public and private sites is obtained prior to collection. Public grounds require some lead time as the authorizing agent or representative may be difficult to locate. Permission is likely to be granted when applied for with prerequisite liability insurance and a release from indemnity form. Public agencies require up to 1 million dollars of coverage. Conditions of collection are; the plant is not to be harmed or its natural beauty impaired, all debris be removed and disposed, and the site be left clean.

Private sites have lessor quantities of seeds yet often of a higher quality. In approaching private sources, the unique opportunity of trade liaison presents itself. I am frequently asked questions concerning common horticultural problems. Time with the owner is an opportunity to extol the benefits and virtues of landscaping. For rare, valuable, or prolific seed stands, it may be appropriate to offer a gratuity for access. This act may lead to annual collection privileges.

Harvesting equipment is basic with few changes over the years. Essential equipment includes ladders, telescoping poles, pruners, cone hooks, mauls, hand shears, and various mesh screens. Netting, shade cloth, tarps of canvas or 6 mil polyethylene, trays, barrels, burlap, and poly-woven sacks are used to capture and transport the seed pods and fruit. Requirements to engage in safe and sound principles of harvest and collection are necessary. Essential safety equipment includes climbing harness and ropes, street cones, signage, particle and dust masks, protective eyewear and safety hats and shoes. Harvest of the crop is simple in concept, yet made more difficult in practice. Simply put: "get the seeds from the plant to the sack for transport and cleaning", does not do the task justice.

Techniques for collection and cleaning vary according to three recognized fruit types(Pollock and Roos, 1972).

Dry Fruits **(I).** Comprising the majority of seed formations, dry fruits are collected prior to dispersal. The seed-bearing structure or fruit is removed whole from the plant when slightly immature. Fruit, branchlets, or complete branches are cut. Pruning ethics are required to maintain the parent and insure future growth and cropping. The plant material spread in shallow layers upon tarps, afterripens as it drys to maturity. Frequent pitching and rotation of the drying crop is required to foster uniform ripening and discourage mold and fungi development from inadequate air circulation. Threshing or beating the crop releases fully mature seeds from the parent. Outdoors, the crop should be covered at night if dew or moisture is anticipated. Insects, animals, or birds may be devastating to your unprotected crop (cones: *Cedrus, Pinus*; pods: *Brachychiton, Eucalyptus, Grevillea, Jacaranda, Lyonothamnus, Wisteria*; umbels: *Agapanthus, Cyperus*; follicles: *Agonis Liquidambar, Magnolia*.)

Non-Dehiscent Fruit **(II).** Covered with an adhering fruit or outgrowth these are the second group. Mass collections require fruit to be fully mature. Fruit is hand

picked, failed with tall poles, or shaken loose to fall upon tarps. Ripe seeds readily dispersed by wind make collection feasible only during calm dry weather. Wet or foggy conditions allow the seeds to remain attached to the parent requiring excessive shaking or failing to release the crop (samaras: *Acer*, *Fraxinus, Liriodendron*; nuts: *Pistacia, Quercus*.)

***Fleshy Fruits* (III).** Surrounded by fleshy pulp or skin, the fleshy fruits are easily identifiable. Collection is made by hand picking, knocking, or shaking ripe fruit upon tarps. Parents may bear differing degrees of ripened fruit. Only those that fall freely are harvested. "Green fruit" is left for follow-up collections. Twigs, insects, and leaf debris are promptly removed from the collected crop. Limiting fermentation and composting heat is important. Fruit is transported in breathable burlap sacks allowing air circulation. Storage of fruit should be brief and cleaning initiated promptly.

The cleaning facility need not be extravagant. A large drying location, preferably with southern exposure, sufficiently large to avoid cross contamination between collections is desirable. A covered outdoor area is extremely helpful during times of inclement weather. Indoor shop facilities include a fanning area to air-blow collections for preliminary processing, a wash area for water-processed seeds, a machine cleaning area, and a finish cleaning section. Nursery hygienic practices are essential. Trays, barrels, screens, and implements need to be clean and sanitized regularly. A bleach (diluted with water) wash (1 : 9, v/v) is safe, economical, and effective.

***Dry Cleaning*.** Seed types I and II are predominately cleaned dry. Seed extraction releases dust and debris. Adequate ventilation and respiratory protection is essential. People with sensitive respiratory systems should avoid this process. The cumulative effects of these dusts are unknown. All persons should exercise caution. Reactions from irritants found in *Agapanthus*, *Brachychiton, Cortaderia, Fremontodendron, Platanus*, and *Wisteria* range from simple topical skin irritations to impaired respiratory function.

Following drying, the collection is threshed releasing seeds from the fruit. Hand threshing requires rubbing the fruit through wire screens, beating the seed capsules in trays, flailing with poles upon tarps, or pounding in sacks. Durable seeds may be machine processed in a hammermill, although lawnmowers and yard vacuums can be effective. Attention to both motor speed and material flow is critical. Too fast an engine speed and seeds become chipped, too slow and the process is ineffective. Lower speeds and high volumes are most productive. Experience and patience are the key. Processing the seeds over several runs is effective to remove free seeds and eliminate problems of chipping or cutting. Machine threshed include; *Albizzia, Ceratonia siliqua* (carob), *Cercis*, and *Cistus*.

Threshed seeds and their debris are finished cleaned by fanning. The fan speed and height of material fall produce a graded separation. Heavy, sound seed and similar dense debris fall into the first tray. Dirt, leaves, and twigs are blown further into secondary trays. The final finish cleaning is hand sorting of sticks, rocks, and discolored or damaged seeds.

Air separator machines are commonly used in the seed trade to process threshed seeds. They produce a clean graded product requiring little finish work. Threshed material is passed over a scalping screen removing large debris and sticks. Seeds

and similar-sized material falls through sized screens where grading and sizing occur. Air flow blows away small particles, dirt, dust, and hollow or off-sized seeds. A uniform graded seed is discharged. Expertise is required in determining screen size and shape, agitation rate, and material flow. Effective operation requires adequate volume of material to process, hence it is not practical on small lots.

Wet Cleaning. Type III seeds are cleaned with water to free the encased seed from the surrounding fruit and pulp. This family must be cleaned promptly following collection as heat from decomposition and the proliferation of mold and bacteria in this warm moist environment can quickly spoil seeds.

After fanning, fruit is rubbed through wire screens or rubber booted in barrels. Maceration is monitored to avoid splitting or crushing fragile seeds (*Eugenia, Eriobotrya, Ginkgo, Laurus, Rhaphiolepis*).

Hard coated seeds: *Arbutus, Celtis, Cornus, Podocarpus gracilior* (syn. *Aftocarpus gracilior*), *Photinia*, and numerous palms may be machine cleaned in a Dybvig separator. Manufactured by Bouldin Lawson, my model uses a revolving plate to impel fruit within a metal barrel against a stationary vane. The bottom revolving plate is adjusted off the floor of the barrel to allow water and pulp to be flushed from the macerated mass. The larger cleaned seeds are left behind and discharged via a sliding door when the majority of the pulp is dispelled and the water flows clear. Care must be taken with this method. Seeds while exhibiting no external damage, may incur internal damage or bruising. These may expire in storage, show poor germination and vigor, or exhibit abnormal growth.

Floatation is the second step in wet cleaning. Sound, firm seeds are separated from pulped fruit. Heavy, sound seeds sink in water-filled barrels. Pulp and hollow seeds will float or settle above. With strong agitation, the debris can be poured or dipped off. The process is repeated until the water runs clear. Floatation can be enhanced through the use of surfactants (Wilber Ellis R-ll). Care in proper lifting techniques is vital. Clean seeds are poured off upon drying screens leaving behind dense rocks, sand and dirt. A final high-pressure wash is directed through the seeds to remove any trace residue and pulp.

Drying is the final step in the wet processed seeds with several notable exceptions. *Mahonia aquifolium* and *Nandina domestica* are simply drained of standing water and stored wet. Periodic flushing removes accumulated pathogens. To facilitate transport and storage, seeds are dried of surface and excess moisture. Sun drying is only to be used for surface drying. Dark colored seeds can overheat. Unable to give up moisture quickly, the seed coat shrinks and cracks causing the seed to split open (*Aralia, Eriobotrya, Eugenia, Laurus, Pistacia*). Surface moisture should be promptly dried from the white oaks (*Quercus species*) family and *Cordyline* to prevent germination from occurring under these warm moist conditions. Seed moisture content for storage should be sufficiently low to prevent germination, impair heat build up, retard fungi growth, and restrict insect growth and reproduction.

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Seed Testing and Seed Dormancy

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THE SEED TESTING LABORATORY

The job of the seed testing laboratory is to provide information about the quality of a given seed lot. The data reported by the lab is useful for initial cleaning, processing, and labeling as the seed moves into commercial channels.

The primary seed tests done by a certified seed laboratory are the germination or viability test, the physical purity test, seed counts, and the moisture content of the seed.

In the United States there are three main types of certified seed labs: Federal and State Labs, staffed by a member of A.O.S.A. (Association of Official Seed Analysts); company labs, staffed by a Registered Seed Technologist, member of S.C.S.T. (Society Commercial Seed Technologists); and an independent, private, commercial seed testing lab, staffed by an R.S.T. from S.C.S.T.

Seed testing in all three of the above labs is usually performed according to the Rules for Testing Seed put forth by the A.O.S.A. By testing the viability of seeds in paper media and in controlled environmental chambers, information about the seed lot can be obtained in a quick, efficient, and economical manner.

The germination test is performed at a prescribed ideal temperature for a given length of time for the kind of seed being tested. Results are reported on a standard reporting form.

As a laboratory practice, seeds remaining ungerminated at the end of a germination test are cut to determine whether they are dead, empty, or dormant. If dormancy exists, it is a general practice to report this on the reporting form. It might appear in the following way:

Days in test	Germination %	Hard%	Dormant%	Total viable (%)
14	68	---	28	96

Because a seed lab tests seeds that are of all stages of after-harvest maturity, it is relevant to record and report dormant live seed. It is just as important for the group receiving the lab data to understand and interpret the test results and use it in an appropriate manner. In the above data, the total potential viability was 96%, but at the date of testing only 68% of the seed germinated readily under ideal conditions.

WHAT IS SEED DORMANCY AND WHERE DID IT COME FROM?

Definitions.

Dormant: Lying inactive as in sleep, resting.

Dormant seeds: Viable seeds that fail to germinate when provided the correct physical and environmental conditions for the kind of seed in question.

Dormancy. Dormancy is generally a problem and a nuisance to economical crop production, particularly in a place like California where we have a favorable year-

round climate, irrigation systems, and economic pressure to produce crops. Where did dormancy come from? The seed structure as we know it today has had a long evolutionary development. Seeds have emerged from this development with certain properties. Among these is a control mechanism that can exist in all seed species. If over long periods of time all seed populations just dropped off the plant and germinated immediately, most plant species would have become extinct. It is not always advantageous to germinate freely. Survival of a plant species includes distribution of germination through time with new seedlings emerging at irregular intervals (U.S. Dept. of Agric., 1974). The dormancy mechanisms in seeds lead to survival of a species by controlling the time and place for germination. Seeds are dispersed from the mother plant with different degrees of dormancy. As long as the seed remains viable, the possibility exists that it may eventually find itself more favorably placed to produce a plant.

Dormancy is a wild trait. Since the function of a seed is to establish a new plant and dormancy is an intrinsic block to germination, it seems logical for us to take control of this natural phenomenon and change it to our advantage. When we domesticate seeds to produce crops, we try to reduce or eliminate the dormancy control mechanism. Dormancy has developed for survival of plant species and can exist in seeds in different stages. These stages can be defined as follows:

1) Short-term or primary dormancy, or predictable dormancy. Seed has a natural resting period subsequent to harvest, also referred to as an after-ripening period. This form of dormancy is common to our crop seeds. It can last a few weeks or 2 to 4 months.

2) Long-term or deep dormancy. Long-term dormancy can go on for 2 to more than 20 years. Deep dormancy is more common in wild and weedy species.

3) Secondary dormancy, induced dormancy or deep dormancy on and off. A seed which has overcome primary dormancy, but is then subjected to conditions of stress unfavorable for germination can go into a deep, secondary dormancy. This could happen when the seed is planted in the field, during conditioning, or during storage. Secondary dormancy is the most complex to explain and can occur in crop seed or wild and weedy species. This secondary or induced dormancy can be the most surprising and problematical to our industry.

Germination. Germination involves: (1) imbibition of water, (2) activation of metabolic process, and (3) growth of the embryo. If any of these stages are blocked, a state of dormancy exists. The mechanisms restricting germination vary widely by species.

There are two major places where dormancy can occur in seeds. Dormancy can be in the seed coverings, such as seed coats, fruit walls or other structures surrounding the seed. Dormancy can also be based in the embryo itself. (Bewley and Black, 1985). The deeper dormancies usually involve both seed coverings and embryo dormancy. The dormancies based on seed coverings involve permeability of these membranes to water, salts, gases, or physical restraint of the embryo. These dormancies can be overcome in the laboratory by any method which increases membrane permeability. These would include: cold stratification (cold temperature in the presence of moisture), sharp alternation of temperature, light, addition of potassium nitrate (KNO_3), and physical scarification or clipping the seed covering. Gibberellic acid can be effective in breaking embryo-based dormancy, but it does not increase membrane

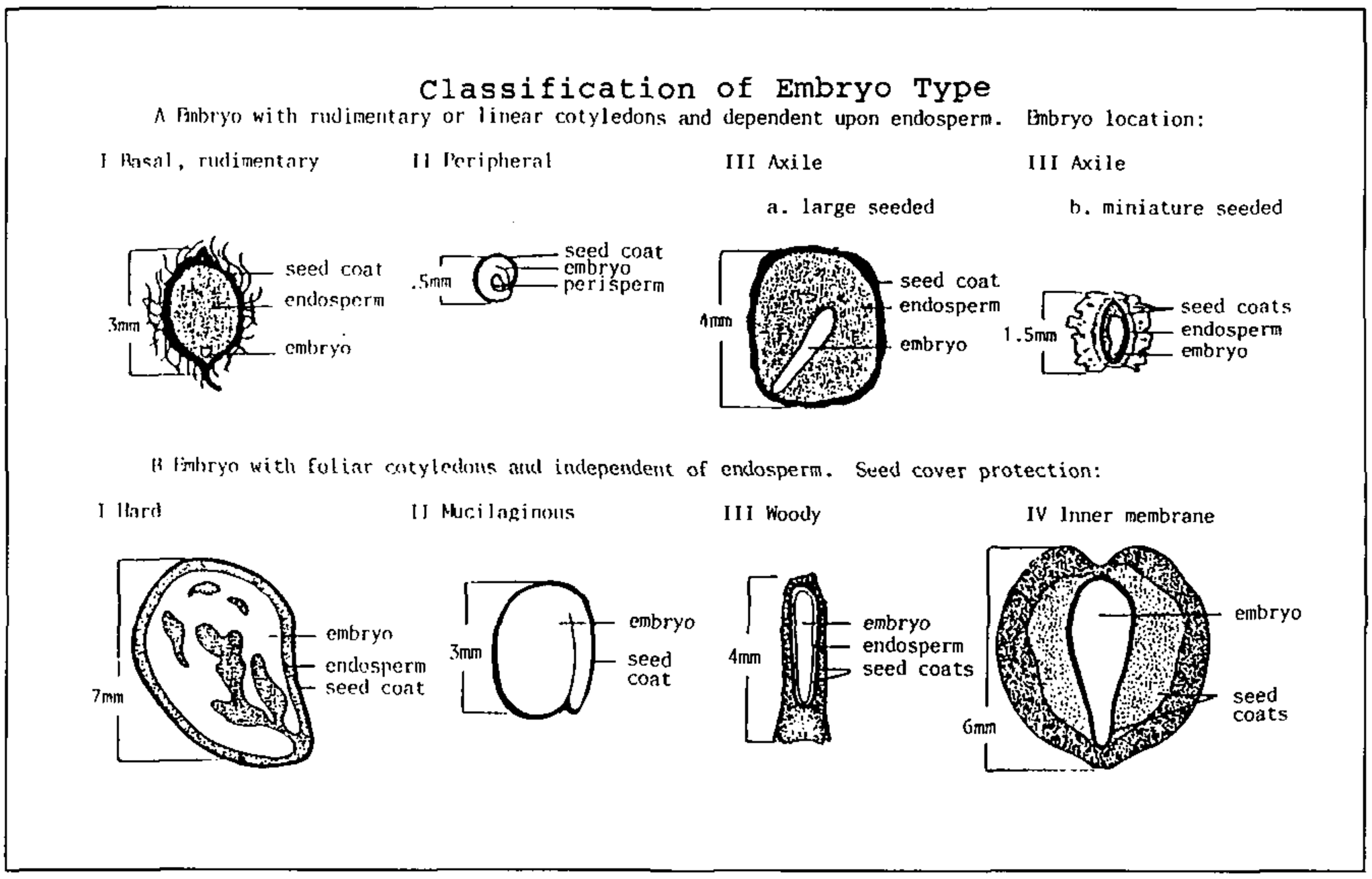

Figure 1. Embryo development, location, and protection (Atwater and Vivrette, 1987).

permeability. It is only effective if the membrane covering the seed is permeable. Cold stratification and sharp alternation of temperature are also effective in breaking embryo based dormancies. In some species high temperature activates the dormant seed. Knowing where the dormancy is likely to reside in a seed is a first step in treating the seed for dormancy (Vivrette, 1991).

There is a close association between seed morphology and the physiology of seed dormancy. Generally, the structure closest to the embryo functions as the barrier to germination (Nikolaeva, 1969). Internal seed structure is very similar for species in the same family or group of families (Atwater, 1980; Corner, 1976; Martin, 1946).

Seeds can be divided into two major groups: seed with a small embryo with food stored in the endosperm (dependent embryos) and seed with a fully developed embryo with food stored in the cotyledons (independent embryos) (Fig. 1). These two groups can be further classified by embryo position, embryo structure, and seed coverings (Atwater and Vivrette, 1986).

CONCLUSION

To begin to understand the whys and whats of dormancy is a complex learning experience. Knowing where the dormancy is likely to reside in a seed is a first step in treating the seed for dormancy. The A.O.S.A. "Rules for Testing Seed", although not requiring that remaining seed be tested for viability, suggests that this be done, and any dormant seed present be reported as additional information. If we want to control the dormancy trait in seeds, we must continue to educate ourselves about the very complex subject of seed dormancy.

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Seed Priming and Pelleting: Tools for Stand Establishment

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Seeds are pelleted for ease of handling, singulation, precision placement, and the incorporation of beneficial chemicals, such as fungicides or microbials. Cereal seeds were the first seeds to be pelleted in Europe. Sugar beets were one of the first seeds to be pelleted in U.S. The outlawing of the short-handled hoe for the lettuce industry created demand for coated lettuce seed as the use of precision field seeders increased. As well, the expansion of greenhouse-transplant production created another arena where pelleted seed would be a labor-saving device, for both vegetables and flowers.

PELLETING

The objective of pelleting is to make the seed rounder, smoother, heavier, and more uniform than the raw seed.

Seed is pelleted when growers need a precision-sown crop and the raw seed is too small, too light, or too variable in size to be sown accurately. Precision seed is needed for production in cell trays in greenhouses, or when strict control for depth of placement and spacing is critical to achieve the highest possible yields. For example, pelleting allows the lettuce grower to precision-seed his crop with a high uniformly spaced population, allowing for the thinning operation to be faster, cheaper, and more accurate.

TYPES OF MATERIALS FOR PELLETING

Basically two types of materials exist, melt coat or split coat. The melt coating dissolves when wet and gradually washes away from the seed. Split coats initially retain their shape when wet, and as water is absorbed by capillary action to the seed, the seed begins to swell and the pellet splits open. The melt coatings were developed in the 1960s while the split-coat pellet was not introduced to the U.S. until the early 1980s.

The split pellet often requires less water during the germination process, allowing for oxygen to get to the seed more quickly. Melt coats on the other hand require enough water and time to wash the coating off of the seed. Because of their affinity to water they perform more reliably in the U.S. greenhouse systems and coastal field conditions, in what seem to be wetter and cooler atmospheres. Split coatings perform best when they are in drier conditions during the germination phase, such as field plantings in the southern portion of the U.S.

HOW IS SEED PELLETED?

The pharmaceutical industry developed technology which the seed coating industry relied upon in the beginning. Even today the candy industry employs similar

techniques to produce some candies. Commercial seed pelleting is done by placing seed in a rotating pan, misting with water or other liquid, and gradually adding a fine inert powder. The wet seed becomes the center of the pellet, and as it tumbles in the pan the seed collects the fine powder, layer after layer. The pellets are rounded and smoothed by the tumbling action in the pan. The fine powder is compacted by compression from the weight of material in the pan.

Uniform size and uniform rate of increase in size are evaluated throughout the process with frequent hand screening. At intervals the seed is removed from the pan and screened. The smaller-sized pellets are then returned to the pan and the pelleting process continues until the pellets are the same size as the remainder of the lot.

After pelleting, the seeds are placed in forced-air dryers for a specified period of time. The seed is collected and screened once again. Pellet size is crucially measured with the standard tolerance at 0.4 mm, seed to seed. The seeds are then ready for packaging.

When the pelleting process began the goal was to have one seed in each pellet. Over the years as technology has advanced, flower growers have been asking for two to eight seeds per pellet depending on the species involved. Begonia growers only want two seeds per pellet because of the price of seed. Lobelia growers on the other hand wish to have six to ten seeds per pellet.

SEED QUALITY

This is a critical ingredient for producing a quality product for the grower. Junk in! Junk out! Measuring seed quality is an elusive piece of the puzzle, since there is no single test that will provide full seed quality information, and each species has its own unique challenges and solutions.

Every aspect of the seed's physiology is important in determining the best product form for the seed. Total germination, light requirements, and temperature thresholds give clues to the seed's requirements for optimal germination. In addition the environment in which the seed will be planted must also be taken into consideration. Various testing methods are applied to make the final determinations for which coating would be used for the grower's conditions. Germination tests may include testing under optimal conditions for the seed, stress conditions, soil tests, greenhouse tests, etc.

Lettuce, for example, has specific temperature thresholds and light requirements. Most types of lettuce go into thermodormancy when temperatures exceed 80F and some types of lettuce will not grow in the dark. Photodormancy is a particular obstacle when lettuce is to be pelleted. Germination of photodormant seed in a melt coat will only begin when enough of the pellet has been washed away to allow light to the seed, and in a split pellet where there is no light the seed will never germinate.

To compensate for these dormancies growers would put melt coatings on the photodormant seed and live with the irregular germination patterns. Seed grown in the desert with melt coatings were a particular challenge to the growers because of the extreme heat during the germination phase. Even watering 12 h on and 12 h off did not always bring the seed to a temperature where germination would occur.

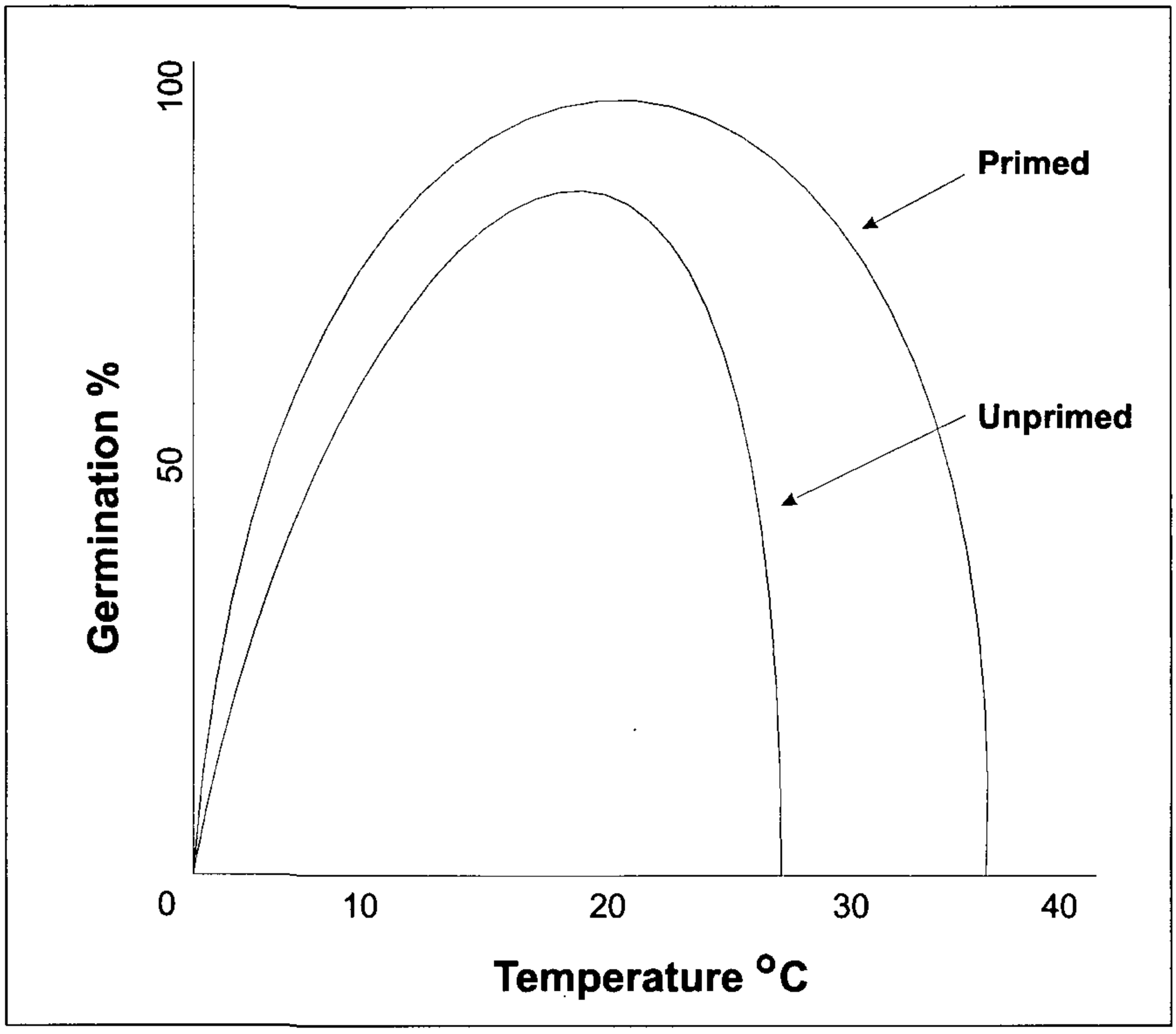

Figure 1. Germination percentages at various temperatures for primed and unprimed seeds.

SEED ENHANCEMENT

There are many different methods to enhance seeds such as milling, fungicide application, biological application, and seed priming. The purpose of these techniques is to increase total germination, and/or to have faster and more uniform germination under a wider range of temperatures, and to break dormancy. This discussion will focus on seed priming in lettuce for desert conditions.

There are various ways to prime seed, three of the more common are osmotic, drum, and matrix priming methods. Each has its own approach to enhance the germination process. Osmotic priming places the seed in an osmotic solution with air, drum priming places the seed in a drum with air, and matrix priming uses a solid medium with the seed with air.

Thermodormancy in lettuce is an important issue for growers, especially those in the southwest trying to establish stands under tremendous temperature stress, where temperatures can exceed 110F in the soil. Commercial priming of lettuce is offered to assist the grower during the germination phase for a better chance at optimal stand establishment. The combination of his watering practices and seed priming allow the seed to be at temperatures that are optimum for germination. When the temperature rises above the acceptable threshold, germination will stop, and will not begin again until the temperatures are again lowered. This stopping

and starting causes irregularities in the stand, which translates to irregularities in the harvest.

Figure 1 shows the differences between primed and unprimed lettuce seed at two extreme temperature ranges. The raw unprimed seed stops germination at 28C while the primed seed continues up to 36C and moves back into a dormant state at temperatures which exceed 36C. With this process growers in the southwest are able to obtain reasonable lettuce stands under their extreme conditions.

Today more than 30,000 acres of lettuce are planted with a primed and pelleted product. That translates into 10,000 raw pounds of seed. Real advancements in pelleting and seed priming have been made and more will follow. Use of this technology combined with advanced genetics allows growers to become more successful and cost efficient.

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Rose Breeding of the Future

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The fossil record dating back 35 million years, indicates that roses were widespread across the Northern Hemisphere. Roses have been a part of various cultures throughout the ages. The first systematic application of the science of breeding and selection to roses was begun in England in 1865. The U.S. Plant Patent Act of 1930 made it possible for breeders to receive revenues for their intellectual property, which in turn enabled them to expand their breeding of roses. The rose is probably the most intensively bred woody ornamental plant in the world. Still, rose breeders have been unable to develop resistance to black spot (*Diplocarpon rosae*), a primary objective. Breeders are looking at genetic engineering as a tool to advance germplasm to the point where breeders can utilize the immunity to black spot found in nature. Biogenetic firms and university researchers are currently exploring the techniques of transformation and regeneration(T-R) and the use of antisense technology, for the expression of new colors, disease resistance, fragrance, and improved shelf-life (cut flowers).

EARLY HISTORY

Roses have been around for a long, long time. The fossil record from the Oligocene, dating back 35 million years, indicates roses were widespread across the Northern Hemisphere. Fossils have been found showing roses at least this old in North America, Europe, and Asia.

Over thousands of years, spanning different cultural periods, we have little information on any breeding or selection in roses. We know roses were selected for desired traits and propagated, because we have written records of directions for propagation, pruning, and even forcing roses from Roman times forward.

EARLY BREEDING

The first written records in Western Europe on seed collection, ripening, sowing, and variety selection come from 17th Century France. Open-pollinated seeds of roses were collected, sown, and desirable seedlings selected and propagated. Large nurseries dedicated to rose propagation and sale developed in France. In the 18th Century, roses became very popular in Europe. Large collections of roses like that of Empress Josephine at Malmaison became popular.

Still, breeding of roses into the nineteenth Century was considered an art and not a directed act with specific goals. Controlled pollinations were not practiced, there was little record keeping and the selection depended on luck, as much as the breeder's skills. Even so, quite famous rose-breeding firms grew up in the early 1800s and by the mid 1850s firms specializing in breeding roses had developed.

The first systematic attempt at applying the science of breeding and selection to roses began in England in 1865. In that year, Henry Bennett wrote that, using the

principles of breeding developed by agriculture and applying them to roses, would bring a revolution to this plant. Unlike the French, who used open-pollinated seed, Bennett chose to select parents whose traits were desired and carefully hand pollinated them with stated objectives for the progeny in mind. He used greenhouses to produce and ripen seed, carefully sowed seed in glasshouses, and ruthlessly selected for desired traits. Success from this approach to rose breeding spread quickly to France, Germany, and the U.S.

MODERN ROSE BREEDING

From 1870 to 1920 all of today's surviving major rose-breeding firms were founded. The great Northern Ireland firms of Dickson and McGredy, the German firms of Tantau and Kordes, the French firm of Meilland, the Danish company Poulsen, and the U.S. firm of Jackson & Perkins all got their start in this period. All of these companies developed large, sophisticated breeding programs based on careful selection of the best parents, controlled crosses, and careful seedling selection, followed by rapid build-up and introduction to the market place. Because of the lack of intellectual property protection, it became necessary to flood the market with new product for 2 or 3 years to capture enough money to pay for research.

All of this began to change with the U.S. Plant Patent Act of 1930 and the first patents issued in 1931. Breeders now had the opportunity to protect their invention and gain an income over time to invest in future research. This increase in revenue helped to rapidly expand breeding of roses in the U.S. It would have the same effect in Europe 30 years later when Plant Breeders Rights were finally accepted and became law.

The result of all this long accumulation of breeding and protection for intellectual property has meant that the rose is probably the most intensively bred woody perennial ornamental plant in the world. Worldwide, hybridizing programs of the major breeders produce over 3 million seed per year and cost an estimated $10 million dollars. With all of this research, breeders of roses are still left with several fundamental breeding goals that remain to be attained.

FUTURE

Breeders of roses, with a tremendous base of advanced germplasm derived from many wild species, still have not accomplished perhaps their most important goal: resistance to black spot fungus (*Diplocarpon rosae*). Even using the diploid species *Rosa multiflora* and *R. rugosa*, immunity to black spot is still on the distant horizon. With rapid mutation by the pathogen and the dilution of resistance by conventional breeding, breeders are looking at genetic engineering as a tool to advance the germplasm base to the point where breeders can take full advantage of the immunity to black spot found in nature. However, fundamental and expensive roadblocks are in place preventing this from happening.

Breeders know almost nothing about roses at the gene level. We do not have gene maps of roses at the diploid or tetraploid level. We do not have linkage maps or marker genes and our knowledge of genetic engineering techniques is at best primitive. Even with this lack of fundamental basic knowledge, genetic engineering in roses is taking place. Perhaps the most famous example of this is the blue rose project by Florigene (formerly Calgene Pacific) of Australia. Florigene began studies into modification of flower color in roses over 10 years ago. They have two approaches

to color modification. The first involves isolation of new genes that can be transferred and expressed in roses. The other approach is to alter color by use of "anti-sense" orientation.

In the first approach, Florigene, by using advanced and elegant genetic engineering techniques has isolated the so-called blue gene in Petunia. Florigene has successfully isolated the 3', 5' - hydroxylase gene and its promoters and successfully transferred them to a rose. They have been able to regenerate the transformed rose cell into a whole plant and have got expression of the gene. However, differences in vacuolar pH and the presence of copigment also affect the blueness in flowers. In the case of this transgenic rose, the vacuolar pH is too low to allow the blue color to be expressed in the petals. Florigene now has to either adjust pH in the vacuole or find a rose with a suitable pH. Both approaches have been examined over the last 2 years. As yet, the blue rose has not emerged.

The second approach, the use of "anti-sense" technology has proved successful in rose, petunia, carnation, and chrysanthemum. The expression of sense and anti-sense constructs in transgenic plants for the enzyme chalone synthase (CHS) is now becoming routine. Commercial testing in chrysanthemum with this technology have been accomplished and cultivars released.

Further research at Florigene on improvement of shelf-life in roses suggests that the use of anti-sense constructs of ACC synthase (necessary for ethylene production) can control ethylene production. The same technology, using ACC oxidase, is also possible. These are the same genes that are used to produce long-life tomatoes.

Other genetic engineering companies are working in this field. DNAP has patented a transformation-regeneration (T-R) system for roses. Moet, in France, has also developed a successful T-R system and has been reported to be working on fragrance expression in roses. Other firms are reported to be interested in using roses in their genetic engineering programs.

It seems that over the short term (10 years), genetic engineering of roses will continue to be done. Until more is learned about the rose itself (mapping, linkage), most genetic engineering will use off-the-shelf patented genes and these will be inserted into the rose and tested. Examples include the ethylene blockers, herbicide-resistance genes, insect-resistance genes and color-modification genes.

In the longer term, as the basic science of the rose is learned and we come to know where individual genes are located, gene transfer between roses will become common place. For example, instead of using diploid species for resistance breeding, individual resistance genes or gene complexes will be transferred to specific tetraploid clones.

Traditional plant breeding will be enhanced with these techniques. The breeder's role will become more directed - the rifle or pinpoint approach to breeding will replace the shotgun approach. Our dream of true resistance to diseases like black spot may finally be realized. Of course, because we are dealing with natural systems, the pathogen may have something to say about this.

"Nursery Propagation by Hardwood Cuttings" Question-Answer Period

No recording.

POSTER SESSION

Seasonal Changes in Adventitious Root Formation in Stem Cuttings of *Prosopis alba*

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Seasonality in rooting response of stem cuttings in relation to exogenously applied K-IBA was studied in nitrogen-fixing trees of genus *Prosopis* (mesquite). Cuttings of field-grown trees were successfully rooted using an intermittent mist propagation bench during a period of high temperature and relatively higher humidity levels (May to September) than in winter months. The adventitious root formation on cuttings was inhibited during the dormant period (November to February). The efficacy of exogenously applied K-IBA concentration varied with the position of cuttings on the stem. An increasing concentration of applied K-IBA appeared to be correlated with the apical and basal end of the cuttings for the optimum root initiation and development.

INTRODUCTION

Nitrogen-fixing trees of genus *Prosopis* are drought resistant and well adapted to poor soils of dry regions (National Academy of Sciences, 1979). Previous research has demonstrated considerable variation in tolerance to cold, salinity, and in pod production (Felker et al., 1981, 1982, and 1984). This variability can be attributed to the fact that several *Prosopis* species are self-incompatible (Simpson, 1977) and thus plants are obligate outcrossers that do not propagate true to type from seed. Cross-fertilization results in wide genetic variations in populations within species of *Prosopis chilensis* and *P. velutina* (Solbrig et al., 1977; Palacios and Bravo, 1981; Munziker et al., 1986). Inter- and intra-specific hybridization results in creation of new phenotypes with a wide range of characteristics such as growth rate, spines, growth habit, and frost tolerance. With respect to the landscape use of mesquite trees, desirable characteristics include: absence of spines, good growth form, frost tolerance, and insect resistance. The development of clonal propagation methods is necessary for large-scale production to be used in the nursery industry.

The purpose of this investigation is to develop a method for vegetative propagation and to relate the seasonal growth pattern of *P. alba* to its rooting ability using a misting propagation technique.

MATERIALS AND METHODS

Propagation of Field-grown Trees. Cuttings were collected monthly during 1993 and 1994 and were obtained from adult individuals over 4-5 years old grown around the Phoenix area. The branches selected were new growth during summer and fall. However, previous year's growth was used as cutting material during early spring.

Cutting Propagation. Each cutting consisted of 3 nodes with leaves removed from the lower nodes. All cuttings that consisted of entirely green stems came from the same trees for each treatment per season. Basal ends of cuttings were given a 5-sec dip in the hormone solution, air dried and then inserted 3 cm into a rooting medium consisting of a of medium grade vermiculite and perlite (1 : 1, v/v). The medium was drenched with 500 mg liter^{-1} Banrot (Sierra Crop Protection Co., Milpitas, CA.) prior to sticking cuttings. The maximum light-intensity at each bench level was 500-550 µmole m^{-2} s^{-1}.

Intermittent mist was provided at an interval of 8 min for a duration of 8-10 sec for the first 3 weeks. The duration of mist was then gradually reduced. Soil temperature was maintained in the range of 30-35C. The rooting percentage was measured after 6 weeks.

Effect of Cutting Position and K-IBA Concentration. In this study, 20-25 cuttings were used per treatment and randomized in the greenhouse. Each experiment was repeated 2-3 times. Root quality determinations were not made in order to avoid root damage.

Preliminary experiments were conducted to determine a range of optimum conditions and K-IBA concentrations for root initiation. In later studies, K-IBA at concentrations of 200, 500, 1000, and 2000 ppm were examined for basal, middle and apical sections of the stem. K-IBA was used (Sigma Chemical Co., St. Louis, MO.). The apical cuttings consisted of the terminal 3 nodes of the stem (apex removed). Middle and basal cuttings consisted of the next 3-6 nodes down on the same stem.

Statistical analysis was performed using the MSTAT statistical program.

Serial Propagation of Rooted Field-grown Trees. The rooted cuttings were planted in 5-gal. containers and then transplanted to the field to be grown as adult trees. Cuttings were taken from field-grown clones and rooted as described earlier. The data provided in this communication is an average of 2 years of experiments.

RESULTS AND DISCUSSION

Preliminary Experiment. In this study a wide range of K-IBA concentrations (200-5000 ppm) were used for tip, middle, and basal sections of the stem. The results indicated that the base of cuttings treated with 5000 ppm K-IBA turned black within 48 h. Similarly, tip cuttings showed blackening at the base of cuttings treated with 1000 ppm or higher concentration of K-IBA. The fungal drenches of Banrot, Subdue and Domain did not affect rooting potential.

Effect of K-IBA Concentration and Stem Position. In the study started in April and May, K-IBA increased rooting on cuttings taken from apical, middle, and basal end of the cuttings. While apical and middle cuttings rooted better with 1000 ppm K-IBA, basal cuttings rooted better with 2000 ppm K-IBA than with other

concentrations.

The maximum vegetative growth took place during the months of May through August. Apical, middle and basal cuttings rooted better in water during the months of June, July, and August as compared to those in April and May. Apical cuttings rooted better (86% to 90%) at 200 and 500 ppm K-IBA than at 1000 ppm K-IBA (53%). Higher concentrations (5000 ppm) of K-IBA inhibited rooting completely. Middle and basal cuttings responded better to higher concentrations of K-IBA than apical cuttings. K-IBA at 1000 and 2000 ppm produced maximum roots (96%) on cuttings taken from middle and basal portions of the stem, respectively.

Stem cutting material started to decline in condition during September and October. It is, however, interesting to note that apical cuttings rooted better with 500 and 1000 ppm (September and October) than with 200 ppm K-IBA. However, rooting response was lower in all K-IBA concentrations compared to those in May-August (Table 1).

Table 1. Effect of K-IBA concentrations on rooting stem cuttings of *Prosopis alba*[1,2].

Month	IBA concentration (ppm)					
Cutting position	0	200	500	1000	2000	5000
April-May						
Apical	16	40	56	77	0	0
Middle	20	43	43	77	43	0
Basal	10	46	57	90	87	23
June-July-August						
Apical	53	87	90	53	33	0
Middle	50	53	57	100	73	0
Basal	40	53	66	86	100	13
September-October						
Apical	23	50	73	66	13	0
Middle	16	46	43	76	53	0
Basal	23	33	43	63	73	6
November-December						
Apical	0	0	5	0	0	0
Middle	0	0	8	0	0	0
Basal	0	0	8	0	0	0

[1]Percent of cuttings rooted.
[2]Thirty cuttings per treatment.

In limited experiments conducted during November-January, a period corresponding with lowest bud activity, rooting was very poor. Maximum rooting achieved was only 5% with apical cuttings and 8% with basal and middle cuttings. Cuttings did not root without K-IBA application.

These seasonal variations in rooting response with K-IBA application indicate that internal physiological conditions of the stock plants are important factors during rooting of stem cuttings. During the period of high temperatures (35-40C) and high humidity (30% to 35% in Arizona), *Prosopis* species grow rapidly and cutting material produces the highest number of adventitious roots. Our results also indicate that very low concentrations of K-IBA are sufficient to produce maximum roots on the apical cuttings. However, the requirement of K-IBA increases with the increase in stem diameter and distance from the apex (basal and middle cuttings).

Earlier studies have reported a similar seasonal decline for *Prosopis* as rooting of six *Prosopis* species dropped from 60% to 100% in spring to only 15% in fall using greenhouse-grown clonal stock plants (Felker and Clark, 1981). Hormonal treatments were found to be ineffective in overcoming the seasonal influence on the rooting of cuttings (Klass et al., 1985).

The results indicate that *Prosopis* cuttings rooted better with K-IBA application throughout the year. However, high concentrations (5000 ppm) inhibited rooting. In general, K-IBA in the range of 200-1000 ppm in water appears to be a suitable level for cuttings taken from *P. alba* trees for root initiation and development. In contrast, studies in Texas of *P. alba* clone B2V50 found both rooting percentage and root number to be higher at 12,000 ppm than at 3000 and 36,000 ppm K-IBA in talc (Klass et al., 1987). A comparison of talc and ethanol showed that four and a half times as much IAA in talc as in ethanol was required to produce the same amount of roots on cuttings of *Ilex* (Heung and McGuire, 1973).

In the present study, rooting of *P. alba* is seasonal. The period of vigorous vegetative growth, flowering, and fruiting in the warm season is directly attributed to the highest rooting response with low auxin application. The very low rooting response in late fall and winter can be correlated with limited endogenous factors during the period of low vegetative activity. The rooted cuttings were planted and produced trees of a uniform height of 10 to 12 ft within 2 years.

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A Straight Line Approach to Minimising Water Stress in the Propagation Environment

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INTRODUCTION

The vegetative propagation of plants by leafy cuttings requires the grower to control turgidity and water loss until roots form. While the importance of maintaining turgor is recognised, even a slight water deficit which may go undetected with no visual symptoms of distress can result in considerable delay or reduction in the rooting response (Evans, 1952; Loach, 1977). Cuttings are most visibly prone to moisture stress and wilting in the first few days that follow severance from the stock plant. Understanding the underlying physiological processes influencing water requirements by cuttings can create opportunities for plant propagators to improve their cutting strike rate through changes in their methods in ways that suit their particular situation.

Water loss from cuttings and hence water stress can be influenced by three interrelated factors: (1) the vapour pressure difference between the leaf and the surrounding air; (2) the resistance to water movement through stomata, the cuticle, and the epidermis; and (3) the plant water content. Plant propagators can aim to maximise plant water content through the use of techniques that decrease water loss, by minimising the leaf to air vapour pressure gradient or by increasing the leaf resistance to water movement, and by maximising water uptake by the stem.

CUTTINGS

Pre-severance.

Water Use Efficiency of Stock Plants. Plant material that has been grown with a restricted supply of water usually produces shoots that are firmer and have a higher water-use efficiency. This could be turned to good effect if growers were to reduce the water supply to stock plants in the period prior to cutting removal. Cuttings produced in this manner should have less tendency to develop moisture-stress in the propagation environment. Sciutti and Morini (1995) demonstrated a beneficial effect where plum plantlets are exposed in vitro to reduced relative humidities. This has a direct impact on water use efficiency during hardening-off (Fig. 1a).

Influence of Time of Cutting Collection. Water stress on stock plants is normally at its lowest level when the water content of cuttings is at its highest in the pre-dawn period just prior to sunrise (Fig. 1b). While this may be the best time to collect cuttings with the highest water content it is not a very popular time with most propagators. Pragmatism usually forces a compromise with the standard practice of collecting cuttings in the early morning, preferably before they are exposed to bright sunlight.

Post-severance.

Wounding. The entry of water to the base of the cutting is dependent on the contact the stem makes with the film of water around the particles of growing medium. Most of the water is taken up by the cut surface of the stem base as the stem itself is relatively impermeable to water. Water uptake by cuttings can be promoted by wounding, the more severe the wounding the larger the area of stem with increased permeability to water (Fig. 2a).

Treatment of cutting bases with strong acid or base has been advocated to enhance root formation in some woody plants (Lee et al., 1976). Cutting treatment in this manner may alter the permeability of the stem and facilitate uptake of water and entry of growth regulators.

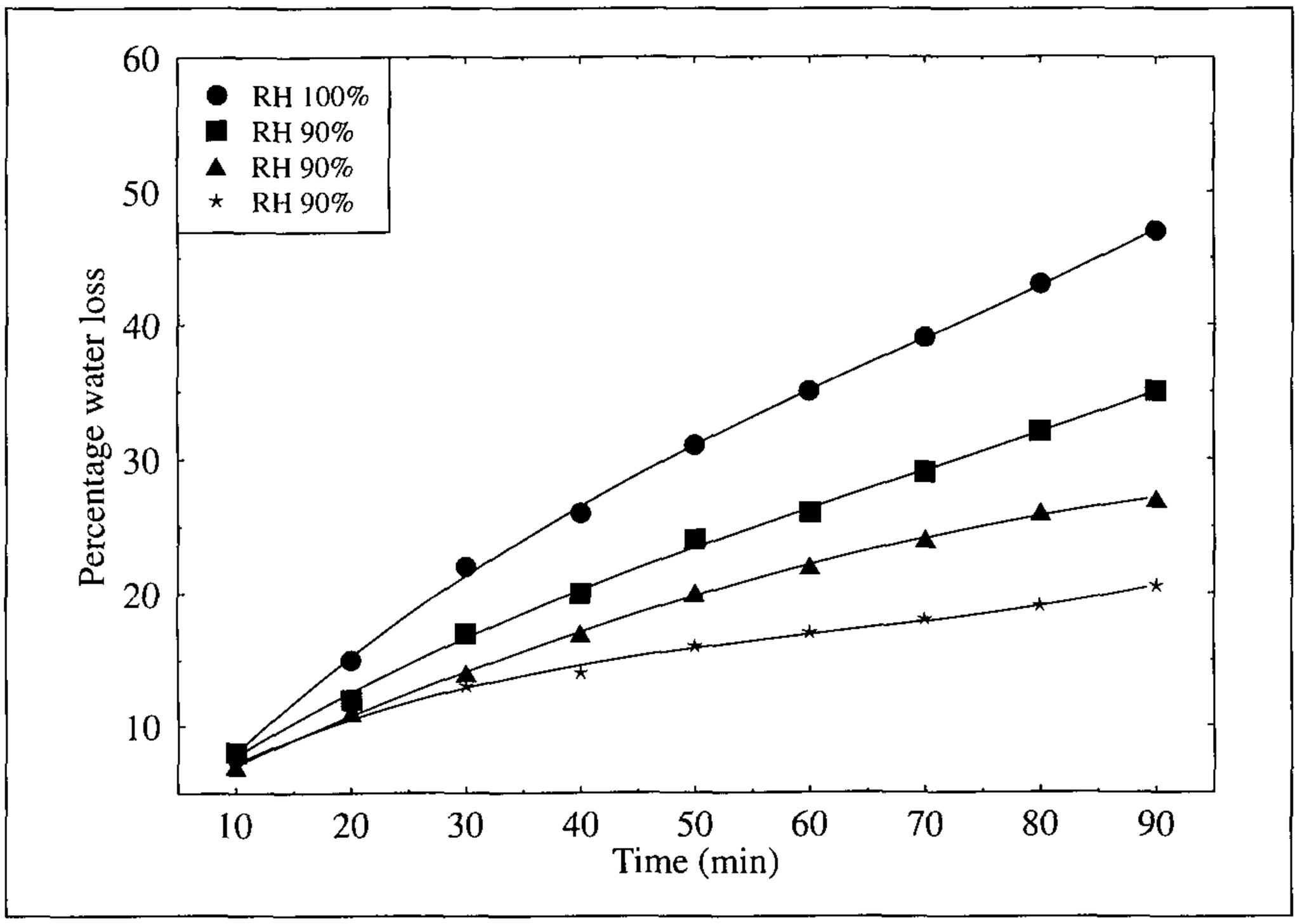

Figure 1a. Influence of relative humidity during growth on water loss during transplanting (Adapted from Sciotti and Morini, 1995).

Leaf Area. Water loss from leaves is related to their age and their size. Very young leaves have a lower diffusive resistance to water movement, which tends to increase as they become fully expanded and leaf tissues become firmer. The more hardened plant material tends to be more water-use efficient and use less water (Fig. 2b). Leaf area is often reduced on large leafy cuttings to reduce water loss where the propagation environment is unable to sustain the cuttings when severed from the stock plants. In commercial practice it is not uncommon to see leaf cutting or removal as an expedient measure to increase sticking density and reduce mutual shading. This pernicious practice should be avoided wherever possible as reduced leaf area delays root formation. Furthermore, cut leaves are more prone to disease entry and senescence, leading to leaf shedding that may spread rapidly in a moist propagation environment.

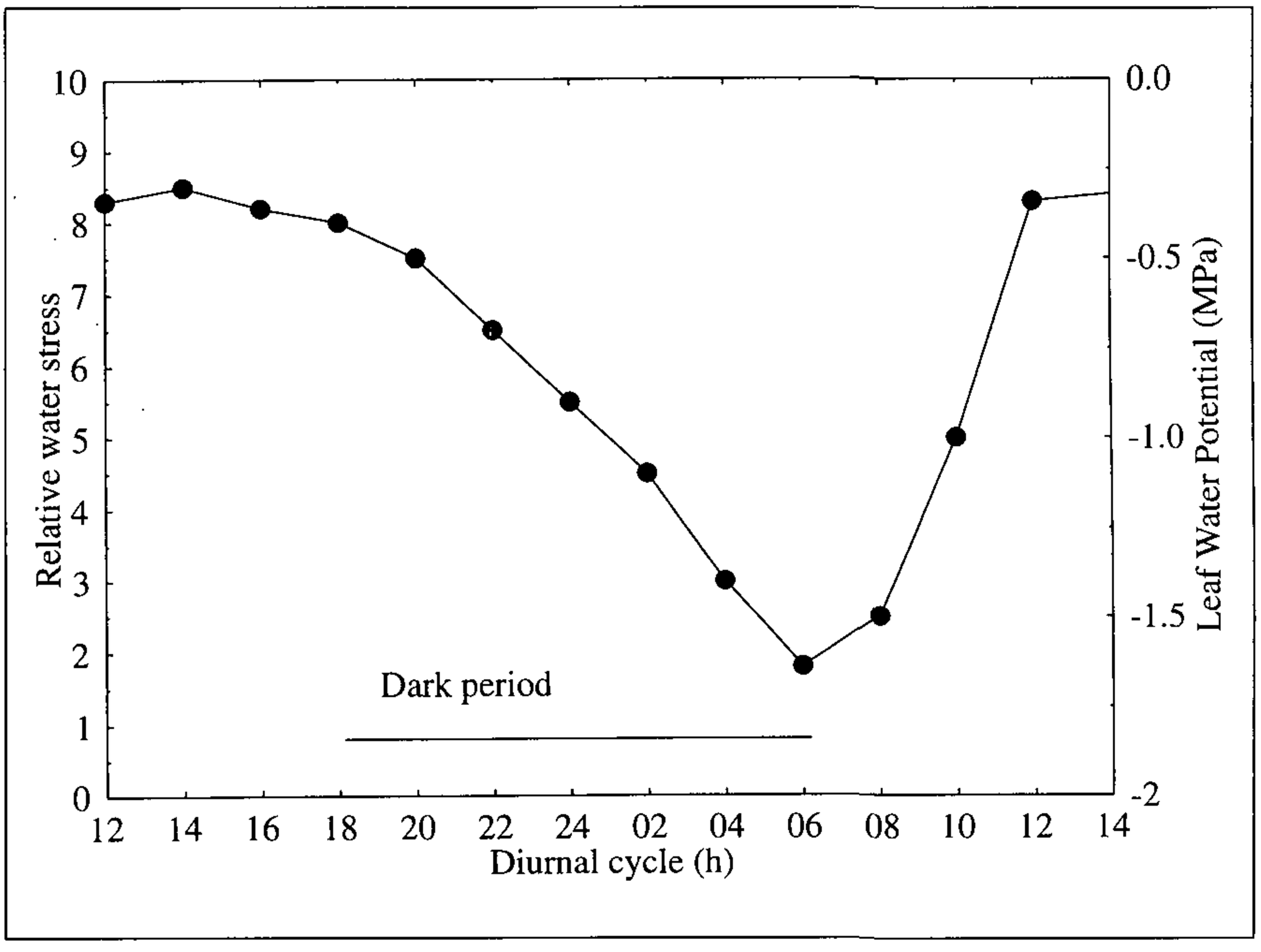

Figure 1b. Typical pattern of diurnal water stress.

PROPAGATION MEDIUM

Influence of Physical Properties of the Medium. Water and oxygen are both required in the propagation medium to promote root formation on stem cuttings. The physical properties of the medium are markedly influenced by the particle-size distribution of the growing medium components. The finer the particles in the growing medium the smaller the pores, this is reflected in higher water holding capacity at the expense of the air supply. The ideal medium is composed of a balance between fine and coarse particles that provide both water and air holding capacity, respectively. The uptake of water from propagation media is increased as the proportion of water in the media is increased in both freshly prepared and older cuttings (Fig. 3a, 3b). Many cuttings may be rooted directly in water, while this may provide a good supply of water, oxygen is frequently limited, particularly when bacteria accumulate in the water. A practical solution to this dilemma is made possible in an aeroponic propagation system, where cutting bases are bathed in a highly aerated water or nutrient spray, combining the requirement for a good supply of both water and air.

Depth of Medium. As the water content of the medium is related to the container depth, and the basal 1 to 2 cm of most propagation and growing media is saturated with severely limited gas exchange, it is prudent to follow Matkin's (1965) advice to use a container as deep as practicable. This will facilitate both drainage and aeration of media, and the base of the cuttings can be set about 3 cm from the base of the container out of the zone of saturation.

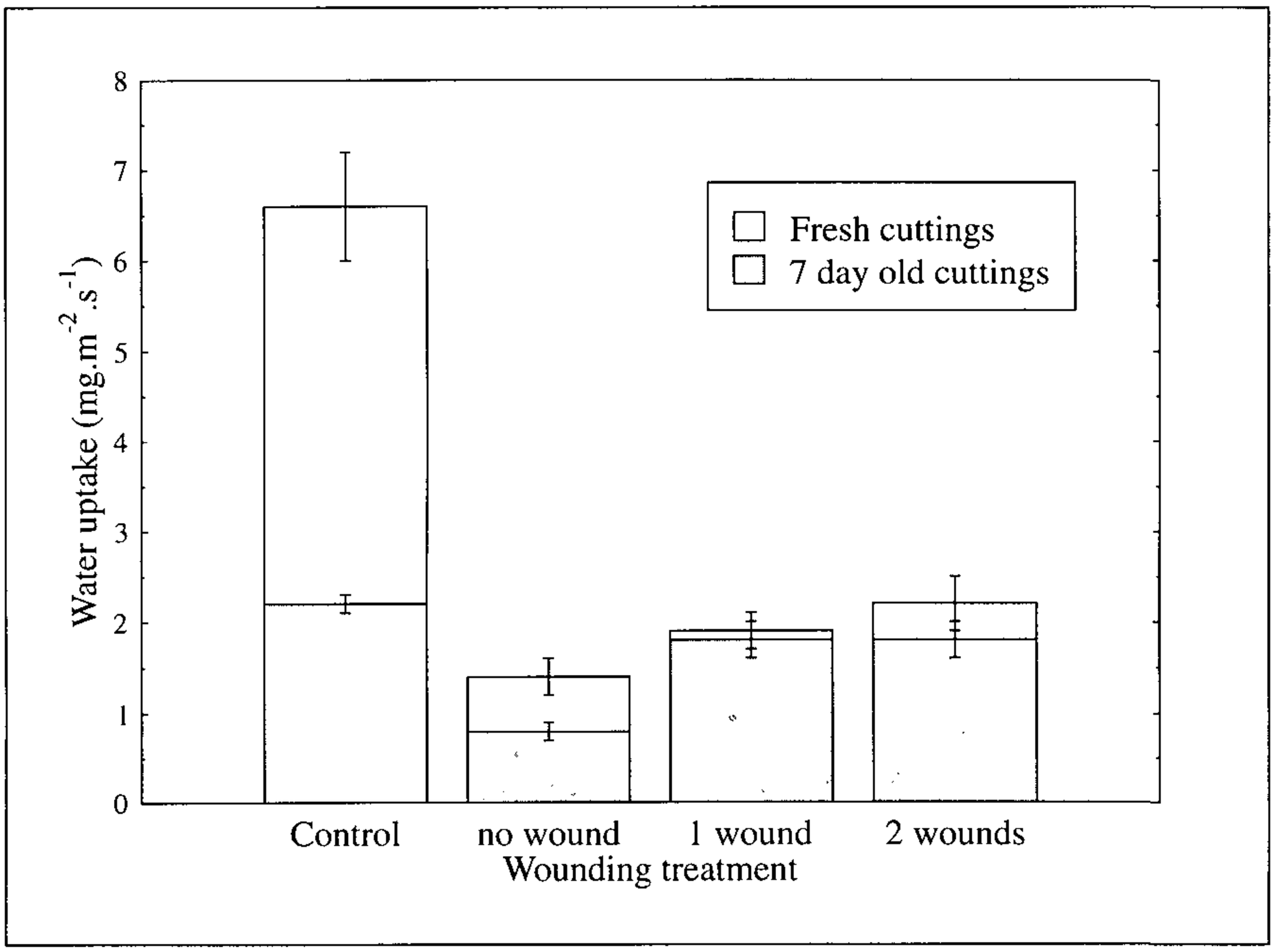

Figure 2a. Influence of wounding on cuttings on water loss in propagation medium relative to a water control (Adapted from Grange and Loach, 1983).

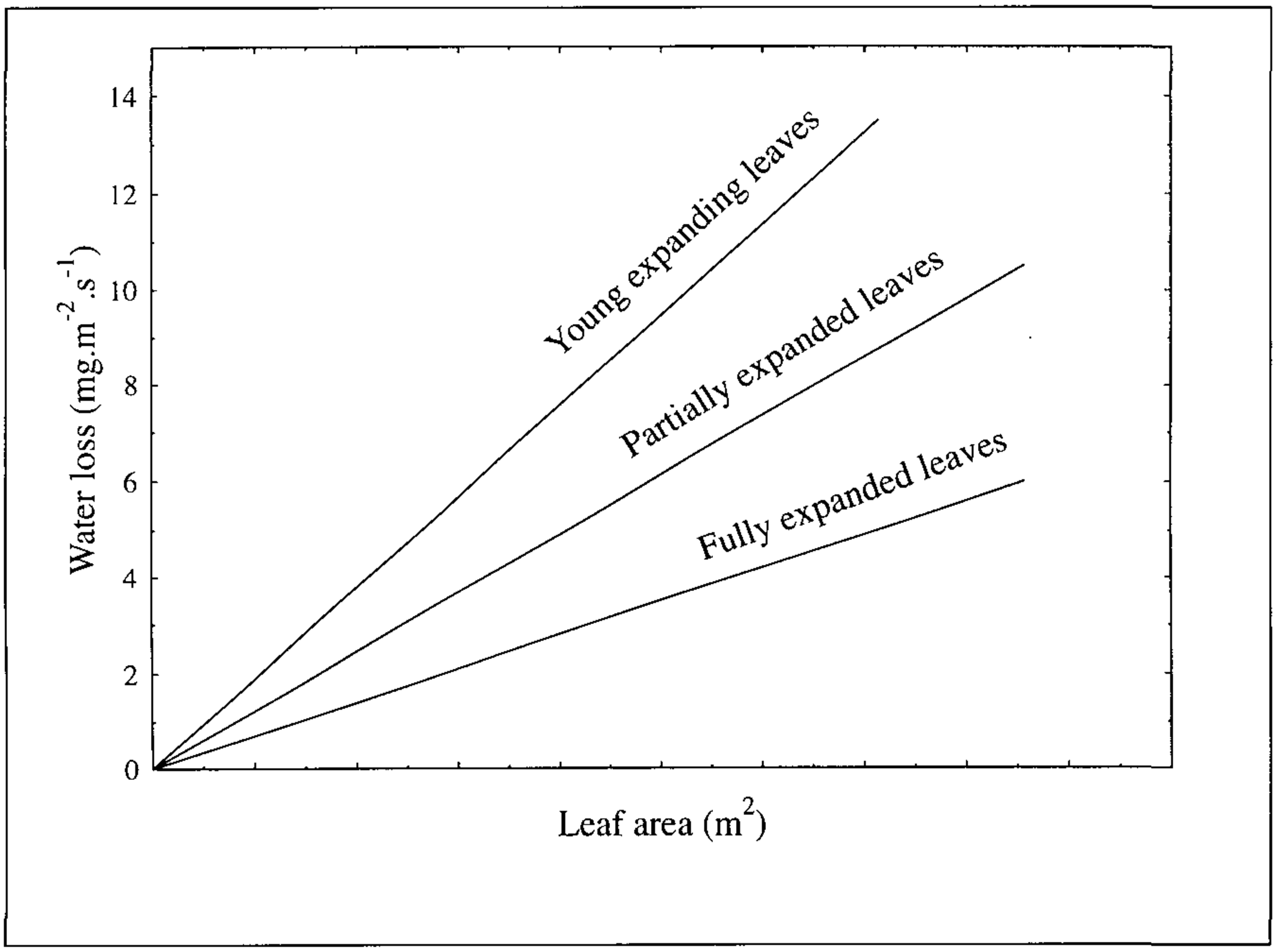

Figure 2b. Typical pattern of water loss by leaves of increasing age.

pH, Acidity and Water Transport. The acidity of the propagation medium has been known to facilitate plant propagation for a long time, and studies with cut flowers have shown that water transport in stems is enhanced by the use of acidified water with a low pH of about 4. This would explain the almost forgotten practice of adding glacial acetic acid to the propagation medium and (among other reasons relating to the physical properties) why peat has been so useful as a universal propagation medium. In many plants root formation is increased as water uptake is increased by decreased pH.

Stem Blockage Physical / Chemical / Microbial. Blockage of the stem appears to be a normal plant response (refer to Table 1) that may be accelerated by using propagation media or water loaded with finely suspended soil particles or micro-organisms. Recutting the base of the cutting restores the flow of water in most plants, but in the meantime, if the cutting is going to survive, then it has to become more water-use efficient with the newly established rate of water use usually less than a freshly prepared cutting. Postharvest treatments used for cut flowers have not provided marked improvements in plant water content or water-use efficiency in our studies with *Camellia* and *Pittosporum*.

Nutrients in the Propagation Medium. Relatively few nutrients are taken up in any significant quantity by unrooted cuttings. If cuttings are held in the propagation medium for an extended time after root formation has occurred, then normal nutrient uptake will occur. During the rooting stage, there is evidence to suggest that while some plants are not responsive, there are indications that nutrients repress root development which may be related to an osmotic stress that reduces water uptake by cuttings. Some investigators have applied nutrient mists to foliage to compensate for leaching of nutrients where an excess of water is applied to cuttings. The results from these studies have suggested there might be some gains from nutrient mist, but in practice, this has been difficult to implement and probably most beneficial with poorly adjusted misting systems, that encourage leaching through repeated excessive application of water.

AERIAL ENVIRONMENT

Water Loss from Leafy/Hardwood Cuttings. The highest rates of water loss from leaves occur in bright light rather than in dull conditions or darkness when stomata are usually more closed. In the dark rates of water loss are typically less than half the rate in the light (Table 1). Water loss by cuttings declines rapidly over time and is markedly influenced by the water availability in the propagation medium.

Leafless hardwood plum cuttings rooted slightly better when cuttings were permitted to loose 10% moisture before treatment with IBA and planting (Nahlawi and Howard, 1972), this improvement in plant performance has been attributed to improved IBA uptake. Related studies with quince cuttings clearly demonstrated benefits from wrapping treatments that reduce water loss from the stem after planting (Blain and Dudney, 1978).

Air Movement. Water loss from leaves increases with air movement. The boundary layer resistance to water movement from a leaf is proportional to the air velocity, therefore it follows that air flow through a propagation area should be

Table 1. Rates of transpiration and water uptake (mg m^{-2} s^{-1}) in several species for fresh and 7-day cuttings before and after removal of 10 mm from the basal stem.

		Uptake rate		Rate of change in cutting weight		Transpiration rate in the light		Transpiration rate in the dark
Species	Treatment	uncut	cut	uncut	cut	uncut	cut	
Nothofagus dombeyi	F	10.7	12.0	0.7	0.0	10.0	12.0	1.5
	7	3.6	7.8	-3.0	2.9	6.6	4.8	0.6
Cornus alba 'Spaethii'	F	11.4	10.4	0.8	-0.2	10.3	10.6	5.5
	7	2.6	10.5	-7.7	2.6	10.3	7.9	3.5
Forsythia ×intermedia 'Lynwood'	F	12.5	11.1	1.8	0.6	10.7	10.5	3.4
	7	1.3	5.1	-3.6	1.8	4.9	3.4	1.5
Garrya elliptica	F	6.8	9.2	0.3	0.6	6.4	8.6	0.6
	7	1.1	3.8	-6.3	0.4	7.4	3.4	1.7
Ilex ×altaclerensis 'GoldenKing'	F	4.9	7.4	-1.3	0.4	6.2	7.0	0.6
	7	2.4	3.9	-4.1	1.4	6.5	2.5	1.1
Skimmia japonica 'Rubella'	F	6.7	6.6	0.7	0.6	6.0	6.1	1.4
	7	3.0	5.3	-3.6	2.7	6.7	2.6	0.7
Hebe 'Amy'	F	3.5	6.1	-0.6	0.4	4.0	5.7	1.2
	7	1.2	5.0	-11.0	2.8	12.2	2.2	0.9

Source: Grange and Loach (1983)

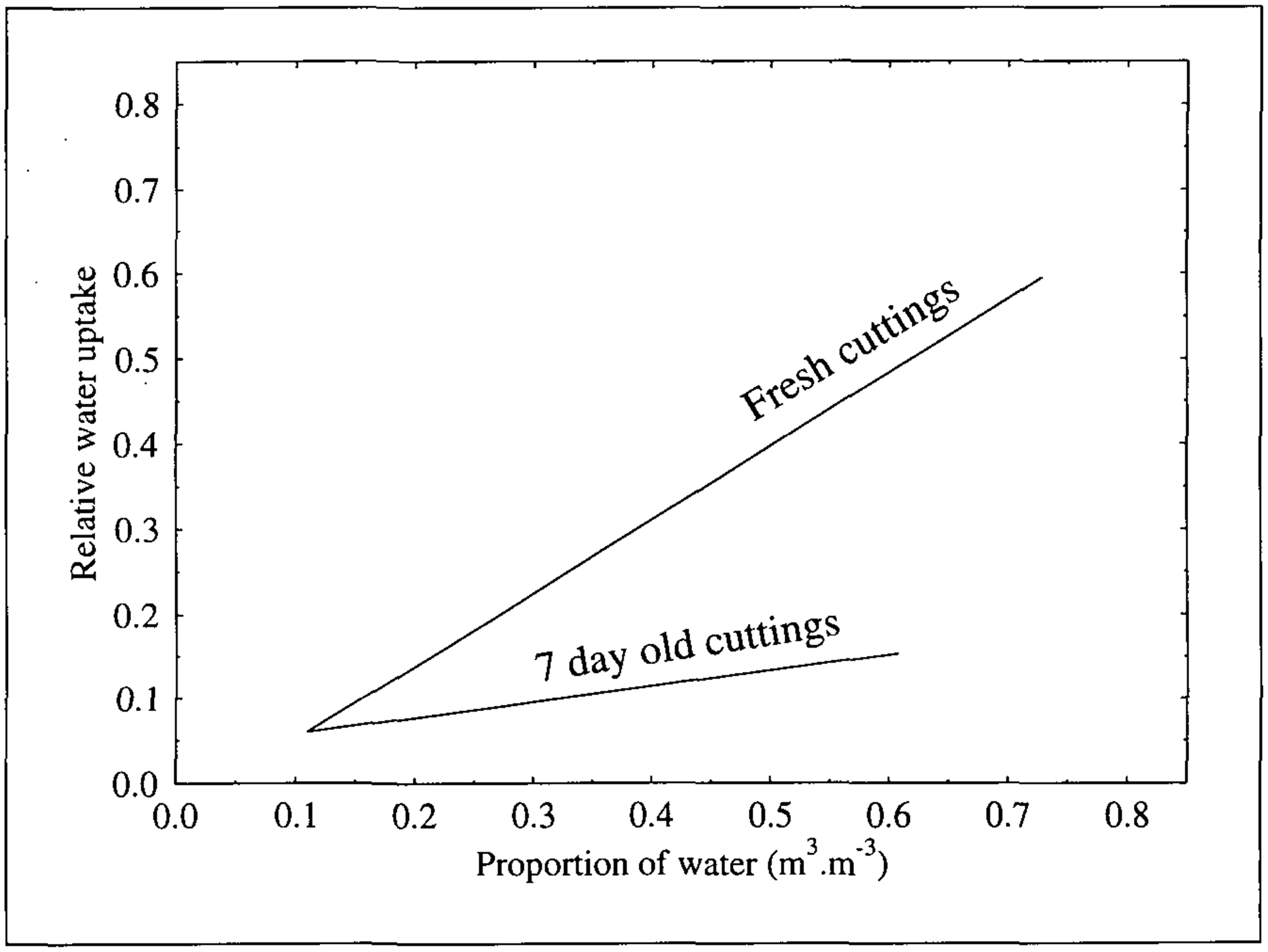

Figure 3a. Typical rate of water uptake relative to pure water in peat and perlite medium at different water contents for freshly prepared cuttings and 7 days after preparation (Adapted from Grange and Loach, 1983).

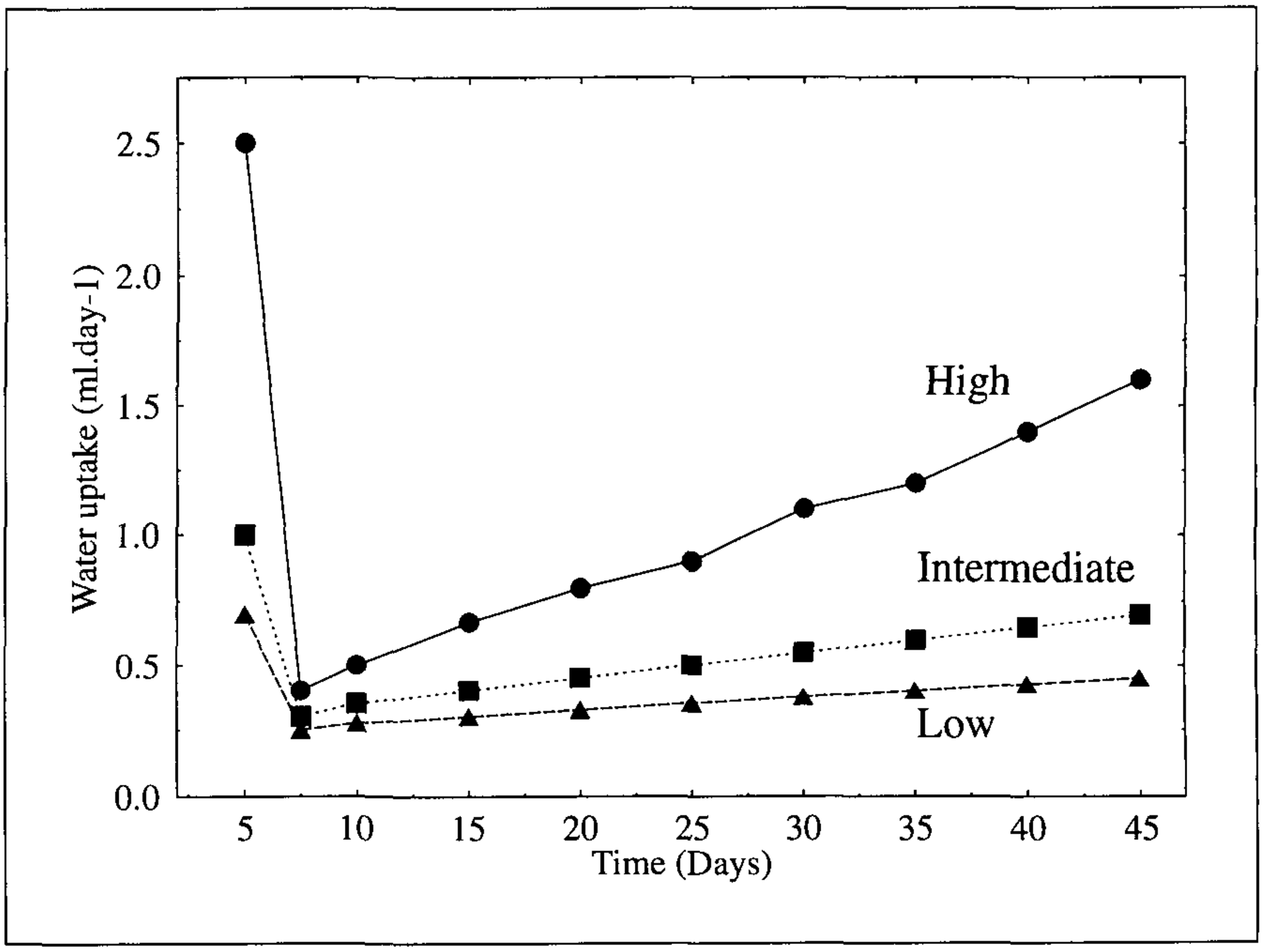

Figure 3b. Typical time course of water uptake in media with three different water contents.

minimised. In practical terms the amount of water lost from a leaf surface doubles as the air speed doubles. Water loss is also a function of leaf geometry with thin leaves loosing more water and being at a lower temperature than thick leaves.

Relative Humidity. This is the ratio of the actual vapour pressure of water (or the amount of water) in the air to the vapour pressure if the air were saturated with water at the same temperature. This is commonly quoted to give an estimate of the amount of water in the air. Water vapour moves from leaves into the air because of a vapour pressure difference between each region. Water loss from cuttings may decrease as the humidity increases but the real driving force for this process is the vapour pressure deficit.

Vapour Pressure Deficit. Water loss by plants increases as the temperature increases because the amount of water required to saturate the air increases rapidly, and unless there is a rapid injection of water into the air, the difference between the moisture content of the air and saturated air at the same temperature (the vapour pressure deficit), will also increase. Many of the strategies employed by plant propagators to reduce moisture stress do so by increasing the relative moisture content of the air to lower the vapour pressure deficit.

MODIFICATION OF AERIAL ENVIRONMENT

Reducing Water Loss from Plant Material.

Solar Radiation/Temperature. Water loss from cuttings is highly correlated with incoming solar radiation. The energy input from sunlight drives up the leaf temperature and water loss from leaves by transpiration, this process helps regulate the increase in leaf temperature. Further temperature regulation can be achieved through evaporative cooling of water applied by misting or irrigation. Many cuttings can be rooted without mist so long as moisture stress is managed. Lowering solar radiation by shading has a direct effect on the percentage rooting (Fig. 4a). Reducing the light level to approximately 20% of full sunlight has a beneficial effect on rooting response, and is reflected in decreased vapour pressure deficit experienced by cuttings in both misted and nonmisted environments (Fig. 4b).

Physical / Chemical Barriers to Water Loss. Antitranspirants have been used with very limited success. Surprisingly, they have little effect on leaf conductance, indicating that cutting turgor is regulated primarily by the vapour pressure gradient between the leaf and the air. Antitranspirants appear to offer most use in environments where the humidity is already relatively high (Gay and Loach, 1977).

Triazole fungicides (Triadimefon) and growth regulators (Paclobutrazol) improve water-use efficiency and may have wider application in protection of plant propagules by reducing water stress (Fletcher and Hofstra, 1988).

Greenhouse Strategies to Minimise Moisture Stress in Unrooted Cuttings. The polytent or closed frame is an inexpensive approach to controlling moisture stress, but it will only work if the incoming solar radiation is low. As the system is passive, relying solely on transpiration and evaporation of condensed water to saturate the air, severe moisture deficits occur if the enclosure is exposed to bright sunlight, because the temperature rises faster than the air can become saturated with water at the new temperature.

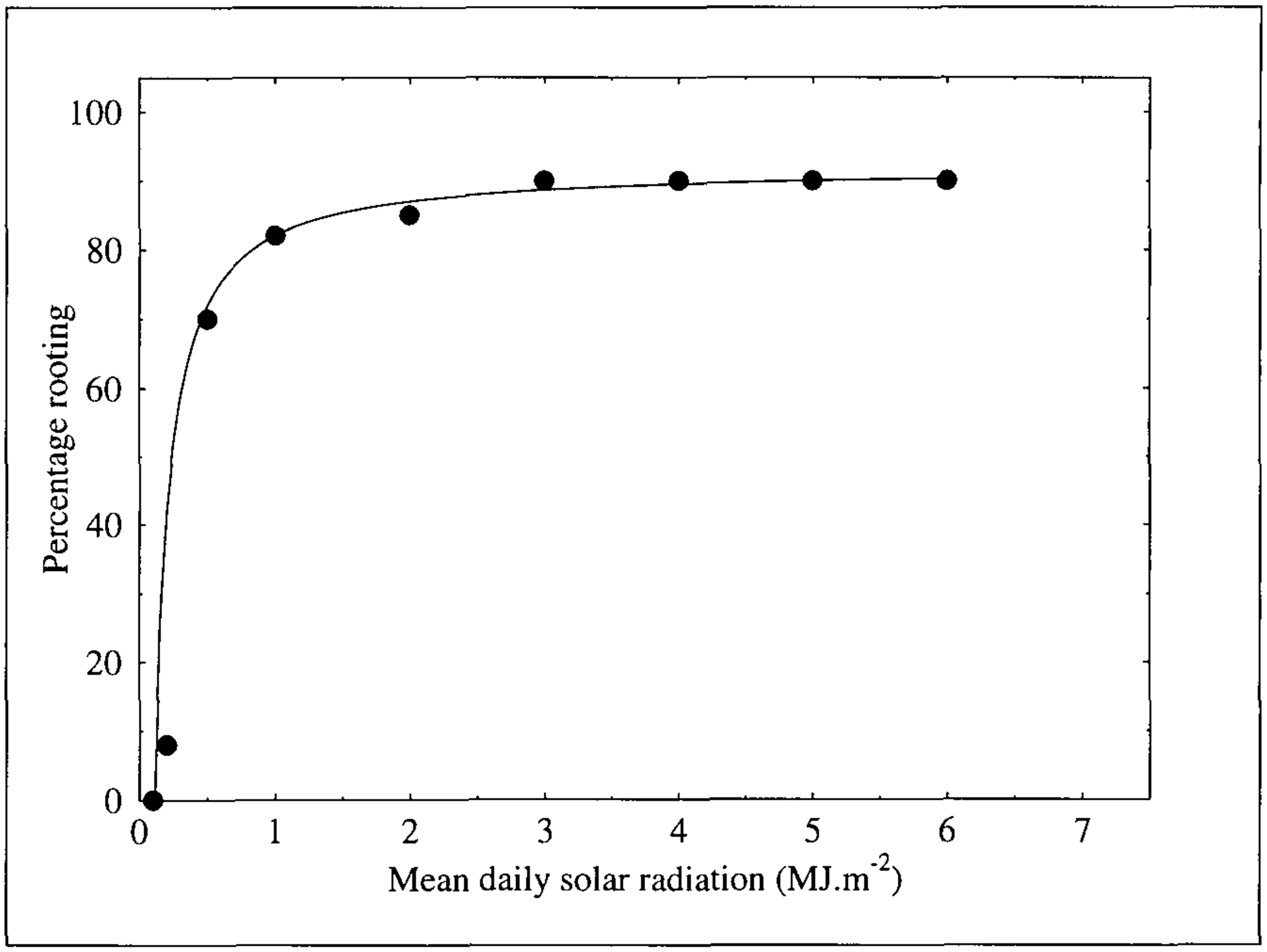

Figure 4a. Typical influence of solar radiation on percentage rooting in a diverse range of plants in an unmisted environment (Adapted from Grange and Loach, 1983).

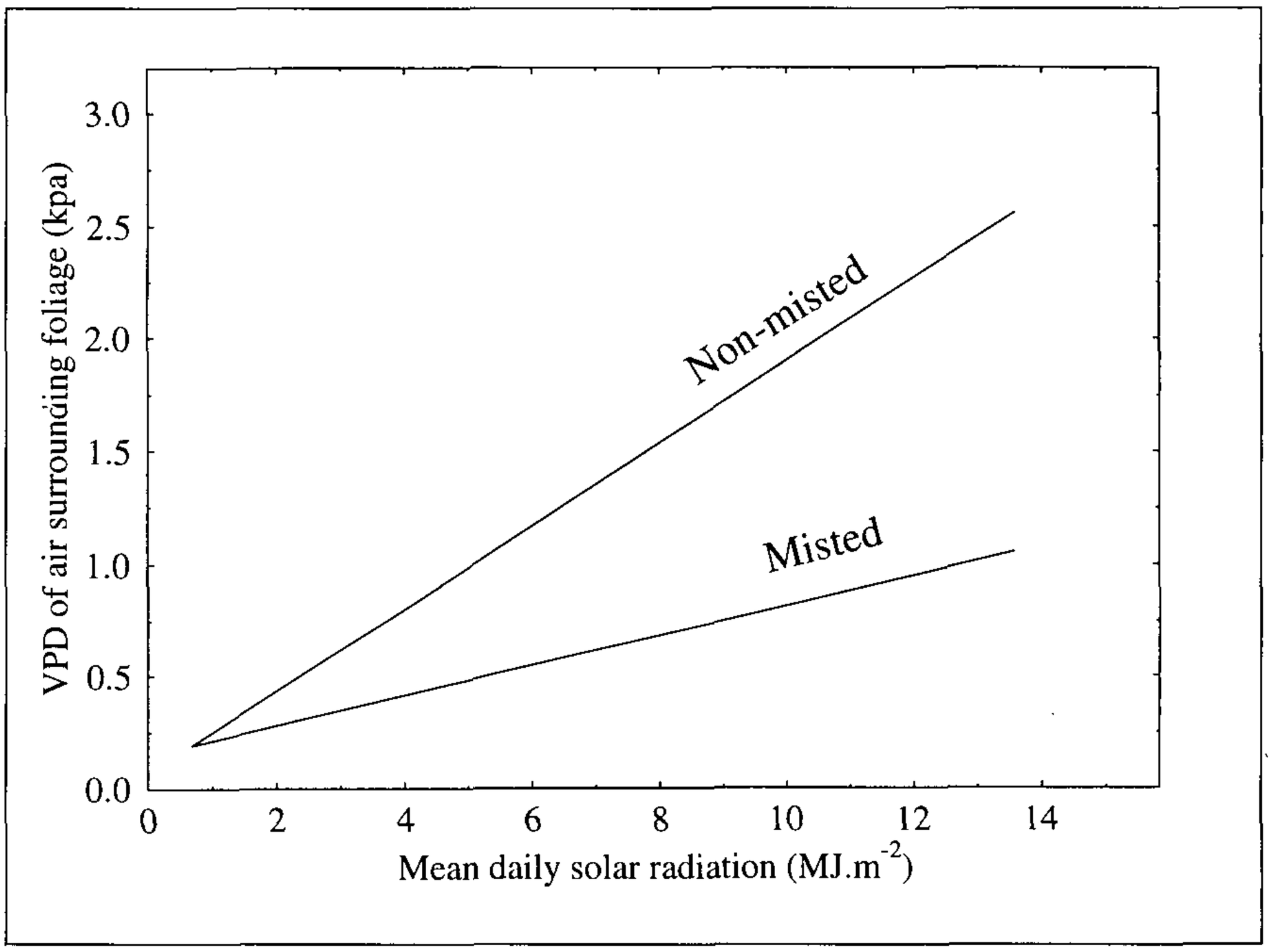

Figure 4b. The relationship between air vapour pressure and solar radiation in misted and nonmisted environments.

More active methods of controlling the moisture vapour pressure deficit utilise techniques to apply water to cuttings as a fine mist or a fog as required. At the heart of all these systems, is a controller that attempts to regulate the loss of water from the leaf surface by applying a film of water or maintaining the atmosphere in a near-saturated condition. Intermittent misting controllers may be based around timing devices that cannot respond directly to changes in the weather and hence the water requirements of the cuttings. Mechanical systems such as a moisture balance that sense the weight of water or the electronic version with an artificial leaf are prone to fault when the sensor is not maintained correctly. The most reliable system is probably based on a solar-integrating sensor that measures the amount of incoming radiation, without the sensors being exposed directly to the potentially corrosive propagation environment.

In conclusion, regulation of water stress is a key issue when propagating plants vegetatively, particularly with leafy cuttings. Many factors are involved in this process, which allows growers to choose a range of strategies that suit their particular enterprise, to manage water loss and increase root formation in different propagation environments.

Acknowledgment. This paper has been prepared with extensive use of reference materials supplied by Dr. Keith Loach.

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Plant Tissue Culture, Dispelling the Mystique

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INTRODUCTION

I have been involved in commercial propagation of plants using tissue culture techniques since 1981. Over these last 15 years, I have seen a dramatic change in our nursery customers' attitudes towards the use of tissue-cultured plants. The need to produce plants in a cloistered environment of a laboratory decked out like an operating theatre, has made it difficult for the average propagator to relate to tissue culture in a similar way as she/he would when producing plants by traditional cuttings or by seed propagation. Nowadays these techniques are used as an everyday tool to bulk up certain lines. In this paper I will discuss the simple steps in the tissue culture process and try to dispel some of the associated myths.

I intend to use the main crop produced at Lifetech Laboratories as an example of how tissue culture can be applied to commercialise this important crop.

ZANTEDESCHIA - THE CALLA LILY

Although a native of South Africa, *Zantedeschia* hybrids have been bred in New Zealand for over 50 years and today, represent the second largest cut flower crop produced in our country, especially grown for export markets. A large demand exists overseas for high quality, healthy *Zantedeschia* tubers.

The natural, asexual multiplication of this plant will result in tuber offsets giving a two to threefold increase per year. Modern tissue-culture techniques mean we can produce as many as one million identical plants in a year, thus enabling breeders to bulk up quickly stocks of new colours to be released as named cultivars.

Figure 1 shows the basic steps involved in tissue culture propagation.

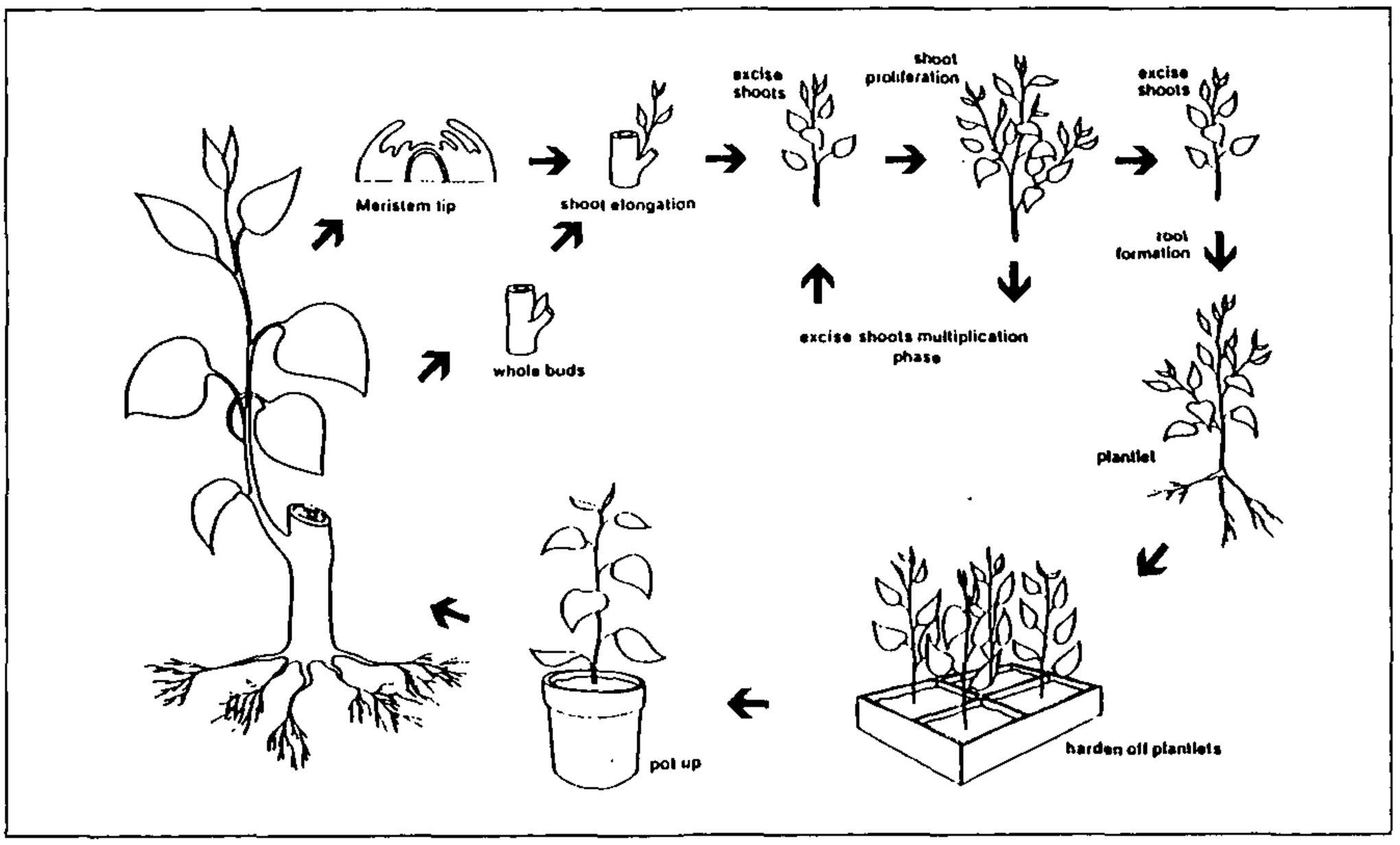

Figure 1. The plant tissue culture process.

There are several clearly defined stages in the process:

Preparation of the Mother Plant. After a rigorous selection from seedlings which show superior characteristics, plants are prepared for the tissue culture process. *Zantedeschia* cultures are initiated from the buds of dormant tubers.

Following virus indexing, the stock plants are subjected to an intense spray programme aimed at eliminating pathogens and other microbes. The new soft growth which is encouraged to emerge under controlled nursery conditions, produces ideal plant material for tissue-culture initiation.

Production of the Growing Medium. There are many different formulations which have been developed for plant tissue-culture propagation. Nutrients in the form of high grade laboratory chemicals are combined in optimum concentrations for plant growth together with a gelling agent such as agar. This medium is then sterilised by heat, usually in an autoclave.

Initiation of the Cultures. Tissue cultures are initiated following the surface sterilisation of excised buds from the tuber. A combination of chlorine (household bleach) and detergents are used to kill all microbes. The *Zantedeschia* tuber taken directly from the ground presents special challenges when attempting to initiate sterile cultures.

Using laminar flow cabinets which provide a sterile air environment, trained operators carry out aseptic procedures to transfer the sterilised buds, called explants, onto the prepared culture medium.

The new cultures are incubated under a controlled temperature and light regime to encourage new growth from the buds.

Culture Multiplication. Following the establishment of sterile cultures, plant hormones, normally cytokinins, are incorporated into the medium to encourage the production of multiple shoots. Commercial multiplication rates are required to justify the expense of using laboratory production. We can achieve rates of 3-4 times every three weeks with the *Zantedeschia*.

Rooting of Plantlets. Once a target quantity of shoots has been produced, rooted plantlets are encouraged by the application of rooting hormones called auxins. For economic reasons, we try to root tissue-cultured plantlets directly into the nursery. However, we root *Zantedeschia* plantlets in vitro, in flasks to enable the easy shipment of large numbers of different cultivars to domestic and international markets.

Nursery Weaning. There have been many changes in nursery technology over the last 15 years. Tissue-cultured plants when taken directly from the laboratory require high humidity and low light, often with bottom heat to enable them to acclimatise and commence photosynthesis. Different nursery methods can achieve this; e.g. using fog, mist, humidity tents, and frost protection cloth.

We have developed a simple yet very effective system of producing *Zantedeschia* tubers directly from tissue-cultured plantlets. A light woven cloth is placed directly onto the plantlets and this is kept in place for about 2 weeks to maintain high humidity. The plants grow quickly in a free-draining soilless potting mix and after about 150 days, natural senescence occurs. The resulting tubers go into dormancy and they are then cleaned, graded, and stored ready for export markets.

SUMMARY

Zantedeschia flower and tuber exports in New Zealand have been able to grow rapidly through the availability of high health clones produced by tissue culture. The technology has been simplified for nurserymen with a wide range of skills and facilities, to grow the latest varieties, enabling them to become part of an expanding export industry

Division, Factors for Consideration in Ensuring Success

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In the course of a year, we divide a significant number of *Hemerocallis, Hosta*, and *Iris* cultivars

There are a number of basic tenets that should be followed to ensure success when propagating by division. I propose to deal with each in turn and cite pertinent examples relating to each.

CORRECT IDENTIFICATION

As plants resulting from division are often sold prior to flowering, it is imperative that the material is correctly named. The propagator must check that newly acquired material is correctly identified. Accurate records detailing the source and location of the stock plants must be kept Perhaps the greatest difficulty encountered by those of us employing staff is inculcating the importance of correct *identification in our staff. It is very difficult when dividing Hemerocallis, for* instance, to identify the plants one from the other without flowers present. I would defy anyone with limited knowledge of the crop to identify one tall bearded iris fan from another.

PLANT MORPHOLOGY

To successfully divide any crop and maximise the number of propagules, the propagator must have a thorough understanding of the morphology of the crop with which he/she is working. Is the crop a rhizome producing a crown with the current seasons roots arising as the shoot develops, as seen in *Hosta* and *Hemerocallis,* or is it a tuber as that found in *Dahlia*? Are there any scraps that will give rise to further plants if they are retained and nurtured? How small can a given rhizome be cut up?

SOIL HUSBANDRY

All stock plants should be grown in healthy vital soil. The addition of organic matter, either through incorporation or as a mulch, will provide this. Organic matter assists in aeration and fosters a healthy worm population and also encourages high populations of beneficial soil organisms such as actinomycetes which will help keep harmful organisms at bay.

Care should be taken to minimise soil compaction through the use of heavy machinery particularly during periods of high soil moisture. The effects on the soil mechanics are long lasting and difficult to remedy Compacted soils are poorly aerated, have slow water infiltration and percolation rates, may sour, and have upset nutrient balances.

Such effects either individually or collectively will lead to poor growth. It is well known that compacted soils will cause root rot in *Hemerocallis.*

WATER

Water is all important. Typically, we find situations in division where we have either too much or not enough. In most instances the candidate for division should not have

been grown under conditions of water stress. If plants are to be divided in dry periods it is recommended that the soil be brought to field capacity at least 24 h prior to lifting. One exception would be the bearded iris, where in fact we dry the rhizomes for a brief period before shipping them

Whereas most other plants require significant levels of water following division, bearded iris require limited water during the re-establishment phase. Excessive quantities of water frequently induce the soft rot complex that is associated with bearded iris.

NUTRITION

Plants supplied with the required levels of nutrition and appropriate water and which are grown in a healthy soil are themselves likely to be healthy and less vulnerable to the depredations of pests and diseases. The old adage, 'a little and often' is well remembered when applying fertiliser to stock plants. The grower must understand the crop being produced and cater for the appropriate needs. To fall back to the already oft-cited bearded iris example, the application of nitrogen in any form while producing strong shoot growth often induces soft rots during the growing season. The application of nitrogen to this crop must be handled with care.

TIMING

'Much has been written, some of it fallacious, some whimsy, some myth, about the time certain crops should be divided. Without doubt some plants are fickle and demand particular care. Others prove to be no more than a challenge. An understanding of the morphology of the plant being dealt with and the growth phase it is in, will often provide the solution to the problem. There are those plants such as *Helleborus* which do have defined periods during which the results will be better. For instance, the *Helleborus* hybrid forms I work with, respond best to division during late summer to early autumn (February - March).

As an aside, I generally avoid dividing *Helleborus* for any purpose other than bulking parents for use in the breeding programme due to the slow recovery following division. Division of *Helleborus* for resale on the scale I need is not a viable option. Hence the breeding programme to produce the required seed lines

PLANT AGE

In all instances the use of young plants that have not become tangled and entwined makes the process of division easier Our Iris beds are replanted every 2 to 3 years. Bearded iris rhizome production is best in the third year after which the rhizome numbers and quality generally diminish. A bed of Louisiana iris that is any older than 3 years is a challenge to separate, as is a 4-year-old clump of *Hemerocallis* and likewise a mature clump of *Hosta*.

VIRUS STATUS

Care must be taken to check all new and existing stock for virus. Often the inexperienced eye will confuse viral symptoms with some other physiological disorder. Until one gains experience with the crop a vigilant eye must be maintained and advice sought when an apparent problem arises. Hostas may suffer from one of two or possibly both viruses. To the inexperienced eye the slight chlorosis resulting from Arabis Mosaic Virus (AMV) or the more general chlorosis caused by tobacco

Rattle Virus may appear to be nothing more than a characteristic of the particular cultivar. Stunting should also be watched out for. In New Zealand both *Hosta* 'Royal Standard' and 'Sweet Susan' have been observed to be infected with AMV. Infected material should be destroyed by burning.

PEST STATUS

Stock plants must be maintained free of pest species. Vigilance is required as the pest species that are likely to do the most damage are often not seen. While aerial species are obvious to the trained eye, those living within the soil are not. Of particular interest are the root knot nematodes, found in many of our soils, which in the case of vulnerable cultivars of the *Iris ensata* hybrids can lead to decline of the plant.

The larvae of the white fringed weevil which develops over the late summer and spring, will do considerable damage to the roots and crowns of some *Hosta* cultivars, severely depleting the plant to the point that it is destroyed. *Hosta plantaginea* and *H. fortunei var. obscura* 'aureo-marginata' are particularly susceptible.

DISEASE STATUS

To ensure success, a spray programme must be prepared to combat fungal problems. This can be graphically illustrated in our instance with bearded iris, where we maintain an appropriate spray programme. Over the last 2 years we have bought in stock to supplement that from our own fields and those we draw from in Australia. The incidence of systemic leaf spot within the material acquired locally was such that the resultant crop was unsalable. The grower concerned had failed to maintain an adequate spray programme.

HYGIENE

During the process of division, care should be taken to minimise the risk of transmitting virus or disease to the propagated material Where we use knives to assist in division they are treated with a quaternary ammonia to destroy any latent virus that may be present in the sap.

POST PROPAGATION TREATMENT

In some instances the material that has been divided is treated with an appropriate post propagation dip to either assist with re-establishment or combat pests and / or diseases Following the lifting and division of raspberry (*Rubus idaeus*), apple (*Malus*), and quince (*Cydonia oblonga*) stools, they are dipped in a solution containing the bacteria *Agrobacterium radiobacter*, to protect the plants from the causative organism of crown gall *A. tumefaciens*.

AFTERCARE

One could write a tome concerning the aftercare of plants following division. Simply remember that in most instances the plant has been severely treated. Often having lost not only its root and shoot mass but also suffering the disruption of the source - sink relationships within the established clump. Consequently one must treat the divisions appropriately to ensure the best possible strike.

Japanese Taro, a New Zealand Perspective

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INTRODUCTION

Taro (*Colocasia esculenta*) is a member of the Araceae family and a native of Northeast India or mainland Southeast Asia (Matthews et.al , 1992). It has been widely naturalised and is now a common food source throughout the tropics and warm temperate zones. Taro was also widely used by Northland pre-European Maori (Matthews, 1985).

Taro is primarily grown for the corm or swollen stem base it produces, although the stems and leaves of some cultivars can also be eaten. The corm and stem contain calcium oxalates so they must be peeled and cooked before eating There are two main types. the common taro (*C. esculenta* var. *esculenta)* which produces one large corm and is imported into New Zealand from the tropics, and Japanese taro *(C esculenta* var. *antiquorium)* which produces many smaller corms (Purseglove, 1974) and is tolerant of a more temperate climate and therefore likely to be more suited to production in New Zealand Japanese taro can grow to heights of 1.0 to 1 5 m with the parent corm producing as many as 30 daughter corms over a season. On a high-producing plant a number of granddaughter and sometimes great granddaughter corms can be produced. Some plants are used in ornamental plantings because of their leaf colour which varies and can range from green to red-violet depending on the density and distribution of anthocyanin. This paper reviews Japanese production methods and preliminary results from Crop & Food Research's programme to evaluate Japanese taro for commercial production in New Zealand.

ENVIRONMENTAL REQUIREMENTS

In Japan, taro is grown on a wide range of soil types from heavy clay to free-draining sandy soils. Production can be improved on most soils by adding organic matter. The soil should be reasonably fertile and slightly acidic. Taro will tolerate highly acidic soils but reduced growth can be expected Soils which are prone to temporary waterlogging can also be suitable for taro production (O'Hair, 1990) In Japan, taro is sometimes grown in paddy fields. Taro is normally grown in a highly humid environment and does not tolerate dry conditions. High rainfall during the growing season or access to irrigation is essential for the commercial production of this crop. Dry soil conditions result in low yields, corm cracking, dry rot, and subsequent storage rotting. Fluctuations in soil moisture can also cause cracking

Taro prefers high temperatures, a long growing season and full sun. A minimum temperature of approximately 15C is required for sprouting with maximum growth

occurring at 18 to 25C. Any environment which experiences out-of-season frosts is unsuitable for growing taro. In New Zealand, we have found Pukekohe, South Auckland to have a suitable climate for taro while the Waikato, because of its occasional out-of-season frost, is marginal. Some shelter is also required to prevent excessive wind damage to the large leaves.

PROPAGATION

In Japan, daughter and granddaughter corms from healthy, virus-free parent plants weighing 30 to 60 g are used for "seed" These corms are broken off the parent plant and dusted with fungicide. At Pukekohe, we have found that all corms, regardless of size, can be successfully used for propagation. Generally, larger corms produce higher yields. At Pukekohe, corms are planted directly into the field if the soil moisture is adequate, or pre-sprouted before planting by placing them in potting mix in well-drained polystyrene boxes in a warm situation with frequent watering. Pre-sprouting, which can take from 6 to 8 weeks, is used primarily to extend the growing season. Corms are planted out when they have three leaves and the plants are approximately 20 cm high. Damaged or misshapen corms are discarded.

PRODUCTION IN JAPAN

Crop Management. In Japan, main crops are planted in April and early May (October and early November in New Zealand). Early production is possible by pre-sprouting the corms in cold frames, by planting on sandy soils which warm earlier in the spring, by covering planted corms with a black mulch, or by growing the crop under cloches or in greenhouses.

In Japan, potassium and nitrogen are considered the most important fertilisers. A typical Japanese farmer would apply 400 kg ha^{-1} lime, 100 kg ha^{-1} N, 180 kg ha^{-1} P and 100 kg ha^{-1} K as a basal dressing. Excessive fertiliser use can cause excessive foliar growth and may inhibit corm swelling. When the first leaf has opened, 20 kg ha^{-1} of K as a side dressing is applied and the soil mounded up by approximately 5 cm. When four leaves have formed, 40 kg ha^{-1} of a compound fertiliser is applied and the soil is mounded up a further 10 cm. In Japan a third application of a compound fertiliser is applied at the end of the rainy season (late summer in New Zealand) and the crop mounded up a further 15 to 30 cm. Mounding encourages tuber swelling. However, excessive mounding causes the tubers to become elongated. Generally, taro is planted 30 to 50 cm apart in rows 1.0 to 1.2 m apart If the climate is dry, mulching and either inter-row irrigation or sprinklers can be used. In Japan, weed control is achieved by hand weeding, mulching, and the use of the pre-emergence herbicides simazine, linuron, trifluralin, or pendimethalin. The desiccant, paraquat, is also commonly used for weed control in taro in the tropics (O'Hair, 1990).

Harvesting. The use of early production techniques can result in harvesting in mid August (February in New Zealand). However, most of the crop is harvested from mid-September to October (March to May in New Zealand) before the first frosts. The stems are removed with a scythe then the corms are dug either by hand or with a modified potato harvester, the soil is shaken off, and the corms are left on the ground to dry. In a wet season, the tubers are cured under cover. Typically, corms are stored for approximately 100 days in high relative humidify at 10C. Average yields are around 25 t ha^{-1}.

PRODUCTION IN NEW ZEALAND

Plant material was imported from Japan to New Zealand for evaluation in 1992 After a growing season in quarantine to ensure the plant material was free of disease, trials were established in the Waikato in 1993 and in South Auckland at Pukekohe in 1994.

Crop Management. In New Zealand, taro should be planted as early as possible after the last frost to ensure as long a growing season as possible. At Pukekohe, planting should be carried out in early October, or in sites free of frost in late September. This means pre-sprouting in mid-August Taro has been planted by hand in a similar fashion to potato. Corms are planted 5 to 6 cm deep, in 15-cm-wide trenches with fertiliser incorporated with soil in the base of the trench. The trench is then covered and mounded up slightly so the top of the mother corm is 7 to 8 cm deep. Fertiliser mixes recommended for potato have been successfully used on taro in the Pukekohe region although side dressings have not been applied

Generally we have planted taro 30 cm apart in rows 75 cm apart. A recent trial evaluating plant densities ranging from 2 7 to 6.7 plants m^2 found that per plant yields decreased from 1040 to 638 g per plant as plant density increased while overall yield increased from 28 to 43 t ha^{-1}. Japanese experience suggesting that irrigation is important for taro has been confirmed in trials in New Zealand. Corm yields were doubled in one trial at Pukekohe as a result of irrigation during the summer and early autumn. Hand weeding is carried out although this is proving expensive. When canopy closure occurs, shading of weeds by the crop tends to reduce weed growth Mulching has been used to control weeds. An evaluation of chemical weed control in New Zealand is required for large-scale production of this crop.

Harvesting. Trials have indicated that maximum yield is achieved by harvesting corms in May. To date, all harvesting has been carried out by hand, but in other parts of the world modified potato harvesters have been used successfully (Krishnan and Smith, 1983) and should be suitable for lifting this crop when grown on a commercial scale in New Zealand. Lifting and corm cleaning has been a problem at Pukekohe because the clay soil tends to stick to the corms. The storage requirements of Japanese taro in New Zealand have not yet been investigated.

Taro yields of 44 t ha^{-1} have been achieved in our trials. Problems with corm cracks, premature corm sprouting (Scheffer, 1995), and storage rots have caused crop losses of around 50% which would give a comparable marketable yield to that quoted for Japanese growers.

Pests and Diseases. Japanese taro is relatively free of pests and diseases during the production phase. In New Zealand, white fly (*Trialeurodes vaporariorum*) and mites have been the only problems to date, apart from storage rots and rodents which can cause postharvest problems.

DISCUSSION

Trials at the Pukekohe Research Centre have shown that Japanese taro grows well in the South Auckland area (Scheffer, 1995) with one trial producing a maximum per plant yield of 3.4 kg. The plant is relatively easy to grow and has suffered from few pests and diseases It will, however, respond well to good management, i.e planting and harvesting at the appropriate times, correct plant density, nutrition, and irrigation Problems with harvesting when it has been grown in clay suggest

that this crop may be better suited to lighter soils. The eating quality of New Zealand grown Japanese taro has been evaluated and found acceptable (Scheffer, 1995; Matthews pers. comm). The main problem to date has been the low marketable yield as a result of corm cracking, premature sprouting and storage rots.

Crop & Food Research is continuing with its trial programme, is currently evaluating a range of cultivars, and will continue to further define the agronomic requirements of the crop. A programme to select taro cultivars low in oxalate has also been initiated.

Japanese taro is seen as a promising crop for the North Auckland, Auckland, Bay of Plenty, Poverty Bay, and Hawke Bay areas which experience long, frost-free growing seasons Production could initially be for the New Zealand market where locally grown Japanese taro could complement imported taro. In the long term, fresh or processed taro could be grown for the out-of-season supply of the Japanese market.

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Preparation and Maintenance of Stock Beds

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INTRODUCTION

The important factors for successful propagation are:

- Vigorous material that is of suitable ripeness.
- Clean and quick handling of the material keeping it moist and cool at all times.
- Correct rooting hormones and the application of fungal treatments upon setting
- A suitable enclosed environment including warmth and moisture. An appropriate rooting media.
- A weaning system that is done in a fashion suited to the crop.

As we know these practices are essential for good results but we must always start with appropriate material.

GROWING AND MAINTAINING STOCK PLANTS

By growing and maintaining our own stock we have greater control over our propagation material which needs to be vigorous, of true form, colour and name, available in required numbers and during the season as we require (often more than once a year). Our aim is to keep our stock in a strong vegetative condition.

There are three main methods of producing propagation material in the nursery.

1) Nursery rows in the open ground.
2) Containerised stock plants
3) Clippings from saleable stock.

Open Ground Beds. Certain factors must be considered for site preparation and planting. These should include drainage, irrigation, frost control, shelter, soil pH,and fertilisation.

The soil type will have a major influence on some of these factors For example a heavy clay soil may only need irrigating in the middle of summer and will most likely need some kind of drainage system.

When planting, spacing between the rows and plants depends on how long you intend to keep them in production and also the ultimate size of the plant. (e.g. a fair spacing for photinias would be 1 1/2 m × 3 m).

Containers. With containerised stock plants a more controlled environment can be achieved. For example, moving lavender to a warmer drier environment such as a crop cover over winter, will encourage propagation material growth for an extended season.

Site preparation is obviously more simplified as they will usually fit in with the nursery stock. This encourages ideal growth by providing a level site, a free draining surface, a source of irrigation and general growth requirements.

The negative factors are that should the chosen environment promote a pest or disease this can affect both saleable stock and mother plants. Also valuable sales

stock space is used and a vigorous repotting and feeding regime needs to be maintained.

Saleable Stock. With this system the advantages are that it is more convenient than maintaining large stock plants and growth produced from the younger plants is more vigorous.

A downfall to this method is that there is often a compromise as to when the material should be taken and when the plants should be sold. Also this does not suit all plant types, like cassias which are usually grown from hardwood cuttings

For all of these methods the following factors are important:

Water. Soil type influences water retention, and a good knowledge of our soil type helps us decide when and how to keep a satisfactory balance of moisture to achieve maximum growth.

Light. You must consider individual plant cultivar requirements, as shading may be needed or full exposure to sunshine. For example, most of our camellia cultivars are grown in full sun, however, *Camellia* 'Baby Bear' seems to grow better in partial shade.

Weed Control. This is necessary to minimise competition for nutrients, water, and even light. Weeds also have a nasty habit of hosting pests and diseases. For example, Puha (*Sonchus* spp.) can host whitefly, mealybug, and aphids to name a few Mulching can inhibit weed growth and also promote microbiotic activity in the soil. We have used wood chips and sawdust spread thickly around the stock plants. This has lasted 2 years and reduced the need for weed spraying as well as the need for irrigating. This is not only a good cultural practice but also a great labour-saving technique.

Nutrition. At least twice a year a side dressing of fertiliser should be applied to top up plant nutrient levels. If using containerised stock, repotting will need to be done regularly, usually when the plants have outgrown their bags or pots, often referred to as being root-bound. In the nursery row, soils require a sidedressing of a general N-P-K fertiliser. Specific crops, such as proteas, may need a more calculated feeding regime. They require less phosphorus than most plant groups.

Pest and Diseases. Experience will tell you the most crucial times of the year to control pests and diseases, but it pays to be observant, especially during conditions favourable to the pathogens growth. Mites enjoy hot, dry conditions in sheltered areas, like the middle of a crop covered batch of *Rosa* 'The Fairy', during the hot summer months. *Botrytis cinerea* seems to thrive in moist, humid, overcast weather on decaying material, especially on *Camellia* flowers in spring.

A good clean-up spray at the onset of winter, which is a dormant period for most pathogens, can easily control populations of scale, mealybug, thrips, and mites. As the weather becomes more favourable for growth there will be a need for more regular spraying. However, the knowledge of a pathogen's growth habits and keen observation will minimise the need for spraying.

Shelter. Many plants will respond favourably if sheltered, especially when young. Generally speaking, wind will inhibit growth by drying the atmosphere and sometimes when severe, causing physical damage. Camellias prefer a sheltered position whereas *Olearia* cultivars prefer a harsher environment.

Pruning. This is an extremely important factor. Plants should be "farmed" in such a way that they will produce material during the desired season, that will suit the plants growth habits and the nursery production system. Pruning serves two purposes, to produce a consistent grade of strong vigorous plant material and remove undesirables such as flowers and weak or dead growth.

When we prune the stock plants at Lyndale Nursery we do so in two steps. Stage one takes place when we take the cutting material for production use. Suitable material is selected and removed with a slanted cut always just above a node with the cut angling away from the bud. In this way we are sure the stock plant will grow away easily without having to recover from die-back caused by poor pruning practices. Sometimes this is the only trimming a plant may get. A good example of this would be our use of *Hebe* stock plants. During the season we may remove four or five batches of growth. Any subsequent growth not required for cuttings will be pruned to inhibit flowering. Plants are cut back to a level they will shoot from readily and evenly. This level pruning on the top and sides but with no rounded corners will expose the greatest surface to the full light and weather. This simple method reduces apical dominance and produces a greater number of evenly grown, strong cuttings.

Age. This is a factor that needs to be addressed. When a plant is not producing vigorous propagation material it should be replaced. This may be noted by recognising poor growth or recording a drop in percentages in production results. Some plants need to be replaced regularly due to their short-lived nature. Examples of these would be *Boronia*, some *Grevillea* taxa and *Cistus*.

These factors will directly influence the success or failure with any given crop. A well-grown batch of stock plants reduces the need for sifting through unwanted wood so collecting is therefore efficient.

Customers of liner growers demand even grading and we only have one growing season to achieve this, so it is imperative that the material is graded from the first cut. When dealing with thousands of cuttings of one plant type this becomes more difficult to achieve.

As a propagator I feel the preparation and maintenance of an established stock bed is essential to producing ideal propagation material. As propagation is the most risky part of plant production we should spend time on the first major step of the operation. Maintaining stock should be taken seriously as the quality you begin with directly affects the quality you end up with.

Commercial Options for Disease and Pest Control in Plant Propagation

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INTRODUCTION

Most disease and pest problems in the nursery are our own fault. For example most races of *Pythium* are opportunistic, only a few races are aggressive. Pathogens and pests are present or lurking nearby all the time, we need to keep plants healthy so that they can cope with them.

Sprays are nasty chemicals which are residual and poison our environment. This is how many of the public perceive sprays of agricultural chemicals; it does not really matter if they are right or wrong, it is what they think

The white-spotted tussock moth eradication programme in the eastern suburbs of Auckland highlights this. The biological insecticide Bt is being used for this programme. We as horticulturalists can appreciate the very low toxicity of this product to all animal life, apart from susceptible caterpillars. However there is much concern among residents of the eastern suburbs with regard to the broadcast aerial spraying and possibility of exposure to the spray.

In my view there is a greater potential occupational health risk in the noise generated from the DC6 aircraft being used to apply the spray.

In a similar spraying programme conducted in Canada, there were 200 recorded instances within 2 days of the spraying, of people notifying medical authorities of various allergies or illnesses which they believed were caused by the spray.

More than 90% of these notifications were proven not to be related to the spraying programme There was no substantiated proof that any of the notifications were related to the spraying programme.

This demonstrates the high level of public concern with regard to agricultural chemicals, in particular direct contact, drift, and residues both in the environment and on products.

As a consequence we must continue to strive to find more environmental and user-friendly crop-protection materials Also we must continue to make the best use of all other methods of protecting our crops from diseases and pests.

1) Control the Soil Environment:

- Reduce the levels of pathogens, e g. pasteurisation.
- Maximise levels of friendly or suppressive microorganisms e.g. *Trichoderma*
- Ensure good air-filled porosity (AFP) and drainage.
- Media should be in the correct pH range say 5.0 to 6 5—watch acidification.
- Media should be in the correct conductivity range—watch salt accumulation.

2) Control the Aerial Environment. To provide conditions to optimise plant growth, in particular temperature and humidity control.

3) Check Water Quality. Treat water if necessary.

4) Maintain Good Nutrition and Nutritional Balance.

5) Manage Watering Effectively. The two most important nutrients for plants are water and oxygen

6) Hygiene. It is easy to let nursery hygiene lapse with the false sense of security of soilless media, plastic pots and trays, and clean growing surfaces. Once root rot diseases strike, 20% seedling losses are common.

7) Common Sense.

IMPORTANT DISEASES DURING THE PROPAGATION AND EARLY GROWTH STAGES OF NURSERY CROPS

For infection by a disease to occur, three things are necessary·

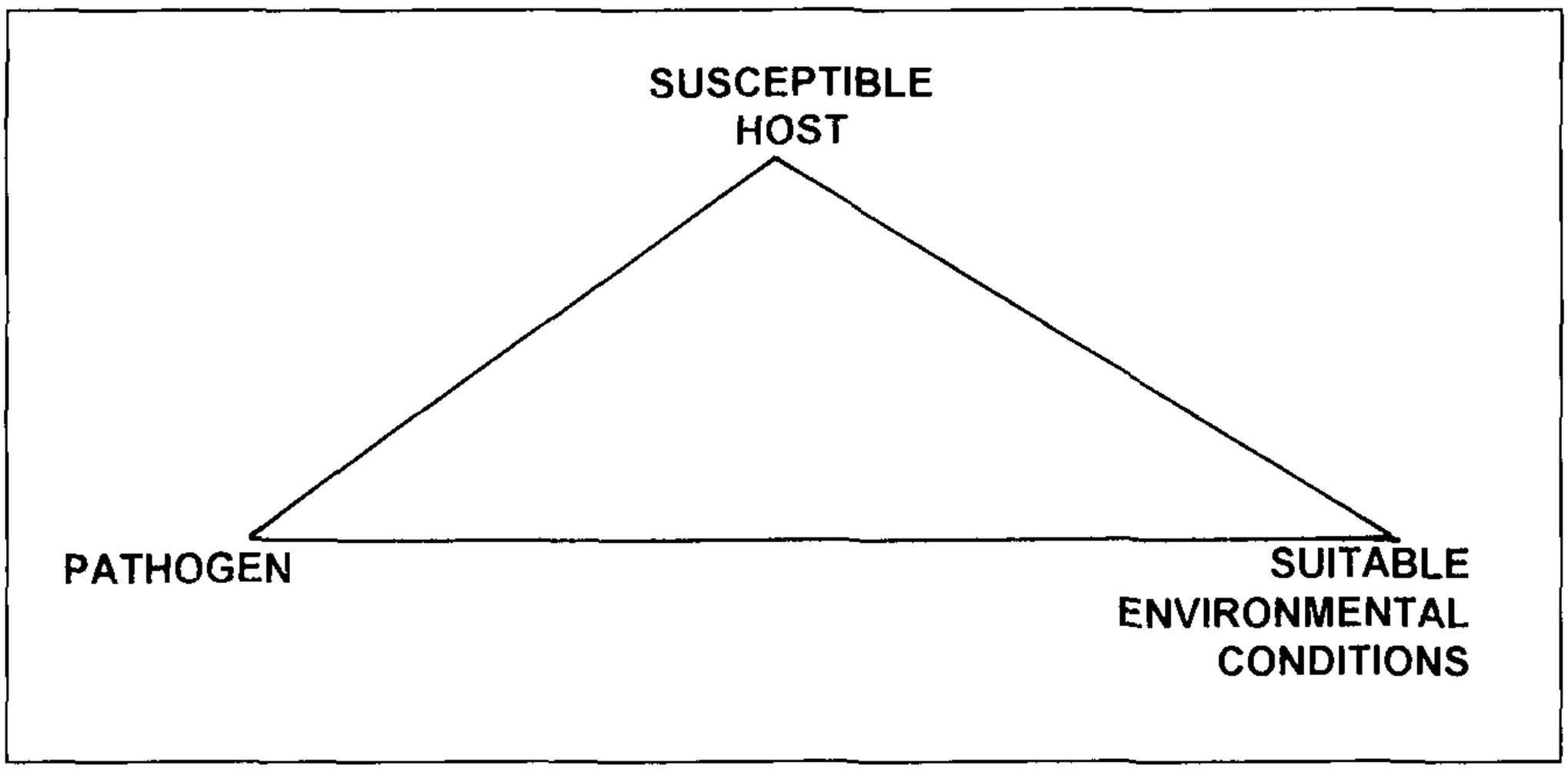

Figure 1. The disease triangle.

Remove any one of these three things and the chance of infection is negligible.

Again, an understanding of the disease triangle demonstrates the importance of environmental control, *Pythophthora* and *Pythium* spp. have a limited ability to infect healthy tissue. The most common point of entry is through damaged or dead root tissue, if conditions in the root zone do not cause damage to the roots, then the chance of infection is very much reduced.

PLANT HEALTH MANAGEMENT

Good plant health relies on the effective management of many production factors. All production decisions must fit together like a puzzle (Fig. 2).

Other pieces which may be included are quarantine, hygiene, and plant inspection.

The two main causes of root rot diseases in containers are :

1) Lack of aeration, e.g. insufficient AFP, waterlogging.

2) Death of roots due to drought or salt injury

Use well aerated media, coupled with better watering practices to reduce the possibility of root rot diseases.

However, conditions conducive to infection do occur at times, problems in opera-

Table 1. Products used to control-media borne pathogens in nursery crops

Product (Active ingredient)	Label claims	Mode of action	Recommended uses
▪ *Phytophthora-Pythium*			
Fongarid 25 WP (25% furalaxyl)	*Phytophthora* *Pythium*	Systemic Protectant (absorbed by roots and moves up in xylem)	Soil Mixes Cutting beds/boxes Potted plants
Terrazole 35 WP Terrazole 25 EC (etridazole)	Soil-borne diseases *Phytophthora* *Pythium*	Protectant (prevents disease spread)	Soil mixes Vegetable seedlings Bedding plants Potted plants Foliage plants Turf
Foschek (40% phosphorus acid) EUP-LS	*Phytophthora* and *Pythium* root rots	Systemic - rapidly absorbed by roots and foliage Preventatives	Foliar Spray Soil drench Tree injection
▪ *Phytophthora*			
Alliete (80% fosetyl-aluminum)	*Phytophthora*	Systemic Rapidly absorbed by roots and foliage Preferably use as a preventative	Foliar Spray Use at 2 5 g l^{-1} every 28 days as preventative Use at 5 g l^{-1} every 14 days as a curative or under high disease pressure

Table 1. (continued). Products used to control-media borne pathogens in nursery crops

Ridomil MZ 72WP (8% Metalaxyl and 64% Mancozeb)	*Phytophthora* tree nurseries	Systemic - upwards Protectant	Seedbeds Drench around trees
▪ ***Pythium***			
Previcur N (60% Propamocarb)	Damping off caused by *Pythium* spp	Systemic- taken up by roots Preferably use as a preventative	Soil Mixes Seedbeds Seedlings Cuttings Pot plants
▪ ***Growth Enhancement***			
Trichopel G (*Trichoderma* spp. in a nutritive pellet)	Growth enhancement Colonisation of media by "friendly" micro-organisms	Protectant Colonises soil and is antagonistic to soil-borne pathogens	Seed planting Seedlings Established plants Bulbs and tubers
▪ ***Rhizoctonia and Fusarium* Spp.**			
Terrachlor 75 (75% quintozene)	*Rhizoctonia* and *Fusarium*	Protectant - direct activity against susceptible fungi	Disinfecting seed boxes Pre-sowing soil treatment Postplant drench Turf
▪ *Rhizoctonia*			
Rizolex (10% tolclofosmethyl)	NR ornamentals *Rhizoctonia*	Protectant Curative	Soil Mixes

Table 1 (Continued). Products used to control-media borne pathogens in nursery crops

Product (Active ingredient)	Label claims	Mode of action	Recommended uses
▪ ***Other Fungicides***			
Octave (46 2% prochloraz)	*Colletotricum* spp	Protectant	Spray twice weekly or as required
	Monochaeta spp	Curative	Dip
Benlate (50% benomyl)	Activity against a range of fungal pathogens	Protectant Systemic - upwards movement	Drench to seedbeds Spray Dip
Topsin M4A (40% thiphanate methyl)			
Rovral WP (50% Iprodione)	*Botrytis* *Fusarium*	Protectant through contact action Some curative action	Seed dressing Drench Spray
Thiram (Various thiram formulations)	Broad spectrum; multi-site active fungicide	Protectant	Seedbeds damping off Bulbs & tubers - botrytis Turf - brown patch Damping off
▪ ***Crown Gall***			
Dygall Biological fungicide (pure culture containing approx 5 billion viable *Agrobacterium radiobacter* bacteria per gram)	Prevents plants becoming infected with organisms which cause crown gall	Preventative	Dip

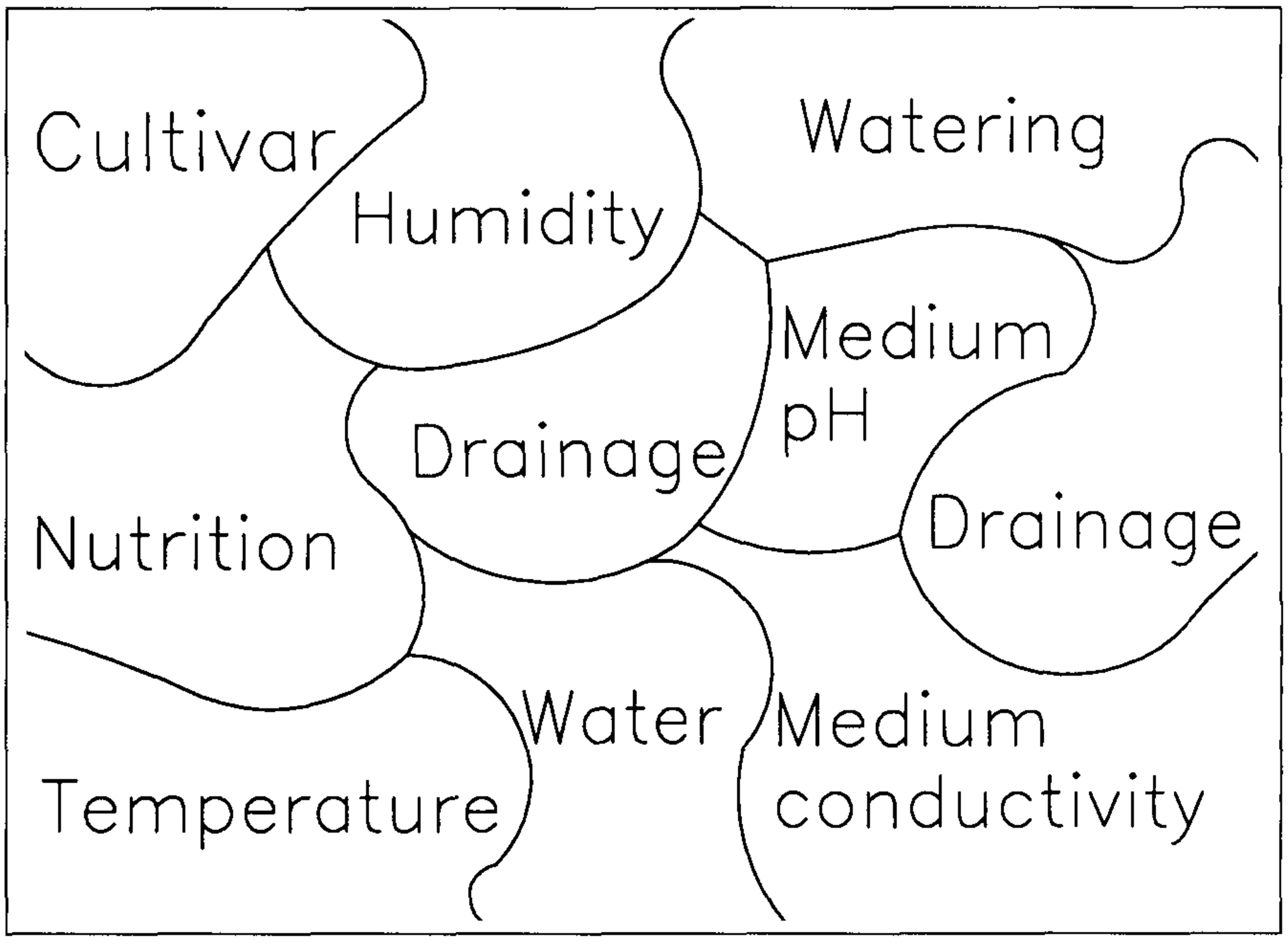

Figure 2. Good plant health relies on the effective management of many production factors which must fit together like a puzzle.

tion of automatic watering or misting equipment may cause propagation media to dry out. Also, some plants at the propagation stage are particularly susceptible to infection, especially through young root hairs.

In these instances we need to support environmental control with other methods such as crop-protection materials. A range of different types of crop-protection materials, both organic and chemical, are available However, there are relatively few materials available especially for use in the plant propagation phase.

COMMENTS

Fongarid

- Resistant strains of fungi may develop.
- Injury to some spp of *Banksia*, *Grevillea*, ornamental stonefruit and Chinese fire fern has occurred
- 6 -10 weeks activity.

Terrazole

- Do not use on vegetable seedlings after transplanting.
- 25 EC formulation contains xylene.
- 6-10 weeks activity

Foschek

- Synthetic build-up of a natural compound.
- Stimulates natural defence mechanism of plant.
- Stimulates plant growth.

Alliete

- Aluminum complex which also breaks down to phosphoric acid.
- Stimulates natural defence mechanism of the plant.
- Can also be used as drench.

Ridomil MZ 72WP

- Resistant strains of fungi may develop.
- Preferably apply to moist ground followed by rainfall or irrigation.

Previcur N

- Soil residual life 3 to 4 weeks - shorter in alkaline soils.
- High margin of safety. Caution with repeat applications at short intervals.

Trichopel G

- Broadspectrum.
- Apply after soil sterilisation / pasteurisation.
- Best results when conditions after application are conducive to rapid colonisation—adequate moisture and pH 4.0 to 6.0.

Terrachlor 75

- 4 - 6 weeks activity.

Rizolex

- Not registered for ornamentals.
- Fungicidal dust - use in soil mixes only.

Octave WP

- Resistance to this DMI fungicide can occur. Do not make more than three applications in any 12-months period.

Benlate / Topsin M4A

- Resistance to benzimidazole (MBC) fungicides has developed in some disease situations e g. botrytis Use in conjunction with a fungicide from a different fungicide group.

Rovral WP

- Resistance to this dicarbonximide fungicide could develop in some disease situations from repeated use. When used for botrytis control, make no more than three applications per season.

Thiram

- Short persistence.
- Thiram suppresses germination and stunts seedlings of *Nemesia, Phlox drummondii, Petunia,* French marigold (*Tagetes patula*), and *Celosia argentea* var. *cristata* Plumosa Group
- Thiram stunts the growth of *Salvia*, African marigold (*T. erecta*), carnations (*Dianthus caryophyllus* and hybrids), and *Lobelia.*

Dygall

- Treatment is normally made prior to planting.
- Treatments should be made away from direct sunlight.
- Keep treated cuttings/seedlings away from direct sunlight until planted.

IMPORTANT PESTS DURING THE PROPAGATION AND EARLY GROWTH STAGES OF NURSERY CROPS

Pest damage during the propagation and early stages of growth of nursery crops is not as common as soil-borne disease problems.

In fact the pests which I will discuss, tend to be a problem in specific crops only, or once crops have established in the nursery or production house.

The key considerations regarding pest damage and control in nursery crops are:

1) The relatively little range of crop protection agents available or with a label claim for nursery crops
2) The toxicity of many crop protection products to the user and limitations on re-entry times with some products.
3) Potential of pest resistance to some insecticides. Common examples in New Zealand are. mites to miticides, grass grub to DDT, leaf-rollers to organophosphates, and whitefly to organophosphates and Applaud. We need to be wary of the potential for resistance to insecticides by targeting and timing applications accurately, applying thoroughly and rotating insecticides if possible

Table 2. Products used to control media borne pests in nursery crops.

Product (Active ingredient)	Label claim	Mode of action	Recommended uses
Broad-spectrum			
Suscon Green (10% Chlopyrifos in a controlled release granule)	Black vine weevil (Fungus gnat) (Mealybug)	Contact vapour Stomach poison	Incorporated 0.75 kg/m^3 1 0 kg/m^3 > 20% bark
Thimet 20 g Phorate (20% Phorate in a pellet)	Aphids, mites, weevils Black beetle Root lesion nematode	Contact fumigant Strongly systemic in plants	0.8 kg per 100 m^2 *or* 30 g per plant
Black vine weevil			
Otinem	Black vine weevil	Direct feeding	Container plants, field grown stock
Bio Insecticide (a parasitic nematode in the form of a wettable powder)	Larvae		Apply *on* first appearance of larvae when soil temps 12 to 20C
Fungus gnat			
Dimilin 25W Insect growth regulator (25% diflubenzuron)	An insect growth regulator which prevents molting Not registered for ornamentals	No contact action Must be eaten by insects Interferes with chitin deposition in the skin	Mushrooms incorporation in compost/media at 40 g/m^3 Drench 4 g/m^2

Table 2. (Continued). Products used to control media borne pests in nursery crops.

Nematodes			
Nemacur 400 EC Nematicide/aphicide (40% of fenamiphos)	Roses Root knot nematode	Systemic - translocates to all parts of the plant Direct effect on nervous system of insects	Roses - soak roots prior to planting
Vydate L Insecticide nematicide (24% oxamyl)	Ornamentals Root knot Lesion Foliar nematodes	Systemic Moves up and down in the plant Mainly upward movement from foliar sprays	Ornamentals Foliar spray Use higher rates for root nematodes
OTHERS			
Diazinon (Diazinon as various formulations)	Various Not registered for ornamentals	Contact Stomach poison	Vegetables

COMMENTS

Suscon Green

- Formulated as a controlled-release granule
- Relatively low user toxicity—harmful substance
- Provides control for up to 2 years

Thimet 20 G / Phorate

- Dangerous poison, can be absorbed through skin
- Do not use in container growing
- Provides 4 to 6 weeks plant and soil life

Otinem

- Parasitic nematode, use within 2 days after refrigeration
- Apply to moist soil and follow with light watering
- Use when spring temperature reaches 12C and until autumn temperature drops below 12C
- If media contains more than 50% bark, contact distributor for advice

Dimilin 25 W

- Slow acting - some plant damage can occur between treatment and death
- Treat early against young larvae

Nemacur 400 EC

- Dangerous poison.
- Residual activity for several months
- Contact re-entry time 7 days

Vydate L

- Dangerous poison
- Contact re-entry time 24 h
- Toxic to bees

CONCLUSION

Several soil-borne pathogens can cause root rot diseases of nursery crops. Plants at the propagation stage are particularly susceptible. Also, certain plants are susceptible in the early growing period or at other times, e.g. when there is additional stress on the plant during flowering.

A number of crop-protection strategies should be used including environmental control of both the growing medium and aerial environment, nutritional balance, watering management, and general hygiene.

Crop-protection products may be needed at the propagation stage and during the growth period of susceptible plants. Several types of crop-protection products, both organic and inorganic, are available. However, there are relatively few materials available within each type, therefore use judiciously, especially products for which pathogen resistance has been known to occur. Use in conjunction with other forms of disease management especially environmental control, hygiene, and common sense.

Pests are a more sporadic problem during propagation and mainly related to growing in soil rather than soilless media and specific crops, e.g. bulb and tuber crops, fungus gnat; carnations and poinsettias, black vine weevil.

Again, only a small number of crop protection agents are available to manage these pests. I recommend using those that are of low toxicity to the user and non-target organisms, have good residual effect and are not prone to development of pest resistance.

Make the Most Use of Healthy plant material, high quality growing media, nutritional balance, good watering management, environmental control, hygiene, and commonsense. If required, select the right crop protection agent.

A Review of Specialised Root Systems, and Their Relevance in New Zealand Nurseries

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INTRODUCTION

It is beneficial to examine how nature endows plants with the ability to survive and grow without fertilisers and often in very impoverished soil conditions. Linderman (1978) at an I.P.P.S. conference several years ago made the point that "no organism in the natural environment can live like a hermit". This referred to the fact that plants usually live in close association with microorganisms. The objective of this review is to describe how the roots of nursery plants utilise these relationships and what considerations need to be taken into account on New Zealand nurseries

MYCORRHIZAS

The term "mycorrhiza" means fungal roots and this is a symbiotic or mutually advantageous relationship between plants and fungi associated with their roots. This topic has been studied since at least the 1840s and the name mycorrhizas was given by Frank in 1885 (Harley and Smith 1983) There have been several articles in the I.P.P S. proceedings over the years with the most recent articles discussing the propagation of mycorrhizal plants, including inoculation (St. John and Evans,1990, St. John, 1994; Galea and Poli,1994).

Most plants growing in soil have mycorrhizal fungi on their roots. These naturally occurring fungi can be found in 83% of dicotyledons and 79% of monocotyledonous plants. The simplest classification is to divide them into three groups·

The Ectomycorrhizas. These form a mantle or sheath on the outside of the root and characteristically occur on plants in the Betulaceae, Fagaceae, and Pinaceae; i e. mainly on the roots of woody plants and only occasionally on herbaceous plants. Pritchett (1979) states that there are more than 2000 species of ectomycorrhizal fungi estimated to exist on trees in North America alone. Most are Basidiomycetes, but certain of the Ascomycetes also form mycorrhizas. Other families exhibiting these microorganisms are the Juglandaceae, Myrtaceae, Salicaceae, and Tilliaceae, all of which may be either ecto- or endomycorrhizal depending on soil conditions.

The Endomycorrhizas. These fungi are the most widespread and important symbionts. They are often referred to as VA mycorrhizas because of the branched feeding organs and storage structures that may form within the plant's internal root cells. Typical host species include most crop and ornamental plants. The fungi are mainly Phycomycetes and do not produce large, above-ground fruiting bodies or wind-disseminated spores as do most ectomycorrhizal fungi.

The Ectendomycorrhizas. This is a relatively small group which has characteristics of both ectomycorrhizas and endomycorrhizas. They generally appear on roots colonised by ectomycorrhizal fungi. Within this group are the mycorrhizas found on members of the Ericaceae and Orchidaceae which may be classified separately since

they, for example, do not form a fungal sheath and involve Asco- or Basidiomycetes (Harley and Smith, 1983).

OTHER TYPES OF SPECIALISED ROOT SYSTEMS

Nitrogen-Fixing Nodules on Roots. Symbiotic nitrogen (N) fixation occurs primarily within the roots of legumes in association with bacteria such as the genus *Rhizobium.* Leguminous trees like *Leucaena leucocephala* (see *L latisiliqua)* are becoming increasingly important in agroforestry (Danso et al., 1992). Non-legumes can also have N-fixing root nodules (actinorhizal symbiosis) as with *Alnus* and *Casuarina. Elaeagnus commutata* and *Shepherdia* spp. are further examples of actinorhizal trees and shrubs (Danielson and Visser, 1990). The microorganism in the latter case is in the fungal genus *Frankia* (Ascomycetes).

Proteoid Roots. These occur on most species within the Proteaceae and therefore are of particular significance wherever species from within this predominantly southern hemisphere family are grown. Some legumes have also been found to have proteoid roots, including *Viminaria juncea* (Lamont, 1972a) and *Lupinus albus* which is an annual (Gardner et al., 1983). The clusters of bottlebrush-like root structures that form seasonally, are not mycorrhizal and are produced by the youngest roots of the root system (Lamont, 1972b).

THE BENEFITS OF SPECIALISED ROOTS

The main benefit of specialised root systems is nutrient uptake in open-ground soils, especially where they are impoverished This contrasts with container-grown methods where high levels of fertiliser nutrients and relatively sterile media often reduce the need or appearance of these root systems.

The prime benefit of mycorrhizas and proteoid roots is the improved uptake of phosphorus The surface area of the roots is usually greatly increased. This allows plants to develop an exploitive system, as in the case of proteoid roots which occur in shallow, well aerated, high organic matter regions of the soil. These can therefore complement the normal deep explorative roots which are much less branched. Mycorrhizal fungi, like proteoid roots, provide the host plant with an improved "mechanism" for growth by providing an extensive surface area for nutrient uptake by virtue of the hyphae which reach out into great areas of the soil. Plants with a large root surface area can be expected to be less responsive to mycorrhizal inoculation than those with a smaller area; for example the native fern *Asplenium bulbiferum* was found to be nonmycorrhizal and this state was attributed to its extensive root system, copious and long root hairs and slow growth rate (Cooper, 1977). Marschner (1995) reviewed these nutritional aspects and pointed out the difficulties of interpreting the benefits related to the uptake of nutrients since there are simultaneous changes in growth, particularly root morphology and physiology, brought about by mycorrhizal colonisation. There can be improved uptake of nutrients other than phosphorus (P) but this will vary greatly with the environment and species of plant and fungus. Mycorrhizas can also benefit plants by deterring root pathogens and increasing the host plant resistance to drought and soil temperature extremes (Dangerfield, 1975).

Legumes and a few nonlegumes grown in New Zealand can benefit from nodulation on their roots In the tropics and subtropics about 200 species form actinorhizal

symbioses (Peoples and Craswell, 1992). Legumes have played an important role in crop rotations for many centuries. The quantity of available nitrogen is normally the most prime or first consideration for achieving rapid growth in plants and therefore plants equipped to gather their own N can have a special place in agroforestry situations. An example of the interrelationship between two different systems is that infection with mycorrhiza (or P fertilisation) will often improve nodulation (Marschner, 1995).

NEW ZEALAND RESEARCH AND USAGE

There is no doubt that mycorrhizas are of great significance in the growth of native and exotic forest trees in New Zealand. A major group of studies were carried out by Professor Baylis and others in the Botany Department of Otago University. For example it was found that the nodule on the roots of species within the Podocarpaceae and in *Agathis australis* were considered to be an adaptation to accommodate endomycorrhizal fungi and thus be functionally equivalent to the short roots of pines (Baylis et al , 1963) Further work on kauris (*Agathis australis*) showed that these nodules have a major role in P uptake (Morrison and English, 1967). Manuka (*Leptospermum scoparium*) and rata (*Metrosideros* spp.) were shown to benefit from endomycorrhizal inoculation (Hall, 1977) and ectomycorrhizas were found on New Zealand beeches (*Nothofagus* spp.) (Morrison, 1956; Mejstrik, 1972). Smaller trees and shrubs have also been studied along with New Zealand ferns Cooper (1976) states that with few exceptions the latter are constantly mycorrhizal in natural or modified communities, even in soils with apparently high levels of P.

Crush (1973) investigated the significance of endomycorrhizas in tussock grassland in Otago. It was concluded that only two high altitude species, of the five species studied, were likely to benefit from mycorrhizas in their natural soils, although infection could be beneficial in impoverished soils or under drought stress.

Matagouri (*Discaria toumatou*) and tutu (*Coriaria sarmentosa*) are two New Zealand plants which produce actinorhizal root nodules which have been studied (Newcomb and Pankhurst, 1982a,b).

There exist many New Zealand native legumes which are also likely to fix N. Mycorrhizas on exotic forest trees including Douglas fir, eucalypts, and *Pinus radiata* have been classified and studied (Chu-Chou and Grace, 1983). *Rhizopogon rubescens* is the most common mycorrhizal (ectomycorrhizal) fungus of radiata pine seedlings in New Zealand nurseries (Chu-Chou, 1979).

In a nutrition trial studying the response of *Pinus pinea* the authors found several fungi came naturally into and onto the media, probably from existing colonisation on the seedlings or media that they were grown in. The growing medium was white with mycelium and it was found that mycorrhizal infection was significantly reduced at high liming levels and unaffected by a range of N, P, and K levels (unpublished results). In contrast proteoid root formation on *Grevillea rosmarinifolia* was significantly reduced by high rates of N or P, but not by liming (Thomas, 1981).

There are few commercial inoculants available in New Zealand for improving the specialised root systems of plants. One is used for the inoculation of pasture legumes with *Rhizobia* spp., and another was developed primarily for the inoculation of blueberries with ericoid mycorrhizal fungi. Powell (1981) discussed the need for inoculation since surveys had shown that infection in nursery and field grown blueberries was sporadic and especially low on young plants. He recommended the

use of a culture of pure mycorrhizal fungus such as *Pezizella ericae* for the inoculation of cuttings or the making up of an inoculum mixture from underneath healthy blueberry bushes that could be used for new planting areas It was important that the inoculum mixture was free of any serious root-rot pathogens.

SIGNIFICANCE

Examples of the great diversity of root associations have been outlined. It is clear that in the "wild", such as in forests and where there are low soil fertility levels, these associations can provide benefit through greater nutrient uptake along with other advantages. It has even been recently postulated that plants in communities can transfer nutrients between themselves via interconnecting fungi (Miller and Allen, 1992)

Certain associations have been shown to have a very clear cut advantage and are necessary for the nursery grower to utilise. Satisfactory levels of ectotrophic mycorrhizas are a requirement for the open-ground production of forestry conifers. The trees tend to be grown in unfertilised ground and the right strains of mycorrhizal fungus confer strong benefit. Past research by the authors on ornamental conifers like *Chamaecyparis* (Thomas et al., 1994) and Leyland cypress (Thomas, 1984) have indicated the advantages of low pH and this may be related to the degree of mycorrhizal infection, as found with *Pinus pinea.* Inoculation of media with ectomycorrhizas can be quite simple, for example pine duff from pine forests is a good source or the growing of pines using cheap seed and then rotary hoeing them into the ground after a year

Proteaceous plants can be grown at relatively high plains of nutrition but it is recommended that moderately low levels of N and especially P are used. An open organic-based mix is also desirable to encourage proteoid roots and this will probably help establishment, avoid nutrient toxicities, and possibly give a longer than usual life span to the plant. Leguminous trees and shrubs could be encouraged to form nodules by avoiding very acid conditions and high N levels. Unpublished work by the authors found that the native leguminous tree, *Sophora tetraptera,* responded quite strongly to N fertilisation in a container trial. This indicates the general principle, that fertilisers can usually replace the need for all types of these specialised root systems, as an alternative to growing at relatively low nutrient levels.

Where plants are slow growing and to be grown with low fertilisation, such as with the Orchidaceae and some in the Ericaceae, the specific mycorrhizas could provide an excellent partial alternative to the total dependence on conventional fertilisers. The majority of plants which commonly depend on endomycorrhizas need to be considered according to their species and their future end use. New Zealand plants that are intended for conservation plantings and others that may be intended for impoverished sites like sand dunes, agroforestry, and native forests could be considered for mycorrhizal inoculation within the nursery.

CONCLUSIONS

- The types of specialised root systems that form on different nursery plants can be very diverse Future research can be expected to further describe this great diversity of form and function.
- Mycorrhizas and N-fixing mechanisms of New Zealand native

plants have been widely researched and shown to be often beneficial.

- Genetic engineering has already been researched to 'tailor-make' the organism's function or special host plant relationship (Lemke et al , 1995) For example there is much potential for biological disease control using beneficial microorganisms.
- All of these systems offer considerable advantage to most plants that will be planted in soils where fertilisers will not be used and especially where there are adverse conditions of low fertility.
- Well fertilised soilless container media tend to reduce the occurrence and the need for specialised roots while in the nursery. There appear to be few studies relating to the establishment of plants from this type of production into unfertilised open-ground sites.
- The significance of ectomycorrhizas in the open ground nursery production of forestry and shelter conifers is well established and generally well understood.
- All of these specialised root systems offer natural advantages to plants for their nutrition and general plant health.

There is probably much room for greater understanding by New Zealand nursery people on the potential to encourage these specialised root systems in plants. We need to consider how we can grow plants in 'natural systems' with low input of raw materials to produce plants which will establish successfully into the New Zealand environment with the specialised root systems they need.

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Integrated Pest Management (IPM) is for Plant Propagators Too

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INTRODUCTION

There is an international trend towards growing plants in ways that are more environmentally friendly. This covers all aspects from energy use, fertiliser, recycling of materials, and plant protection, especially the use of pesticides. These growing systems are sometimes termed integrated plant production and can be linked to the trend to sustainable agriculture and sustainable land management. Integrated pest management (IPM), is the plant protection contribution to more environmentally friendly plant production. This paper will define IPM, outline the pesticide-resistance problems now facing growers, and the use of IPM in practice. Also included are my thoughts on why plant propagators in Europe are changing to IPM and how it works for them.

WHAT IS IPM?

Integrated pest management is defined as "the control of pests by employing all methods consistent with economic, ecological, and toxicological requirements while giving priority to natural limiting factors and economic thresholds" (Brader, 1974). IPM has certain key features:

- Pest and disease control must be effective.
- Selecting from the full range of control techniques available.
- Pest and disease monitoring is an essential ingredient.
- To be successful, IPM must supply produce that meets the standards of the intended market.
- Additional benefits are produce with nil or minimal pesticide residues.
- It can be claimed IPM is not only good for people but for the environment.

All these topics are covered in detail in a Crop & Food Research leaflet (see below under 'More Information').

PESTICIDE RESISTANCE IN PESTS AND PLANT PATHOGENS

An increasing problem for conventional pest control is that pests and plant pathogens have become resistant to many pesticides. This usually shows up when a pesticide no longer works as well as before. A common response is to increase the quantity of pesticide applied and apply it more frequently until the next product becomes available. Pesticide resistance is particularly severe in the ornamental and plant propagation industries because the belief that no pests must be present has led to high frequency preventative applications of pesticides. In New Zealand several pests and plant pathogens relevant to your industry are resistant to pesticides. Pesticide resistance prevention and management strategies for these organisms were published this year (Bourdot and

Suckling, 1996). These strategies are also incorporated into Crop & Food Research's IPM programmes.

PEST AND DISEASE CONTROL IN IPM

For greenhouse crops, techniques available for pest and disease control include: quarantine and screening to keep pests out of crops, manipulating the greenhouse environment to make the environment less favourable for diseases and more suitable for natural enemies of pests, plant resistance to pests and plant pathogens, selective use of pesticides, and biological control. The combination of techniques used depends upon the crop, the kind of greenhouse, the local environment and pest and disease complex, and the market for the plants or produce.

BIOLOGICAL CONTROL

Biological control, that is using natural enemies to control pests, is not an essential element in IPM programmes, though it is a widely used and powerful technique. Growers of ornamental plants and cut flowers are always concerned about using biological control, because the method implies that some pests must be present. In general, there will be a few pests in the crop when biological control is used. However, careful searches also show that pests are present even when only pesticides are used. When biological control is working properly, the numbers of pests in a crop and damage from the pests is less than when pesticides alone are used. Whichever method of pest control is used, pests must be kept below the economic threshold for the crop and market. IPM with biological control can achieve this.

Biological control does require a different attitude to pest and disease control. It is slower acting than pesticides and so requires forward planning. A scheme for crop monitoring is essential so that the manager knows what is happening and that problems are detected at an early stage. It is important that the whole organisation, from the boss to the greenhouse hand, is behind the programme and is properly trained

Before starting, it is also important that a comprehensive pest and disease control programme is worked out so that it is integrated with biological control. This means that you know how to control all (most!) problems without upsetting the biological control. Most growers find it is useful to have regular visits from an advisor during the first few years of using IPM

ADVANTAGES OF BIOLOGICAL CONTROL AND IPM

Several European plant propagators and ornamental plant growers told me why they used biological control. Reasons include:

- Pests resistant to pesticides
- Pesticide residues on produce for export
- Market requirement
- Biological control works
- Philosophical reasons and health

Difficulties controlling pests which are resistant to pesticides has been a major stimulus towards biological control. An increasing number of European growers now seem to be changing because their customer, the supermarket, is demanding alternative growing methods

Once they have made the change growers find other benefits including.

- No withholding period for staff to go in the crop, less disruptive to work schedules
- More convenient, staff like it. No protective clothing required
- Less skill required to dispense natural enemies, whereas special training required for pesticide application
- Plants look and grow better when not sprayed with pesticide
- Plants less prone to pathogens so less fungicide required

When pest numbers are very low, I was told only very susceptible crops are affected, not all plants in the glasshouse.

IPM FOR ORNAMENTAL CROPS IN NEW ZEALAND

Crop & Food Research have developed IPM programmes for cymbidium orchids and glasshouse roses. Full details are available in IPM Manuals Nos 4 and 8, respectively.

Development of IPM for more ornamental crops and for plant propagators depends on three factors. Firstly, a wider selection of biological control agents needs to be commercially available. This is dependent on the private companies producing natural enemies of New Zealand's ornamental crop pests. Secondly, plant propagators must want to use IPM. And thirdly, a specialist advisor on IPM for ornamental plants would improve chances of success.

MORE INFORMATION

Full details about the general principles and advantages of IPM can be seen in a Crop & Food Research leaflet, "What is Integrated Pest Management (IPM)?" Broadsheet No 2 (Feb 1996) It comes with a list of contact people and is available from:

The Publications Coordinator, Crop & Food Research, Private Bag 4704, Christchurch (fax· 0-3-325 2074).

Other leaflets available are:

"Greenhouse technology: a step by step approach". Broadsheet No. 1.

"Western flower thrips. 1. Biology, identification and life cycle". Broadsheet No. 35

"Western flower thrips. 2. How to reduce your risk from the pest and how to control it". Broadsheet No. 36.

"Tomato spotted wilt and Impatiens necrotic spot - viruses spread by thrips". Broadsheet No.59.

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Germination Strategies for New Ornamental Species

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INTRODUCTION

Maximisation of germination is a major part of successful introduction for new species of plants which may prove of some horticultural importance or value. The difficulties associated with importation of live plant materials, (such as seeds and other propagating materials), and the obvious high costs involved leads to the logical conclusion that any strategies which may lead to increased germination rates of seeds particularly, are worthy of investigation. This short discussion will focus on the application of a relatively unusual and apparently not widely known method of enhancing the germination of recalcitrant species, namely "smoking".

GERMINATION USING CONVENTIONAL STRATEGIES

Table 1 shows germination rates for some reasonably well known species from the Cape, South Africa. These species were germinated using laboratory germination techniques, with the seed sown on filter paper, soaked in distilled water. A regime of 16 h light and 8 h dark was used in the trials. A temperature of 20C was maintained.

Table 1. Germination rates for a range of South African species, under controlled conditions.

Species	Average germination rate (%)
Dietes grandiflora	13
Moraea loubseri	1
Lobelia valida	6
Greyia radlkoferi	16
Ceratotheca triloba	18
Monopsis lutea	Less than 1
Tarchonanthus camphorata	Less than 1

It is obvious from the data in this table that the germination rates of these species are very low. The likely success rates for small numbers of seeds would be a little disappointing, time consuming for little or no result, and potentially fruitless considering the small number of seeds available for some species. It is known that a large number of other species exhibit similar rates of germination under conventional germination strategies. Any strategy that enhances germination rates should be utilised to ensure efficient and cost-effective germination.

THE FYNBOS ASSOCIATION

The species listed in Table 1 represent a range of plant types; biennials *(Ceratotheca)*,

cormous perennials (*Moraea*), herbaceous perennials (*Lobelia*), and shrubs (*Tarchonanthus*). Some of these plants form part of the fynbos association. Fynbos is characterised by the presence of "restios", (reed-like plants), heathers (*Erica*), and members of the Proteaceae, such as *Protea, Serruria*, and *Leucadendron.* There is also an abundance of species from such genera as *Helichrysum, Watsonia, Moraea, Gladiolus*, and *Disa,* to name a few.

THE CAPE FLORAL KINGDOM

The focus of this discussion will be on plants from South Africa; in particular, plants from the fynbos, the prevalent vegetation type of the Cape Floral Kingdom of Southern Africa (see Fig. 1).

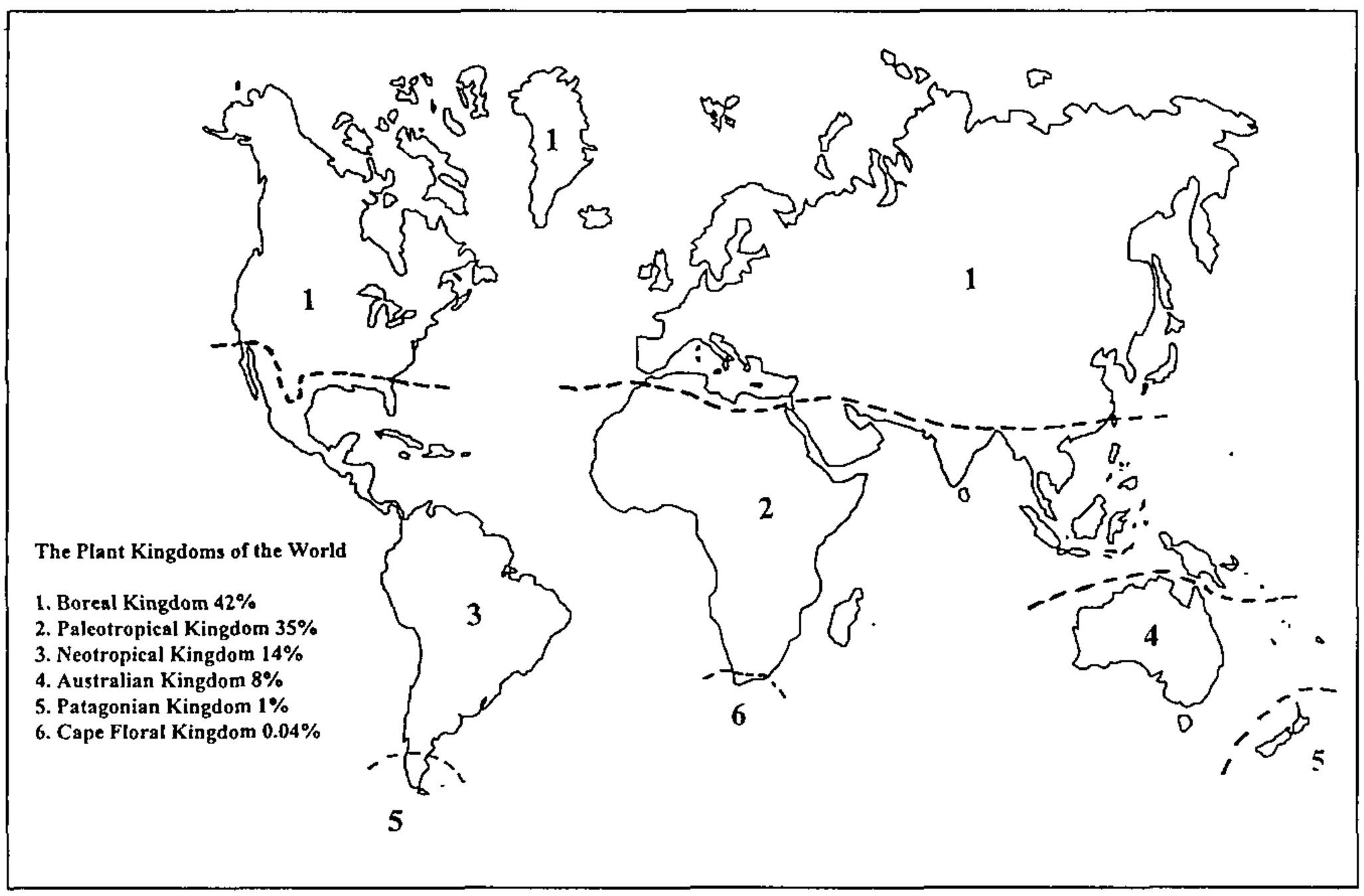

Figure 1. Location of the Cape floral kingdom, or fynbos biome.

The Cape Floral Kingdom has only 0.04% of the land surface area of the Earth, yet it contains more than 8500 species of plants. More than 6000 of these species are endemic to the kingdom (growing nowhere else on Earth naturally), and there is a very concentrated variety of plants, with some areas containing over 120 species per 100 m^2. In short this is a very rich area botanically, and a wealth of plant material awaits evaluation for adventurous horticulturists. Many of the species are already widely grown, but the overall picture is one of opportunities for those wishing to experiment with new introductions.

The flora making up the fynbos association is typically fire adapted. This fire adaptation has led to the discovery of a germination enhancing technique which has important implications for the potential introduction of otherwise difficult-to-germinate species.

This paper will discuss very briefly the practical implications of recent and ongoing research into the germination of otherwise difficult seeds, using the smoking technique. Research in this area was initiated in South Africa, and has progressed

to the point where approximately 200 species have been tested for smoke sensitivity, with approximately half of these showing positive response to the treatment. It is interesting to note that the process can apparently be generalised to plants from Australia and the Mediterranean. All of these floras show some fire adaptation, or even fire dependence for continued healthy existence.

Some of the most outstanding results achieved so far are from the genus *Erica,* which in one species has shown an increase in germination rate from 14 seeds per gram of untreated seed to 1000 seeds per gram for smoke-treated seed.

A species of "restio", *Rhodocoma* showed an astounding increase from 10 seedlings per gram, untreated, to 2400 seedlings per gram treated. These results show that it is indeed worth pursuing smoke treatment as a strategy to improve germination.

SMOKING PROCESS

The process does not need any special or elaborate equipment. Figure 2 shows the general layout of a simple apparatus that will produce the desired results. Equipment needed is as follows:

- A suitable drum in which to light a smoking low fire. A close fitting lid and air inlet are required.
- A small tent to contain the smoke, this may be a child's pup tent, or a more elaborately constructed plastic structure.
- A suitable hose or pipe to conduct smoke from the fire to the tent arrangement.
- A supply of dry and green plant materials from fynbos (in this case) vegetation. Save all your *Protea, Leucadendron, Restio, Watsonia, Freesia,* trimmings.
- Seed trays containing sown seed.

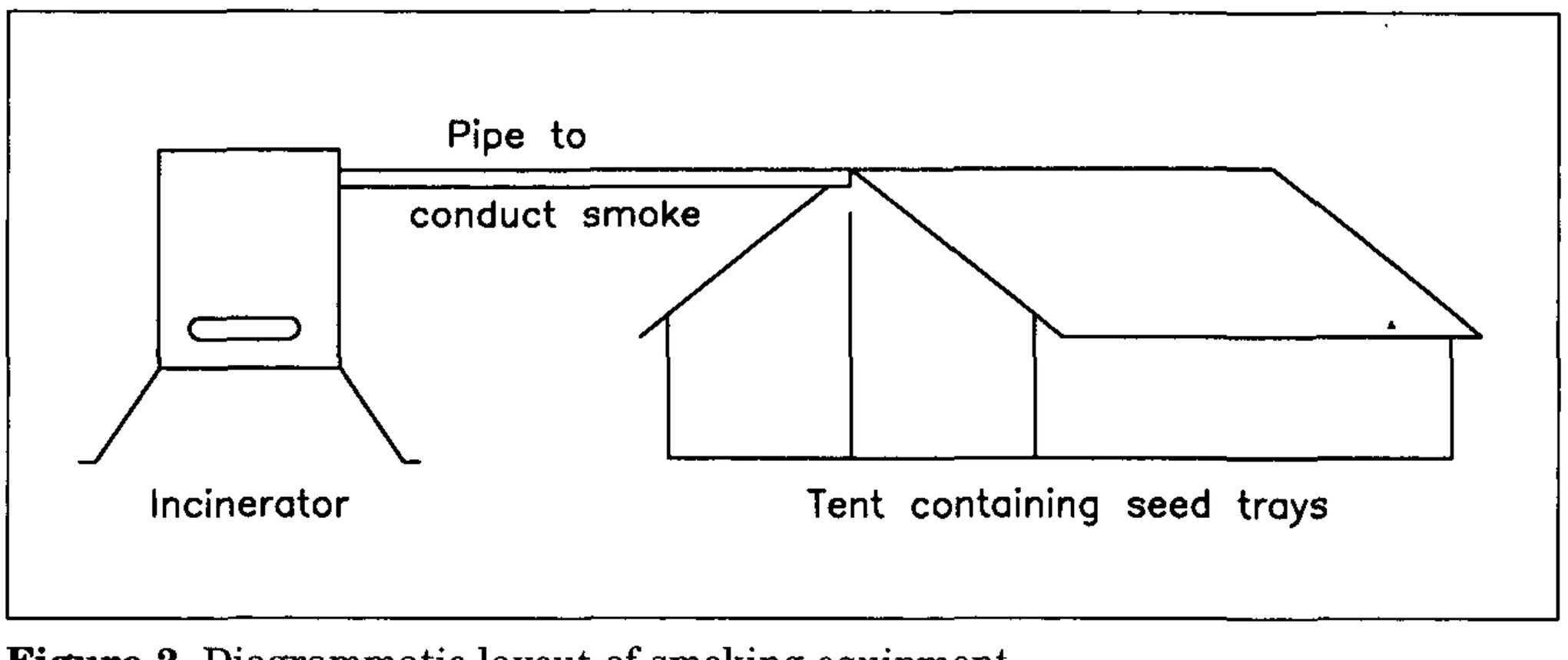

Figure 2. Diagrammatic layout of smoking equipment.

The method of smoking the seed is simple. The fire should be lit and tended so that it does not burn too fiercely, but instead produces a large amount of smoke. Adjust the flow of air through the drum so that smoke fills the tent, through the pipe. It may be useful to cool the smoke by keeping the pipe cool with water. Continue the process for about an hour (up to 2 h has been used). When the smoking process has been completed, the seed trays should be removed and watered sparingly. It is recommended that overwatering should be avoided to prevent leaching of the germination enhancers from the seed-raising mix.

AUSTRALIAN PLANTS

The same process has been used to aid in, and enhance the germination of, Australian plants, with some 70 species from 38 genera showing extremely positive results so far. Some familiar names occur in the list, e.g. *Conospermum, Epacris, Eriostemon, Hybanthus, Lechenaultia, Pimelea.* Some of the species concerned were previously very difficult or impossible to propagate successfully using seed. The Australian research shows germination can be increased as much as 50 times for some species. As has been observed earlier, there are important implications here for the preservation of rare plants and cost-effective propagation for some promising ornamental species. Some of the species are described as being impossible using conventional germination techniques.

INSTANT SMOKE

A recent development from the Conservation Biology Research Unit at Kirstenbosch in South Africa is "Instant Smoke", which consists of absorbent paper impregnated with smoke saturated water. In practice the papers are soaked in a small amount of water, and seeds are soaked in the resultant solution. After a predetermined period of soaking (usually 24 h), the seeds can be removed from the smoke solution and sown as usual. An alternative strategy is to drench sown seed-trays with a solution of "instant smoke" in water. The effects of this treatment are the same as for the physical smoking exercise, without the problems associated with collection of fynbos materials to burn, and lighting of fires.

CONCLUSION

In our own nursery we propose to experiment further with the effects of different types of vegetation being used as the source of smoke. It will be apparent that it is difficult to collect enough foliage from South African plants with which to keep a fire going for up to 2 h. As we are now in a position to produce our own seed from a number of genera and species, mainly *Moraea* and *Gladiolus,* it appears worthwhile to see if equivalent results to those described above can be obtained by using more readily obtainable local vegetation.

It has been our own experience that germination of seeds of some species of *Protea* and *Erica* and many bulb species is very difficult using conventional techniques. There is a high frustration level in sowing expensive seed and getting mediocre results. In addition, the smoking process should provide an effective method of building up numbers to saleable volumes.

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Propagation of New Zealand Native Flora By Seed

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INTRODUCTION

At Taupo Native Plant Nursery, our primary objective is to produce, hardy ecologically sourced New Zealand native plants. Our production this year is expected to be between 1 and 1.2 million plants. Thus for both practical and economic reasons 90% to 95% of our plants are produced from seed.

For the purpose of this paper I will highlight certain areas that a high level of proficiency is required for native seedling production.

TREE IDENTIFICATION AND TYPE SELECTION

Initial correct plant identification is essential in any collection of plant material. The identification of whether the plant is endemic to that site also needs to be attained i.e. the correct genotype identified, if plants are to be used for eco-sourcing.

Eco-sourcing refers to the sourcing of indigenous New Zealand plant propagation material from natural stands of vegetation that are derived from naturally occurring parents and the planting of the subsequent plants back in the same ecological district or locality from which they originated.

The reasons for this practice are:

- Maintain beneficial genetic purity, both morphological and physiological differences can vary in the same species from different ecological districts, e.g. manuka (*Leptospermum scoparium*).
- Increase plant survival. Plants of one particular species sourced from different ecological regions or localities can have distinctly different environmental tolerances such as frost or salt winds.

The Practical Aspect of Eco-sourcing. The plants sourced from different ecological regions or localities can have distinctly different environmental tolerances. These tolerance limits are largely set by the genetic makeup of the plant, so hybridisation or plants from a different ecological source may produce offspring intolerant of local environmental conditions. Thus botanical provinces have been produced (Fig. 1). New Zealand has been divided up into 85 ecological regions and 268 ecological districts. These have been based on landform, geology, climate and biological content.

Even in "clean" areas interspecific and intergeneric hybrids may occur but are fairly rare. Second generation progeny may occur naturally but normally the next generation is sterile, e.g. *Celmisia*.

SEED SET AND MATURITY

The early indications of flowering and seed set is necessary data that should be noted. Certain native plants are well documented for irregular flowering.

The flowering and seed production in beech trees varies considerably from year to year. In years of high seed set, known as "mast years" there can be a 50-fold increase in seed productivity. The trigger mechanism is not fully understood, but indicators

are that hot dry conditions in the late summer and autumn will be followed by a mast year in the following spring and summer.

Some ecological districts may have different flowering patterns. Thus one low seed set in one area may be offset by a heavy set somewhere else. I have also noticed bi-annual bearing occurring on some trees which is another factor to consider when mapping out a site.

Resulting from indifferent weather or other environmental stimulus, flowering may occur outside normal seed set timings. This normally produces very low or nil seed set, e.g. cabbage tree (*Cordyline* spp.).

HARVESTING.

Harvesting procedures depend on:

How Much Seed is to be Collected. In rare and endangered plants only very small amounts are normally collected to allow as much natural seed dispersal as possible. When collecting seed from species which produce seed in copious quantities, e.g., raupo (*Typha orientalis,* syn. *T. muelleri*), only one seed head needs to be collected to produce thousands of plants. Seed produced in minute amounts may require a huge effort to collect the same amount of seed.

Timing of seed collection is crucial; there are great seasonal and geographical variations. One of the biggest problems in untrained seed collection is the harvesting of immature seed. Often immature seed will not ripen once picked and or will not store well.

Local fauna populations also have an effect on the amount of seed that can be gathered. In off-shore islands with very high bird populations there is often very little seed left to be collected. Thus harvesting of immature seeds may be the only way to collect seed material, e.g., *Knightia excelsa*.

In some cases seed may still be present even into the next flower season, e.g., *Pittosporum* spp.

Seed types:

Capsules and pods	Kowhai (*Sophora* spp.)
Fruity berries	*Coprosma* spp.
Daisy-type seed heads	*Olearia* spp.
Raceme-like seed heads	kamahi (*Weinmannia racemosa*)
Nut and large berries	karaka (*Corynocarpus laevigata*)
Grass-type seed heads	*Carex* spp.
Small seeds	*Hoheria* spp.
Receptacle-grain type	totara (*Podocarpus totara*)
Coned seeds	kauri (*Agathis australis*)
Pip fruit seed	kawakawa (*Macropiper excelsum*)
Fine capsule-borne seed	pohutukawa (*Metrosideros excelsus*)

Much of our seed is hand picked. Podocarps may be either hand picked, e.g., bog pine (*Dacrydium bidwillii*), or areas matted out to collect the falling seed, e.g., rimu (*Dacrydium cupressinum*).

SEED PROCESSING AND STORAGE

Processing procedures will depend on the type of seed material and the condition of seed material. At our nursery all berry/drupe-type seed are fermented and rubbed

to remove as much fleshy material as possible. Failure to do so in some cases can leave germination inhibitors contained in the pulp still attached to the seed. This not only causes uneven germination but may cause rot to occur in the stratification process that may follow. Certain seed types may require drying to crack the capsules open, e.g., immature manuka (*Leptospermum scoparium*).

At any of the seed processing procedures, prolonged exposure to environmental conditions that encourage desiccation will decrease seed viability or perhaps introduce or reintroduce seed dormancy.

The main mechanisms that cause seed dormancy are:

1) Environmental factors.
   - Light requirement for germination positive or negative
   - High temperatures
   - The absence of water
2) Internal factors.
   - Seed coat prevention of gas exchange
   - Seed coat mechanical effects
   - Embryo immaturity, rudimentary embryos
   - Low ethylene concentration
   - Presence of inhibitors
   - Absence of growth promoters
3) Timing mechanisms.
   - After ripening
   - Disappearance of inhibitors
   - Synthesis of growth promoters

Dormancy is broken following the subjection of the seed to various environmental conditions which may include: frost, prolonged period of cold, prolonged exposure to cool moist conditions in the presence of oxygen i.e. stratification, intense heat, physical abrasion, fungal attack, passage through the intestine of birds, etc.

In my experience the optimum temperature of native seed storage is at a rigid 4 to 5C. If seed is stored too wet or too dry seed longevity and viability is reduced. Regular inspection of seed is required to check for rotting or remove any inhibitory gases or alkaloids which may have built up.

SOWING AND GERMINATION

If all the correct procedures have been followed, sowing is only a process of timing. These have already been recorded in books and journals.

Seed covering is a matter of choice. I try to emulate the natural seed conditions for germination which may vary from surface sowing to the use of heavy grit.

The observations of seedling growth and performance characteristics are tools for checking for genetic pollution or outstanding characteristics, e.g., tolerance to environmental conditions or leaf colour, which then can be used for type selection.

All the activities from seed collection to plant despatch are documented to produce a comprehensive data base. This ensures Taupo Native Plant Nursery is at the forefront of native plant supply throughout New Zealand.

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Biological Control and Natural Products as Alternatives to Synthetic Pesticides

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Biological control provides an alternative to the use of synthetic chemicals with the advantages of greater public acceptance and reduced environmental contamination.

FOOD SAFETY—A MAJOR MARKET ISSUE

Consumer perception of food safety is a major market issue for New Zealand horticultural production. The viability of New Zealand's horticultural industry depends on the efficient production of high quality produce for export. World trends towards reduced pesticide availability and use require effective alternative controls for plant disease.

Many presently used synthetic pesticides will be removed from world markets within the next 5 years because of their toxicity or the high cost to re-register.

Some persistent synthetic pesticides have created environmental problems (e.g., DDT, PCP, and 2,4,5-T). Methyl bromide is used widely in New Zealand as a broad-spectrum fumigant biocide prior to planting for a range of horticultural crops. Up to 10% of the stratosphere ozone loss has been attributed to methyl bromide, resulting in legislative procedures to reduce and eventually halt its production.

Without alternatives to methyl bromide, New Zealand will lose at least 10% of its horticultural exports currently valued at around $NZ1.5 billion per annum.

Research programmes in HortResearch's Natural Products Group are focused on the urgent need for improved alternative control systems using microbial biological control agents and biodegradable natural products as part of a sustainable, integrated approach to plant pest and disease management.

Development of novel biological controls will enhance the reputation of New Zealand produce on world markets and protect our market access. Biological control also provides an alternative to pesticide use with the advantages of greater public acceptance and reduced environmental contamination.

HISTORY

In natural ecosystems, such as undisturbed native bush of New Zealand, a balance or equilibrium has evolved over the millennia through biodiversity and the interactions between microorganisms, plants, animals, and the environment.

The concept of natural disease suppression achieved by growing plants organically was clearly understood more than 5000 years ago by the Persian philosopher Zarathustra and described in his book, Zend Avesta, the earliest and most complete encyclopedia of gardening and agriculture, with an explanation of all the underlying principles of nature.

It shows how all the elements of nature collaborate in a garden, and describes the right way to produce the best foods through cooperation with all natural

forces and Laws.

Intelligent correlation of all the forces and laws of nature, the use of composting, and the development of a worm population form the three pillars of a natural system of food production.

BIOLOGICAL CONTROL AND NATURAL PRODUCTS

The use of beneficial microorganisms such as biological control agents, seeks to restore the balance so often lost in the crop situation.

Trichoderma has been a useful biological control organism, the best strains producing high quantities of 6 pentyl alpha pyrone. This compound has shown good activity against sap-staining fungi, e.g. *Ceratocystis picea,* initially in petri dishes and then on wood. In field trials at a mill site various extracts from fungi and higher plants have given longer anti-sap-stain control than standard commercial products.

A second example comes from *Botrytis cinerea* on fruit while a third concerns the attack by *Armillaria* fungi on trees, kiwifruit, and vines. *Trichoderma* strains can be used to prevent this fungal attack or to permit regained vigour, via injection of *Trichoderma* or the pyrone itself. When a compost containing *Trichoderma* is used with the kiwifruit the vine becomes more vigorous and *Armillaria* is suppressed. Therefore the best delivery system may be the organism itself.

In the case of *Pinus radiata,* dipping the roots in a suspension of *Trichoderma* gave good protection against *Armillaria*. Soil mixes or composts containing *Trichoderma* have given good control of *Phytophthora.*

INDUCED RESISTANCE

A variety of plant defence responses can be induced by extracts of microbial and plant origin, such compounds are commonly referred to as elicitors. The use of elicitors to activate inducible responses in susceptible plants and thereby increase their resistance to pathogens has been suggested as an alternative approach for crop disease control. This is referred to as induced resistance and it is proposed that the elicitor treatment sensitizes plants to express a more rapid and intense resistance to subsequent attempted infection by pathogens.

Elicitors such as salicylic acid have been shown to induce the activities of phenylalanine ammonia-lyase and peroxidase in both kiwifruit (*Actinidia* × *deliciosa*) and *Pinus radiata.* These are key enzymes in lignification and phenolic biosynthesis and have been shown to be useful early indicators of a resistance response in other plant species. Further, elicitor treatment has been shown to induce resistance against *Sclerotinia sclerotiorum* in kiwifruit leaves in the laboratory and under orchard conditions. Research on the ability of induced resistance to control fungal pathogens of *P. radiata* is in progress.

ADVANTAGES OF NATURAL PRODUCTS

Advantages of biological control agents and natural products from microorganisms and plants include:

- Reduced pesticide use and residues—environmental safety, safer produce
- Greater public acceptance
- Produce natural products that are pesticidal
- Production relatively inexpensive

- A renewable resource
- High specific activity—used at a few grams per hectare
- Usually target specific
- Biodegradable—do not persist in the environment, no residues

Research on biologically active natural compounds may also lead to the discovery of novel compounds which are pharmaceutically important or have useful applications in agriculture.

CONCLUSION

The viability of New Zealand's horticultural industry depends on the efficient production of high quality produce for export.

World trends towards reduced pesticide availability and use require effective alternative controls for plant diseases.

A Plantsman's Perspective of our New Biosecurity Protocols "Introductions and Consequences"

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Horticulture in New Zealand spans back many hundreds of years. To be a success the plant growers had to import a number of plants to supplement the meager selection available at hand. Careful cultivation of the imported material was needed and highly skilled plant propagators maintained and selected cultivars over long periods of time.

Forward in time, perhaps 700 years, a new wave of importations have been made. The vast majority of these up to the present day providing food, shelter, and beauty to everyday life, enabling us to add the arts, crafts and culture that we need as a civilised society. The simple fact that we had totally transformed what had been until 1000 years ago, primeval forest with its unique multispecific habitats, into highly cultivated farm land with grasses, livestock, and timber trees, had largely gone unnoticed by most citizens. It is only of recent years ecology and all its connotations has been the thing to be "involved in", even politicians are vaguely aware of it. With all major experiments there are on one hand pitfalls, mistakes, failures, on the other hand successes both great and small. The lists we have to contend with are large on both sides of the story. Our climate dictates the results of actions taken, it involves each and every one of us, mainly as importers of new genetic material and secondly as citizens.

We should take a brief look at a few previous importations to see what results our actions have brought about, excluding but not forgetting animals. There are possibly 50 major weeds, possibly 100 lesser ones, a number of these were imported by choice to fulfil a purpose, i.e., gorse for hedges, *Tradescantia*, honeysuckle, flowering ginger (*Hedychium*) all ornamental. These main four perhaps, are the worst of a bad bunch and we can see that "ornamental" has a bad start. Many other weeds have come in as extras in wanted species, grass seed giving cover to many weeds introduced unintentionally.

On the other hand success with kiwifruit *Actinidia* ×*deliciosa*, *Sandersonia,* and *Zantedeschia* are just three of many chance importations that make millions of export dollars annually.

It can be seen horticulture is first in line for unwanted species making the escape, although horticulture has also the widest chance for breakthroughs into new products, but for these things to happen input is a necessity. Plant breeders need as wide a gene pool as can be obtained. Much of this source is already in the country and should be maintained to the highest degree possible by private or public institutions, unfortunately both are failing dismally. There have always been major retrenchments in "parks" every few years or so when collections of plants are disposed of, only to be recollected and amassed by enlightened management at some later date. The same procedure goes for the nursery trade trying to make a dollar. The time is arriving at full speed when recollection will only be made at great expense or not at all as the original genetic source has disappeared. Species are being wiped out at a great rate; lose the species and you have lost the hybrids as well.

Formerly it was fairly simple to import seeds and plant material from most countries and costs were minimal, but to comply with new rules being laid down it becomes complicated and costly to say the least. Most suppliers will be unable to give information needed by the importer to satisfy the regulation standards. Though these changes have taken place, in general at a first glance, it is still fairly easy to obtain a wide range of seeds which are on the basic list. But for plant breeders and collectors interested in obtaining the unusual or undescribed species collected in the wild for evaluation there is the "too hard basket" which the authorities are still working on and it may take some years before the situation becomes clear!

New Zealand plant breeders are a "maverick" lot. They wander the world looking at plants, most of the time taking opportunities as they come for plant swapping, seed swapping, extending their understanding of the plant kingdom to the limit. Few if any are millionaires. That there is now legislation in the pipeline that will certainly curtail their activities will be New Zealand's loss.

Oaks to Know and Grow:The Promise and Problems of the Genus

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INTRODUCTION

The oak genus, *Quercus*, comprises one of the most useful, diverse, widespread, and fascinating of all genera of woody plants. Unfortunately, the oaks constitute a nightmare for taxonomists, with species that merge and collide like freeway traffic. They can present some complex and frustrating problems for propagators as well.

No one person ever really has known all the oaks. There may be some 500 species (depending upon how one chooses to define a species in this plastic genus), and potentially thousands of hybrids distributed within, but normally not across, the subtle boundaries of several primary subgeneric groups. Oaks can be large trees or prostrate groundcover plants; they can display brilliant fall colors or be fully evergreen; and they can thrive in, and frequently dominate, habitats ranging from desert scrublands to deep swamps.

NATURAL DISTRIBUTION OF THE OAK GENUS

Oaks constitute a major component of the flora over much of the Northern Hemisphere. Here in eastern North America they are known especially for their seasonal attributes: prominent staminate catkins and colorful early foliage in spring; glossy or rugose summer leaves, and toughness in the face of hot weather; acorn massed in the autumn, coupled with the rich and long-lasting fall color of many species; and a diverse winter portfolio that includes evergreen oaks, marcescent oaks, and fully deciduous oaks, all with the venerable character for which the genus is famous and admired.

Western North America has fewer species but can boast a broader range of infrageneric oak groups. The ubiquitous white oak group (section *Quercus*, formerly called *Lepidobalanus*) grows in mixture with the endemic American group called red oaks (section *Lobatae*, often known as *Erythrobalanus*) and the western American endemic golden oaks (section *Protobalanus*). All share woodland habitats in the western states and adjacent areas of Mexico (and, for one species only, western Canada).

The Mediterranean region of Europe and North Africa includes several white oak species which have evolved under similar conditions as have our western species, and which resemble some of them closely in striking examples of parallel evolution. They frequently are evergreen, and are extremely tolerant of drought and of hot summers. Other regions of Europe support more mesic white oak species, which resemble their white oak counterparts of eastern North America as closely as the Mediterranean species do the oaks of the American West.

In Asia, oaks have achieved a very high level of diversity. China alone has 130 species, some of which are members of the unique *Cyclobalanopsis* or ring-cupped oaks, a distinct Asian taxonomic subgenus sometimes assigned generic rank. Mexico is an even greater center of diversity for oaks, with at least 150 known

species. Rounding out the genus, Central America and the adjacent north edge of Columbia in South America contain perhaps 30 species, mostly in mountainous areas.

OAK CULTIVARS

Considering the plasticity of the genus and its notorious propensity to form interspecific hybrids, relatively few oak cultivars have been selected and propagated. The notable exception is the common European (pedunculate, or English) oak, *Q. robur*, which has spawned more than 100 cultivars. Several selections have been made from *Q. ilex* also. Other European species such as *Q. petraea* and *Q. cerris* have contributed a few, as have some American species (whose cultivars usually have been selected and propagated in Europe).

Virtually no cultivar selections have come as yet from the oak-rich regions of Mexico and Asia, with the almost singular exception of a few forms and hybrids of *Q. dentata*. The development of oak cultivars is lagging in another way as well: many existing oak selections were made from aberrant material, and exhibit the horticultural oddities of which the genus is capable as opposed to its most superior characteristics. This seems to represent a juvenile stage in plant selection, with individuals and clines of outstanding performance potential initially being overlooked in favor of conspicuous curiosities.

The primary hurdle in oak cultivar development has been the difficulty with which oaks are grafted, rooted from cuttings, increased through micropropagation, or otherwise reproduced asexually, coupled with problems associated with transplanting, container production, mildew under irrigation, and other aspects of nursery practice. Without successful and dependable techniques to replicate and grow ramets faithful to the ortet from which it was selected, a selection by definition cannot become a cultivar. These techniques are becoming available today, or are in our immediate future, as we will learn from the speakers who follow.

WHAT ELSE SHOULD WE PROPAGATE?

The famous "oakmasters" of Europe, like J.R.P. van Hoey Smith of Trompenburg, Michel Decalut of Waasland, and Allen Coombes of Hilliers, are intensely observant and dedicated people who will continue to seek and find unusual and superior characteristics worthy of ornamental cultivar status. They can be counted upon to continue to enrich our horticultural lives with new selections and hybrids, if only we can find ways to propagate these selections successfully. As new species and clines are introduced into the great European collections in larger numbers from Asia and the Americas, look for useful forms and hybrids to be selected from a much broader species palette than that which has contributed most oak cultivars to date. There are other reasons, though, besides perpetuating yet another variegated leaf type or another columnar or plagiotropic growth form, to propagate certain oaks.

Heritage Trees. We should perpetuate the genotypes of superior specimens such as national champion trees. We might not yet know why, other than for subjective or sentimental values, but the old tinker's rule of saving all the pieces certainly applies to preservation of a potentially unique genetic base which helps enable an individual organism to succeed beyond all others of its kind. Similarly, we should attempt to maintain living reference collections of type specimens, when such trees can still be found, so that future taxonomists with new techniques will be able to

review something more revealing than crumbling old herbarium specimens. We also should propagate individual oaks associated with our American aboriginal or written history.

Such trees might be unique only in their stochastic circumstance of being in the right place at the right time, or in surviving long enough to be recognized for their size, age, or association with historic human events. But ancient and champion trees arguably rank among the most inspirational of nature's works, and they impart to receptive people a spiritual presence and a mirror in which to view our own mortality. They also serve as living connections to the past and, by their genuine and obvious venerability, they establish a time scale to place history in perspective. Such trees, particularly oaks, have inspired human interest in these ways for centuries, and at worst they may be effective when used to draw public interest to a just cause or to recruit financial or political support for worthy scientific purposes.

Rare or Restricted Endemic Species. The general importance of propagating rare or restricted endemic taxa for ex situ conservation is widely accepted. This need cannot be overemphasized in dealing with a genus so polymorphous and so characteristically heterozygous as *Quercus*. There are many oak taxa confined to habitats so restricted that much or most of the genetic diversity of such taxa is at risk of catastrophic loss. This category might include the golden oak *Q. tomentella* and the red oak *Q. parvula*, both virtually limited in nature to the Channel Islands of California, and the white oak *Q. hinckleyi* from Solitario Peak in the Presidio of Texas. It also should include more cold-tolerant species, like the red oak *Q. acerifolia* (syn. *Q. shumardii* var. *acerifolia*) from Magazine Mountain in the highlands of western Arkansas and the surprisingly hardy white oak *Q. oglethorpensis* from the vicinity of Ninety-Six, South Carolina.

Nor should our conservation concerns be limited to American species. The beautiful *Q. alnifolia* is found in nature only on the Mediterranean island of Cyprus, and should be brought into more extensive cultivation. *Quercus baloot*, from the Himalayas, was probably unknown in cultivation until a pilot happened to bring a few seeds back to Europe recently, out of curiosity, in his shirt pocket.

Many rare oak species in the biodiversity centers of China and Mexico may be disappearing, due to the pressures of human population, before they can be brought into cultivation or even described. *Quercus uxoris*, a unique tropical montane winter-deciduous oak from southwestern Mexico, has been studied so little that the botanist who named it in 1972 lamented that even he had not seen enough fruiting material to describe it fully. This species, due to its autumn-deciduous habit (unusual for this climate zone), might be adaptable to much colder habitats than those of its isolated natural range; yet it was brought into cultivation only in 1995, by an expedition which included two of the people at this conference.

Unique Individuals or Populations. Many oaks constitute one-of-a-kind taxa. Single groves, or even single trees, represent species or hybrids which may have scientific or commercial value. No one knows the exact identity of the Langtry oak growing along a tributary of the Pecos River in Texas, but we do know that it's an unusual, annual-fruiting analog of the biennial-fruiting red oak *Q. gravesii*, and that much of it is being destroyed by dam construction. No one knows exactly what the Fendler oaks of Lincoln, New Mexico are. They could be a super-hardy cline or hybrid of the beautiful Mexican blue oak (*Q. oblongifolia*); we do know that only a few

individuals are left, and that at least some already have been cut for firewood.

The original cross *Q.* ×*vilmoriniana*, a hybrid of the European *Q. robur* with the Asian *Q. dentata*, is an ancient specimen declining from root decay in the Arboretum des Barres in France. Hopefully, it will be propagated vegetatively while there is still time. And who knows why *Q.* ×*organensis*, the supposed hybrid of two semideciduous species in southern New Mexico, is evergreen? We do know that it exists only as a few individuals, growing at a fragile oasis in desert mountains precariously on the edge of a military bombing range.

The outlier population of magnificent Nuttall's oaks (*Q. texana*, formerly *Q. nuttallii*) I discovered in 1972 at Horseshoe Lake in Illinois thrive many miles north of the natural range of the species and display unusually brilliant fall color. But there were only two trees remaining after the great flood of 1993, and the largest, fully 2 m in diameter, is nearly gone now due to storm damage. One nurseryman is rooting cuttings from this unique provenance, and I have propagated it from seed as well, for ex situ conservation.

Politically Isolated Species. Political considerations might make it difficult for us to obtain material from additional provenance to broaden the genetic base of a species in cultivation. Are you willing to spend hundreds of dollars for a permit to bring material back from Costa Rica? Would anyone volunteer to collect acorns of *Q. infectoria* var. *boissieri* (syn. *Q. infectoria* ssp. *veneris*) from its native range in Iraq?

Plus Trees. Superiority in selected performance parameters can demand the vegetative propagation of plus trees for forestry and of additional ornamental selections. Provenance could play a major role in identifying commercially useful, cold-hardy sources of cork, for example, by selectively testing promising individuals of *Q. suber* var. *occidentalis*, the biennial-fruiting northern form of cork oak. Lime-tolerant species such as *Q. pubescens* and *Q. muhlenbergii* might be used in hybridization programs, or as grafting understock, for areas where alkaline soil conditions restrict the use of other oaks.

Examples of ornamental oak cultivars selected for superior, rather than abnormal, characteristics include *Q. frainetto* 'Hungarian Crown', *Q.* ×*libanerris* 'Rotterdam' (an improvement over the older hybrid selection 'Trompenburg'), and the superior *Q.* ×*saulii* #168 and *Q.* ×*bebbiana* #190 I currently am naming and introducing. They all are uncommon individuals of common taxa, and their superior ornamental characteristics cannot be replicated dependably except via asexual propagation.

A New Frontier Underfoot for Oak Propagators. For centuries, humans have been enchanted by the venerable qualities of giant, ancient oak trees, and understandably so. But the genus *Quercus* offers us something else, which to date we have not sufficiently appreciated nor exploited. It is time to direct some attention to the diminutive oak species which have so much potential for horticultural and habitat purposes.

There are rambling groundcover species, like the waist-high *Q. havardii* that stabilizes hundreds of miles of shifting sand in Texas, New Mexico, and Oklahoma. Tame it, maybe grow it on a non suckering rootstock, and it's a shrub with great potential. Cross it with some larger species, which it does frequently in nature, and you might have a mid-sized oak with the best characteristics of both parents. The same can be said for *Q. gambelii*, *Q. georgiana*, *Q. prinoides*, and *Q. incana*, all small

oaks which have proven hardy for us in the heart of Illinois in U.S.D.A. Zone 5.

Quercus ilicifolia, another hardy dwarf species that spreads to form thickets, already has been domesticated into a refined shrub cultivar Nana at Arboretum Trompenburg in the Netherlands. *Quercus palustris* 'Swamp Pygmy' is a miniature globe form of pin oak discovered by the Bomer Nursery Boomkwekerij, also in the Netherlands. These and similar selections from our North American red oaks must await the perfection of propagation techniques that can circumvent graft incompatibility before they can be introduced into the trade on a commercial scale.

We also might explore the possibilities of the truly dwarf, knee-high oaks, which may prove to be root-hardy in winter climates far more severe than their native haunts. *Quercus minima* and *Q. pumila*, stoloniferous oaks (respectively white and red) from the Southeast, could fit this mold, as might the creeping *Q. monimotricha* from China and the ultimate dwarf oak, *Q. repanda* from the great volcanoes of Central Mexico.

THE KEY TO THE FUTURE

We are at a crossroads in the development of oaks for ornamental horticulture, forestry, wildlife, and conservation uses. Advancements in propagation techniques can lead the way to a prodigious reservoir of superior oaks for the future. But the oaks are like fine, spirited horses, and will not be tamed easily. People at the leading edge of propagation science—people who have the motivation to participate in conferences like this one—must rise to meet this challenge. Nothing truly great comes easily!

Oak Propagation from Start to Finish

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INTRODUCTION

Possibility Place Nursery was started in 1978 at which time we started to grow native and typical horticultural plant material. Five years later (1982) I decided to eliminate almost all typical nursery stock and concentrate on native woody plants of which oaks would compromise a large percentage of the trees (eight species). I realized the current growing methods would not work. Fortunately a gentleman in Oklahoma named Carl Whitcomb devised a system of growing bottomless containers to grow bags. I have taken much of Carl's system and modified it to our needs.

SEED PROPAGATION

Seed Collection. I collect nine oak species within 150 to 200 miles of the nursery. The trees that are collected from have typical characteristics of that species. First I check for weevils by cutting 5 to 10 of them open. If they are weevil infested I do not collect them. If the seed is good, I get my rake and shovel and start in.

Seed Storage. Oak seed is immediately processed by putting them in moistened soilless mix of peat and pine bark. The flats are then stacked on pallets in the shade outside until threat of serious frost. They are then moved into an unheated insulated seed house and stacked against the wall. Stacking of the flats reduces varmint damage (mice, rats, squirrels, and blue jays). I also use poison, such as Decon, but I prefer mouse and rat traps as well as "stickum" traps.

Greenhouse Propagation. In the first week in March or when the boiler decides to work, the seed flats are brought out of storage. The flats are placed on bottom-heated benches made of hardware cloth. Heat is set at 70F. Ten to sixteen days later the oak acorns germinate. I like to transplant before they get their first leaves. The acorns are then transplanted into bottomless containers with soilless mix. The mix is peat, perlite, and pine bark (1 : 1 : 3, by volume) with fertilizers Osmocote 18N-$6P_2O_5$-$12K_2O$ with Micro Max added. Irrigation is by a mist system. We tried other systems and always had difficulty in getting good water distribution.

Culling which is very important in the production of uniform plants begins with seed germination. Any seedling that does not look like the norm is eliminated. It is cheaper to cull now then to cull in the field.

Container Growing. In early June, depending on the weather, we move the bottomless-container seedlings to mechanical air-pruning 1-gal containers. The same soilless mix and fertilizers are used as in the greenhouse. The containers are spaced 6 to 8 in. apart to allow the plants room to grow. They are also placed on plastic which helps to control weeds and prevents roots from growing into the gravel. I do use the herbicide Treflan at the recommended rates on the containers. Irrigation is supplied overhead on an as-needed basis. Culling is again paramount and 20% to 30% of the bottomless containers are discarded at this stage.

Field Growing. Our growing fields are tiled before use and checked for fertility, then fertilizer is applied according to the recommendations. The field is plowed in the fall and then chiseled plowed and disked in the spring. Lastly irrigation lines are put in for drip irrigation. Once the field is ready, root bags are installed. We have used root bags since their inception and have gone through seven different fabrics trying to get the best one—now I believe we are very close to the right fabric. We began using 22-in. bags, but have changed to 18-in. bags. Our market is 1.5- to 2.5-in. caliper trees and 18-in. bags provide a generous medium volume for good growth. The trees are field planted in September. They are immediately watered and then watered on an as-needed basis until the first week in October. We cull again before the trees go to the field. Usually 20% of the trees never leave the 1-gal containers.

Harvest. Trees are ready to be harvested at 1.5-in. caliper 5 years after they are planted in the field. Harvesting is done with a skid steer and Hawk bucket. We place the trees and shrubs on pallets before loading them on to wagons in the field. The plants are then brought to the holding yard. The best trees are those loaded on somebody's truck and I have the money in hand.

CONCLUSION

The objective in growing oaks is to have a tree that not only survives but flourishes in the customer's yard. This can be accomplished only if we work diligently on our growing methods and just as diligently if not more on education of the public on selection, placement, and care of their trees. The consumer must have success with oaks or the oaks will never become a popular tree in our landscape.

JOHN WILD: Are you doing work with mycorrhizal fungi?

CONNOR SHAW: No we are not.

DEB MCCOWN: What conditions are you culling for?

CONNOR SHAW: Our background is forestry and we are looking for the best growth but we prefer diameter over height. We are looking for the norm and eliminate runts as soon as they become apparent.

CLAYTON FULLER: You are potting your oak in a round hole in a round container. Have you looked at the roots after a number of years to see how they are growing.

CONNOR SHAW: The reason we went to this fabric was that it was made to allow the roots to penetrate it but cuts down on the diameter of the roots that go through it. Other fabrics we tried did allow some circling of the roots. Therefore, you obtain good penetration into the surrounding soil.

Container Production of Oaks: A Successful Reality

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The production of oaks in the field can pose several problems, most of which begin with the liner. For many species the problem in the past has been availability. With others it has been an insufficient root system or coarse-rooted liners that fail to break uniformly if at all. Oaks are notoriously bad transplanters with frequent high losses due to slow root regeneration.

Conventional field whip production practices take up to 5 years to produce salable plants. In the first year, seeds are sown in fall or spring and seedlings are harvested at 1 or 2 years of age. These seedlings are then lined out in field rows for 1 or 2 more years and then cut back to 2 in. in height in spring to produce a vigorous young whip of 5 to 8 ft. This entire process takes 3 to 5 years to produce a 1-year whip. The resulting plant generally has a coarse root system with little to no fibrous roots and at best recovers slowly and in too many cases not at all. For example, root regeneration in red oak via new root initiation occurs almost exclusively in spring and can take 40 days under standard greenhouse conditions. Consequently, field-grown coarse-rooted species are difficult to transplant because they have virtually no intact root tips when harvested.

To meet these challenges we have adapted with some modifications the Ohio Production System (Struve and Rhodus, 1990) for the production of oaks as well as other species of shade and flowering trees. Our primary objective was to produce a cost-effective container-grown liner with an improved root system that would be more vigorous when transplanted to the field.

The oaks we grow originate in two ways. The secondary source is from purchased 1-year seedlings preferably of known provenance of species we cannot collect ourselves. The first and most important source is the acorns we harvest or have harvested for us from known sources. This gives us the best control on the finished tree because we know something about the parent tree or at least the area from which it comes. Records are kept on sources of seed or seedlings to determine how they perform. After collecting, we place the seed in a plastic bag with moth balls for 3 days to rid the acorns of any insect larvae. The seeds are then sown in trays of damp sand for germination. Members of the white oak group germinate within days. Members of the red oak complex are chilled until January or February and then warmed sufficiently to induce germination. Germinating acorns are removed from the sand when the radical is 1/2 in. to 1 in. long and placed in the corner of 2-7/8 in. $\times$ 5 in. Anderson Bands which have an open bottom. The acorn is only lightly pressed into the medium with the radical pointed downward in the corner of the pot which acts as a "grow straight" for the root. The bands are placed in flats which are held above bottom-heated benches by an inverted flat to air prune the tap roots. Supplemental lighting is supplied at night to promote additional growth.

In mid to late May the seedlings are removed from the greenhouse to a 70% shaded polyhouse for acclimatization. This is an important step to avoid severely shocking the plants. After 2 weeks the plants can be removed from the shade and transplanted to 2-gal containers treated with Spin Out™. Research at Ohio State University has

shown that plants growing in copper-treated pots have improved root morphology and distribution in the container. As a result, plants are able to use water and nutrients more efficiently. Our medium is a 60% pine-bark-based mix with Osmocote 18N-6P_2O_5-12K_2O 8- to 9-month or Polyon 24N-5P_2O_5-12K_2O 6 month fertilizer incorporated in the mix. The plants are staked and grown under overhead irrigation in our container area for the balance of the growing season. At the end of the growing season, the oaks will vary greatly in height, depending on species, and generally range from 2 to 5 ft. Container size is a limiting factor in production. When plant root systems reach the capacity before the end of the growing season the plants stop growing.

In October the trees are graded and the best seedlings preferably 30 in. or taller are planted in the field on widely spaced rows for large-caliper shade-tree production 1 year after falling from the tree as an acorn. Trees that do not make grade are stored in unheated polyhouses and grown for a second season before moving to the field.

We have found that these trees will quickly reach salable size with almost perfect stands with a more fibrous root system than a field-grown whip and at a reduced cost and without the transplant losses. We have proven from a nursery viewpoint that from little acorns mighty oak trees grow.

LITERATURE CITED

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GUY STERNBERG: Are you pruning to encourage a branched root system?

BILL HENDRICKS: The open-bottomed pots allow for air pruning and this encourages branching.

GUY STERNBERG: I was thinking of pruning when the root is about 1/2 in. long to produce a fibrous root system immediately below the acorn instead of just at the bottom of the initial pot.

BILL HENDRICKS: I think I will try that.

MIKE YANNY: We obtained good root systems when we pinched the roots at an early stage when we grew them in pots but when we tried it in the field, the method did not produce good seedlings.

Oak Production in Alkaline Soil: Advantages of *Quercus* ×*schuettei*

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Oak production is a challenging endeavor. At Johnson's Nursery, alkaline soil conditions and a B&B production system make it even more difficult. Our recent use of *Quercus* ×*schuettei* (*Q. bicolor* × *Q. macrocarpa)* has made field growing oak trees easier and more successful.

Historically, *Q. bicolor*, swamp white oak, has been one of the best species of oaks for B&B nursery production and landscape use. It has been easy to transplant because of its relatively fibrous root system. Swamp white oak has shown tolerance to heavy, compacted soils and has an adequate growth rate. Unfortunately, at Johnson's Nursery where the soil pH ranges from 7.2 to 7.6, *Q. bicolor* usually becomes chlorotic due to nutrient deficiency. Lowering the pH with applications of granular sulfur to the soil has not been a satisfactory remedy for this problem.

Quercus macrocarpa, bur oak, is another oak species with great potential as a landscape plant. This long-lived species has an adequate growth rate and is extremely tough. It is tolerant of many soil types and survives drought. Unlike swamp white oak, bur oak thrives in alkaline soils.

A major drawback to bur oak is its poor transplantability. Because of its very coarse, deep root system, it is very hard to move successfully. At Johnson's Nursery unacceptably large losses have occurred when transplanting 5-, 6-, and 7-ft bareroot whips of this species in spring. There has also been a problem with transplanting large-sized B&B bur oak trees. Oftentimes, so few roots are present that the root balls fall apart while digging or handling. Even trees with solid root balls frequently don't survive transplanting.

In 1989, we made an observation that prompted us to begin growing *Q.* ×*schuettei* seedlings. We noticed that our blocks of *Q. bicolor* trees were chlorotic and growing very poorly, except for an occasional tree. The chlorotic trees were no surprise to us. We had experienced similar alkaline-soil-induced deficiency symptoms on *Acer rubrum* in the past. We concluded the same malady was plaguing our swamp white oak blocks. However, we did not understand why a few trees grew exceptionally well with deep, dark green leaves. These healthy trees were located randomly in the blocks, indicating to us that no drastic pH changes were present. We theorized that the genetic make-up of these healthy seedlings may have enabled them to grow in alkaline soil. We thought that these standout trees may have had some bur oak "blood" in their genetic background.

Knowing that a hybrid between *Q. bicolor* and *Q. macrocarpa, Q.* ×*schuettei*, did exist (Miller and Lamb, 1985), we began searching for trees that fit its description in wild areas of Southeast Wisconsin. We went to areas where the two species, *Q. bicolor* and *Q. macrocarpa,* occurred in close proximity to each other, sometimes side by side. These areas were typically lowland settings that graded upward into bur oak openings. We found some trees with intermediate characteristics. We saw trees with acorns that looked like bur oak yet had the flaking, exfoliating bark which is

characteristic of swamp white oak. Some trees had typical swamp white oak acorns with 2-in.-long fruit stalks yet had fringing on the edge of the caps like bur oak. Some trees had many swamp white oak characteristics, except the leaves looked consistently like bur oak with deep lobing, almost to the mid-rib near the middle and base of the leaves. Several of the trees had extremely large acorns, larger than any of either species we had seen in the area.

Acorns were collected from trees thought to be hybrid. Records were kept to track individual mother trees of each seed lot. We planted acorns in field beds and harvested seedlings the following spring. They were root pruned to a 2- to 3-in.-long root stub and planted in a transplant bed for 1 year. The trees were dug again the following spring and graded for root quality. Those with poorly branched root systems were discarded. Trees with quality root systems were root pruned again and planted in close rows 1 ft apart for production of whips. The close-row trees were kept as pest-free and weed-free as possible. They were band fertilized three times a year with a slow release, 19N-6P_2O_5-8K_2O, fertilizer. The following spring, the trees were undercut. The second year in close rows, the oaks received identical treatment as the previous year, except they were not undercut. In spring of the third year, the tops of the oaks were cut to a 2- to 3-in. stub. Shortly thereafter, shoots emerged from the stub. One shoot was selected, and all others were removed. A Gro-straight® stake was placed next to the tree to prevent dog-legs. The trees were staked with 5-ft steel rods and tied to the rods periodically. A leader was maintained on the trees, and all side shoots were removed. Fertilization and insect control continued. At the end of the third season in close rows, 3-, 4-, and 5-ft whips were available for lining to the field for B&B tree production. Throughout the time when trees were in close rows, culling was done of chlorotic trees. Depending upon the seed source, chlorotic culls made up only 1% to 10% of the *Q.* ×*schuettei* crop. The whips were spring dug, graded, and lined 4 ft apart in the same high pH nursery soil.

The transplanting of the *Q.* ×*schuettei* whips was successful with losses being reduced dramatically compared to experiences with *Q. macrocarpa* in previous years. The health and growth rate of the trees also improved tremendously. Chlorotic trees, so common in earlier blocks of *Q. bicolor* were uncommon in these new blocks of *Q.* ×*schuettei*. This spring we dug *Q.* ×*schuettei* B&B for the first time. Preliminary results look promising. The few 1-1/2-in.-caliper trees that were dug for sales transplanted well.

It seems that the use of *Q.* ×*schuettei* may enable Johnson's Nursery to meet the increasing demand for native oak trees. Furthermore, this hybrid which tolerates alkaline nursery soils may also prove to tolerate the tough conditions of urban landscapes.

LITERATURE CITED

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BILL BARNES: When you take the side shoots off the oak stems do you remove them close to the main stem?

MICHAEL YANNY: We pinch them out close to the stem.

BILL BARNES: If you leave a little stem that will encourage the main stem to increase in caliper and then in the fall you can trim the short stubs off.

I have a further comment relating to the last paper and weevils in oak seeds. If you put the seeds in a plastic bag and place them in a refrigerator at 35F for 3 days all the weevils will leave the seeds and concentrate on the bottom of the bag.

On another subject, you can encourage branching of oaks by selectively moving the containers in and out of a polyhouse because direct sun will stimulate lateral branches.

KEN TWOMBLY: Is there any likelihood that the hybrids will not be able to tolerate wet sites.

MICHAEL YANNY: We are looking for the hybrids at lowland sites were the swamp white and bur oaks overlap. So I suspect they will have tolerance to the lowland conditions.

Graft Incompatibility in Red Oak: Theory and Practice

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According to a theory of graft incompatibility proposed by the senior author, successful long-term graft unions could only be developed in red oak (*Quercus rubra* L.) when stock and scion produced identical cambial isoperoxidase enzyme band patterns. Analyses of peroxidases in the seedling rootstocks and scions of 73 "failing" intraspecific grafts of red oak revealed that 82.2% (60/73) of those grafts could have been predicted as potentially incompatible on the basis of enzyme phenotypes. On the other hand, only 13 of 32 (40%) of grafts that had not shown incompatibility symptoms for 4 or 5 years had the same enzyme bands in stock and scion, while 60% (19/32) did not match. The use of seedlings from any particular tree as rootstocks for scions of that tree might not result in any greater enzyme-matching frequency. Future work to further test the theory and reproduce select clones for a seed orchard is briefly discussed.

INTRODUCTION

The paucity of oak (*Quercus*) cultivars currently available in the American nursery trade is certainly a reflection of the difficulties of vegetative propagation of select trees in this genus. This is especially true with regard to species in the subgenus *Erythrobalanus* (Spach) Oersted, the red or black oaks. Grafting would appear to be a reasonable method of multiplying mature trees with superior form, autumn leaf color, or other characteristics but there have been major problems with graft incompatibility.

Santamour (1988a) proposed an hypothesis that graft incompatibility could be related to variation in cambial isoperoxidase enzymes in stock and scion in certain genera. Peroxidases mediate the polymerization of cinnamic alcohols into lignin and the reconstitution of a working vascular system across the graft interface occurred only when the stock and scion produced the same peroxidase isozymes. This work was followed by detailed studies (Santamour, 1988b; 1988c) to "test" this hypothesis in Chinese chestnut (*Castanea mollissima*) and northern red oak (*Q. rubra*). Anagnostakis (1991) analyzed the progenies from controlled crosses in *Castanea* and concluded that the genes coding for the two major anodal peroxidases were allelic. More recently, however, Huang et al. (1994) studied various chestnut grafts and stated that "Comparisons of cambial isoperoxidase isozymes between successful and unsuccessful grafts did not support the hypothesis that peroxidase isozymes are indicators of rootstock-scion compatibility". S.L. Anagnostakis (pers. comm.,

1995) attempted to duplicate the work of Huang et al. (1994) and found that the major enzyme bands ("A" and "B") studied by her (Anagnostakis, 1991) and Santamour (1988 b) were not the same as those of Huang et al. (1994). Obviously, there are problems here that must be resolved.

Still, over the past several years, more than 500 chestnuts have been enzyme-typed in the senior author's laboratory for nurserymen and scientists, and the results have supported the peroxidase enzyme hypothesis.

Since 1984, the junior author has directed a tree improvement program for red oak in Indiana, and the background and philosophy of the project were presented by Coggeshall and Beineke (1986). Essentially, 180 superior trees were selected on the basis of growth rate, stem form, and apical dominance from native stands in Indiana and from provenance test plantations in Indiana and Ohio. These select "plus-trees" were spring bench grafted to seedling understocks and outplanted according to a prescribed design to serve as a clonal seed orchard that would be utilized to produce superior seedlings over several generations of selection. Grafting "success", the formation of a cohesive union between stock and scion, has averaged about 92% over the years. However, symptoms of graft incompatibility became apparent in many plants 4 to 5 years after grafting, and included vigorous suckering from the rootstock, swelling at the graft union, precocious flowering, and reduction of scion vigor. Death of the scions in these incompatible combinations may occur from 5 to 8 years after grafting.

Thus, we were drawn together by our mutual interests in oak propagation and the genetic improvement of trees. Furthermore, the earlier work that supported the enzyme hypothesis was based on "bark-ring" grafts (Santamour, 1988b; 1988c) that were not intended for propagation. The research program in Indiana presented a real-world propagation situation that demanded a solution if it were to fulfill its goal to improve the growth and form potential of the nearly 250,000 red oak seedlings produced annually by State nurseries in Indiana.

From 1992 through 1995, we have cooperated, as time and the availability of plant materials have permitted, in studies designed to help explain these grafting problems and to offer possible solutions for continuation of the Indiana program.

MATERIALS AND METHODS

All of the plant material was collected from the nursery areas and test plantings of the junior author in Indiana. All enzyme typing was performed at the U.S. National Arboretum and included, in the following sequence: (1) 66 select clones, (2) 73 seedling rootstock sprouts arising from below the failing graft unions of 47 of those clones, (3) 132 seedlings derived from open-pollination of six clones of known enzyme constitution, and (4) the roots of 32 grafts that had shown no symptoms of incompatibility after having been grafted for 4 or 5 years. Details of sample preparation and starch gel electrophoresis of enzymes have been published (Santamour, et al., 1986) and the various enzyme bands have been illustrated (Santamour, 1983; 1988c).

RESULTS AND DISCUSSION

This section will follow the same sequence of analyses presented in Materials and Methods. The 66 select clones were enzyme typed as follows: (A) 15, (AB) 28, (B) 12, (AC) 3, (BC) 7, and (C) 1. As in previous work, the majority of trees, 55 of 66 (83.3%),

had enzyme phenotypes of A, AB, or B. Roughly 83% of the 47 grafted clones were also A, AB, or B. The 73 seedling understocks, typed from sprouts, were more variable: (A) 16, (AB) 26, (B) 12, (AC) 8, (ABC) 2, and (C) 1. All of the above data are given only to show the variation encountered in red oak. The most important finding from this study was the fact that 60/73 (82.2%) of the graft failures could have been predicted on the bases of enzyme typing, with stock and scion having different enzyme phenotypes. There are probably other biochemical, physiological, or biological reasons for the other 13 graft failures.

The enzyme phenotypes of the open-pollinated seedlings are given in Table 1. Since we did not know the inheritance patterns of the enzyme bands in red oak nor did we have any progenies from controlled crosses, the analyses of these seedlings might provide some insight on enzymes inheritance. It is obvious that the use of seedlings from any given tree as rootstocks for the grafting propagation of that tree might not result in reduced incompatibility levels compared to nursery-run seedlings. The limited variability among seedlings derived from mother trees with A, AB, or B phenotypes is indicative of the predominance of A and B pollen that would be expected from trees of similar enzyme constitution. A higher degree of variation would be expected, and was found, in progenies from trees with AC and BC phenotypes. The seedlings in those progenies that had a C phenotype probably resulted from self-pollination, but what about the ABC individual? If the expression of the band A, B, and C were codominant, and the genes coding for those enzyme bands were allelic, a maximum of two different bands should be present in any given plant of this diploid species. Santamour (1988c) reported that about 5% of the 463 trees he investigated had ABC phenotypes. McArdle and Santamour (1987) also found three isoperoxidase bands in some trees of *Koelreuteria paniculata* Laxm. in which the genes were thought to be allelic. They postulated that chromosomal crossing-over might be the cause of this phenomenon.

Table 1. Distribution of isoperoxidase phenotypes in seedlings derived from open-pollination of mother-tree clones having various phenotypes.

Clone no.	Seedling phenotype							
(phenotype)	A	AB	B	AC	BC	C	ABC	No.trees
43(A)	15	13	-	-	-	-	-	28
107(AB)	6	13	1	-	-	-	-	20
93(B)	-	13	7	-	-	-	-	20
123(AC)	4	12	-	5	2	2	-	25
116(BC)	-	3	2	8	1	1	1	16
94(C)	-	-	4!	2	3	9	5	23
								Total 132

We were certainly not prepared for the results of the analyses of the seedlings produced by clone 94, which had a C phenotype. It would appear fortunate that C-type trees are relatively rare: 1 of 463 (Santamour, 1988c) and 2 of 139 (this study). As would be expected from a C-type parent there were no progeny with A or AB phenotypes. However, there should also be no progeny with a B phenotype, but four seedlings were found with only this band (of the three major bands). All four B-type seedlings also had a strong-staining enzyme band that migrated slightly above the A band. This "above-A" band was also found in two of the nine seedlings with C phenotypes. Although further investigation of these anomalies might prove interesting, they may not be important in the general scheme for oak grafting and incompatibility.

Up to this point, we had not examined any supposedly successful grafts, those that had not exhibited any signs of incompatibility for 4 to 5 years following grafting. There were relatively few grafts available for study and the graft unions on many trees were so low that sampling the stem cambium of the stock plant would have been extremely difficult. Still, such material had to be analyzed in order to obtain a more balanced view of the situation. Fortunately, we found that the enzymes in the root cambium were exactly the same as those in the stem cambium, and it was an easy matter to obtain a few roots for analysis. We analyzed the enzymes in the rootstock roots of 32 such grafts and also double-checked the enzyme patterns in the grafted scions. Although we had expected a high proportion of enzyme "matches" in this material, with both stock and scion having identical enzyme patterns, such was not the case. Only 13 (40%) of the graft combinations exhibited matched enzyme patterns while 19 (60%) were definite mismatches.

THE FUTURE

Has the isoperoxidase enzyme theory of graft compatibility been proved in practice? No, but neither has it been disproved. The long-term survival of those grafted trees that have survived for 5 years can only be determined after many more years of observation. If the distribution of enzyme phenotypes in the general red oak population were similar to that found in the 463 trees analyzed by Santamour (1988c), the probability of achieving enzyme matches from random samples is only 30±5%. That level of grafting success is not acceptable in a program designed to establish a seed orchard for the production of superior seedlings. At the moment, the isoperoxidase enzyme theory may be worth exploring further.

As recommended by Santamour (1988c), the production of seedling rootstocks of the three major enzyme phenotypes (A, AB, B) could be accomplished by the creation of isolated seed orchards containing only parent trees having certain phenotypes. That sort of scheme is, of course, a long-term proposition. The junior author is currently planning a more direct approach to complete the requisite number of successful grafts needed in his project. Using the young seedlings that have already been enzyme typed, he will establish cutting stock blocks of plants having each of the seven enzyme phenotypes. These plants will then be "hedged" to produce juvenile shoots for cutting propagation of a range of rootstocks that should be compatible with all of the selected "plus trees".

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Oak Grafting Techniques

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INTRODUCTION

The vegetative propagation of oak species via grafting is a fairly efficient means by which valuable germplasm can be replicated for both horticultural and forestry purposes. While softwood cutting propagation, and even tissue culture technologies, have been successfully applied to the genus, at least on the research level, these methods have been generally confined to either just a few species and/or limited in their success to only juvenile plant material. Although it can be argued that mature clones of some species can be successfully rooted via softwood cuttings (Zaczek et al., 1993), the resulting plants may fail to overwinter, or grow very slowly, and may even display plagiotropic-type growth habits. For these reasons, it is quite likely that the propagation of oaks via grafting and budding techniques will be the method of choice for those of us interested in this valuable genus. The purpose of this paper is to provide a short review of the grafting techniques that are currently being employed at both the research level and also in commercial nursery operations.

An earlier review of oak grafting techniques was offered to this Society by Flemer (1962). Much of the information presented in that paper is still appropriate today. In addition, new insights can be added in terms of the work conducted by Santamour (1983, 1988) on delayed graft compatibility problems, which can be especially troublesome for species in the red oak subgenus.

SCION/STOCK RELATIONSHIPS

It is intuitive that greater success rates will be achieved by matching the scion to a rootstock of the same species. This can be especially true when propagating species and cultivars in the red oak subgenus. However, in the case of species in the white oak group, there is considerably more latitude available. The common practice is to utilize understocks that are capable of producing a more fibrous root system, such as *Quercus bicolor* or *Q. michauxii*. For planting in areas with high soil pH, *Q. muhlenbergii* might be an appropriate understock species to use.

There seems to be little, if any, compatibility problems associated with species in the white oak subgenus. As an illustration of this fact, a total of 252 valid cultivar names for oaks have been cited by McArdle and Santamour (1985, 1987a, 1987b). Of these, 119 were for English oak (*Q. robur*), and only 28 represent species in the red oak subgenus. It is acknowledged that the red oak subgenus is not native in Europe, and nurserymen in the United States have generally not been focused on selecting many oaks for ornamental purposes. However, one other important factor needs to be considered, namely delayed graft compatibility. It can be a definite problem for species in the red oak subgenus. This may at least partially explain the imbalance in the numbers of named cultivars between the white oak and red oak subgenera.

The potential reasons for delayed compatibility problems in oaks have been reviewed by Santamour (1983, 1988). For a graft union to be successful, callus tissue must form a "bridge" between the scion and stock, followed by cambial strands that

later differentiate into vascular bundles of phloem and xylem. Incompatible graft unions result when no vascular tissue develops, but is instead filled by ray tissue that fails to lignify. This interruption of vascular continuity between the scion and stock is the definition of incompatibility.

Santamour (1988) discussed a number of potential causes of graft incompatibility including the presence of viruses in either the scion or stock, wound compartmentalization ability, and cell wall lignification. Lignification of the cell walls ultimately provides the physical strength for tree growth. For some "difficult" genera such as the oaks, the peroxidase enzyme, which is directly involved in the polymerization of alcohols into lignin, has been shown to be genetically variable (Santamour, 1983). If the scion and stock do not possess genetically identical forms of the peroxidase enzyme, then lignin bonding of adjacent cell walls will be disrupted, resulting in a lack of vascular development (Santamour, 1988).

For the white oak subgenus, there appears to be little, if any, variation for the cambial peroxidase enzyme. This means that different species within the subgenus can be successfully employed as scion and stock material. However, in the red oak (*Lobatae*) subgenus, a total of seven different phenotypes of this enzyme have been detected (Santamour, 1983). It also appears that certain species within the subgenus express different levels of variation for this enzyme, with northern red oak (*Q. rubra*) being the most variable. As an example of how widespread this problem can be, delayed compatibility symptoms for a 180-clone collection of northern red oak in Indiana began to be noticeable 5 years after grafting and reached 17% by age 8 (unpublished data).

SCIONWOOD HANDLING

Collection of scionwood during the dormant season is fairly straightforward. Robust, 1-year-old wood is normally collected in January or early February. Care should be taken to store the scionwood dry in plastic bags in a cooler just above freezing. Experience has shown that no moisture-retaining material (such as sphagnum moss) is needed in the scionwood bag, and in fact may contribute to mold development. I have stored scions of several genera in this fashion for up to 3 months. Scionwood can also be stored successfully for up to 6 weeks by waiting to collect it in late March, or as long as it is dormant. Once collected, it can be dipped in a 10% bleach solution, wrapped in moist paper towels, placed in closed plastic bag, and *stored in a refrigerator (Earl Cully, pers. comm.).*

GRAFTING METHODS

A number of grafting techniques for oaks have been reported in the horticultural and forestry literature and will be reviewed here. Undoubtedly, there may be additional variations that have been attempted on an informal basis by a number of propagators. A case in point has been my experience in pot grafting large numbers of *Q. rubra* and *Q. alba* clones in a greenhouse in the spring.

A short description of the following techniques will be provided: pot grafting, bench grafting, root grafting, field grafting, acorn grafting, and summer budding.

Pot Grafting. This approach to oak propagation is perhaps the most reliable method for those of us who do not enjoy the pleasures of living in a mild climate like the Pacific Northwest, or in Britain. My personal experience has been to expect at

least a 90% success rate by grafting northern red oak and white oak selections onto potted rootstocks in the greenhouse in the spring. The key to this success is to focus on rootstock health and size, and the use of robust scionwood. The process begins in late January-early February, by either potting up large size 1-0 seedlings into 14-in.-deep pots, or moving stored seedlings grown the previous year in 8-in.-deep pots into a cool greenhouse. Depending upon the daylength and temperature regime within the greenhouse, the actual grafting operation can commence in approximately 3 to 4 weeks. The timing is dependent upon bud swell on the rootstock. I do not focus upon root growth, but rather begin to graft as soon as the rootstock buds become noticeably active. Success rates will tend to decrease as the stage of leaf expansion and development on the rootstock increases.

Dormant, 1-year-old scions are removed from storage and grafted using a side veneer graft onto the rootstock approximately 2 in. above the soil line. The actual scion possesses only a single lateral bud and the tapered wedge cut is approximately 1.5-in. in length. The scion is inserted into a previously made corresponding cut on the rootstock and wrapped with a budding band. This budding band is firmly (not tightly) wrapped with spaces between each wrap. The entire graft is covered with Parafilm, a plastic tape product which allows for gas exchange while preventing desiccation of the cut surfaces. The actual top of the rootstock is removed just above the scion approximately 10 days after grafting. Depending upon the temperature within the greenhouse, bud break of the scion should be expected in approximately 14 days. The Parafilm covering will not impede the shoot development of the scion in any way, even if the bud is covered with 3 or 4 layers. Temperature regimes within the greenhouse range from 65 to 95F. No supplemental lighting is used.

Grafts are moved out of the greenhouse after any danger of spring frosts, and placed in a shade structure for about 10 days. The shadecloth is then removed and the potted grafts are exposed to full sun all summer and watered as needed. Since the graft union is quite weak, it is recommended that the scion be staked with a bamboo cane. Two flushes of growth can be expected during the first summer if the pots are top dressed with a time-release fertilizer such as Osmocote 17N-6P_2O_5-12K_2O (3-4 months). Grafts can be outplanted in the field the following spring.

Flemer (1962) suggested that oaks could also be successfully pot grafted in a humid greenhouse in August. Scions from the current year's growth are collected and the leaf area is reduced by one-half.

A large number of oak cultivars are propagated via grafting in the Low Countries of Europe by specialty nurseries. The common understock species are English oak (*Q. robur*) for all white oak species, pin oak (*Q. palustris*) for the red oak group, and Turkey oak (*Q. cerris*) for the Mediterranean species and their hybrids. The propagation of evergreen oaks can be troublesome due to a lack of hardiness of the roostocks. A potential solution is to plant the graft deep, after wounding the scion so as to promote the rooting of the scion (Michel Decalut, pers. comm.).

Bench Grafting. Bare-root seedlings can be used as understocks in oak grafting when combined with the use of a hot callus pipe device (Lagerstedt, 1981). This device allows for the rapid callusing of the graft union while the distal end of the scion and also the rootstock is completely dormant. The graft is prepared as in pot grafting including the use of Parafilm, and placed within the slot in the pipe. A constant temperature of 75 to 80F for a 2-week period will result in healthy callus development.

The root systems are heavily mulched with damp sawdust or sphagnum moss to prevent cold winter injury. The graft can then be removed from the pipe and placed in cold storage for either subsequent outplanting or potting up in the spring. This particular approach to oak propagation has a number of advantages. No heated greenhouse or potted rootstocks are needed, and the work can be conducted throughout the winter season, which is a traditionally slower time of year.

Root Grafting. The use of root sections as a source of understock material was described by Leiss (1984). Root pieces of English oak (*Q. robur*) were potted up in clay rose pots in mid December. The root piece was covered with peat except for the very top and covered with opaque plastic. Temperatures within the greenhouse ranged from 43 to 68F. Root growth began in approximately 3 weeks and grafting operations began in mid February. Side veneer grafts were made using 3 to 4 bud scions of *Q. robur* f. *fastigiata* of similar diameters as the root pieces. Completed grafts were placed in a grafting case covered with glass sash. Temperatures within the case ranged between 68 and 82F. The grafting case was gradually vented over a 4-week period. The grafts sprouted uniformly and there were no suckering problems, which is common when using seedling rootstocks.

Leiss (1995) provided a further description of root piece grafting to this Society and addressed the challenge of propagating red oak group species and cultivars. His answer was to employ the same technique as described above and simply use root pieces harvested from either the original plant, or an obviously successful graft.

I conducted a small grafting experiment using root pieces in conjunction with a hot callus pipe device for four northern red oak (*Q. rubra*) clones. Despite the fact that only 2 of 48 grafts developed any callus tissue, it appears that this strategy may warrant additional testing. In this initial attempt, the temperature within the pipe fluctuated during the callusing period due to equipment malfunctions. In addition, I failed to completely cover the graft union with Parafilm over the entire length of the scion and root piece that was within the callus pipe. If any uncovered tissue is exposed within the callusing pipe, it will desiccate resulting in graft failure (Robert Tomayer, pers. comm.).

If it can be shown that root piece grafting in conjunction with a hot callus pipe device is possible, it could result in a method for producing grafts of red oak species and cultivars. Root sections could be harvested from older grafts that are obviously compatible and used as understock material in a hot callus pipe device. For certain species, the optimal temperature within the pipe and/or the duration of the callusing period will need to be determined. Dunn (1995) provided some insight into how grafts are bench grafted using a hot callus device in Britain. His recommendation was to place the grafts into the pipe for 17 days at 75F. He reported a success rate of 95% to 99%.

Field Grafting. Propagators in the Low Countries of Europe employ the use of cleft grafting onto established rootstocks in the field. This approach is also successful in Britain, where the cool, moist spring weather conditions are ideal for this method. Scions are collected in March and grafted when the rootstock buds begin to swell, usually in April (Dirr and Heuser, 1987).

High rates of success can be expected in the Midwestern U.S. by employing the use of either side veneer or cleft grafts on vigorous rootstocks up to 2 in. in diameter. This can be an effective technique when establishing a new stock block. Scions are tied

with budding bands, waxed, and held in place with black electricians tape (Earl Cully, pers. comm.). As with any other grafting technique, high rates of success are dependent upon the use of vigorous rootstocks and scionwood.

Acorn Grafting. This technique utilizes newly germinating seeds as the understock source, and could also be considered as a form of rooting. Newly emerging shoots are decapitated just prior to leaf development, and the hypocotyl is carefully split with a grafting knife. Small diameter scions are cleft grafted onto this hypocotyl and carefully wrapped with cotton string. The scions are collected at the onset of budbreak in the spring. The completed grafts are potted up in containers and placed in a polytent under shade in a greenhouse. The polytent is gradually vented as shoot development begins on the scions. This grafting technique was described by Goggans and Moore (1967), and reportedly resulted in a 50% success rate for both chestnut oak (*Q. prinus,* syn. *Q. montana*) and pin oak (*Q. palustris*). It has also been reported to be a successful grafting technique for *Castanea* and *Camellia* species in which root formation actually developed on the scions.

Summer Budding. This is the method of choice for the production of shade tree whips on the West Coast. Depending upon experience, various nurseries begin their budding operations in late July or early August. Some propagators bud oaks into early September. Both 1-0 and 2-0 seedling understocks are used. The length of the chip bud ranges from 1 1/4 to 1 1/2 in. long. Clear budding tape is used to tie in the chip buds. Success rates generally exceed 80%, with some cultivars approaching 100% (Michael Reish, pers. comm.). It is common to expect an 80% bud take and 5-ft tall, lightly branched whips when using 1-0 understocks. A 2-0 understock will result in 7- to 8-ft tall whip, but the success rate is usually lower, only about 60% (Earl Cully, pers. comm.). Since compatibility is not a great concern for species in the white oak subgenus, English oak (*Q. robur*) and swamp white oak (*Q. bicolor*) are the understock species employed, depending on the cultivar. Selections of Hungarian oak (*Q. frainetto*) are budded onto *Q. robur* (Keith Warren, pers. comm.).

In the Midwest, oak selections can be chip budded onto 1-0 seedlings of either swamp white oak (*Q. bicolor*) or bur oak (*Q. macrocarpa*) that have been fertilized heavily in the field for an additional growing season. Timing is in late July to early August. Buds are wrapped with 1.5-mil white budding tape and the top of the rootstock is removed the following spring. Despite the fact that the buds will knit well together, they may fail to grow the following spring or else die and fall off during the winter. Success rates can be somewhat erratic due to the subsequent winter temperatures (Earl Cully, pers. comm.). These same problems were also reported by Flemer (1962) in New Jersey. High rates of success are dependent upon the use of vigorous understocks. Also, collection of the budsticks from well maintained and irrigated stock blocks is critical to achieving high rates of success.

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Preliminary Progress on the Asexual Propagation of Oaks

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INTRODUCTION

There are many techniques propagators use to induce adventitious root formation on softwood cuttings. The application of auxins and the manipulation of stockplant juvenility and light, however, have proven to be powerful factors in the battle to asexually propagate difficult-to-root woody species by cuttings. The use of root-promoting hormones such as IBA is the most common treatment given to these recalcitrant species; however, the effects of juvenility and light have not been fully exploited as treatments in the cutting bench. Juvenility is the use of explant material taken from the biologically juvenile portions of the stock plant. In a number of species, juvenile tissue is the only tissue which will generate adventitious roots. As an example of the importance of physiological age versus chronological age, cuttings of Douglas fir were taken from 26-year-old trees. Cuttings taken from the bottom third of the trees rooted 71% while those from the top third rooted 52% (Roberts and Moeller, 1978). Although there has been no single explanation for this occurrence, there have been some common theories expressed as to the relationship between juvenility and adventitious root initiation. Stem anatomy, levels of endogenous rooting co-factors, and presence of preformed root initials are factors most commonly associated with the effect (Clark, 1982).

In *Hedera helix* for example, the stems of mature tissue contain a ring of sclerenchyma fibers that some have suggested may be a physical barrier to root development (Clark, 1982). Cuttings taken from juvenile portions of the plant have fewer of the thick, lignified sclereids and fibers, thus making it easier for the elongating root primordia to penetrate the periderm (Davies, 1984). Juvenile shoots of English ivy also appear to possess increased levels of rooting co-factors, while mature tissue of the species contains higher levels of rooting inhibitors (Clark, 1982). Preformed root initials are also abundant in the juvenile shoots of English ivy, while the mature stem portions are completely lacking any such characteristics (Clark, 1982). Regardless of a physiological explanation for increased adventitious root formation in juvenile stem tissue, its effect is indisputable, and is considered one of the most important and most overlooked factors in propagation by cuttings.

A third technique propagators will often consider when trying to propagate difficult-to-root species is that of etiolation. Etiolation as a pretreatment to cutting propagation involves excluding light from stock plants as the new shoot emerges from the dormant bud. Before these shoots are gradually acclimated to normal light conditions, a black Velcro™ band (approx. 2 cm diameter) can be placed at the base of the new shoot, which will become the cutting base, enabling that portion of the stem to remain in an etiolated state. The anatomical effects of etiolation can be compared to those of juvenility. Herman and Hess (1963) studied the effect of etiolation on *Phaseolus vulgaris* L. and *Hibiscus rosa-sinensis* L. They found that etiolated shoots possessed some root primordia in the stem while the light-grown plants did not. They also found the cells of etiolated plants were less lignified, with

thinner walls and less cellular differentiation within the stem tissue. The etiolated tissue was more sensitive to auxin treatments, and contained higher concentrations of endogenous auxin, compared to light-grown tissue. All of these effects should hasten the process of adventitious rooting either by aiding the development of root primordia or facilitating their easier emergence. Maynard and Bassuk (1987) experimented extensively with etiolation and banding and have been successful in increasing rooting percentages of a variety of species using this technique. Four-year-old seedlings of *Castanea mollissima* did not root at all when grown in light conditions, with or without the blanching effect of an applied band. The etiolated plants, however, rooted 44% without a band, and 100% with a band applied. Likewise, *Quercus coccinea* did not root under any treatment except the etiolated and banded treatment (46%) (Maynard and Bassuk, 1987).

Currently, most oaks used in the landscape are propagated by seed, with the resulting seedlings varying in traits (Drew and Dirr, 1989). Unfortunately, a good, quick method for asexual oak propagation has yet to be perfected. Tissue culture, although it has made great improvements recently (93% rooting of *Q. suber*), still takes well over 12 months with several subcultures every 4 weeks (Romano et al., 1992). This process would appear to be too expensive and labor intensive for the small nurseryman. Budding and grafting has only produced limited success (Hartmann, et al., 1990), while Drew and Dirr (1989) received moderate to poor success from various species using softwood and semihardwood cuttings.

OBJECTIVE

The objective is to develop an improved method for clonal propagation of *Quercus* species. Improving the rooting percentage of oaks would greatly aid research efforts that are trying to select for superior types to incorporate into the urban setting. Also a simple, effective propagation method would help the nursery industry in selecting those oak clones which show better pest resistance, branching habits, and fall color.

We manipulated stock plant juvenility and light levels during this project. We also employed the traditional, yet modified method of stooling. Our modification allowed new shoots which emerge from the cut back stock plant to be grown in complete darkness, compared to the traditional method of continually mounding around shoots as they grow in the light. Shoot tips were allowed to see light only after their bases had been mounded with soil following the initial etiolation phase. This would combine the acknowledged rejuvenating effect of stooling with etiolation at a crucial stage of stool shoot emergence.

Because propagation by cuttings is still the most cost-effective method (Davies and Hartmann, 1988), we wanted to see if this process would work for cuttings taken from etiolated seedlings. Here the shoots which emerge from the buds were totally etiolated for a short time as they grew to eventually be used as cuttings.

We looked at the effects of etiolated versus nonetiolated shoots, the effects of different IBA concentrations, and whether GA applications to force bud break affects rooting of cuttings.

MATERIALS AND METHODS

Stooling. Potted oaks 5 to 8 years old were brought into a 75F day/65F night greenhouse on 11 Jan., 1996 after they had received a 3-month-cold requirement at 36 to 38F. Just before bud break, the stems were removed just above the soil level

and half were placed under black cloth. Once etiolated shoots had elongated 10 to 20 cm, they were sprayed on their lower halves with 8000 ppm of IBA in two different carrier solvents, 50% aqueous ethanol and 20% aqueous DMSO.

A pot with the bottom cut out of it was placed over the top of the plant with its bottom resting on the soil. A light weight soilless potting mix was then filled in and around the etiolated shoots until they are completely covered. Shoots emerging from this soil were allowed to grow under normal light conditions. Eight weeks later, shoots were examined for root formation.

Cuttings. Acorns of *Q. bicolor* were sown in December 1995, and allowed to germinate and grow under normal greenhouse conditions. Once seedlings set bud they were sprayed with a solution of 500 ppm GA_3 dissolved in ethanol and water (15 : 85, v/v) in order to force subsequent bud break. Plants were sprayed every 3 days until bud swell. As buds began to swell, they were black clothed or grown in full light. When shoots elongated 10 to 15 cm, they were banded and slowly readjusted to light growing conditions over the period of 1 week. After 3 more weeks, shoots were removed just below the band, dipped in varying concentrations of IBA and stuck in a propagation bench under mist for rooting.

Dormant 1-year seedlings of various species were also brought into the greenhouse and forced to break bud. Just before bud break, they were black clothed and treated as the *Q. bicolor* seedlings above. Several oak species were used during the experiments, including, *Q. acutissima, Q. bicolor, Q. macrocorpa, Q. palustris, Q. robur,* and *Q. rubra.*

RESULTS AND DISCUSSION

***Quercus bicolor* Seedlings.** Buds enlarged and elongated approximately 1 week after the first application of GA_3 were used to induce a second flush of growth from which cuttings could be taken. Other researchers have shown an increased rooting percentage of cuttings treated with GA. Sagee, et al. (1990) applied a ring of 2.9 mM GA dissolved in a lanolin paste to the stems of hardened citrus shoots just before bud break. Cuttings were taken from the subsequent growth that emerged and were dipped in a 29.6 mM IBA rooting powder. Ninety percent rooting was achieved with this treatment compared to 19% rooting when shoots were treated with IBA alone. Ernstsen and Hansen (1986), however, found that when the apex of new cuttings of *Pinus sylvestris* were treated with an aqueous solution of GA_3 (2.0 mM) immediately following excision, rooting percentage was significantly decreased. In the current experiment we saw no significant difference between the etiolated (16.7% rooting) and the light grown shoots (9.3% rooting) (P=0.07). There was, however, a highly significant difference between the banded (17.6% rooting) and the unbanded (5.1% rooting) shoots (P=0.0025) (Table 1). This is very obvious with the light-grown plants, 0% rooting unbanded, compared to 27.8% rooting when the shoot was banded (Table 1). This may suggest that it is not solely the extent of etiolation during shoot development that influences adventitious rooting, but rather the etiolated state of the shoot at the time of excision that matters. It is no surprise that there was a significant difference between the 0 mM and the 19.7 and 39.4 mM IBA concentrations (P=0.005 and 0.03, respectively) (Table 1). Although the difference between the 0 mM and the 39.4 mM treatments was statistically significant, the lower rooting percent of the 39.4 mM may suggest that this concentration is super optimal to the

young shoots. However, it should also be noted that there is no significant difference between the 19.7 mM and the 39.4 mM IBA concentrations (P=0.17). Further research is needed to determine the optimal IBA concentration for cuttings of this species.

Table 1. Percent of shoots of *Quercus bicolor* which formed adventitious roots.

	Percent rooting				
	Etiolated		Light grown		
IBA (mM)	-B	+B	-B	+B	Total %
0	8.3[a]	11.1[a]	0.0	0.0	4.9
19.7	--	33.3[b]	0.0	27.8[b]	20.4
39.4	8.9[a]	16.7[a,b]	11.1[a]	16.7[ab]	13.2
Total %	8.3	20.4	3.7	14.8	

Treatments with the same letter were not significantly different at the P=0.05 level .
+B = banded; -B= unbanded.

Based on these results, we would expect the banded shoots treated with 19.7 mM IBA to root with the highest percentage. This, in fact, was the case with the etiolated plants. The etiolated, banded, and 19.7 mM IBA percent rooting (33%) is two times greater than either of the similar treatments (etiolated, banded, 0 mM — (11%), etiolated, banded, 39.4 mM — (16.7%), and over a standard error away. The light-grown plants were not quite so convincing. Although the light-grown, banded, 19.7 mM IBA-treated cuttings had the highest percent rooting (27.8%), it was not significantly higher than the 39.4 mM (16.7%). Based on these results, it appears that cutting propagation of *Q. bicolor* should be approached using the banding technique, with or without etiolation, and a quick dip of 19.7 mM IBA in 50% ethanol.

Future research should concentrate on reducing the instances of iron chlorosis in the stock plant. Based on current research in a separate experiment using *Quercus bicolor*, and a similar procedure, we expected much higher than the 33% rooting which was achieved here. Despite the weekly application of fertilizer with micronutrients and the foliar application of ferrous sulfate, nearly all of the shoots exhibited symptoms of iron chlorosis. The chlorosis in some of the shoots was so severe that they were completely white. A nutrient analysis of these white shoots revealed an iron concentration of 12 $\mu g\ g^{-1}$ dry weight compared to 276 $\mu g\ g^{-1}$ dry weight in a nonchlorotic shoot.

Rooting of Cuttings from 1-Year-Old Plants. *Quercus bicolor* rooted at much higher levels in this experiment, suggesting that iron chlorosis in the seedlings was a highly significant factor in depressing rooting percentage. Treatments of *Q. bicolor* plus *Q. macrocopa*, *Q. palustris*, and *Q. robur* consisted of etiolated and light-grown

Table 2. Percent rooting of shoots from 1-year-old stock plants of four *Quercus* species.

Species	Treatments +E+B+GA	+E+B-GA	+E-B+GA	+E-B-GA	-E+B+GA	-E+B-GA	-E-B+GA	-E-B-GA	Average
bicolor	90.9 (9)[A]	80.0 (13)	45.5 (15)	55.6 (17)	100.0 (0)	72.7 (14)	36.4 (15)	30.8 (13)	64.0
macrocarpa	88.9 (11)	50.0 (28)	40.0 (24)	40.0 (24)	50.0 (18)	0.0 (0)	0.0 (0.)	0.0 (0)	33.6
palustris	92.3 (7)	83.3 (11)	77.8 (14)	84.6 (10)	75.0 (13)	78.6 (11)	70.6 (11)	58.8 (12)	77.6
robur	50.0 (16)	61.5 (14)	7.1 (7)	0.0 (0)	29.7				
Average	70.4	56.4	54.4	60.1	75.0	50.4	26.8	22.4	

Abbreviations: +E = etiolated, +B = banded, +GA = sprayed with GA_3, -E = light grown, -B = no band applied, -GA = no GA_3.
Number in ( ) is standard error.

Table 3. Rooting percentage of greenhouse grown oak stoolbeds.

	Etiolated					
	DMSO			Ethanol		
	Shoots rooted/total	Percent	Std. error	Shoots rooted/total	Percent	Std. error
Q. acutissima	1/1	100.0	0	3/24	12.5	6.8
Q. bicolor	14/31	45.2	8.7	3/24	12.5	6.8
Q. macrocarpa	5/7	71.4	17.1	6/10	60.0	15.5
Q. palustris	3/3	100.0	0	1/2	50.0	35.4
Q. robur	13/14	92.9	6.9	9/24	37.5	9.9
Q. rubra	1/4	25.0	53.5	3/6	50.0	20.4
	37/60	61.7	6.3	22/66	31.9	5.6

	Light grown			
	DMSO		Ethanol	
	Shoots rooted/total	Percent error	Shoots rooted/total	Percent error
Q. acutissima	0/24	0	0/25	0
Q. bicolor	0/14	0	0/9	0
Q. macrocarpa	0/4	0	-	0
Q. palustris	0/30	0	0/28	0
Q. robur	0/4	0	0/7	0
Q. rubra	0/76	0	0/69	0

stockplants both of which were banded or not banded when shoots reached 5 to 7 cm. Before bud break half the stockplant buds were sprayed with 500 ppm GA_3 at 3-day intervals until bud break occurred. All cuttings received an IBA quick dip at 8000 ppm.

Again, *Q.bicolor* showed a consistently positive effect of banding without a clearly beneficial effect of either GA_3 or etiolation (Table 2). With *Q. macrocorpa,* etiolation plus banding plus GA_3 gave the highest rooting percentage (89%) while two out of the three treatments showed an intermediate effect. Shoots from light-grown plants without GA_3, regardless of banding showed no rooting.

Q. palustris showed reasonably good rooting with all treatments; the sole poorly rooting treatment occurring in the light-grown, unbanded and no GA_3 group. Even with only four of the eight treatments, *Q. robur* showed a clearly beneficial effect of etiolation.

Stoolbed Results. The modified greenhouse-grown stoolbeds showed some intriguing possibilities that warrant further research. Although previous researchers have shown no benefit from using stooling to propagate oaks, our modification using etiolated shoots and more penetrating carriers of IBA appears to have much promise. As the buds began to swell on the cut back plants, half were put under black cloth and half were light grown. When shoots reached 10 to 20 cm half of the shoots of each light treatments were sprayed on their lower halves with 8000 ppm IBA dissolved in 20% DMSO and the other half in 50% aqueous ethanol prior to mounding with soilless medium. Shoots were uncovered and rated for rooting after 8 weeks. None of the light-grown stool shoots rooted regardless of IBA carrier treatments (Table 3). The pre-etiolated shoots showed some impressive rooting. Of the species with reasonable replication, *Q. bicolor, Q. macrocarpa*, and *Q. robur*, rooting percentages in the DMSO treatment were 45.2%, 71.4%, and 92.9%, respectively (Table 3).

The ethanol treatment was lower in most all cases. Taking all the species together, DMSO increased rooting about 100% from 31% with ethanol to 61% with DMSO.

Further work examining the results of manipulating juvenility, IBA and light levels in oak propagation are being planned.

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DAVE BAKKER: What is the concentration of your DMSO?

NINA BASSUK: 20%.

CHARLES HEUSER: What was your survival?

NINA BASSUK: About 75% but we are not concentrating on survival at this time.

Looking to the Future

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INTRODUCTION

Many changes have occurred since the initial meeting of this Society in 1953. Currently, concern exists regarding whether the direction programs are taking has remained relevant to the membership. Those currently responsible for the I.P.P.S. Eastern Region annual meeting program want to provide meaningful information for the membership. However, it is members who will ultimately determine the future of I.P.P.S.

I was asked to look at past programs from the North American regions. Hopefully, the resulting analysis will provide insight into not only how Eastern Region programs have evolved but also into those of Southern and Western Regions.

MATERIALS AND METHODS

In doing this analysis, I established four arbitrary categories for presentations:

- Propagation.
- Cultural practices including irrigation, pests, fertilizer, etc..
- Strictly plant presentations with essentially no culture or propagation information.
- Other presentations which include everything else such as talks on medicinal, marketing, etc.

Categories were determined by reading the title of a presentation and, when the title was insufficient, referring to the proceedings. Any success was due to the generosity of R. T. Bullington who willed me his complete proceedings.

I counted the number of programs in each category for each North American region during this decade, in 1981 and in 1971. I felt that this would give us some insight into recent trends as well as provide the opportunity to compare recent programs to those of 15 and 25 years ago. These years are a convenient milestone plus, I think, give us valid comparisons with other regions. Western Region was formed in 1959 with presentations included for the first time in the Combined Proceedings in 1963. By 1971, they were firmly established. Southern Region was formed in 1976. By 1981 Southern Region programs were established.

RESULTS AND DISCUSSION

From its inception, Southern Region has had fewer papers presented than either Western or Eastern. They have averaged a total of 19 presentations per annual meeting during the years evaluated with numbers declining in recent years. They will have 15 formal presentations at the meeting in Louisiana next week. Western Region has averaged 25.5 with 25 scheduled for 1996. Eastern has averaged 30.2 with 30 scheduled this year.

The percentage of presentations at the annual meeting focusing on propagation has ranged from 20% to 86%. Eastern Region has averaged 58% for the years considered with the average being 51.7% for the 1990s. Western, the next oldest North American Region, has averaged 47.8% with 41.9% for the 1990s. Southern

has averaged 39.4% with 38.6% in the 1990s. There has been a decline in the percentage of propagation programs at annual meetings from 15 and 25 years ago in the Eastern and Western Regions. Except for 1996, in which the percentage is an all time low of 20%, Southern Region has remained fairly constant since its beginning.

The percentage of cultural practices presentations at annual meetings has been highest in the Southern Region with an average of 37.9% for the 1990s. In the Western and Eastern the percentages have been highly variable. However, the Western Region has consistently had more presentations on cultural practices than the Eastern Region. Their average for the 1990s was 32.6% while Eastern Region has averaged 20.6% cultural practice programs at the annual meeting.

The number of plant programs at annual meetings has been highly variable. In 1971, Western Region had none. In 1991 they had none again and Southern Region had none in 1994. However, at times both of these regions have had plant programs comprising 20% or more of their annual meeting. Eastern Region, on the other hand, has had at least one program devoted solely to plants at their annual meeting in each year considered with an average of 13% of the total annual meeting presentations being on plants in the 1990s. The trend to include programs exclusively on a particular plant or group of plants has been increasing in all regions for the past couple of years.

The "other" category has been highly variable in Eastern Region, averaging 18.8% in the 1990s. Southern Region averaged 15.4% and Western averaged 16.7% of their annual meeting filled with these diverse programs. This is a dramatic increase from programs 15 and 25 years ago when one "other" or none was normal. This increase in "other" programs probably reflects the diversity of issues facing modern nurserymen.

CONCLUSIONS

There is no right or wrong here. Regions are not in competition to have the "right" program. In Eastern Region, we have changed the days of the week when we meet, the months when we meet, the nature and timing of our tours, and many other components that make up our annual meeting. Here, I just considered program numbers and content.

All I have done is show you what has happened and tried to answer those who have said we are changing too fast and those who think we are not changing fast enough. The truth is that, except for an occasional year with a dramatic emphasis on a particular "hot" topic, we haven't changed a great deal in recent years.

Eastern and Western Regions tend to be more purists in that they focus more on propagation topics while Southern Region has tended to emphasize cultural practices. The number of programs focusing primarily on plants has generally increased slightly in the Eastern Region while fluctuating from no strictly plant presentations to 20% of the annual meeting in both Southern and Western Regions. "Other" programs have increased in all regions . . . probably reflecting the diversity of the membership and its interests.

We need to consider questions about change in I.P.P.S. Does Eastern Region want to continue to have a larger number of presentations and high percentage of propagation topics? Do we want to have a higher percentage of presentations on cultural practices each year like Southern Region does? Do we want to continue to increase the percentage of papers that tell us about our product and often one of our passions, i.e., plants? Please share your views with each upcoming program chair and the Board.

The Propagation of Lesser Known and Unusual Maple Species

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INTRODUCTION

Urban trees are highly valued by urban populations although their lifespan is often severely curtailed. Lack of adequate planting space is perhaps the single most difficult problem that urban trees face as they continue to be squeezed into seemingly impossible situations. Soil in these sites is often quite compacted, preventing root growth while pavement further complicates the situation by preventing precipitation from reaching the root zone. As a result, trees can be left with less than adequate soil moisture for satisfactory growth. What water does get into the root zone may be contaminated by road salt providing even more stress. To make matters even worse, the abundance of concrete in buildings and sidewalks drives soil pH to very high levels limiting the availability of iron, manganese, and zinc (Craul, 1992).

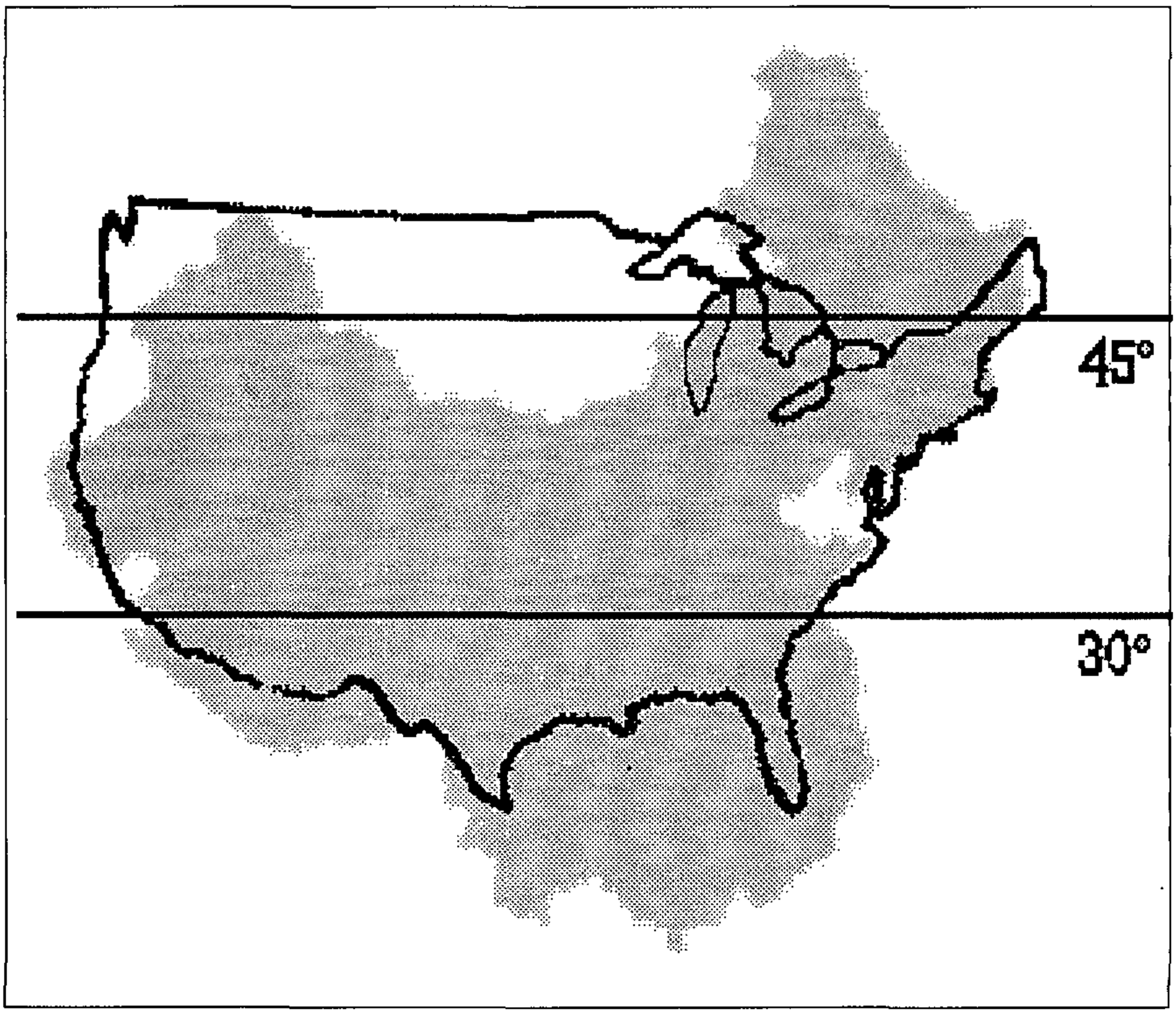

Figure 1. Similarity in latitude between North America and China.

Table 1. Purported tree characteristics.

Acer species	USDA zone	Height	Habitat	Fall color	Origin	High pH	Comments
carpinifolium	3-4	7-8 m	Small tree	Yellows and browns	China	Yes	The most unusual leaf of the maples, more beech like than maple. Very thick lustrous leaves with a beautiful texture.
cissifolium	5	10-12 m	Tree	Yellow, pink, and orange	China and Japan	Yes	Related to the American box elder but not invasive, trees are either male or female, excellent compact branching habit.
glabrum	3-4	7-8 m	Small tree	Yellow, reds, and orange	Western U.S.	?	Extremely variable in habit and possibly, hardiness. Ranges over a wide variety of habitats from Alaska to Mexico. Red twigs in the winter and very colorful in the fall.
mandschuricum	5	8-10 m	Tree	Yellow, red, an orange turning to dark pink	China and Siberia	?	Related to *A. griseum* but much more tolerant of drought and more cold hardy. Fine texture foliage resembles bamboo. Colors up earlier than most trees.
miyabei	5	10-12 m	Tree	Yellow	Japan	Yes	Uniform in habit since most material originated from one source. Hybridizes with *A. campestre* and can often be difficult to differentiate hybrids from the true species. Possess all the virtues of *A. campestre* but grows more upright.

monspessulanum	4-5	6-12 m	Tree	Yellow, pink, red, and orange	Western and Central Europe	Yes	Highly variable, most forms known are bushy and slow growing while others grow rapidly into excellent small trees
pseudosieboldianum	4	10-12 m	Tree	Brilliant yellow, red, and orange	China	?	Closely related to *A. palmatum* but significantly more drought tolerant and cold hardy
truncatum	5	8-10 m	Tree	Yellow, red, orange	China	Yes	Extremely variable in leaf form, habit and possibly, hardiness Apparently only one form in the trade Crosses with *A. platanoides* (e.g 'Pacific Sunset' and 'Norwegian Sunset'

Obviously with all these adversities it makes sense to think carefully about tree selection in the urban environment. Trees must not only be adaptable to city life but they must also be able to fit in the limited spaces often afforded urban trees. Tall growing trees must be frequently pruned away from utility lines and large vigorous roots may heave sidewalks and clog pipes.

Where do we look for tough trees that can stand up to all the hardships associated with city living? All trees used for planting originally came from the wild yet nowhere have trees evolved to grow in cities. What makes some species more urban adaptable than others are the attributes which made them successful in their native habitats which may mimic certain urban environments. By carefully observing the climate and soil profiles of a region, likely locations with potentially good trees can be found. One such place has provided a wealth of horticultural treasures and is not about to stop yielding surprises is China (Zhang and Jia, 1992). The most interesting feature of China is that in addition to tropical and subtropical regions it also has many temperate areas with similar climates to those in the United States. From Figure 1 the similarity in latitude between North America and China is apparent.

However, due to the local weather patterns and the moderating effect of the ocean, China's climate is a bit more mild around the coastal region compared to regions of the United States with similar latitudes. The most promising areas are the inland, northeastern regions which are colder and dryer (Chang and Yang, 1993). China is a very unique place which not only has an abundance of calcareous-based soil (Wang and Zhu, 1990) in the north but it is also known for its harsh summers and winters (Chang and Yang, 1993; Gilbert, 1994).

Moreover, this region also has a very unique geologic history. Fortunate to have been spared by the worst of the last major glacial episode, it possesses flora that had been extirpated from other temperate regions around the northern hemisphere (Li, 1992). China is a botanical wonderland full of hardy plants which are well adapted to some of the harshest conditions encountered in temperate North America (Xie et al., 1991; Zhang and Jia, 1992).

However, China is not the only place to find good plant material. The Mediterranean regions of the world are full of plants which are naturally adapted to drought. What's more, not all Mediterranean regions are warm year round so there are some places with winter temperatures similar to temperate North America. Also of important consideration is that many regions in Turkey, Greece, Italy, and France possess calcareous soil. Last but not least there are some locations in North America such as the eastern side of the Rocky Mountains which due to altitude, shadow effects, and calcareous soil conditions (Eicher and Diner, 1989) also possess potential sources for urban trees.

MATERIALS AND METHODS

Once a region has been selected and potential urban trees identified, their propagation, testing, and introduction to the trade comes next. All too often, there have been many good plants which were rarely available due to difficulties in their propagation. Here we have chosen several species of *Acer* to work with based on studies of their native habitats, reported characteristics and landscape preferences (Gelderen, 1994; Dirr, 1993; Fang, 1939; Hortorium, 1976). A summary of these characteristics is presented in Table 1.

Where stock plant material was available, we used the techniques of etiolation and

Table 2. Good rooting potential.

Acer species	Source of cuttings	IBA (ppm)	Light grown (%)	Light grown with band (%)	Etiolation (%)	Etiolation and band (%)	Plant age
carpinifolium	Greenhouse	0	15.0±7.64*				4-5 years
		1000	38.3±8.50				
		5000	85.0±7.64	90.0±4.08	93.2±4.86	95.0±3.34	
		10,000	33.0±9.37				
	Field	0	48.4±8.96				~90 years
		1000	41.2±5.96				
		5000	88.6±4.89				
		10,000	86.6±3.76				
cissifolium	Field	0	51.1±10.06				~60 years
		1000	90.0±5.38				
		5000	94.0±3.06				
		10000	83.3±6.05				
truncatum	Greenhouse	0	51.1±10.06	44.4±11.44			4 years
		1000	56.0±11.47	84.0±8.84			
		5000	24.5±8.83	43.5±8.63	74.6±7.18	88.0±9.98	
		10,000	32.5±10.06	39.4±9.07			
	Field	0	0.0				~16 years
		1000	15.8±5.61				
		5000	21.3±6.10				
		10,000	15.7±7.55				

*=Percent rooted ± standard error.

Table 3. Moderate rooting potential.

Acer species	Source of cuttings	IBA (ppm)	Light grown (%)	Etiolation and band (%)	Plant age
glabrum	Greenhouse	0	45.8±9.35*		4-5 years
		1000	36.7±10.68		
		5000	46.9±6.46		
		10,000	34.2±9.79		
	Field	0	16.5±15.9		~30 years
		1000	15.8±18.48		
		5000	9.0±11.7		
		10,000	19.3±18.6		
monspessulanum	Greenhouse	5000	23.3±9.19	41.7±10.85	4 years
	Field	0	10.0±4.47		~100 years
		1000	32.8±8.58		
		5000	52.0±11.15		
		10000	25.7±7.54		

*= Percent rooted ± standard error.

banding described by Maynard and Bassuk (1987). However some plant material was difficult to acquire so only basic softwood cutting propagation was employed.

The work involved containerized stock plants which were 3 to 5 years of age. They were given 3 months of chilling in a 36 to 38F cooler and were then brought out of dormancy starting in February into a 68F day and 58F night greenhouse. Half of the plants were enclosed in a tent made of a double layer of black cloth to exclude all light (etiolation treatment) and the other half were grown in full light. Shoots soon emerged and half of the light grown and the etiolated shoots were banded as soon as they were 2.8 cm or more with a 2.5 by 2.5 cm band of black Velcro™ (Maynard, 1987). Immediately after, one side of the etiolation tent was gradually pulled up day by day over 1 week until the etiolated plants were exposed to full light. After 3 weeks, shoots were taken and made into cuttings. All except for the controls were dipped for 20 sec in various concentrations of IBA dissolved in 50% aqueous ethanol. Cuttings were then stuck in peat and perlite medium (1 : 2, v:v) under intermittent mist. Rooting occurred in 3 to 4 weeks.

RESULTS AND DISCUSSION

Results are divided into three groups based on ease of rooting: Good Rooting Potential, Moderate Rooting Potential and Minimal Rooting Potential (Tables 2, 3, 4). *Acer carpinifolium, A. cissifolium,* and *A. truncatum* are listed in the first table: Good Root Potential. Greenhouse-grown cuttings of *A. carpinifolium* rooted 15%, 38.3%, 85%, and 76.7% respective to hormone levels of 0, 1000, 5000, and 10,000 ppm. Further results were obtained, with light-grown banded, etiolated, and banded + etiolated treatments using 5000 ppm IBA; they were: 90%, 93.2%, and 95% respectively. Field-collected cuttings of *A. carpinifolium* from a nearly 90-year-old tree rooted 48.4%, 41.2%, 88.6%, and 86.6% respective to hormone levels of 0, 1000, 5000, and 10,000 ppm. The next species, *A. cissifolium* rooted 51.1%, 90%, 94%, and 83.3% respective to hormone levels of 0, 1000, 5000, and 10,000 ppm. The age of the tree which provided the cuttings was approximately 60 years old. Lastly, *A. truncatum* rooted 51.1%, 56%, 24.5%, and 32.5% respective to hormone levels of 0, 1000, 5000, and 10,000 ppm. Further results were obtained just with light-grown banded cuttings at 0, 1000, 5000, and 10,000 ppm IBA; they were: 44.4%, 84%, 43.5%, and 39.4%, respectively. Etiolation and 5000 ppm IBA resulted in 74.6%, rooting while etiolated + banded rooted 88.0%. Field-collected cuttings of *A. truncatum* from several 16-year-old trees rooted 0%, 15.8%, 21.3%, and 15.7% respective to hormone levels of 0, 1000, 5000, and 10,000 ppm.

The Moderate Rooting category includes the species *A. glabrum* and *A. monspessulanum*. Greenhouse-grown cuttings of *A. glabrum* rooted 45.8%, 36.7%, 46.9%, and 34.2% respective to hormone levels of 0, 1000, 5000, and 10,000 ppm. Field-collected cuttings rooted 16.5%, 15.8%, 9.0%, and 19.3% with respect to 0, 1000, 5000, and 10,000 ppm of IBA. Light-grown cuttings from greenhouse-grown stock of *A. monspessulanum* rooted 23.3 % when treated with 5000 ppm IBA while etiolated + banded cuttings rooted 41.7%. Field-collected cuttings rooted 10%, 32.8%, 52%, and 25.7 with respect to 0, 1000, 5000, and 10,000 ppm treatments of IBA.

The last category includes *A. mandschuricum, A. miyabei,* and *A. pseudosieboldianum*. Greenhouse-grown cuttings of *A. mandschuricum* rooted 0%, 3%, 16%, and 33% with respect to 0, 1000, 5000, and 10,000 ppm of IBA. Field-

Table 4. Minimal rooting potential.

Acer species	Source of cuttings	IBA (ppm)	Light grown (%)	Light grown with band (%)	Etiolation (%)	Etiolation and band (%)	Plant age
mandshuricum	Greenhouse	0	0.0				4-5 years
		1000	3.0±2.04*				
		5000	16.0±6.87	29.0±9.54	63.0±11.2	85.0±4.15	
		10,000	33.0±9.37				
	Field	0	0.0				~90 years
		5000	0.0				
miyabei	Greenhouse	0	2.5±2.5	5.7±3.45			4 years
		1000	8.6±5.95	17.1±14.23			
		5000	0.0	16.7±9.54	40.0±12.4	57.1±13.4	
		10,000	7.5±5.26	17.1±8.59			
	Field	0	4.5±3.03				~10 years
		1000	29.1±7.31				
		5000	33.3±10.0				
		10000	19.0±6.05				
pseudosieboldianum	Greenhouse	0	1.4±1.4	0.0			4-5 years
		1000	5.3±4.06	9.7±5.42			
		5000	9.2±5.33	26.4±10.16	54.8±12.2	55.0±10.3	
		10,000	18.1±7.83	38.1±10.13			

Field-tree 1	0	14.3±0.0	16 years
	1000	31.0±2.39	
	5000	58.3±8.36	
	10,000	60.7±10.75	
Field-tree 2	0	0.0	16 years
	1000	0.0	
	5000	0.0	
	10,000	0.0	
Field-tree 3	0	0.0	16 years
	1000	0.0	
	5000	0.0	
	10,000	0.0	
Field-tree 4	0	0.0	16 years
	1000	0.0	
	5000	0.0	
	10,000	14.3 ±14.33	

*= Percent rooted ± standard error.

collected cuttings treated with 5000 ppm produced 0% rooting. Greenhouse-grown cuttings of *A. miyabei* rooted 2.5%, 8.6%, 0%, and 7.5% with respect to 0, 1000, 5000, and 10,000 ppm of IBA. Further results were obtained just with banding, and 0, 1000, 5000, and 10,000 ppm IBA; they were: 5.7%, 17.1%, 16.7%, and 17.1%. Etiolation, and 5000 ppm IBA resulted in 40% rooting while etiolation + band rooted 57.1%. Field-collected cuttings of *A. miyabei* from a 60-year-old tree rooted 4.5%, 29.1%, 33.3%, and 19.0% respective to hormone levels of 0, 1000, 5000, and 10,000 ppm. Lastly, greenhouse-grown cuttings of *A. pseudosieboldianum* rooted 1.4%, 5.3%, 9.2%, and 18.1% with respect to 0, 1000, 5000, and 10,000 ppm of IBA. Further results were obtained just with banding, and 0, 1000, 5000, and 10,000 ppm IBA; they were 0%, 9.7%, 26.4%, and 38.1%. Etiolation, and 5000 ppm IBA resulted in 54.8% rooting while etiolation+band rooted 55%. Out of four 16-year-old, field-grown trees, only one produced relatively fair rooting percentages of 4.5%, 29.1%, 33.3%, and 19.0% respective to hormone levels of 0, 1000, 5000, and 10,000 ppm. Two did not root with any or the four hormone levels previously mention but the last one did root 14% with 10,000 ppm IBA.

It appears that the addition of some combination of etiolation, and banding significantly increased rooting in all but the easiest-to-root species. With further research the appropriate combinations of light, and IBA will be determined.

The genus *Acer* is diverse in form and habit; represented by species form all parts of the northern hemisphere. Only a handful were mentioned here due to limited availability of stock plants for our research. Even though many of these trees may require some not-so-traditional means of propagation such as etiolation or banding, they deserve to be propagated not only for ornamental purposes but because the may prove to be adaptable urban trees. For the most difficult-to-root species it is good to know that etiolation or banding can provide better rooting, and in some instances the combination of the two techniques provides exceptional results. Further, the different rooting abilities noted with *A. pseudosieboldianum* demonstrate the need for cultivar selection for characters such as rootability.

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Bare-Root Shade Tree Whip Production in Containers with Special Reference to Red Oak

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INTRODUCTION

The Ohio Production System (OPS), a method for producing shade tree whips in containers, was first described in these proceedings (Struve et al., 1987). Under OPS conditions, seeds are germinated and seedlings produced in SpinOut™-treated quart containers in a heated greenhouse. The greenhouse period lasts 10 weeks, February to May. After the last frost, seedlings are moved outdoors under shade for 1 week and then potted into SpinOut-treated No. 3 nursery containers. After up-canning, whips are produced by tying and staking the terminal shoot as under field production. Growth can be rapid; 2 m (about 6 ft) tall red oak can be produced by October. Whips can be fall transplanted, or overwintered in containers in polyhouses or held as bareroot material in refrigerated storage and then transplanted in spring. Many species can be produced via OPS (Struve et el., 1994).

One disadvantage of OPS whips is their bulk, relative to bare-root whips. If bare-root whips could be produced in containers, then the survival and high re-growth potential of container stock could be combined with the handling ease of bareroot stock. This paper describes media suitable for bareroot whip production, overwintering alternatives, mineral nutrition, transplant survival and re-growth potential of container-produced bareroot whips.

MEDIA

Originally, a pine bark, peat, Comtil (composted municipal sewage sludge, City of Columbus, OH) and sand (3 : 0.5 : 0.5 : 1, by volume) container medium was used. However, the pine-bark-based medium was unsuitable for bareroot production because it did not readily separate from the roots. Several media were developed that would readily separate from a plant's roots (Table 1 and Struve and McCoy, 1996). Plants grown in these media were barerooted by shaking the plants three or four times causing the media to fall off the roots. Because of lower bulk density, rice-hull-based media are preferred over sand-based media. All media had acceptable physical and chemical properties (Struve and McCoy, 1996). The standard medium now used is rice hull and Comtil (3 : 1, v/v).

ROOT SYSTEM MORPHOLOGY

Whips grown in the bareroot media have fibrous root systems with many intact root tips. The increased density of the root system is attributed to a well aerated medium and to the root-pruning effect of SpinOut-treated containers.

OVER WINTERING ALTERNATIVES AND TRANSPLANT SURVIVAL

Bareroot red oak whips can be successful overwintered by lining out in mid October, by placing containerized whips in a polyhouse followed by spring barerooting and

lining out, or by barerooting in early winter (December), placing the whips in refrigerated storage, and lining out in spring (Struve, 1996). In one study, red oak whip survival was excellent; only one of 220 whips died (Struve, 1996). Average height increased 97 cm (38 in.) the first season after lining out and 89 cm (35 in.) the second season.

Table 1. List of media suitable for containerized bareroot whip production. All media support rapid growth under Ohio Production System conditions and separate readily from plant root systems.

Media	Ratio of components (by vol)
Sand : Comtil[w] : Isolite[x]	3 : 1 : 1, 2 : 1 : 2, 2 : 2 : 1
Sand : Comtil : Zeolite[y]	3 : 1 : 1, 2 : 1 : 2, 2 : 2 : 1
Rice hull[z] : Comtil : Isolite	3 : 1 : 1, 2 : 1 : 2, 2 : 2 : 1
Rice hull : Comtil : Zeolite	3 : 1 : 1, 2 : 1 : 2, 2 : 2 : 1
Rice hull : Comtil	1 : 1

[w] Comtil is composted municipal sewage sludge obtained from the City of Columbus, OH.
[x] Isolite, Grade CG 2, Sumitomo Corp. of America, Denver, CO.
[y] Zeolite, a crystalline, hydrated alumino-silicate clinoptilolite mineral, Teague Mineral Products, Adrian, OR.
[z] Rice hull, Dock Site, Warsaw, IL.

MINERAL NUTRITION AND EFFECT ON RE-GROWTH POTENTIAL

Various fertilization methods were tested to determine optimum nutrition for whip production (Struve, 1995). A combination of 60 g (4 tbsp) per container of controlled-released fertilizer (21N-4P_2O_5-10K_2O, Woodace) supplemented daily with 3.8 liter (1 gal) of 25 ppm N from water soluble fertilizer (Peter's, 15N-16P_2O_5-17K_2O) resulted in the largest red oak whips. However, the efficiency of plant N recovery ranged from 4.1% to 8.1%. In general, the lower the rate of fertility, the higher the rate of N recovery. Unfortunately, high N recovery (i.e., low fertility treatment) did not yield vigorous growth. Growers have a dilemma; increasing the fertilizer rate increases plant growth, but also increases the potential for nutrient loss. Whips under the higher fertility levels grew taller after lining out than plants grown at lower fertility levels (Table 2). Whips receiving a combination of 60 g slow-release fertilizer per container and season-long 25 ppm N fertigation maintained their first-year height advantage for 2-years after transplanting, even though all whips received 9.8 kg N m^{-2} $year^{-1}$ (2# N 1000^{-1} ft^2 $year^{-1}$) after transplanting (Table 2).

Recent research has indicated that daily fertigation with 3.8 liter of 200 ppm N from 20N-20P_2O_5-20K_2O water-soluble fertilizer for 3 to 4 weeks after up-canning followed by fertigating once weekly with 3.8 liters of 200 ppm N gives growth similar to season-long (1 June to 1 Sept.) daily fertigation with 3.8 liters of 200 ppm 20N-20P_2O_5-20K_2O (Struve, unpublished data). This fertility program reduces N application by five fold (69.9 g vs. 12.2 g N) without significantly reducing plant growth.

Table 2. Influence of first year fertility program on red oak whip height, plant percent N recovery, and height 2 years after lining out.

Media	Fertilizer treatment	Whip height (cm)	Height (cm) after lining out	
			First year	Second year
Pine bark[z]	SR[y]	42	121	160
	WS[x] + SR	62	170	208
Bare root[w]	SR	40	140	180
	SR + WS	60	170	202

[z] Pine bark medium: 3 : 0.5 : 0.5 : 1 (by volume) pine bark, peat moss, Comtil (composted municipal sewage sludge), and sand.

[y] Woodace 21N-4P_2O_5-10K_2O slow-release fertilizer top dressed at 30 g (two 15 g [tablespoon] applications; June and mid July) per container.

[x] Plants were fertilized daily with 3.8 liter day at 25 ppm N from Peter's 15N-16P_2O_5-17K_2O water-soluble fertilizer from 1 June 1 to 30 Sept.

[w] Bare root medium: 2 : 2 : 1 or 2 : 1 : 2 (by volume) rice hulls (Dock Site, Warsaw, IL.) : Comtil : Isolite (Grade CG 2, Sumitomo Corp. of America, Denver, Colorado) : or Zeolite (a crystalline, hydrated alumino-silicate clinoptilolite mineral, Teague Mineral Products, Adrian, Oregon).

POSSIBLE REASONS FOR INCREASED SURVIVAL AND RE-GROWTH POTENTIAL OF CONTAINER-GROWN BAREROOT WHIPS

There are at least two reasons for high survival and re-growth potential of container-produced whips: rapid root regeneration and retention of carbohydrates and mineral nutrients.

Rapid Root Regeneration from Intact Root Systems. Plants grown under OPS conditions retain high root regeneration potential. Circling root development is inhibited with the use of SpinOut-treated containers, so corrective root pruning before transplanting is reduced. There are many rapidly regenerating intact root tips present at transplanting (Arnold and Struve, 1987). Thus root regeneration and establishment are rapid.

Retention of Storage Compounds. Root loss at harvest in field-grown plant material is great (Watson and Sydnor, 1987). The great root loss and corresponding diminished water-absorbing ability are factors contributing to transplant shock. Another contributing factor to transplant shock is the significant loss in carbohydrates and mineral nutrients to the plant when roots are pruned. Root pruning red oak seedlings reduces plant weight by 42% to 50% and root dry weight by 48% to 61% (Struve and Joly, 1992). Carbohydrates constitute 20% to 40% of root weight (Farmer, 1975, Larson, 1978) and roots of dormant red oak seedlings contain 80% of the plant's nitrogen (Struve, unpublished data). Thus root loss at harvest reduces the plant's carbohydrate and mineral nutrient reserves.

In conclusion, bareroot whip production in containers combines the high survival and re-growth potential of container stock with the handling ease of bareroot stock,

offering a viable alternative to field-produced bareroot liners. Further, difficult-to-transplant species can be successfully produced and transplanted using OPS.

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Ornamental Seed Production in Field Cages with Insect Pollinators[1]

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RATIONALE

The North Central Regional Plant Introduction Station (NCRPIS), located at Iowa State University in Ames, is one of the primary sites of the U.S. National Plant Germplasm System (Roath et al., 1990; White et al., 1989). The NCRPIS specializes in the management of germplasm of agronomic and horticultural crops and their wild relatives that are primarily allogamous (outbreeding). Each year, crop-specific curators at the NCRPIS regenerate seeds of hundreds of germplasm accessions in the field and under glass, controlling pollination to preserve the genetic integrity of the collections. Pollinations for some crops, such as pumpkins, domesticated sunflowers, and corn, are made by hand. A few others, such as amaranths and chenopods, can be regenerated in plastic tents without special pollinators (Williams and Brenner, 1995), provided there is some air movement in the tents. But most crops maintained at the NCRPIS are insect pollinated in nature and their flowers are tedious to pollinate by hand.

In the late 1970s, researchers at the NCRPIS developed a field-cage system wherein managed populations of insects pollinate germplasm accessions (Ellis et al., 1981). The system had to be sufficiently sturdy to withstand midwestern wind and storms, quickly assembled and disassembled, and readily storable when not in use. Ideally, the system would also consist of widely available, inexpensive materials. Prototypes of our field cages, when used with nucleus boxes of honeybees, generally produced so much more seed per investment when compared to hand pollinations that, by the early 1980s, the NCRPIS adopted this system for many crops and began to refine it. Beyond the increased seed production, there were secondary benefits resulting from this system. The cages protect the plants from herbivorous insects that either cause direct damage or serve as pathogen vectors and from birds and mammals that consume the fruits and seeds.

Although many International Plant Propagators' Society members propagate plants by seed, many purchase their seeds from outside suppliers. Those that do produce seeds in house generally rely on spatial and temporal isolation to preserve the seeds' genetic purity. Such methods greatly restrict the number of populations of any one species that can be regenerated per year. For insect-pollinated species, effective pollinators may not be present in sufficient numbers at the proper time for pollination. And for those species with fleshy or nutritious fruits and seeds, birds or other animals may reduce seed harvest when unprotected. Taken together, these advantages suggest that our field-cage and insect-management methods should be valuable to commercial propagators, who seek to produce "genetically pure" seeds.

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FIELD CAGES

The cages now in use at the NCRPIS are constructed of 1.3-cm (0.5-in.) diameter galvanized pipe frames, connected by key clamps, and covered with one-piece UV-resistant lumite mesh fabric. The edges of the mesh screens are buried in trenches that are dug around the frames. Entry to the cages is through Velcro-sealed openings in the screens.

There are two standard cage sizes. We have about 1000 cages measuring 1.6 m × 1.6 m × 6.5 m (5.25 ft × 5.25 ft × 21.33 ft) (height × width × length) for plants that grow less than about 1.5 m (5 ft) tall. For taller plants, such as wild sunflowers, hollyhocks, and many shrubs, we have about 120 3.2 m × 3.2 m × 6.5 m (10.5 ft × 10.5 ft × 21.33 ft) cages. These larger cages require interior cable bracing to enable them to withstand high winds.

POLLINATING INSECTS

Both bees and flies have been used to pollinate the plants in the field cages. In most cases, we employ queened honeybee (*Apis mellifera*) colonies housed in specially designed, 16.8 cm × 26.9 cm × 48.5 cm (6.6 in. × 10.6 in. × 19.1 in.) (height × width × length), nucleus boxes holding six frames and ca. 5000 worker bees. Cox et al. (1996) provides further information about this system in a detailed description of honeybee management at the NCRPIS.

In recent years, we have field tested other bees, such as bumblebees (*Bombus* spp.) and various solitary bees, as germplasm pollinators. We are now regularly using hornfaced bees (*Osmia cornifrons*) on a large scale for oilseed *Brassica* and on a trial basis for many other plants. These bees are active at cooler temperatures than are honeybees, and they hold pollen on their abdomens, which readily touch the stigmas of *Brassica* flowers as the bees forage. Portable *Osmia* domiciles can be made from 5.1-cm (2-in.) diameter pvc pipe filled with nesting straws. On a smaller scale, we have also been using bumblebees (*Bombus bimaculatus*) for plants, such as snapdragons, with flowers better suited to a larger pollinator with a relatively long tongue or that require buzz pollination. In addition, house flies (*Musca domestica*) are reared at the NCRPIS for use in conjunction with bees in cages of Apiaceae. About 250 fly pupae are placed in the cages weekly to supplement bee activity. It is also possible to purchase house flies commercially, although to date we have not done so.

TESTS OF OUR SYSTEM AND VARIOUS POLLINATORS

A series of experiments has been conducted to test the integrity of our cage system for preventing pollen flow from outside the cages and, more broadly, to preserve the genetic integrity of our collections. Wilson (1989) conducted a 3-year study of various honeybee management strategies with caged pollen-sterile sunflowers. He showed that the NCRPIS regeneration system reduced cross-contamination to an extremely low level (0.1 to 0.2%). Widrlechner et al. (1992) evaluated allozyme profiles for 157 different pairs of cucumber seedlots produced both by uncaged hand pollination and caged insect pollination. They found no statistically significant differences in the overall enzyme composition, or in the frequencies of rare allozyme alleles; but there was a significant increase in homozygosity with caged pollination, suggesting that the genetic integrity of individual accessions is better maintained with caged pollination.

Table 1. List of ornamental genera regenerated at the NCRPIS with insect pollinators in field cages. All genera were pollinated by honeybees unless otherwise indicated.

Genus
Agastache
Alcea
Althaea
Antirrhinum (both honeybees and bumblebees)
Aronia (hornfaced bees)
Calendula
Campanula
Celosia
Chrysanthemum
Consolida
Cuphea
Dianthus
Duchesnea
Echinacea
Flueggea
Gypsophila
Hesperis
Lavatera
Leucanthemum
Ligustrum
Linum
Malva
Melampodium
Monarda
Petrorhagia
Potentilla
Pycnanthemum
Salvia
Sanvitalia
Silene
Simsia
Sorbaria (both honeybees and hornfaced bees)
Spiraea (hornfaced bees)
Tagetes
Tanacetum
Tithonia
Vaccaria
Verbena
Viola
Zinnia

The efficacy of various pollinators and combinations of different pollination protocols has also been tested for carrot (Wilson et al., 1991), sunflower (Wilson and Collison, 1988), *Cuphea* (Wilson and Roath, 1992), and *Brassica* (Wilson et al., in review). Those studies indicated that: (1) a combination of house flies and honeybees produced significantly higher quantities of carrot seed than did either insect alone; (2) the use of different races of honeybees did not result in significant differences in sunflower seed production; (3) small numbers of bumblebees were at least as efficient as a colony of honeybees in effecting *Cuphea* pollination; and (4) hornfaced bees were equally effective pollinators for *Brassica* as were honeybees and leafcutter bees.

ORNAMENTALS SUCCESSFULLY REGENERATED WITH OUR SYSTEM

The first caged increases of ornamental plants at the NCRPIS were conducted in 1981 on annual zinnias. In 1986, we established our first 2-year field, which enabled us to regenerate biennials and perennials that would not flower without overwintering. More recently, we began testing various shrubs in larger cages 2- to 3-year trials of our regeneration system. Table 1 lists the ornamental genera successfully regenerated in field cages, along with the pollinators used.

LIMITATIONS

The NCRPIS cage regeneration system is not without limitations. Some of our most severe challenges are related to our local climate. For biennial and perennial ornamentals that overwinter in the field, death may occur from low-temperature injury or poor drainage. On warm, sunny days with light winds, very high air temperatures [up to 46C (115F)] can occur inside the cages, which may damage flowers, destroy pollen, and, ultimately, lower seed quality. Conversely, stormy days with very high winds can wreak havoc on cages, by deforming frames, breaking joints, and unearthing or tearing screens.

Another challenge stems from the poor match between the number of honeybees that can be nourished by the pollen and nectar produced by the flowers inside a cage versus the number of bees required to maintain a colony. At even the densest planting rates, there are generally fewer than 200 plants in a cage. Ayers and Widrlechner (1994) recommended a field planting of at least 307 m^2 (3300 ft^2) of anise hyssop (*Agastache foeniculum*), a very productive nectar source, to support one honeybee hive. Clearly, 200 plants inside a cage cannot support honeybees without special intervention. We have used two approaches to maintain our honeybees: allowing them to work periodically outside the cages or feeding them syrup and pollen substitute. One can design a schedule allowing the bees to forage outside the cages, if the nucleus boxes are equipped with a sliding drawer, so that bees can only work inside or outside the cage, but not both. This system works best when there is sufficient local forage to support the number of colonies on site. Otherwise, labor-intensive artificial feeding is required. We expect that solitary bees and social bees, such as bumblebees, which have much smaller colonies than do honeybees, may ultimately prove better suited for caged pollination.

At the NCRPIS, research to refine caged seed production is ongoing. We are now testing our system on previously untried plants, refining methods to establish honeybee colonies quickly in the spring, developing protocols to produce and manage bumblebees and solitary bees, and measuring the relative effectiveness of various pollinators for particular crops.

PLANS FOR YOUR OWN CAGES

If you wish to experiment with field cages for seed production, we can provide plans for field cages, screens, and the various structures used to house the pollinators. Please contact us at the address shown at the beginning of this paper, or contact Craig Abel by e-mail at: cabel@iastate.edu.

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Mycorrhizal Associations and Plant Propagation

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INTRODUCTION

All plants of commercial or ecological value can have their "roots" traced back to the forest. All we have done is collect them from the forest, propagate them in some fashion and then plant them in various manmade environments, such as tree plantations, orchards, roadsides, urban landscapes, shopping centers, and pots in the patio. Regardless of where these plants are now growing, they still have the genetic requirements they acquired over some 300 million years of development in forests. Most of these requirements are related to the soil. Forest soils typically have a well-defined surface layer of organic litter, large porous channels caused by roots and animal activity, high amounts of decomposing organic matter, and an accumulation of woody debris on the surface. Most of these characteristics are missing in man-made environments. The perennial root systems of most forest plants support diverse macro- and microorganisms in the forest floor, soil, and rhizosphere (i.e., fine root surfaces). The organisms disintegrate and decompose organic matter, and then release (recycle) the nutrient elements for eventual re-absorption by forest vegetation. Nutrient and water absorption by forest plants is synchronous and interdependent.

Large amounts of essential plant elements, i.e., N, P, K, Ca, Mg, Fe, Zn, etc., are bound and unavailable to plants in the organic matter and mineral components of the forest soil. Only small amounts of these inorganic elements are made available in soil solution by microbial activity at any specific time. In temperate forest soils, rarely are there more than 5 to 10 ppm of either available inorganic N or soluble P in soil solution at any time during the growing season. Forest plants have evolved biological systems or "partners" to assure them of adequate supplies of these essential elements from soils of low fertility.

Microorganisms are abundant on or near the fine absorbing roots of forest plants and they play vital roles in numerous physiological and chemical processes. These dynamic processes are mediated by activities of microorganisms participating in saprophytic, pathogenic, and symbiotic associations on roots of forest plants. Certain species of saprophytic bacteria oxidize mineral elements, like P, into soluble forms, fix atmospheric N, stimulate root growth by producing plant growth regulators, act as biological deterrents to root-disease causing microbes, and decompose man-made organic chemicals in the rooting zone.

MYCORRHIZAE

The most widespread symbiotic association on roots of forest plants is mycorrhiza (fungus-root). The term mycorrhiza is used to describe a structure that results from a mutually beneficial association between the fine absorbing roots of plants and species of highly specialized, root-inhabiting fungi. The mycorrhizal fungi derive most, if not all, of their needed organic nutrition (carbohydrates, vitamins, amino acids) from their symbiotic niche in the primary tissues of absorbing roots. Evidence

suggests that the mycorrhizal habit has evolved as a survival mechanism for both partners in the association, allowing each to survive in the existing forest environments of low soil fertility and water, disease, and temperature extremes. Because of this coevolutionary process, mycorrhizae are as common on the root systems of forest plants as are chloroplasts in their leaves. In examining forest plants in a natural environment, the question should not be "are these plants mycorrhizal" because they all are, but rather "what type of mycorrhiza is present and what is the degree of mycorrhizal development on the roots"?

Endomycorrhizae. This type of mycorrhiza is the most widespread and comprises three groups. Ericaceous mycorrhizae occur on four or five families in the Ericales and include *Rhododendron*, laurel (*Kalmia*), cranberry (*Vaccinium macrocarpon*), and blueberry (*Vaccinium*). Orchidaceous mycorrhizae are a distinct type that occur only in the plant family Orchidaceae. These two groups of endomycorrhizae are not widespread and will not be discussed further. Vesicular-arbuscular mycorrhizae (VAM) form the third group of endomycorrhizae. Vesicles and arbuscules are structures produced by the endomycorrhizal fungus in or on roots. VAM occur on more plant species than all other types of mycorrhizae combined and have been observed in roots of over 1000 genera of plants representing some 200 families. It has been estimated that over 90% of the 300,000 species of vascular plants in the world form VAM. These include agricultural crops, turfgrass, fruit and nut trees, most hardwoods, vines, desert shrubs, flowers, and woody ornamentals. VAM fungi are ubiquitous in all natural soils except where they have been eliminated by prior land-use practices. Inoculum density and fungal species diversity, however, vary greatly in different soils supporting different plants. There are about 150 species of VAM fungi identified to date. None can be grown in pure culture in the laboratory. VAM fungi cannot grow saprophytically in soil and, therefore, will only grow while in symbiotic association with their plant hosts. They may, however, survive for decades in soil as dormant spores without plant associations. VAM roots are not changed in either color, shape or form as are ectomycorrhizae. VAM can only be confirmed microscopically.

VAM increase a plant's uptake of water and certain nutrients, particularly P, Cu, and Zn. These elements are relatively immobile in soil, and zones of depletion normally develop near absorbing roots. The extramatrical growth of hyphae from VAM fungi extends beyond the absorbing roots and, thereby, increases the volume of soil from which these elements are absorbed. The additional nutrient and water absorption capability due to VAM can result in several-fold growth increases in plants.

There are other significant benefits of VAM to plants. VAM are capable of increasing plant resistance to various fungal root pathogens and parasitic nematodes. VAM have also been shown to enhance water uptake, increase tolerance to heavy metals, saline soils and drought, decrease transplant shock, and bind soil into semistable aggregates.

Ectomycorrhizae. This type of association occurs on about 10% of the world flora. Trees belonging to the Pinaceae (pine, fir, larch, spruce, hemlock), Fagaceae (oak, chestnut, beech), Betulaceae (alder, birch), Salicaceae (poplar, willow), Juglandaceae (hickory, pecan), Myrtaceae (*Eucalyptus*), Ericaceae (*Arbutus*), and a few others form ectomycorrhizae. Some tree genera, such as *Alnus*, *Eucalyptus, Casuarina, Cupressus, Tilia, Ulmus,* and *Arbutus* can form both ectomycorrhizae and VAM,

Table 1. A few of the plants that are known to benefit from mycorrhizal fungal manipulations.

Ectomycorrhizal
Forest and Urban Trees
birch 4 spp. (*Betula*)
cedrus 2 spp. (*Cedrus*)
cottonwood (*Populus*)

Eucalyptus 4 spp
fir 3 spp. (*Abies*)
hemlock 2 spp. (*Tsuga*)
larch (*Larix*)
oak 9 spp. (*Quercus*)
pecan (*Carya illinoinensis*)
pine 27 spp. (*Pinus*)
poplar (*Populus*)
spruce 4 spp. (*Picea*)

VAM Forest and Urban Trees
ash 2 spp. (*Fraxinus*)
cypress (*Taxodium*)
empress tree (*Paulownia*)
gums 3 spp.
Leyland cypress (×*Cupressocyparis leylandii*)
maples (*Acer*)
magnolia (*Magnolia*)
palm (*Elaeis*)
redbud (*Cercis*)
redwood (*Sequoia*)
sycamore (*Platanus*)

VAM Fruit, Nut, Vine and Berry Plants
apple (*Malus*)
avacado (*Persea*)
banana (*Musa*)
blackberry (*Rubus*)
cherry (*Prunus*)
cocoa (*Theobroma*)
citrus (Citrus)
coffee (*Coffea*)
grape (*Vitis*)
mango (*Mangifera*)
olive (*Olea*)
papaya (*Carica*)
peach (*Prunus persica*)
pear (*Pyrus*)
pineapple (*Ananas*)
pistacia (*Pistacia*)
plum (*Prunus*)
raspberry (*Rubus*)
strawberry (*Fragaria*)

VAM Grasses, Legumes, etc.
bahiagrass (*Paspalum notatum*)
bluegrass (*Poa*)
bentgrass (*Agrostis*)
clover (*Trifolium*)
centipedegrass (*Eremochloa*)
lespedeza (*Lespedeza*)
ryegrass (*Lolium*)
sunflower (*Helianthus*)
switchgrass (*Panicum*)

VAM Ornamentals
aster (*Aster*)
barberry (*Myrica*)
bearberry (*Arctostaphylos*)
boxwood (*Buxus*)
chrysanthemum (*Dendranthema*)
dogwood (*Cornus*)
geranium (*Geranium*)
hibiscus (*Hibiscus*)
hydrangea (*Hydrangea*)
hawthorn (*Crataegus*)
juniper (*Juniperus*)
lily (*Lilium*)
marigold (*Tagetes*)
pittosporum (*Pittosporum*)
poinsettia (*Euphorbia*)
privet (*Ligustrum*)
rose (*Rosa*)

VAM Transplanted Field Crops
asparagus (*Asparagus*)
peppers (*Capsicum*)
tobacco(*Nicotiana*)
tomatoes (*Lycopersicon*)

depending on the soil conditions, tree age, and availability of mycorrhizal fungal inoculants.

Numerous fungi have been identified as forming ectomycorrhizae. In North America alone it has been estimated that more than 2100 species of fungi form ectomycorrhizae with forest trees. Worldwide, there are over 5000 species of fungi that can form ectomycorrhizae on some 2000 species of woody plants. Most of these fungi produce mushrooms or puffballs. However, less than 20 percent of the mushroom or puffball-producing fungi are mycorrhizal, the majority are saprophytic litter and wood decomposers in the forest.

In ectomycorrhizae, intercellular hyphae surround cortical cells forming the Hartig net, and several hyphal layers cover the outside of the feeder root forming the fungus mantle. Ectomycorrhizal colonization normally changes the feeder root morphology and color. They may be unforked, bifurcate, nodular, multi-forked (coralloid), or other shapes. Their color, which is usually determined by the color of the mycelium of the fungal symbiont, may be jet-black, red, yellow, brown, white, or blends of these colors. Unlike VAM, many ectomycorrhizal fungi can be grown routinely in pure culture in the laboratory. An important aspect of both VAM and ectomycorrhizal fungi is that neither group can grow saprophytically in nature, they can only grow while in the plant root association. Spores or other resistant structures of the fungi, however, may survive long periods in soil without a plant host.

Ectomycorrhizal fungi aid the growth and development of trees. For some trees, such as *Pinus*, they are indispensable for growth under natural conditions. The obligate requirement of pine for ectomycorrhizae in a natural environment has been clearly shown by numerous workers in tree regeneration trials in former treeless areas and in countries without native ectomycorrhizal trees. Trees with abundant ectomycorrhizae have much larger, physiologically active, root-fungus area for nutrient and water absorption than trees with few or no ectomycorrhizae. This increased absorptive surface area is a combination of the multi-branching habit of most ectomycorrhizae and the extensive vegetative growth of fungal hyphae from the ectomycorrhizae into the soil. As with VAM, these extramatrical hyphae function as additional nutrient and water-absorbing entities and promote maximum nutrient and water capture from the soil by the host plants. Ectomycorrhizae have been shown to increase the absorptive surface of root systems of 4-month-old pine by over 700% when compared to nonmycorrhizal roots. Ectomycorrhizae are also able to absorb and accumulate more N, P, K, and Ca in the fungus mantles, more rapidly, and for longer periods of time than nonmycorrhizal roots. They also increase the tolerance of trees to drought, high soil temperatures, soil toxins (organic and inorganic), and extremes of soil-acidity caused by high levels of sulfur or aluminum. They also function as biological deterrents to root pathogens, such as species of *Pythium* or *Phytophthora,* and to parasitic nematodes. Plant hormone relationships induced by fungal symbionts result in ectomycorrhizal roots having greater longevity (length of physiological activity) than nonmycorrhizal roots. Not all species of fungi form ectomycorrhizae that have equal benefit to their hosts; some are more effective that others.

PRACTICAL CONSIDERATIONS

Over 20,000 research papers have been published on mycorrhizae since the turn of the century. A considerable amount of this research has been done on the response

of plants to mycorrhizal fungus inoculations under a variety of test conditions. Table 1 shows just a few of the plants that are known to benefit from mycorrhizal fungal manipulations. Many others are not listed because of limited space. These results should not be surprising since they are all forest plants and mycorrhizae have been the natural state of their absorbing roots in forest soils for millions of years. Unfortunately, our modern-day plant propagation practices discourage the natural occurrence of abundant mycorrhizae. Artificial potting mixes and sterilized (fumigated/steamed) soils contain few, if any, propagules of mycorrhizal fungi. High fertility and frequent irrigation also discourage mycorrhizal development even if adequate fungal propagules are present. Research has repeatedly shown that plants in the nursery phase can benefit, i.e. increased growth, more flowers, hardier, less transplant shock, etc., by increasing the degree of mycorrhizal development on absorbing roots. Many other plants, especially woody plants like forest trees and urban landscape trees, survive better, develop new roots faster, and are generally healthier than plants with few or no mycorrhizae in field plantings.

Commercial plant propagators can now return the missing "forest" component to their plants i.e., the "natural-state of absorbing roots", by using commercially available inoculants of mycorrhizal fungi. These inoculants can be added to a variety of plant propagation stages to promote the development of mycorrhizae. Remember, in nature, mycorrhizal plants grow where other plants fear to grow!

Winter Propagation and Liner Bed Production of Conifers

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Whenever we look to new and innovative techniques in plant propagation, we must always consider the principles involved. Those are to provide the optimum conditions and environment for plant growth and development while being as efficient and economical as possible. At Ridge Manor Nurseries we utilize a method for production of *Taxus, Thuja,* and *Juniperus* which is not new, in fact it is quite old. It is, however, very economical for us and I wish to explain it to you today. Although I have used other methods and know of other methods which are used, my intent is not to compare different philosophies or practices but to discuss our procedure and explain why it works for us.

Ridge Manor Nurseries is located in Madison, Ohio nestled against the southeastern shore of Lake Erie. While we do suffer from an abundant amount of snowfall annually, the loamy, sandy soils and buffering affect of the lake in spring and fall make for ideal growing conditions for conifers. All of our cutting wood is collected from our own field or container stock and each cutting is hand-made. Because we believe there is no sense taking or sticking a bad cutting we use no combines or band saws to collect or make our cuttings. Cuttings are made individually with hand clippers. Cutting length is 6 to 8 in. depending on the plant being propagated. Sides and tops are trimmed with side branches being trimmed off rather than torn to eliminate putting down and picking up clippers. Cuttings are then adjusted so that all the ends are even and given a 5-sec quick dip. Our hormone is 2500 ppm KIBA. It is purchased in the crystalline form (100% IBA) and dissolved in distilled water. Cuttings are then bundled in flats, approximately 750 to 1000 per flat, and taken out to be stuck in sand benches. Beds 4 ft wide with a 1-ft walkway are constructed on the ground using treated 1 in. × 8 in. lumber. These beds are filled with brown concrete sand, leveled with a board, and watered in.

We stick these cuttings in December and January knowing they will not begin rooting until late May or June, because we do not have time in May or June to stick all our conifers. We essentially keep them in cold storage until warmer weather. There is no mist system used and a heater only keeps the ambient temperature at 35F. Cuttings are stuck 1 in. apart within rows which are 1 in. apart. In a 4000 ft^2 house we are able to fit 250,000 cuttings. In late June, once rooting has begun, the poly is replaced with 50% shade. Cuttings are hand misted every day and watered every other day.

By the end of the second winter all cuttings have developed a strong secondary root system and are ready for bed planting. It is this secondary root system which is the basis to our whole program. Greenhouse propagated cuttings which are produced in 6 months using mist and bottom heat usually have a large number of primary, brittle roots. These cuttings, when bedded out, tend to make little or no top growth the first year because they are producing a secondary root system.

Rooted cuttings are bedded out in five row beds on a 12 in. × 12 in. spacing. Each cutting is stomped to insure it is straight and securely in the ground. This and our healthy cuttings reduce transplant loss and improve growth. After 1 year of growth

in the beds the rooted cuttings of *Thuja* and *Juniperus* are 6 to 10 in. in diameter.

After 2 years they are 12 to 15 in. and ready for field planting. Our *Taxus* are left in the beds for 3 years and are harvested as 10- to 12-in. plants. This eliminates the need to field plant them and makes them an even more efficient crop.

In conclusion, we feel that the keys to this program are our being able to produce a very inexpensive rooted cutting by using no mist and no extra heat, and having a rooted cutting with a secondary root system in place. This allows us to gain an extra year of growth on most plants and, therefore, harvest sooner.

RALPH SHUGERT: Mike what are your rooting percentages on *Juniperus, Thuja,* and *Taxus*? What about transplant losses or transplant shock?

MICHAEL BYERS: On *Juniperus* and *Thuja* the rooting percentages are never less than 90%. *Taxus* are around 80%. We have transplant losses in wet areas of the fields sometimes but no transplant shock.

Breeding Witchhazel at The Holden Arboretum

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RESEARCH OVERVIEW

Research formally began in 1991 with the addition of staff with advanced training in breeding, genetics, and plant physiology. The centerpiece of research is breeding woody ornamental plants. Complementary work involves: studies related to reproductive biology, genetic diversity, elucidation and utilization of biochemical markers, cytogenetics, propagation, and documentation of the inheritance of important traits.

By formal agreement, The Holden Arboretum acquired the germplasm accumulated by David G. Leach who has been a prodigious breeder of *Rhododendron* for over 50 years. Acquired in 1986, the plant collection is one of the best for cold-hardy *Rhododendron* germplasm. Staff were added in 1992 to help bolster research at this satellite research station of over 20 acres which is located within 30 miles of The Holden Arboretum.

A new building was built at The Holden Arboretum to provide research space and greenhouse/headhouse areas to meet the expanding needs of the organization. Completed in 1994, our Horticulture Science Center provides over 4000 ft^2 in office, herbarium, darkroom, and laboratory space for research. To date, plant breeding at Holden has emphasized work with several genera including: *Aesculus, Cercis, Cornus, Hamamelis, Magnolia,* and *Rhododendron*.

This note provides a progress report on breeding and research activities of *Hamamelis* at The Holden Arboretum.

PLANT ACQUISITION

Currently, the research collection of *Hamamelis* includes 58 cultivars and 13 selections of *H. japonica* (6), *H. mollis* (8), *H. vernalis* (20), and *H. ×intermedia* (37). The rationale to acquire this material was to evaluate plants in a common garden. Plant vigor, leaf size, leaf condition (incidence of powdery mildew and fall color), petal size, petal color, bloom period, fertility, calyx color, and fragrance are some of the characteristics that will be evaluated. Cultivars and selections will constitute the backbone of a breeding program for spring-blooming witchhazel.

Considerable effort has been made to acquire wild-collected *H. virginiana*. Seed requests were made to numerous cooperators throughout the U.S. and Canada who collected and sent seed from 65 populations in Fall 1994 and 1995. These populations came from 21 states and one Canadian province including: AL, DE, IL, IO, LA, MA, ME, MI, NC, NH, NJ, NY, OH, OK, ONT, PA, RI, TN, TX, VA, VT, and WI. Eighteen populations were collected from Ohio.

Seed Germination. Seed from wild-collected populations of *H. virginiana* were stratified for 8 weeks (wk) warm followed by 20 wk cold (4C). In general, seed germination was excellent and averaged 67%, with a range of 0% to 100%, and a mode of 72%. Several populations had excellent germination (>95%) including DE, OK, OH, and VA. Seed from other populations germinated poorly (<5%) including

OH, MI, and WI. The extremes in germination may be related to latitudinal differences between populations. We are testing the hypothesis that more northerly populations require a longer cold period during stratification for optimum seed germination.

Other germination experiments included an evaluation of seed harvest date on germinability. Seed collected in August and early September did not germinate. Seed collected in mid September and October, germinated at more than 20% and 40%, respectively. Stratification pretreatments were also tested for effectiveness. Stratification of 8 wk warm followed by 20 wk cold was superior to 8 wk warm followed by either 10 or 15 wk cold. Others have conducted similar work including a comprehensive study by Gaut and Roberts (1984).

POLLINATION AND BREEDING OF *HAMAMELIS*.

Most named cultivars are spring-blooming Asiatic types (either *H. japonica, H. mollis*, or their interspecific hybrid *H. ×intermedia*). Field-grown plants are difficult to work with given they bloom in late February to March when weather is unpredictable and often inclement. In fact, pollinating witchhazel in the field is not recommended if potted plants are available which can be moved to protected quarters for pollination and pollen collections.

Attempts to self pollinate various selections of *Hamamelis* have not yielded mature fruit. Presumably, there is a self-incompatibility system that prevents self-pollen from being successful. Clearly, if witchhazel are self-incompatible, breeding can be conducted without emasculating the flowers. Research has been initiated to verify whether an incompatibility system exists.

The size and proximity of the stigma to the anthers is quite close (1 to 3 mm) and flower manipulation while making controlled crosses is tedious. *Hamamelis* apparently are insect pollinated (though no published studies have been located that document what insects pollinate these interesting flowers). Research is ongoing to develop a system where small groups of *Hamamelis* can be brought together and allowed to naturally cross pollinate. If successful, this approach would eliminate the need to manually pollinate large numbers of flowers. However, such a system would also require a method to determine the pollen parent of each seedling (i.e., whether seedlings were a result of self or cross pollination). To determine the pollen parent, staff have identified three plant genes that are straightforward to evaluate and unequivocal in their mode of inheritance (see the Biochemical Markers section below).

BIOCHEMICAL MARKERS OF WITCHHAZEL.

Plant proteins can be evaluated by electrophoresis. Specifically, staff are working to elucidate isozyme differences that are easy to evaluate and simply inherited. Currently, we have identified three genes that control isozyme differences in two enzyme systems of *Hamamelis*. Fortunately, isozyme profiles are not influenced by the environment and are characteristic of the individual. Isozymes are analogous to blood type in humans. While several individuals may have the same genotype, other individuals are different. These differences in plant proteins can be detected by starch gel electrophoresis. Like blood type, isozymes are simply inherited and can be used to help substantiate paternity. Research includes genotyping *Hamamelis* selections for each of three isozyme genes.

Consider a scenario where two different individuals of witchhazel are in close proximity within a garden (perhaps 2 m apart). Assume plant-1 has an "*aa*" genotype and plant-2, a "*bb*" genotype. If the two plants cross pollinate, the resultant seedlings would have an "*ab*" genotype since parent-1 can only contribute an "*a*" allele to its offspring, and parent-2, can only contribute a "*b*" allele. Similarly, if parent-1 self-pollinates, the resultant seedlings can only have an "*aa*" genotype.

Using this logic, a closely spaced grouping of 13 witchhazel is being studied. This planting includes a mixture of cultivars which were established in 1986. The plants regularly set fruit and are spatially close together (individuals are about 2 to 3 m apart). In 1995, seeds were collected from four cultivars which were critically evaluated for isozyme genotypes and rates of cross pollination were estimated. Outcrossing estimates were considerably higher than expected at 71%, 81%, 83%, and 100%. Knowing the genetic composition of the small population of thirteen plants as we do, our data conservatively estimates cross pollination.

Included in this group of 13 witchhazel was a single plant of *H. vernalis* 'Red Imp' surrounded by 12 Asiatic witchhazel. This 'Red Imp' was hybridizing with Asiatics at greater than 80%. This is the first known report that *H. vernalis* freely hybridizes with Asiatic witchhazel.

By knowing the genotypes of the plants of interest, desirable parent plants can be brought together (spatially) to create small breeding populations. By knowing the inheritance of the isozyme markers and genotypes of the selected parents, paternity of the seedlings can be easily determined.

Other research at Holden involves comparing the genetic similarity among cultivars. This work uses DNA analyses and may help to substantiate whether groups of cultivars are closely related or even if two cultivars likely are half-sibs (having one common parent). This analyses suggests that *H. vernalis* is quite dissimilar to the Asiatic witchhazel but that interspecific hybrids likely exist between *H. vernalis* and plants with Asiatic backgrounds (Marquard et al., 1997).

Micropropagation. Traditionally, witchhazel are propagated by grafting with H. virginiana as the rootstock. The major disadvantage of this method is that the rootstock may sucker and out-compete the scion. Cuttings can be rooted successful, however, overwintering survival has been marginal (Dirr and Heuser, 1987). As we acquire sufficient plant material, we will evaluate clonal differences in rooting success and survival associated with various overwintering regimes.

Micropropagation provides an alternative to traditional propagation. Research at Holden has demonstrated that shoot tip explants of *Hamamelis* can be established, will proliferate, and will root in vitro with moderate to excellent success. Staff continue to evaluate basal salt composition on culture initiation; the affect of BA and NAA concentrations on shoot proliferation; the affect of IBA concentration on rooting, and differences in overwintering regimes on plant survival. Equally important will be to compare differences in clonal performance of plantlets grown in culture.

CONCLUSION

Hamamelis research at The Holden Arboretum is proceeding on numerous fronts including: acquisition of cultivars, selections, and wild-collected material; plant evaluations; studies related to genetic similarity and reproductive biology; while developing methods to facilitate the creation and verification of hybrids.

Acknowledgment. *The able assistance of* Charlotte Chan, Eric Davis, and Arthur Richwine in conducting this research is greatly appreciated.

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PETER DEL TREDICI: Have you crossed *Hamamelis vernalis* by *H. virginiana*?

ROBERT MARQUARD: No, but we are planning on doing it. We have crossed *H. vernalis* by the Asiatic species.

DARREL APPS: Have you seen any disease symptoms, particularly with the *H.* ×*intermedia* cultivars?

ROBERT MARQUARD: Our main stock is growing in containers and we have observed none.

VOICE: Why are you using tissue culture in your work?

ROBERT MARQUARD: The main reason is experimental and we hope to develop a reliable propagation system.

Preventing Frost Heaving of Late-Planted Perennials

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The information presented in this paper is the result of field observations rather than the collection of research data. Also, the concept of using a cover crop for winter protection of newly propagated plant material such as woody plant seedlings was reported at previous I.P.P.S. Eastern Region meetings by Wayne Lovelace of Forrest Keeling Nursery, Elsbury, Missouri. The methods developed by Lovelace were applied to late planted *Hemerocallis* divisions (planted after September 30th) to provide winter protection and prevent "frost heaving" of the crowns. Normally *Hemerocallis* divisions would not be planted in the field after August 30th but in the digging of field-grown *Hemerocallis* plants for fall containerizing there are also surpluses and grade outs left. These plants represent part of the profit that can be made from the crop so it would be advantageous to save these plants if at all possible; hence the late planting in the field. A major problem that can occur when perennials are planted too late for complete establishment takes place is frost heaving, i.e. the movement of the crown to the soil surface due to the alternating freezing and thawing of the soil. The crown of the plant desiccates in the winter and the plant dies.

Between October 1 and 15, 1995 winter rye (*Secale cereale)* was sown on the soil surface at the rate of 2 and 4 bushels per acre in late plantings of several cultivars of *Hemerocallis*. The seed was not covered. Germination of the early sowing was satisfactory but due to lower than normal temperatures early in the season the later sowing did not have complete germination. In the spring when the rye was approximately 15 in. high it was killed with Fusilade 2000 (fluzaifop-P-butyl) at the rate of 1 qt per acre. A non-ionic surfactant was added and 20-gal spray acre^{-1} was used.

Hemerocallis divisions that had protection of complete rye coverage had nearly 100% survival while those that did not have any or limited rye coverage the survival rate was less than 10%. The loss was due to frost heaving of the crowns. Growth of the surviving plants appeared to be normal as the 1996 season progressed.

An added benefit of using winter rye cover is the reduction in weed growth for up to 6 weeks after the rye has been killed. Masiunas et al. (1995) and Smeda and Weller (1996) reported that winter rye cover crops suppressed weed growth in newly planted tomatoes. The suppression was a result of the release of allelochemicals into the soil by the rye residue as it decayed after being killed (Masiunas et al., 1995; Smeda and Weller, 1996). The use of rye cover crops will not solve the weed control problem but it can be a weed control tool to be used with other control methods.

RECOMMENDATIONS:

1) Sow winter rye (*S. cereale*) at the rate of 3 to 4 bushels acre^{-1}.
2) Use the higher to eliminate the need for covering the seed. Cost is approximately $30 to $40 acre^{-1}.
3) Sow prior to rainfall or use overhead irrigation to moisten soil and seed. Germination will start within 48 h.
4) Sow seed approximately 3 weeks before average date of the first frost in your area.

5) In spring kill the rye with Fusilade 2000 at the rate of 1 qt acre^{-1}. Make certain that the perennial crop, if emerged, is on the Fusilade label.
6) The rye between the rows can be mowed rather than killed if this fits the management program of the grower.
7) Do not use a preemergence herbicide 4 months prior to the sowing of the rye cover crop.

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Syringa: A Challenge!

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It's called enthusiasm. You must have it to go into the nursery business, or you have to be a little crazy. A combination of both works well. We all have our favorites and thank God we all do not agree. One of mine is lilacs, or as they're better known in this group — *Syringa*. Now if you were my mother, you'd know very well that a *Syringa* was a mockorange, because her mother told her so! How could it be a lilac? Now I'm no botanist, but I do know a *Syringa* when I see one.

So you want to propagate Lilacs? Actually there's nothing to it. All you have to do is propagate your selection asexually so it reproduces true to color, size, and vigor. Plant it, prune it, fertilize it, weed it, water it, etc. for several years. Now this all happens while you grow plants that really make you money like red-leaved barberries and pussy willows. So after you've struggled for several years with a group of plants that really interest you, they bloom. Now you've either struggled right from the initial propagation or you've paid out good money for your favorite color and WOW! What do you get sometimes—a dog! Its bloom is no more purple than the side of your house. Flowers are single when they should be double, the growth rate does not compare with the selected cultivar, etc. This quick description certainly does not happen in all cases, but in all too many cases it does. Years and years of effort to produce the chosen cultivar results in frustration and disappointment.

History — In the I.P.P.S. Today, there are many, many members younger than I am. I would like to talk briefly about the time in this organization when there were many, many members older than I am. My introduction into plant propagation was in the era of closed cases, glass sash, and shading cloths. Lilac production from softwood cuttings was very erratic and uneconomical. With the advent of polyethylene plastic results improved. This increase in percentages was also aided by an increase in the range of root-inducing hormones available. "Plastic tent" propagation was quickly followed by the advent of continuous mist propagation (Jim Wells, Koster Nursery). This in turn, was quickly followed by intermittent mist (Harvey Templeton, Phytotector). These practices have continued up to today's current production by tissue culture.

Millions of softwood cuttings have been propagated successfully by these various methods. There is, however, one very important fault that has continued through all the years and all the propagation methods — "Un-true Plants"!

Keeping Cultivars True to Name. I am not up here to find fault or criticize anyone, or any company. I am here to discuss the challenge lilacs present. We all need to be positive of our propagating material no matter how the cultivar is to be reproduced. While it's usually not possible to propagate from the original selection it is in many cases possible to propagate from older established plants of the selected cultivar. Even so, we cannot all do this. So, we rely on our proven suppliers. And following all this we keep meticulous records!

During my plant propagation tenure I have been lucky enough to have been given some managerial responsibilities. Now we all know the fringe benefits that come

with this kind of a job. For instance:

- Being on call 24 h a day. This entitles you to the company's problems, as well as your employees problems.
- You get to deal happily when the sheriff comes to serve a summons at lunch time. " Hah! Got ya!"
- You deal with irate wives or girlfriends over who is going to get his pay check.
- And then there are always the "Byfielders". A local source of labor. Every company has its Byfielders. They are the back bone of the digging crews. They may not all chew, but they sure can dig.

I would like to relate a true occasion regarding Byfielders and lilacs. I was not present, but one of our planting crews was made up of four men. Snipe, Boob, Mink, and Nucky. A stalwart bunch to say the least. They were sent out to plant a large number of lilacs. The lilacs were properly planted and to make the job look better all of the labels were removed. The boss was angry, the owner furious, and the reply from the Byfielders was: "What difference do it be?" "They all be lay-locks!"

It makes no difference how we all propagate the genus *Syringa*. The challenge is to eliminate the question: "What difference do it be?" "They all be lay-locks!"

Trials and Tribulations of Producing *Acer pensylvanicum* 'Erythrocladum'

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INTRODUCTION

Acer pensylvanicum 'Erythrocladum' was introduced by Spath Nursery of Berlin, Germany in 1904. It is a fast growing tree with striped green and white bark in summer. Its pendulous racemes of yellowish flowers appear in spring before the foliage. Attractive foliage turns clear yellow in fall. But its most important attribute is its bark, all of which, from the ground up to the tips, starts turning to pink in the fall with the cool weather, becoming a startling bright coral-red during the winter. It is a superb plant for the winter landscape.

This paper is the result of work by two nurseries and one arboretum.

PROPAGATION RESULTS

Softwood Cuttings.

Arnold Arboretum.

- Hormone F at 5000 ppm and 10,000 ppm under mist.
- Medium: pumice, perlite, and peat (6 : 3 : 1, by volume).
- Ten cuttings were stuck, five of which rooted.

Broken Arrow Nursery.

- Took four cuttings in late July, two of which rooted under fog.

Twombly Nursery.

- 1 : 20 Dip 'N Grow (1 : 20, v/v) 750 ppm under mist.
- Medium: pumice and peat (9 : 1, v/v).
- Fifteen cuttings taken late June, nine rooted 4 weeks later.

Grafting.

Arnold Arboretum.

- First attempt used a veneer graft: 27 grafted, eight took, three survived.
- Second attempt was grafted onto *A. negundo*; 40 grafted, three lived until summer.
- Third attempt was chip budded: 43 were grafted but they did not have a record of the results.

Broken Arrow Nursery.

- Side-grafted four on Feb. 1996, using the hot pipe method: three out of four took and two survived.

Twombly Nursery.

- Veneer grafted onto *A. pensylvanicum*.
- Understock brought in after 1 Jan. and grafted as soon as white

root appeared: 15 grafted, eight took and leafed out, but only four lived to be potted.

CONCLUSION

It is clear that much additional work has to be done to find a successful way to propagate this plant in high percentages. We will be trying stick budding in August under plastic. At this stage it looks like rooting softwood cuttings is the best method.

Economical Fertilizer Applicator: Keep it Simple

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Sometimes in this day of high technology we forget that some things are better left simple. We feel that our dispenser does that at a minimal cost. There are no moving parts, nothing to rust, and it is unaffected by weather conditions.

COMPONENT PARTS

- Rubbermaid vanity wastebasket 10 in. long × 6 in. wide × 10 in. high with rolled edge for better strength.
- 15-in. automotive funnel.
- 16 in. length of 3/4-in. polyurethane pipe.
- 1-in. tiedown strap with adjustable buckle.
- Two 1-1/2-in. hinges.
- 3-in. screen door handle.

ASSEMBLY

- Attach the 3-in. screen door handle to the funnel to give the operator better control
- Cut the discharge end of the 3/4-in. polyurethane pipe at a 45° angle approximately 1-1/2- in. up the pipe so that the prills will stay in container.
- The length of the pipe is determined by height of the applicator.
- Attach 1-1/2- in. hinges to the basket on the narrow sides so it can move with the applicator.
- A slot is cut in one side of each hinge to accept the strap with adjustable buckle. Strap is long enough to hang from around the waist of the operator. We tried hanging the basket from the neck, but found it was not ergonomically feasible.

COSTS

Applicator completely ready for work with approximate cost:

basket	$ 3.11
funnel	2.79
handle	0.59
adjustable strap	4.89
hinges	0.29
pipe	0.50
labor	5.00
Total	$17.17

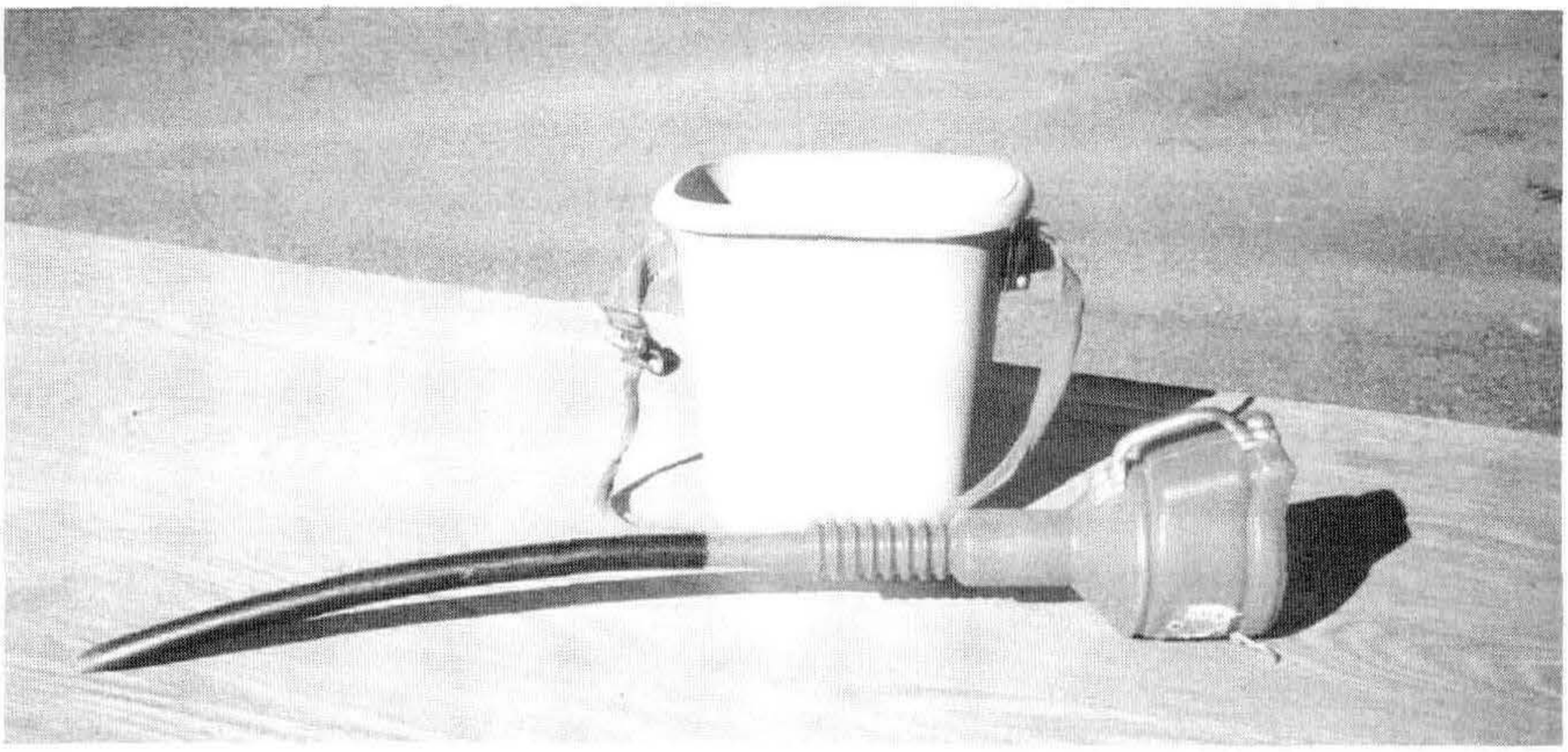

Figure 1. Fertilizer applicator.

USE

The operator, standing in one spot, can reach containers in a 180° angle and 3 ft diameter. The basket holds approximately 10 lbs of fertilizer, or 4540 g.

CONCLUSION

With the different size scoops available from manufacturers of slow-release fertilizers, it is simple to give the operator the correct scoop for whatever size container used, thereby eliminating any confusion in adjusting equipment to do the job properly. We find that production costs of applying fertilizer have been reduced by 50% with the use of this dispenser.

Fertilizing Stressed Plants

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As growers, we all know our most important tool is our eyes. We are always observing and analyzing growth patterns, color of plants, abiotic and biotic plant damage, and stressed plants in order to produce the healthiest, most vigorous plants possible. The belief has long been that the strongest, healthiest plants were the plants with a vigorous growth rate. We have long emphasized fertilization with nitrogen in order to improve the plants growth and equated this with plant health. However, a fast growing plant doesn't always withstand the stresses of the homeowner's environment.

Dr. Paul J. Kramer, the noted plant physiologist, stated in 1956, "We will learn how to grow trees by learning how trees grow". Dr. Kramer is stating we can't just depend on our eyes to grow healthy plants, we need to understand what occurs within the plant that allows it to grow and survive. When we take a look into the plant's physiological mechanisms we will find that fertilization will often limit a plants natural resistance to environmental stresses.

Dr. Daniel Herms, our research entomologist at The Dow Gardens, has addressed through his research many questions regarding current fertilization practices and the effects nutrients have on the plant's ability to withstand stress. Dan has found that fertilization encourages growth but decreases in secondary metabolite production. These secondary metabolites defend the plant against insects and diseases, attract pollinators, protect the plant from U.V. light, provide structural support, act as temporary nutrient storage, regulate phytohormone activity, promote drought resistance, help facilitate nutrient uptake, and mediate plant relationships with symbiotic nitrogen-fixing bacteria. These metabolites are termed secondary only because they are not direct products of photosynthesis. As one can see, the health of the plant is very dependent on these metabolites.

There is strong evidence that fertilized trees have lower concentrations of secondary metabolites and thus are more susceptible to insects and diseases, as well as abiotic stress. It is well documented that succulent growth is susceptible to sucking insects (i.e. aphids, scales, leaf hoppers, and spider mites), and diseases (fire blight), with decreased winter hardiness and structural support. Other studies confirm fertilization increases growth but with a trade off in terms of decreased insect and disease resistance. A study on the gray willow (*Salix cinerea*) showed fertilization increased growth, with decreased concentrations of starch, lignin, tannins, and reduced resistance to a leaf-feeding beetle (*Galerucella lineola*). In other studies fertilization increased growth of Yukon white birch (*Betula neoalaskana*) and quaking aspen (*Populus tremuloides*) and decreased their concentrations of defense compounds, lowering resistance to snowshoe hares and leaf feeding insects. Balsam fir (*Abies balsamea*), grand fir (*Abies grandis*), and loblolly pine (*Pinus taeda*) have all shown increases in growth and a decreased resistance to insects in response to fertilization. When there are high levels of water, sun, and nutrients, secondary metabolites seem to take a back seat to growth.

Those who grow plants in order to utilize the secondary metabolites for profit have long recognized the value of growing plants under stressful conditions. Rubber trees

produce more rubber when growing slow, and in dry conditions Tobacco plants have higher levels of nicotine when growing in hot temperatures And let's not forget the *Cannibus sativa* which is more potent when grown under some stress

One can use the teeter totter to picture the effect fertilizer has on plants The more fertilizer one applies, the more growth but with a reduction of secondary metabolites and environmental resistance. Plants under some stress will have a reduced growth but will be more resistant to the environment

In evaluating the health and fitness of a plant, we may find that the vigorous, fast-growing plant may not best tolerate the homeowner's environment Rapid growth has its consequences: decreased production of natural defenses. These defenses are important for the survival and well being of the plants we are producing.

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Significance of Mycorrhizal Management in the Production of Trees and Shrubs

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INTRODUCTION

Another paper in this Proceedings described the basic biology and the important roles that mycorrhizal associations play in normal growth and development of forest plants. It also emphasized that all commercially important plants, especially woody plants, regardless of where they are grown still have the genetic requirements their species have acquired from the forests over millions of years of evolution. One such biological requirement is abundant mycorrhizal development on their root systems. The purpose of this paper is to discuss factors affecting mycorrhizal development and to present a few examples of somé of the worldwide research done on mycorrhizal manipulations of commercially important forest and landscape plants. There are hundreds of publications that could be used in this discussion. However, only a few are used here to show the importance of managing mycorrhizae—the missing part of the forest—in propagation and productivity of these plants in our man-made environments.

FACTORS AFFECTING MYCORRHIZAL DEVELOPMENT

Many factors affect mycorrhizal development and they must be considered in any commercial application. It is necessary, however, to distinguish between factors that affect the plant and those that affect the mycorrhizal fungi. Generally, any soil or above-ground plant condition that affects root growth (i.e. carbon allocation to roots) also influence mycorrhizal development. The first prerequisite to mycorrhizal development is that the plant must produce a susceptible feeder root. Second, viable inoculum of a mycorrhizal fungus must be present in the rhizosphere or immediate rhizoplane. Third, chemical, physical, and biological soil conditions must favor successful root colonization. Photosynthetic potential, soil fertility, and soil water appear to be the main factors affecting susceptibility of roots to mycorrhizal colonization. High light intensity, moderate soil fertility and soil water promote development; low light intensity and excessive amounts of nitrogen and phosphorus and irrigation tend to reduce development. Research has shown that it takes 10 to 15 times the N and P ordinarily found in most forest soils to significantly suppress mycorrhizal development. In other words, it may take over 150 $\mu g\ g^{-1}$ of P and 450 $\mu g\ g^{-1}$ of N in soil solution to significantly reduce development (Cline and Marx, 1995). Mechanical defoliation that reduces photosynthetic surfaces reduces mycorrhizal development. Increased photosynthesis due to CO_2 enrichment of the atmosphere increases development. Light intensity, fertility, and soil water influence the carbohydrate status of roots and the synthesis of new roots. Both of these cases are manifestations of carbon allocation. Rapidly growing roots in highly fertile soil contain little available soluble carbohydrates which are needed by the fungi to successfully establish mycorrhizae. Photosynthates supplied to the fungi by the plant are essential to the development, function, and maintenance of mycorrhizae.

Many factors regulate the survival of the fungi in the soil or their growth on roots. Extremes of soil temperature, pH, moisture, etc. and the presence of antagonistic soil microbes can reduce the survival of certain propagules (spores or mycelia) of these fungi, and thereby, their inoculum potential in the soil. Certain fungicides stimulate mycorrhizae while others inhibit the development. Rarely have other pesticides been reported to directly affect mycorrhizal development (Marx, 1991).

MYCORRHIZAL MANIPULATION TO IMPROVE PLANT PERFORMANCE

Most of the published research on mycorrhizae has been done on forest trees and it dates to the early 1900s. In the early 1970s, research began in southern bareroot and container nurseries to produce tree seedlings with specific mycorrhizae for the purpose of improving their survival and growth on clear-cut forest sites, and on adverse sites, such as coal-mined lands, borrow pits, and severely-eroded areas. Research in the South was successful and research soon spread worldwide. Most of the research on pine and oak was done with *Pisolithus tinctorius* (Pt), a puffball-producing ectomycorrhizal fungus, with a very broad tree host range. Subsequent research has shown this fungus to have unique characteristics that aid trees of all ages to deal with environmental stresses. Over 25 species of other ectomycorrhizal fungi have also been used to successfully inoculate a wide variety of tree species.

Table 1. Response of 10- to 12-month-old pine seedlings to *Pisolithus* (Pt) or naturally occurring ectomycorrhizae in bareroot tree nurseries.

Treatment	Height (cm)	Stem diameter (mm)	Total fresh wt. (g)	Culls (%)
Pinus echinata (shortleaf pine)				
Pt	20.50	6.20	26.70	38.00
Natural	19.30	5.80	21.30	70.00
P. taeda (loblolly pine)				
Pt	28.30	4.70	15.30	16.00
Natural	23.20	4.40	12.20	30.00
P. ponderosa (ponderosa pine)				
Pt	24.20	7.50	37.90	28.00
Natural	22.10	7.10	31.40	42.00
P. strobus (Eastern white pine)				
Pt	18.80	5.70	23.20	19.00
Natural	15.00	5.30	18.90	41.00

Nursery Propagation. In the mid-1970s, research by the U.S.D.A. Forest Service began to develop a commercial inoculum of Pt. For over a decade, research on various commercial formulations was compared to research-grade inoculum for efficacy in over 45 bareroot and container nurseries belonging to forest product industries, and various federal and state agencies throughout the U.S. Table 1 shows representative results from bareroot nursery tests in fumigated soils. (Marx et al., 1984). Ectomycorrhizal development by Pt increased seedling size and reduced the

percentage of cull seedlings. Similar results have been obtained with 23 other pine species. An important point to remember in this and other research on ectomycorrhizae is that the noninoculated controls in fumigated soil or containers always have naturally occurring ectomycorrhizae from airborne spores of local fungi. In no tests, therefore, are nonmycorrhizal seedlings ever compared to ectomycorrhizal seedlings. The comparisons are between different species of fungi. Table 2 shows the effects of Pt ectomycorrhizae on container-grown oak seedlings in Missouri (Dixon et al., 1984). All of the oaks with Pt ectomycorrhizae were taller, had thicker stems, weighed more, and had larger leaf areas that did control seedlings. All of these oaks were grown under high soil fertility and irrigation protocols. Similar data has been published on six other oak species.

Table 2. Response of 20-week-old container-grown English, black and white oaks to *Pisolithus (Pt)* or naturally occurring ectomycorrhizae.

Treatment	Height (cm)	Stem diameter (mm)	Total wt. (g)	Leaf area (cm)
Quercus robur (English oak)				
Pt	34.00	8.00	17.30	334.00
Natural	23.00	6.00	8.50	272.00
Q. velutina (black oak)				
Pt	15.00	5.00	6.70	181.00
Natural	13.00	4.00	4.30	115.00
Q. alba (white oak)				
Pt	16.00	5.00	6.00	201.00
Natural	13.00	4.00	4.50	162.00

A considerable amount of nursery research has been published on the response of various hardwoods to endomycorrhizae, i.e., vesicular arbuscular mycorrhizae (VAM). An example is the work by Kormanik et al. (1982) shown is Table 3. These results clearly show that in soils containing normal forest soil amounts of available P (i.e., 10 to 15 $\mu g\ g^{-1}$), these eight species of hardwoods have an absolute requirement for VAM, i.e., they could never be competitive in a forest without VAM. Without VAM, they rarely grow beyond the primary leaf stage. Similar research is published on over 35 other hardwood tree species.

Field Performance. The ultimate value of mycorrhizal manipulation is to increase plant growth during nursery propagation, as just discussed, and to improve their field performance on their final planting site. Table 4 shows 8-year results with loblolly pine on an old-field reforestation site in Georgia. The differences in survival and growth was related to yearly rainfall. During 4 dry years, trees with Pt ectomycorrhizae grew at rates comparable to their growth rates during wetter years. Trees with only naturally occurring ectomycorrhizae slowed growth considerably during the dry years. There are numerous other publications presenting even more dramatic responses of trees to specific ectomycorrhizae formed by Pt and other fungi on mined lands, borrow pits, reforestation sites, and afforestation sites in Latin

Table 3. Response of eight hardwood tree species to VA mycorrhizae after 10 months in a bareroot nursery.

Treatment	Height (cm)	Diameter (mm)	Total wt. (g)
Prunus serotina (black cherry)			
VAM	70.00	6.90	29.30
Control	12.80	1.50	0.40
Acer negundo (boxelder)			
VAM	45.10	10.10	23.70
Control	12.80	3.20	0.70
Fraxin*us pennsylvanica* (green ash)			
VAM	37.40	8.60	23.00
Control	6.70	2.00	0.40
Acer rubrum (red maple)			
VAM	35.80	6.60	10.40
Control	8.30	2.40	0.40
Acer saccharum (sugar maple)			
VAM	9.30	3.30	3.06
Control	7.10	2.50	0.80
Liquidambar styraciflua (Sweetgum)			
VAM	29.60	7.0	12.10
Control	4.40	2.0	0.40
Platanus occidentalis (sycamore)			
VAM	66.60	12.90	71.30
Control	19.90	4.20	3.60
Juglans nigra (black walnut)			
VAM	24.80	7.90	85.60
Control	21.00	5.70	17.00

America, Asia, and Africa (Marx, 1991, Marx and Ruehle, 1989). Recently, mature oak and pecan trees in stressed urban landscapes have been inoculated by soil injection with ectomycorrhizal fungi which significantly stimulated root and mycorrhizal development.

There are numerous reports on the significance of VAM to field performance of a variety of plants including hardwood trees, desert shrubs and grasses, and woody ornamentals, grasses and flowers. Table 5 shows the response of yellow poplar after 4 years on three reforestation sites in Tennessee (Hay and Rennie, 1989). Survival and growth were significantly improved by preforming the VAM on seedling roots prior to outplanting.

CONCLUSIONS

Much is known about the biological value of mycorrhizae to plants. Research on the response of a variety of commercially and ecologically important plants to inoculation with diverse mycorrhizal fungi has shown the potential practical value of the mycorrhizal technology. Today, there are commercial inoculants of both

Table 4. Response of *Pinus taeda* (loblolly pine) after 8 years on an old-field site to *Pisolithus* (Pt) or naturally occurring ectomycorrhizae.

Treatment	% Survival	Height (m)	Volume/ha (m^3)
Pt	72.00	8.10	854.00
Natural	58.00	7.70	540.00

Table 5. Response of yellow poplar (*Liriodendron tulipifera*) after 4 years to VAM on three field sites (averaged) in Tennessee.

Treatment	Survival (%)	Height (cm)	Diameter (mm)	Plot vol. (cm^3)
VAM	66.00	108.00	22.50	363×10^4
Control	46.00	70.00	14.80	71×10^4

ectomycorrhizal and VAM fungi available for use to improve the biological quality of plants in various applications. By inoculating with the proper mycorrhizal fungi, we are bringing back that biologically essential part of the forest missing from our plants on man-made landscapes.

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Perennial Production in Europe: An Overview

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INTRODUCTION

The popularity of herbaceous perennials has affected all parts of the ornamental plant industry in the U.S. While perennials were formerly produced only by a small group of specialty growers, today bedding plant and even "woody" nurseries are propagating and growing herbaceous perennials. While domestic production has increased, growers and retailers in the U.S. still depend on seeds, plants, and ideas imported from Europe.

NETHERLANDS

When we think of perennials from Europe, most people think of bulbs from the Netherlands. Even though bulbs still constitute a huge Dutch export market, perennial production, particularly for the export market, is increasing. Much of this increase is being shipped to the U.S. Even though we are producing more and more perennials in this country, the demand still outpaces the supply.

Much of Holland is below sea level. Large parts of the country are drained areas, called polders. Boskoop, located about 30 miles south west of Amsterdam is located in one of these polders and has been home to several thousand small, "traditional" Dutch nurseries. The production areas surrounding Boskoop are characterized by small fields, usually a few acres in size, and are often surrounded by canals, so the water table is less than 3 ft below the surface. Although the peat soils are deep, sometimes as deep as 40 ft, they are not well adapted to heavy machinery, so most nurseries specialize in producing plants in small 9- and 11-cm pots which are shipped to local or regional markets. Production of bareroot plants is usually limited to specialty items that are produced in relatively low numbers. Due to space and soil limitations in the Boskoop area, production is shifting to the bulb-growing areas near Lisse, west of Amsterdam, where fields are larger and sandy-textured soils can support heavy harvesting machinery. In fact, several nurseries which formerly grew bulbs have recently shifted their entire production to growing bareroot perennials for export to the U.S.

In order to ship bareroot plants into the U.S., they must be washed so that all soil is removed, then inspected for pests. To accomplish this the U.S.D.A. has found it more efficient to establish inspection stations in the Netherlands, rather than do all inspections at ports of entry into the U.S.

Not all plants produced in Holland can be shipped to the U.S. Several are on banned lists, while others are poorly adapted to the storage and other treatments required before they are shipped. For the majority, once plants are washed they are placed in storage for a short time, then they must be heat treated to kill pests, particularly root knot nematodes. Heat treatment is tricky because plants are placed in large cookers and heated nearly to the plant killing temperature in order to kill the offending pest. While many plants withstand these temperatures, others may be

killed in the process. The Dutch government, in cooperation with grower groups, has recently funded an experiment to evaluate the effects of temperature and heating time in relation to when plants are placed into storage. The preliminary field results that I saw clearly indicated that some plants are heat intolerant, especially when they have not been properly acclimated to storage conditions. Further, my personal observations of plants that have been shipped to the U.S. also indicated that, if heat is not closely controlled, plants can be severely damaged or killed outright.

Once plants have been lifted, they are washed, heat treated, and inspected before being put back into storage to await shipment to the U.S. The perennial shipping season begins in early January. Plants are placed in large containers where temperatures are regulated and recorded. Once they arrive at the U.S. port of entry, shipments are broken down and shipped either directly to growers or to distributor warehouses for shipment at times when they can be potted up directly and placed outside. Some air freight shipping continues well into the spring for specialty items or to make up for shortages.

The Dutch are aggressive traders, a survival mechanism. The country is about the size of Vermont, but has a population of more than 18 million. We depend on them for standard bareroot items as well as new perennials for introduction into the American market. The Dutch government works hand in hand with the growers to develop new plants and ways to produce them more efficiently. Dutch nurserymen travel extensively, especially to the U.S., both to sell their plants and to look for new ones. They participate in trade shows, garden shows like Floriade, and industry or government sponsored and maintained trial gardens.

GERMANY

While the Dutch are the traders, Germany is the economic powerhouse of Europe. With an affluent population of about 80 million and a keen interest in gardening and their environment, Germans are great consumers of plants, especially perennials. Production from German nurseries is also in square 9- and 11-cm pots, but almost their entire production is sold domestically. In fact, the Dutch are such efficient shippers that if German nurseries want to ship plants to the U.S., they do so through the Dutch!!

Germany has had some outstanding plant breeders and many of our new introductions originate in Germany. For example, Georg Arends and astilbes, Ernst Pagels and salvias, Karl Foerster and grasses, Heinz Klose and peonies, to name just a few. In addition, the Jelitto and Benary seed companies produce much of the high-quality seed used in Europe as well as the U.S. Several modern U.S. gardening trends also originate in Germany; ornamental grasses, the use of water plants, and even the display of perennials is much more ecologically compatible than in American garden centers. In Germany, perennials are classified and displayed in groups according to the ecological niche they occupy in nature. Information like this might go a long way toward softening the shrill cries of the native plant advocates in this country. Indeed, many plants probably would not be "thugs" if they were planted in habitats that more closely matched their native ones.

German nurseries are as technologically advanced as they are neat. Only in Germany have I seen employees vacuuming up leaves that dropped into the pot. Reducing water contamination and pollution also receives a great deal of attention. Modern concepts of greenhouse recirculating irrigation systems and fertilizer

management are being applied to their outdoor perennial production. Further, German pot manufacturers are trying, with some success, to introduce paper pots to perennial growers. Soon, nurseries will be required by law to accept used plastic pots back to their nurseries. They would much prefer to plant the pot with the plant. Research has focused on developing fiber binding agents so pots will hold up long enough to produce the plant, yet will disintegrate when the pot is placed into the landscape.

DENMARK

To the north and bordering on Germany is Denmark, where I had the privilege to live during the Winter of 1995-96. If the Dutch are noted for field-grown perennials, the Danes are known for their potted plants. Even though they grow relatively few taxa, they grow millions of them. Plants like *Asters, Penstemon, Gypsophila, Platycodon, Astilbe, Coreopsis, Armeria*, and *Lythrum* are just a few. However, the herbaceous perennial crop that they grow in the greatest numbers is *Campanula carpatica*, and the blue selections are especially popular. Campanulas are propagated in greenhouses by either seed or division, then potted into 11-cm pots and raised in outdoor nursery areas. They remain outdoors where they are naturally cooled. Then, beginning in late November, they are brought into the greenhouse, trimmed, and forced under HID lights. More than 5 million of these lovely perennials are produced each year, and the majority are sold in Germany.

Recently, two new fully double *Campanula carpatica* cultivars have been introduced in Denmark. Key to this introduction has been the cooperation between industry and government research scientists. For some time the nurseries Thorplund and Petersminde, leaders in *Campanula* production, had noticed that some *C. carpatica* were partly double. Armed with this information they went to the pot plant research station at Aarslev on the island of Fyn. Here plant breeder Kirsten Brandt and her colleagues developed two cultivars, one white and one blue, that were fully double. Since they require asexual propagation, crop production times are easier to predict and these plants can be more easily legally protected. Negotiations are presently under way to introduce these perennials into the American market.

In summary, Europeans continue to have a strong influence on the herbaceous perennial market in the U.S. While we benefit directly from imported plants, American nurserymen in increasing numbers are traveling to Europe to develop contacts, to observe new methods, and to find those new gems to being back and enhance their inventories.

Recent Developments in Seed Germination of Ornamental Herbaceous Crops

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INTRODUCTION

Seed propagation is the major production system for ornamental herbaceous crops. It is also an area of propagation that has seen a tremendous increase in innovative techniques used to enhance quality plant production. Much of this innovation has developed in response to plug production of seedlings. A plug is a seedling grown under near optimum conditions in a small volume of growing medium. This increases production efficiency because more plants can be grown per unit area of greenhouse space. Seed germination is the critical initial event that determines success in plug production. This has led to increased emphasis on seed quality and techniques to enhance seed germination. This review will briefly cover the recent advances in the area of seed germination including:

1) Seed treatments to enhance germination and seedling emergence.
2) Seed vigor testing.
3) Mechanical seed sowing.

TREATMENTS TO ENHANCE SEED GERMINATION

The seed industry has invested in a variety of treatments to enhance the potential for rapid, uniform seedling emergence. The techniques available commercially include seed coating, "select" or "elite" seeds, seed priming, and pregermination.

Seed Coating. Seed coating uses the same technology and equipment used by the pharmaceutical industry to make medical pills (Kaufman, 1991). Seed coatings include pelletized and film coated seed. Pelletized seeds are coated with inert powders like diatomaceous earth. The purpose of seed coating is to provide a round uniform shape and size to small or unevenly-shaped seeds. This is very important for precise mechanical sowing. After sowing the pellet "melts" away allowing the seed to imbibe water. Flower seeds that are commonly pelletized are the small-seeded crops like ageratum, begonia, dusty miller, portulaca, and petunia. This allows for precision sowing of one seed per cell in a plug flat. However, some crops perform better with multiple seedlings in a single plug. This has led to the development of multi-seeded pellets that reduce sowing time because only one "seed unit" needs to be sown. Lobelia and alyssum are commonly sold in multi-seeded pellets.

Film coated seeds have a thin polymer film that covers the seeds. Film coating only adds 1% to 5% to the weight of a seed compared to over 1000% for pelletized seed, but this can still aid in mechanical sowing. Fungicides can be added to film coatings and this is a major benefit of film coating. Incorporating the fungicide in the polymer material eliminates the dust associated with traditional slurry applications of fungicides and the coating does not come off the seed when handled. Film coatings are usually colored to add attractiveness to the product and to avoid accidental human or animal ingestion if a fungicide has been used. Only a few species of

bedding plants, like marigold, are commercially available with film coating, but additional types of seeds will probably be offered commercially as this technology progresses. Various polymers are being researched that have different properties related to temperature, oxygen, and water that could prove useful as seed treatments.

Select Seeds. These are seeds that have been "selected" from the original seed lot and promoted as having improved germination. This usually means the seeds test above 90% in the companies seed testing lab. The most common technique uses seed size and uniformity as a major criteria for separation of "select" seed from the bulk seed of the original seed lot. Select seeds can improve the number of useable seedlings in a flat and may be related to seed vigor (see seed vigor later in this paper).

Primed Seeds. Seed priming uses osmotic (osmoconditioning) or matric forces (matriconditioning or solid matrix priming) to imbibe seeds for an extended time without radicle emergence. After a specific priming time, the seeds are dried back to near their original dry weight. These seeds can be handled as normal raw seeds or pelletized prior to sowing. Seeds that have been primed will usually have higher seed vigor compared to raw seed (Bradford, 1986). Priming can provide faster, more uniform seedling emergence, especially when environmental conditions for germination are not ideal. The two bedding plant species most commonly offered as primed seeds are pansy and impatiens. However, most seeds can be primed by commercial seed treatment companies on an individual grower basis. Pansy has the largest market for commercially primed seeds because priming reduces the problem pansy experiences when germinated at high summer temperatures (Carpenter and Boucher, 1991). The grower must weigh the additional cost of primed seeds with their potential for improved seedling emergence.

Pregermination. The goal of each grower is to establish a "stand" (seedling emergence) of 100%. This provides a useable seedling in each greenhouse plug cell. In concept, pregermination can take place under optimum conditions and only seeds showing radicle emergence are sown providing near 100% stand. Pregermination is a relatively new commercial technique. Impatiens is the only pregerminated seed crop being sold in 1996. Seeds are induced to synchronously germinate and arrested as the radicle emerges (<3 mm). Seeds are then dried and stored at low temperature until used by the grower. Pregerminated seeds have a short life-time and are relatively expensive. However, better growers are establishing near 100% stands using this type of seed and it is expected that more bedding plant species will be available as pregerminated seed in the near future.

VIGOR TESTING

Although state and federal seed laws currently require only purity and standard germination tests as measures of seed quality for seed lots, seed companies and many crop producers are performing vigor tests prior to sale or use. The Association of Official Seed Analysts state that "seed vigor comprises those seed properties which determine the potential for rapid, uniform emergence, and development of normal seedlings under a wide range of field conditions" (Association of Official Seed Analysts, 1983). Standard germination tests do not always adequately predict seedling emergence. Seed vigor tests can provide a grower with additional information that can help predict germination where conditions may not be ideal. Various vigor tests have been developed and certain tests are applied to different species

(Association of Official Seed Analysts, 1983; Hampton, 1995). Vigor tests used most often for bedding plants have included seedling grow out tests, and temperature stress tests. Recently, tests using accelerated aging and digital image analysis have been developed for bedding plant species.

Seedling Growth Rate. This test is an extension of the standard germination test for percentage germination. After a period of time at a controlled temperature (this varies between species), shoot and root length or seedling weight is determined. This may be done under greenhouse conditions to determine useable seedlings for a seed lot. Recently (1995), Ball Seed Company (West Chicago, IL) introduced the Ball vigor index that employs computer analysis of video images of seedlings in plug trays after a predetermined number of days. The index is suggestive of seedling greenhouse performance. Growers are expecting to see measures of seed vigor for a given seed lot. Expect to see more digital imaging systems in the future used to access vigor in bedding plant seeds.

Cool Test. This is a standard vigor test used for agronomic crops especially corn. It uses procedures identical to the standard germination test except the temperature is lowered to 18C. A similar tool is being used to evaluate flower seed vigor. It uses a sophisticated thermal gradient table to provide various warm or cool temperatures by circulating warm and cold water under the table. This simultaneously determines the range of permissive temperatures for germination in a seed lot. Higher vigor seeds germinate better at the extreme temperatures on the table. Thermogradient tables have also been useful in determining the highest temperatures for germination in bedding plant species that might experience thermodormancy or thermoinhibition.

Accelerated Aging. This test has been commonly used for agronomic and vegetable seeds. Prior to a standard germination test, seeds are subjected to high temperatures (40 to 45C) and high relative humidity (near 100%) for 2 to 5 days. This partially hydrates the seed without permitting radicle emergence. High vigor seeds tolerate this stress better than low vigor seeds as shown by higher germination percentages in the standard germination test. The smaller seed size of most bedding plant species has meant that the systems used for agronomic species can not be applied directly. However, modifications to the standard accelerated aging protocols are being developed for bedding plant species and may prove very useful for determining seed vigor and predicting seedling emergence.

MECHANICAL SEED SOWING

Plug production requires the use of a mechanical seeder (Bartok, 1994). When evaluating a seeder, growers must consider cost as well as the seeder's ability to deliver seeds at the desired speed without skipping cells due to poor seed pickup or delivery. A grower may also need the flexibility to sow a variety of sizes and different shaped seeds. It is also important to consider the volume of flats to be seeded, and the ability to sow multiple seeds per cell. Three types of seeders are commonly available to plug growers. These are template, needle and drum seeders.

The template seeder is the least expensive type of seeder. It uses a template with holes that match the location of cells in the plug flat. Template seeders use vacuum to attach seeds to the template. Releasing the vacuum drops the seeds either directly into the plug flat or into a drop tube to precisely locate seeds in

each cell of the plug flat. Templates with differently sized holes are available to handle differently sized and shaped seeds. A different-sized template is also required for each plug flat size. Template seeders work best for round, semiround, or pelleted seeds. It is a relatively fast seeder because it sows an entire flat at once. However, this is the least mechanized of the commercially available seeders. It requires the operator to fill the template with seeds, remove the excess and then move the template to the flat for sowing.

The needle seeder is a moderately priced seeder. It is fully mechanical using vacuum pressure to lift single seeds from a seed tray and deposit one seed per plug cell. Individual needles place seeds directly in plug cells or into drop tubes for more accurate seeding. A burst of air can be used to deposit seeds and clean tips of unwanted debris. The needle seeder can seed a range of sized and shaped seeds including odd-shaped seeds like marigold, dahlia, and zinnia. Although slower than the drum seeder, it is still relatively fast, sowing up to 100,000 seeds per h.

The drum or cylinder seeder has a rotating drum that picks up seeds from a seed tray using vacuum and drops one seed per plug cell. This is the fastest, most precise and most costly of the commercial seeders. Most drum seeders require a different drum for each plug flat, but newer models have several hole sizes per drum that can be selectively put under vacuum pressure. Drum seeders work best with round, semiround, or pelleted seeds. Large plug growers choose drum seeders because they seed a high volume of seeds quickly. Drum seeders can sow up to 800,000 seeds per h. Sophisticated drum seeders "eject" seeds from the drum using an air or water stream for precise seeding location in the flat.

CONCLUSION

There is a trend in the bedding plant industry toward mechanical transplanting seedlings from plug flats into larger celled containers for eventual retail sale. Mechanical transplanters are expensive, but significantly reduce labor costs and their transplanting speed can increase production. Mechanical transplanting will put even greater pressure on the plug grower to produce near 100% useable seedlings per plug flat. The ability to accomplish this starts with quality seed. The grower will require additional efforts to improve techniques to enhance seed germination and standard tests that reliably report seed vigor for any given seed lot.

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Ginseng: Seed Germination and General Culture

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INTRODUCTION

American ginseng, *Panax quinquefolius*, was first discovered in Quebec, Canada in 1704 by Michael Sarrasin and was later rediscovered near Montreal, Canada in 1716 by a Jesuit missionary, Father Lafitau. Father Lafitau began searching for the plant after reading an article written by a Jesuit missionary in China which extolled the medicinal value of the Chinese ginseng, *P. ginseng*, and suggested that the plant might also occur on the North American continent. Samples of the root were sent to China for confirmation that it was the medicinal plant desired. By 1720 a company was formed to gather, dry, and ship the root to China. Gathering of the wild root continued through the years and by the mid-1800s had resulted in the decimation of wild ginseng in much of its natural range. By the beginning of the 20th century, several individuals were attempting to cultivate ginseng. One of the problems of successful ginseng cultivation involves seed germination, which requires up to 20 months under natural conditions.

American ginseng bears small greenish white flowers in an umbel. There may be well over 150 flowers in the umbels of cultivated ginseng, but seldom over 50 (commonly 7 to 30) flowers in the umbels of wild ginseng. The flowers are self-fertile and though they may be pollinated by several different insects, insect pollen transfer is not necessary (Carpenter and Cottam, 1982). Flower opening begins on the lower part of the umbel. Fertilized flowers develop berries which turn bright red in late summer or fall. Ripe berries may be found on the lower part of the umbel while unopened flowers may still be found at its center.

The fruit of ginseng is a drupe bearing 1 to 4 seed (pyrenes) and is composed of a fleshy sarcocarp surrounding a fibrous endocarp commonly called the seed husk. One gallon of randomly collected fruits from a commercial planting had seed per fruit distribution as follows: single seeded 16.3%, double seeded 77%, triple seeded 6.5%, and four seeded 0.2% (Stoltz and Garland, 1980). The weight of the seed decreased as more seed occurred in a fruit. Moist seed weight generally varied from 50 to 60 mg each with 8000 to 10,000 seed per pound. The seed measure 5 to 7 mm in length, 4 to 6 mm in height, and 2 to 3 mm thick. The embryo within the seed measures 0.4 to 0.5 mm in length and occupies a small gelatinous-filled cavity at the micropylar end of the seed. At the time the fruit ripens the embryo is in the heart or early torpedo stage of development. During an 18- to 20-month stratification period the embryo undergoes growth and development and at the time of germination is 4 to 6 mm in length.

The fibrous endocarp of the seed has a suture line which runs around its narrowest dimension. The seed can be opened by cutting along the suture line and prying it open to expose the endosperm which is enclosed in a thin tan to brown membrane. During stratification splitting of the husk along the suture line occurs 2 to 4 months prior to germination. Splitting of the husk allows the endosperm to swell and permits the developing embryo to actually grow longer than the original length of the intact seed.

HARVESTING

By late July or early August berries set on the lower part of the umbel will begin to ripen and turn red, while unopened flowers will still be present at the top of the umbel. For maximum seed harvests hand picking of the berries should begin when about half of the berries in the umbel have turned red. If picking is delayed the early ripening berries will be lost by falling on to the bed. Two or three pickings are necessary. Pink and green berries have seed which are not adequately developed and should not be picked.

CLEANING

Two methods are commonly used to separate the berry skin and pulp from the ginseng seed. Mechanical macerators break the skin and float the skins and pulp away in a flow of water. A batch of seed can be cleaned in 10 to 20 min by these machines. After cleaning the seed should be floated to remove light seed.

A more common method is to place the berries in a burlap bag and trample the bag to mash the berries and start fermentation of the pulp. A force of water from a hose is used to wash the pulp through the bag. The bag should be trampled, hosed, and turned over at least once each day for 7 to 10 days. Finally the seed are removed from the bag and placed in buckets to float off the skins, remaining pulp, and light seed. The seed must be kept moist at all times; if the seed are allowed to dry at any stage from harvesting to germination their percent germination will be reduced. The macerator gives a much cleaner seed than does the fermentation process (Polczinski, 1982).

TREATMENTS BEFORE STRATIFICATION

After the seed are cleaned and floated they are commonly treated with formaldehyde diluted with water (1 : 85, v/v) for 1 h, Clorox diluted with water (1 : 9, v/v) for 10 to 20 min, or the seed may be dipped in a fungicide slurry such as Captan, Ridomil, Topsin, etc. before being placed in the stratification medium. Some growers do not treat the seed prior to placing them into stratification.

STRATIFICATION

Stratification boxes are constructed with a wire screen on the bottom and top to protect the seed from rodents and to allow water to readily penetrate the mixture. The boxes are placed in pits with gravel at the bottom for drainage or they may be placed on top of the ground and mounded over with soil. There should be a minimum of 4 in. of soil on the top and 12 in. of soil on the sides. In the spring, some growers remove the boxes and refloat the seed to remove any which have rotted or have precociously germinated. The seed are restratified until September when they are lifted and sown into prepared beds.

One grower was using naked stratification of the seed in fiber drums kept in an unheated workroom where he could keep the winter temperature from going below freezing. The drums were opened frequently to check moisture content and then placed on their sides and rolled to stir up the seed, to provide better aeration throughout the drum.

FUNGICIDE TEST

Poor seed germination is frequently encountered. Soil pathogens often contribute to

a low seedling stand. A test to determine if fungicides would increase seedling stands was done using seven fungicides. All treatments were applied at 1.5 oz of product for 25 lbs of seed and the seed sown into an outdoor shade bed previously fumigated with methylbromide. The seed were sown at 1-, 2-, and 3-in. spacing in rows 6 in. apart. The percent germination was recorded in June and the plants were harvested and weighed at the end of the first growing season to obtain root weights. The materials used and the results are presented in Table 1. None of the treatments resulted in significant increases in seed germination or root weight. However, Bayleton significantly decreased plant stand and may be phytotoxic to ginseng seedlings.

Table 1. Average percent germination and average root weight resulting from seven different fungicide treatments.

	Average germination (%)[y]			Average root weight (g)		
	Seed spacing in inches					
Treatment	1	2	3	1	2	3
Untreated	77.8 a[z]	61.1 a	75.0 ab	0.52 b	0.90 a	0.73 a
Benlate 50W	77.8 a	76.4 a	87.5 a	0.78 ab	0.94 a	0.78 a
Dithane M-45 80W	76.4 a	86.1 a	45.8 b	0.78 ab	0.91 a	0.82 a
Vitavax 200	71.5 a	81.9 a	69.2 ab	0.76 ab	0.93 a	0.67 a
Topsin M 70W	70.8 a	79.0 a	90.0 a	0.74 ab	0.95 a	0.82 a
Ridomil 2E	70.1 a	76.4 a	77.5 ab	0.82 a	0.70 a	0.73 a
Bay NTN 19701 25WP	59.0 a	81.9 a	70.8 ab	0.65 ab	0.91 a	0.67 a
Bayleton 50W	28.5 b	19.4 b	15.0 c	0.69 ab	0.94 a	0.00 b

[y] Average of three 36-in. rows.
[z] Values in a column followed by the same letter are not significantly different (DMRT, P=.05).

WATER ABSORPTION

The fibrous tissue of the seed husk poses no restriction to water absorption or the passage of dissolved chemical compounds at least up to the molecular size and configuration of aniline blue dye. Seed placed in an aniline blue water solution, withdrawn at 1-min intervals and cut open to observe staining on the inner surface of the husks showed some staining at 1 min and moderate to heavy staining in 10 to 20 min. However, no dye was observed to pass the thin membrane which covers the endosperm tissue even after 40 h of soaking in the dye solution. These results indicated that gibberellic acid (GA_3) in solution should readily penetrate the seed husk.

GIBBERELLIC ACID TREATMENT

Gibberellic acid has been reported to be effective in stimulating embryo growth of freshly harvested Chinese ginseng seed (Choi, 1977; Grusvickij, 1965; Varob'eva

and Gutnikova, 1967) but had no effect on germination. Gibberellic-acid-treated seed stratified for 165 days at 15C also showed no significant increase in percent germination (Choi, 1977).

Two groups of freshly harvested American ginseng seed from (1) cultivated northern plants and (2) wild Kentucky native plants were treated with 0, 500, 1000, 2000, and 5000 ppm GA_3 for 16 h and stratified in moist sand at a constant 20C. Ten embryos from each treatment were measured monthly for 19 months. Most elongation of the embryo of the treated seed had occurred by 4 months; embryos of treated seed were longer than those of untreated seed at every measurement interval.

In a separate test four lots of 50 seed each were left untreated or placed in either water or 1000 ppm GA_3 and aerated for 24, 48, or 72 h. The seed were stratified in moist sand at 5C for 5.5 months and then examined for seed splitting or germination. Gibberellic acid treatment resulted in a significant increase in splitting of the seed husk (Table 2). The average seed husk splitting for GA_3 treatments was 60% vs. 1% for water-aerated seed. The endosperm of many of the GA_3-treated seed were swollen to 150% the size of the seed husk. Examination of these seed showed that the center of the endosperm tissue had been liquified but the embryos were still less than 1 mm in length. The seed were planted in sterile soil, and placed on a greenhouse bench at 22C day temperature. After 5 months, no germination was observed and most seed had rotted.

Table 2. Percent seed showing no change, splitting of seed husk,or germination as a result of aeration in water or 1000 GA for 24, 48, or 72 h.

	Treatment						
	H_2O			1000 ppm GA			Untreated
Seed condition	24	48	72	24	48	72	
No change	97.5	99.0	98.5	55.5	27.0	35.0	99.5
Splitting of seed husk	2.5	1.0	1.5	42.5	73.0	65.0	0.5
Germination	0.0	0.0	0.0	2.0	0.0	0.0	0.0

WATER CONTENT OF STRATIFICATION MEDIUM

Forty-two lots of 110 ginseng seed each were stratified in 100 g of dry sand to which was added 0, 5, 10, 15, 20, or 30 g of water; seven lots for each moisture level. This was done in September. Each month one lot from each moisture level was selected. From each lot 10 seed were randomly selected to determine seed dry weight, fresh weight, and percent moisture content. The embryos of the remaining 100 seed were measured. The seed were held at 20C until over 50% of the embryos were 1.5 mm in length and then transferred to 5C (this occurred in Jan.). I am of the opinion that the embryo of the seed must be about 2.5 mm in length to receive the stimulus of the second cold period for germination to occur.

The results indicate that a stratification medium moisture content between 10% and 20% is best. No moisture, as expected, eventually killed the seed and at 30%

moisture, oxygen availability to the seed was probably limited and prevented embryo development; 5% moisture is considered somewhat detrimental. For all seed with moisture supplied the percent moisture content of the seed varied between 38% and 43% at all measurement times.

LEACHING TEST

American ginseng seed stratified outdoors have minimal growth of the embryo for the first 7 to 8 months (Stoltz and Snyder, 1985). Such restriction of embryo growth indicated that an inhibitor might be present in the seed which is eliminated during this period. After elimination of the inhibitor (probably by natural leaching) and warm soil temperatures are encountered the embryo begins to elongate. Lee, et al., (1983) have reported that sodium hydroxide seed treatment may have eliminated an inhibitor and promoted embryo growth. Choi and Takahasi (1977) have reported inhibitors in the sarcocarp, endocarp, and endosperm of *P. ginseng*.

Table 3. Average embryo length as affected by leaching in running tap water for various time periods.

Temp. held at °C	Date measured	Embryo lengths in mm: Days of leaching 0	4	8	12	16	20	25
20	Sept. 84	----------	----------	----------	0.53	----------	----------	----------
5	Dec.	1.50[z]	1.63	1.60	1.63	1.66	1.49	1.77
	Feb. 85	2.0	2.01	2.09	2.08	2.14	2.14	2.60
	Apr.	2.31	2.44	2.76	2.96	2.80	2.24	2.38
20	June	3.22	2.55	2.91	3.25	2.50	3.20	3.40
	July	2.52	2.77	3.00	2.87	2.84	2.81	3.21
	Sept.	2.86	2.72	2.83	3.03	3.10	3.79	3.00
5	Nov.	2.61	2.87	3.26	3.74	2.94	3.73	3.29
	Feb. 86	3.01	3.29	3.72	3.75	3.38	3.61	3.49

[z] Statistical analysis showed no significance among days of leaching.

To determine if leaching of ginseng seed would stimulate embryo development and give early germination, 50 g lots of fresh seed were leached in running tap water for 0, 4, 8, 12, 16, 20, and 25 days. After leaching the seed were stratified in moist sand and held at 20C for 3 months, 5C for 5 months, 20C for 6 months, and finally 5C for the remaining time. Ten seed were removed from each lot at various times and the average embryo length was determined (Table 3). Embryo growth does not appear to be benefitted by leaching.

PRECOCIOUS GERMINATION

Precocious germination, which is considered to be a problem by growers, should be viewed as having a potential benefit. Seed germinating the first spring should be selected out and planted into a separate area for subsequent seed production. Once this is done, two approaches are possible. Ideally, each resulting plant could be numbered and the seed identified as to parent source. Parent plants which produce higher percentages of seed with precocious germination can be selected for continued seed production and their progeny also planted into source identifiable plots for further selection. The second approach involves essentially the same procedure except the seed are not identified as to the parent plant source but each succeeding generation of precociously germinating seed would be planted into identifiable plots for seed production. By either method, selection for precocious germination should result in seed crops which have high percentage germination in the first spring after seed ripening.

SUMMARY

The embryo of American ginseng seed must equal or exceed 50% of the length of the seed before it can be induced to germinate; this would translate to an average embryo size of 3 mm in length. Treatment with GA_3 and stratification at 20C for 3 months can accomplish this objective. A second necessary part of ginseng seed germination appears to be a cold requirement after the embryo has attained a certain minimal size.

The treatment of seed with fungicides prior to seeding did not show any significant advantage to fungicide treatment. However, these seedings were planted into soil previously gassed with methyl bromide. If seedings are planted into untreated soil, fungicide treatments are a good insurance against early disease losses. Any of the fungicides used in these tests, except Bayleton, could be used.

Although inhibitors are reported to occur in both the fruit and seed of ginseng, leaching in running water did not improve the rate of development of the embryo. It is possible that the inhibitor is still present (i.e., not leachable) and its effect is not restrictive of embryo development but rather acts to keep the radicle from growing until the embryo has attained a critical size. Some preliminary work I have done indicates this possibility.

Finally I believe the concept of precocious germination should be utilized to begin selecting for strains of American ginseng that will germinate the first spring after seed ripening.

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Using Computers to Plan Perennial Production

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I have always considered PLANNING as the first step in perennial production. Using computers to help plan perennial production is a great way to save time and improve accuracy of planning. The main advantage is that using computers forces you to be organized in a logical fashion. Like using many types of computer programs, it will take some time to get used to using a program, but once you have it mastered, it will allow you to be very productive in your planning process.

Some reasons to use a computer program to help you in your production planning are:

1) Using computers will force you to become organized, and you will become more productive.
2) There are so many perennials that you should have in your list to have a good product mix. The more plants you have, the more complicated the planning process becomes.
3) Very few perennials can follow the same production "recipe". Every plant is different, and you may find that a certain crop will not grow the same in successive years, even though the production schedule is the same.
4) You want to be able to offer perennials when your customers want them. There is a small window of opportunity to sell your crop.
5) You do not want to leave any cultivars out especially if you grow a large number of cultivars.
6) You may have a special order for custom growing some plants.

Once you have decided that using a computer can help you become more organized and productive, you need to decide if you will buy a program specifically suited for your needs, or try to create a program on your own.

If you decide to buy a computer software program to help in your planning, you need to search the market to see what is out there. Expect to pay up to several thousand dollars for software programs that are specific for the nursery industry. Often you may find one of your fellow nurserymen is happy or not happy with a program he/she is using, and that may help you to narrow down your choice. Check trade publications for their "buying guides" to look up computer companies, or visit some trade shows to see what is on display. Since this is a decision that you will need to live with for a long time, be sure to ask the computer software company some questions: (1) Does the program allow you to keep growing information in the product file for each plant, such as finish time, percent harvest, plug tray size, source for seeds, cuttings, etc. (2) How sophisticated is the growing program — can you create reports that tell you which plants to produce, how many plants, when to start the plants, materials lists, square footage needed, etc. (3) Does the program include the ability to track maintenance schedules, such as when to apply fertilizer, when to prune, when to make chemical applications? Another helpful feature would be the ability to track those chemical applications, and track chemical inventory. (4) Does the program allow you to track orders, so that you know how many plants of an item you have sold (orders committed), have left to sell, have in production, and when the

Table 1. Spreadsheet explant to help organize production.

PERENNIAL PRODUCTION SCHEDULE												
	Spring production						Plug-tray production					
A	B	C	D	E	F	G	H	I	J	K	L	M
Achillea 'Moonshine'	1000	12	4	0.95	1053	8	0.90	1170	72	17	4	4
Achillea 'Moonshine'	1000	14	4	0.95	1053	10	0.90	1170	72	17	4	6
Achillea 'Moonshine'	1000	16	4	0.95	1053	12	0.90	1170	72	17	4	8
Achillea 'Moonshine'	1000	18	3	0.95	1053	15	0.90	1170	72	17	4	11
Coreopsis 'Sunrise'	600	12	6	0.95	632	6	0.95	665	200	4	5	1
Coreopsis 'Sunrise'	600	14	6	0.95	632	8	0.95	665	200	4	5	3
Coreopsis 'Sunrise'	600	16	6	0.95	632	10	0.95	665	200	4	5	5
Coreopsis 'Sunrise'	600	18	5	0.95	632	13	0.95	665	200	4	5	8
Rudbeckia 'Goldstrum'	2000	12	5	0.98	2041	7	0.95	2148	98	22	4	3
Rudbeckia 'Goldstrum'	2000	14	5	0.98	2041	9	0.95	2148	98	22	4	5
Rudbeckia 'Goldstrum'	2000	16	5	0.98	2041	11	0.95	2148	98	22	4	7
Rudbeckia 'Goldstrum'	2000	18	4	0.98	2041	14	0.95	2148	98	22	4	10
Rudbeckia 'Goldstrum'	2000	20	4	0.98	2041	16	0.95	2148	98	22	4	12

Column definitions

A = Plant species to by produced
B = Total quantity of plants desired to sell (sales quota)
C = Number of the week (calendar year) needed
D = Weeks needed to finish from transplanting to sale
E = "Harvest percentage" given in decimal equivalent (this give the grower the number needed to transplant — based on experience — in order to sell the desired quantity.
F = Number of plants to transplant to achieve sales quota (Column B ÷ E)
G = Week number to transplant plugs to finished container (Column C - column D)
H = "Harvest Percentage" of cells in plug tray, decimal equivalent
I = Number of cuttings or seedling needed (column F ÷ column H)
J = Number of cells per plug tray
K = Number of plug trays to start (column I ÷ column J); the resulting number should be rounded up to the next whole number
L = Weeks needed to finish from sticking cuttings or sowing seed until plug tray will be ready to transplant
M = Week number in which to start the plug tray (seed or cutting)

next crop will be ready. Arrange to have the company demo the program so you can actually see the program work, or visit a site where the program has been installed. If you want to try to create your own program to plan perennial production, a software package with a spreadsheet or database may be all you need, and may give you a way to customize the reports to your liking. Expect to pay a few hundred dollars for this type of software.

I put together a very simple spreadsheet that can help to organize your production (Table 1). You may want to have different spreadsheets for summer production, winter production, custom orders, plug tray production, finished production, etc. This spreadsheet can include any kind of information that is important to you in your production, and once you make the template for the information you need, and set up the formulas for each cell address, you can let the spreadsheet do the work. The goal of the process is to organize your production to make you and your employees more productive. You can make this spreadsheet as simple or as complicated as you want. The left hand column (column A) has the plant listed for each crop needed. Column B has the total quantity needed to sell for that week. Column C has the week number (based on calendar year) that the plants are needed to sell (the finish week). Column D has the number of weeks that are required for the crop to finish (from transplant to sale), column E is the "harvest percentage" given in decimal equivalent. This gives the grower the number he/she needs to transplant (based on experience) in order to sell the desired quantity. Column F has the number of plants actually need to be planted to achieve the total needed and takes into consideration that you may harvest less than 100% of what you pot, so the formula for column F would be column B divided by harvest percentage. Column G may be the most important column on this spreadsheet because it tells you the week that you need to transplant the plants in order for them to finish in the week needed. Therefore, the formula for column G is the value of column C minus the value of column D. This spreadsheet also takes into consideration that a crop may finish faster when started later in the spring, as shown in the bottom line for each plant, where the weeks to finish is less. Other information you can include would be:

- Materials list — calculate the number of containers, flats, fertilizer, soil mix, etc. you will need for each crop.
- Space requirements — calculate the number of square feet you will need for each crop.

The Plug Tray Production spreadsheet would be a companion to the finished report because you could plan your spreadsheet to calculate when you need to stick your cuttings so that the plug trays will finish on time to be transplanted. The formulas in the cells on this spreadsheet tell what week to stick the cuttings, and the number of trays to stick depending on the size of your plug tray.

The spreadsheets could be printed and kept in a notebook so that you or the production manager knows what needs to be produced in any given week. Ultimately, using computers will force you to get your perennial production organized in a logical fashion, and that can only help as your business grows.

Review of Current Practices for Overwintering Container-grown Herbaceous Perennials

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INTRODUCTION

Most container-grown herbaceous perennials require winter protection if they are to survive low temperatures and wide winter temperature fluctuations typical of many regions in the United States and Canada (Iles et al., 1993). Ideally, overwintering systems should insulate plant roots and crowns from undesirable high and low temperatures, and should buffer rapid temperature fluctuation. Over the last 10 years, researchers have studied several freeze-protection methods for container-grown perennials (Iles et al., 1993; Perry, 1990; Still et al., 1987; Still et al., 1989). However, little is known about which methods growers, retailers, and other nursery and landscape professionals actually favor for sheltering container-grown herbaceous perennials from winter injury. Therefore, the primary objective of this study was to identify and investigate the effectiveness of winter protection systems used by landscape and nursery professionals in U.S.D.A. Hardiness Zones 3 through 8.

MATERIALS AND METHODS

Data for this study were collected by using a mail questionnaire. Survey questionnaires were sent by first-class mail on 20 Aug. 1996, to 634 members of the Perennial Plant Association involved in container production of perennials. Mailed questionnaires included a cover letter explaining the objective of the research and instructions for returning the completed questionnaire. Perennial Plant Association members surveyed were assured of the confidentiality of their responses. On 6 Sept. 1996, a follow-up reminder postcard was sent to the 634 firms originally contacted.

The questionnaire contained 13 numbered questions in both closed-end and open-end form, and addressed the following areas: (a) cultural practices performed before overwintering, (b) overwintering method(s) used, (c) approximate dates for covering plants in fall and uncovering in spring, (d) assessment of factors responsible for plant loss, and (e) herbaceous perennials difficult to overwinter.

Completed questionnaires were received from 260 firms (41.0% response rate) in 38 states, the District of Columbia, and five Canadian provinces. Because expected low temperatures in a region have a direct effect on overwintering methods used, respondents were grouped by U.S.D.A. Hardiness Zone for analysis. Incomplete data for questions unanswered were not adjusted, and percentage results presented in tables are based upon actual reported totals.

RESULTS AND DISCUSSION

General Information. A majority of respondents identified their business type as either retail nursery/garden center (39.7%) or production nursery (49.2%). The remaining participants were distributed in the following manner: landscape design/

installation (6.9%), rewholesale nursery (1.5%), and other (2.7%) which included botanic and public gardens. A majority of respondents in U.S.D.A. Hardiness Zones 3, 4, and 5 were retailers, while Zones 6, 7, and 8 were most heavily represented by respondents from production nurseries (Table 1). The largest percentage of respondents (45.0%) were located in Hardiness Zone 5.

Table 1. Reported business type of respondents overwintering container-grown herbaceous perennials with respect to U.S.D.A. Hardiness Zone.

Business type	Hardiness Zone (% response)					
	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Retail	57.1[z]	56.4	44.4	29.6	18.7	27.3
Landscape	---	12.9	7.7	5.6	3.1	---
Rewholesale	---	2.5	2.6	---	---	---
Production	42.9	28.2	41.9	63.0	71.9	72.7
Other	---	---	3.4	1.8	6.3	---
	n=7	n=39	n=117	n=54	n=32	n=11

[z] Percent determined by dividing number of respondents within a business type by total respondents from the respective Hardiness Zone.

Table 2. Reported date of final fertilizer application by firms overwintering container-grown herbaceous perennials with respect to U.S.D.A. Hardiness Zone[z].

Date	Hardiness Zone (% response)					
	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Aug. 1	14.3[y]	17.9	13.7	14.8	---	---
Aug. 15	28.6	30.8	19.7	3.7	6.3	9.1
Sept. 1	---	10.3	16.2	20.3	21.9	18.2
Sept. 15	42.8	17.9	22.2	18.5	28.1	18.2
Oct. 1	---	2.6	10.3	16.7	21.9	18.2
Incorp.[x]	---	17.9	12.0	16.7	15.6	9.1
Other	14.3	2.6	3.4	7.4	6.3	27.2
	n=7	n=39	n=117	n=54	n=32	n=11

[z] Respondents were queried as to when during the growing season do they fertilize their container-grown perennials for the final time.
[y] Percent determined by dividing number of respondents applying fertilizer on a particular date by total respondents from the respective Hardiness Zone.
[x] Fertilizer incorporated into potting medium at planting time.

Acclimating Perennials for Storage. Research findings do not support the widely held belief that late season fertilizer application decreases plant cold hardiness (Pellett and Carter, 1981), however, many nursery operators are reluctant to fertilize nursery stock in September and October. In this study, respondents were asked when during the growing season do they fertilize container-grown perennials for the final time. Although trends were difficult to identify, a majority of respondents reported final fertilizer applications are made on or before 15 Sept. (Table 2). Those that do fertilize perennials after 15 Sept. are primarily located in Hardiness Zones 5, 6, 7, and 8. Several respondents in every zone except Zone 3 reported fertilizing only at potting when slow or controlled-release fertilizer is incorporated into the medium.

Water stress has been shown to enhance cold hardiness of many plants (Levitt, 1980). But in this study, a majority of respondents (54.0%) reported they do not make a conscious effort to reduce the amount of water given to container-grown perennials in the fall. Only in Hardiness Zone 7 did a majority of respondents (53.1%) indicate they purposely reduced fall irrigation to improve cold hardiness (Table 3).

Table 3. Reported fall irrigation practices by firms overwintering container-grown herbaceous perennials with respect to USDA Hardiness Zone[z].

	Hardiness Zone (% response)					
Practice	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Reduce water	42.9[y]	43.6	44.4	44.4	53.1	45.5
Don't reduce water	57.1	53.8	53.0	55.6	46.9	54.5
	n=7	n=39	n=117	n=54	n=32	n=11

[z] Respondents were queried as to whether they limit or reduce the amount of water given to their container-grown herbaceous perennials in the fall in preparation for winter.

[y] Percent determined by dividing number of respondents reporting a particular irrigation practice by total respondents from the respective Hardiness Zone.

Cultural Practices. Cultural practices performed at time of covering are often as important to plant survival as the overwintering system itself. A majority and equal number of respondents in Hardiness Zones 3 and 4 said they remove dead or dying foliage from plants and apply a rodenticide before winter protection is put in place (Table 4). Removing foliage was the most important cultural practice before overwintering for respondents in Zones 5 and 6, followed by applying a rodenticide and irrigating plants. In Zones 7 and 8, irrigating plants before providing winter protection was most important to respondents. Other cultural tasks mentioned by respondents included, tipping plants on their side, weeding, transplanting to the

next largest-sized container, and applying slug bait.

Table 4. Reported cultural tasks performed before providing winter protection by firms overwintering container-grown herbaceous perennials with respect to U.S.D.A. Hardiness Zone[z].

Cultural task	Hardiness Zone (% response)					
	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Irrigate	28.6[y]	66.7	63.2	40.7	68.8	36.4
Fertilize	---	5.1	5.1	7.4	9.4	9.1
Fungicide	14.3	15.4	39.3	40.7	43.8	9.1
Rodenticide	71.4	69.2	70.1	51.9	40.6	---
Remove foliage	71.4	69.2	85.5	68.5	56.3	27.3
Other	28.6	12.8	6.0	5.6	6.3	---
	n=7	n=39	n=117	n=54	n=32	n=11

[z] Respondents were queried as to what cultural practices they performed before storing container-grown herbaceous perennials for winter.

[y] Percent determined by dividing number of respondents performing a cultural task by total respondents from the respective Hardiness Zone.

Overwintering Systems. Respondents in this study used a wide variety of systems to overwinter their container-grown herbaceous perennials. But in Hardiness Zones 3 and 4, a majority of respondents reported using only one method or system to protect their container-grown stock. By comparison, a majority of respondents in Zones 5, 6, 7, and 8 reported using two or more systems for winter protection.

Protecting plants with so-called structureless systems may be the simplest and least expensive method for overwintering nursery stock (Beattie, 1986). With these systems, plants are consolidated container-to-container and covered with a sheet(s) of material having insulating qualities. Over two-thirds (72.7%) of the respondents in this study reported using a type of structureless overwintering system (Table 5). Covering plants with a thermal blanket and an additional layer of white polyethylene film was the method preferred by the largest percentage of respondents in Zones 3, 4, and 5, while firms in warmer zones were more apt to use single layer coverings, or depend solely on consolidating plants pot-to-pot for low temperature protection. Other structureless methods used by respondents included covering consolidated perennials with spunbonded fabrics (either alone or in combination with other insulating materials), utilizing several variations of the "sandwich" technique (poly-straw-poly for example), surrounding plants with bales of peat, and creating an artificial blanket of snow.

Table 5. Reported use of structureless systems by firms overwintering container-grown herbaceous perennials with respect to U.S.D.A. Hardiness Zone[z].

	Hardiness Zone (% response)					
Structureless system	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Plants consolidated	---	5.1[y]	6.8	5.6	34.4	36.4
Plants surrounded with Kraft paper	---	---	---	1.9	---	---
Plants surrounded with straw bales	---	15.4	5.1	7.4	3.1	9.1
Plants covered with white poly	---	5.1	5.1	22.2	18.8	9.1
Plants covered with thermal blanket[x]	---	15.4	21.4	37.0	18.8	18.2
Plants covered with thermal blanket and white poly	28.6	35.9	30.8	16.6	9.4	9.1
Other	42.9	28.2	17.1	9.3	9.4	9.1
	n=7	n=39	n=117	n=54	n=32	n=11

[z] Total respondents using structureless overwintering systems (189/260 = 72.7%).
[y] Percent determined by dividing number of respondents using a structureless system by total number of respondents from the respective Hardiness Zone.
[x] Thermal blanket defined as .25 inch thick microfoam, or 1-mil polyethylene bonded to .25-in. thick microfoam.

Polyhuts are low-profile, white polyethylene-covered hoop houses used principally for overwintering herbaceous perennials, groundcovers, or low-growing woody plants (Beattie, 1986). Surprisingly, only 34 respondents (13.1%) reported using polyhuts for winter protection, with the majority of those located in Zone 5 (Table 6). Among all respondents using polyhuts, most (70.6%) consolidated plants within the structure without any additional covering.

Large, quonset-type polyethylene-covered structures, commonly called polyhouses, were used by just over one-half (51.5%) of the respondents in this study (Table 7). Consolidating plants within the polyhouse with no additional protection, and covering consolidated plants with a thermal blanket were the most common ways to overwinter perennials in these structures.

Growers and retailers requiring maximum insulation from low temperature frequently overwinter their perennials in polyhouses with inflated double polyethylene covers. In this study, 81 respondents (31.2%) reported using polyhouses with inflated double-poly, and a majority of those (75.3%) used heaters to maintain root zone temperatures just above freezing (Table 8). Because these structures are more costly to build and operate than those previously mentioned, space within them is usually reserved for very small plants in plug trays, flats, and/or cell packs, cold-sensitive species, or high-value perennials.

Table 6. Reported use of polyhuts by firms overwintering container-grown herbaceous perennials with respect to U.S.D.A. Hardiness Zone[z].

	Hardiness Zone (% response)					
Polyhut system	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Plants consolidated	---	---	12.0[y]	13.0	3.1	18.2
Plants covered with white poly	---	---	0.8	---	3.1	---
Plants covered with thermal blanket[x]	---	5.1	5.1	3.7	3.1	---
	n=7	n=39	n=117	n=54	n=32	n=11

[z] Total respondents using polyhuts as overwintering systems (34/260 = 13.1%).
[y] Percent determined by dividing number of respondents using a polyhut system by total number of respondents from the respective Hardiness Zone.
[x] Thermal blanket defined as .25-in. thick microfoam, or 1-mil polyethylene bonded to .25-in. thick microfoam.

COVERING AND UNCOVERING

Determining the optimal date for covering and uncovering herbaceous perennials is a difficult management decision. In the fall, plants should be covered as late as possible, but before root or crown damage occurs. In spring, covers should be removed as early as possible so that heat buildup under the covers does not result in excessive or etiolated growth, but late enough to avoid low temperatures that could cause root or shoot damage. A majority of respondents in Zones 4 and 5 cover their perennials sometime in November (Table 9). Covering in mid November to mid December is more common in Zones 6, 7, and 8. Several respondents remarked that date of covering is largely dependent upon the species to be protected; the least hardy are covered first. Others stated the date of covering is dependent upon the system(s) being used. In general and irrespective of Hardiness Zone, polyhouses or polyhuts are covered first, with insulating blankets within these structures applied later. Plants to be protected by structureless systems are covered last. In spring the order is reversed as structureless systems are dismantled first.

A majority of firms in Zones 6, 7, and 8 reported uncovering perennials by early to mid March (Table 10), however, several respondents stated that periodic warm spells often make it necessary for them to uncover or vent several times throughout the winter. In the colder Zones (3, 4, and 5) most respondents uncover plants from mid March to mid April.

Table 7. Reported use of polyhouses by firms overwintering container-grown herbaceous perennials with respect to U.S.D.A. Hardiness Zone[z].

	Hardiness Zone (% response)					
Polyhouse system	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Plants consolidated	14.3[y]	5.1	28.2	55.6	62.5	27.3
Plants covered with white poly	---	2.6	6.8	5.6	12.5	---
Plants covered with thermal blanket[x]	14.3	10.3	23.9	16.7	9.4	---
Plants covered with thermal blanket and white poly	---	5.1	6.0	1.9	---	---
	n=7	n=39	n=117	n=54	n=32	n=11

[z] Total respondents using polyhouses as overwintering systems (134/260 = 51.5%).
[y] Percent determined by dividing number of respondents using a polyhouse system by total number of respondents from the respective Hardiness Zone.
[x] Thermal blanket defined as .25-in. thick microfoam, or 1-mil polyethylene bonded to .25-in. thick microfoam.

PLANT LOSS

A majority of the respondents in this study reported minimal plant losses (0% to 10%) as a result of their winter protection methods (Table 11). In fact, only 45 respondents (17.3%) reported losses ≥11%.

The largest percentage of respondents in each Hardiness Zone said excessive moisture inside the overwintering environment was most responsible for plant loss in their overwintering system (Table 12). Respondents cited low temperatures and damage from animals as the second and third most likely factors responsible for plant loss.

Among those reporting losses ≥11%, an equal number (53.3%) stated low temperature and overly wet conditions were most responsible for plant loss. A majority of these respondents (66.7%) also reported using structureless overwintering systems in which ventilation is usually poor and plants at the perimeter are often subject to injurious low temperatures.

Table 8. Reported use of polyhouses with inflated double-poly by firms overwintering container-grown herbaceous perennials with respect to USDA Hardiness Zone[z].

	Hardiness Zone (% response)					
Double-poly system	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Plants consolidated	---	2.6[y]	15.4	14.8	12.5	---
Plants covered with white poly	---	---	2.6	---	3.1	---
Plants covered with thermal blanket[x]	14.3	7.7	5.1	3.7	3.1	---
Plants covered with thermal blanket and white poly	---	---	---	---	---	---
House heated	42.9	12.8	28.2	22.2	21.9	9.1
	n=7	n=39	n=117	n=54	n=32	n=11

[z] Total respondents using polyhouses with inflated double-poly as overwintering systems (81/260 = 31.2%).
[y] Percent determined by dividing number of respondents using a double-poly system by total number of respondents from the respective Hardiness Zone.
[x] Thermal blanket defined as .25 inch thick microfoam, or 1-mil polyethylene bonded to .25 inch thick microfoam.

PERENNIALS DIFFICULT TO OVERWINTER

Certain herbaceous perennials are more difficult to overwinter than others. The 15 genera most difficult to overwinter as reported by respondents in this study are listed below. In addition, 26 respondents mentioned ornamental grasses as being difficult to overwinter.

Iris (n=38)
Delphinium (n=27)
Papaver (n=26)
Lavandula (n=25)
Phlox (n=21)
Lupinus (n=20)
Asclepias (n=18)
Coreopsis (n=18)
Dianthus (n=18)
Anemone (n=14)
Campanula (n=13)
Gaillardia (n=13)
Hosta (n=13)
Scabiosa (n=11)
Perovskia (n=10)

Table 9. Reported approximate target period for covering container-grown herbaceous perennials with respect to U.S.D.A. Hardiness Zone[z].

Period	Hardiness Zone (% response)					
	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
15-30 Sept.	---	---	0.8[y]	---	---	---
1-15 Oct.	14.3	7.7	1.7	5.6	3.1	---
16-31 Oct.	28.6	7.7	5.1	5.6	6.3	---
1-15 Nov.	14.3	59.0	41.0	18.5	12.5	---
16-30 Nov.	14.3	17.9	32.0	22.2	18.8	27.3
1-15 Dec.	---	5.1	11.1	27.8	31.3	36.4
16-31 Dec.	---	---	1.7	5.6	15.6	---
Other	28.6	2.6	5.1	1.9	12.5	18.2
	n=7	n=39	n=117	n=54	n=32	n=11

[z] Respondents were queried as to their approximate target period for covering or protecting container-grown herbaceous perennials.
[y] Percent determined by dividing number of respondents covering their container-grown herbaceous perennials during a particular period divided by total respondents from the respective Hardiness Zone.

Table 10. Reported approximate target period for uncovering container-grown herbaceous perennials with respect to USDA Hardiness Zone[z].

Period	Hardiness Zone (% response)					
	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
1-15 Feb.	---	---	2.6[y]	3.7	18.8	27.3
16-28 Feb.	---	---	0.8	7.4	---	9.1
1-15 Mar.	14.3	7.7	26.5	40.7	37.5	27.3
16-31 Mar.	42.9	17.9	17.1	11.1	3.1	---
1-15 Apr.	28.6	51.3	36.8	18.5	18.8	---
16-30 Apr.	14.3	7.7	1.7	1.9	6.3	---
1-15 May	---	2.6	4.3	1.9	3.1	---
Other	---	12.8	7.7	5.6	15.6	18.2
	n=7	n=39	n=117	n=54	n=32	n=11

[z] Respondents were queried as to their approximate target period for uncovering or removing protection from container-grown herbaceous perennials.
[y] Percent determined by dividing number of respondents uncovering their container-grown herbaceous perennials during a particular period divided by total respondents from the respective Hardiness Zone.

Table 11. Reported plant loss resulting from winter protection methods used by firms overwintering container-grown herbaceous perennials with respect to U.S.D.A. Hardiness Zone[z].

	Hardiness Zone (% response)					
Plant loss	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
No loss	---	---	0.8[y]	1.9	9.4	9.1
1-10% loss	71.4	76.9	79.5	79.6	78.1	72.7
11-25% loss	28.6	17.9	16.2	14.8	9.4	9.1
26-50% loss	---	5.1	1.7	1.9	---	---
>50% loss	---	---	---	---	---	---
	n=7	n=39	n=117	n=54	n=32	n=11

[z] Respondents were queried about plant losses attributable to their overwintering methods.
[y] Percent determined by dividing number of respondents reporting a particular plant loss category divided by total respondents from the respective Hardiness Zone.

Table 12. Reported factors responsible for plant loss by firms overwintering container-grown herbaceous perennials with respect to U.S.D.A. Hardiness Zone[z].

	Hardiness Zone (% response)					
Loss factor	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8
Low temp.	14.3[y]	43.6	31.6	31.5	40.6	36.4
Too wet	71.4	51.3	51.3	46.3	56.3	45.5
Too dry	---	17.9	18.8	13.0	9.4	---
Late getting covers on	---	10.3	6.8	13.0	3.1	---
Late getting covers off	---	17.9	11.1	1.9	3.1	---
Animal damage	28.6	38.5	36.8	33.3	25.0	9.1
Disease	14.3	10.3	23.1	22.2	31.3	9.1
Other	14.3	23.1	12.0	20.4	18.8	9.1
	n=7	n=39	n=117	n=54	n=32	n=11

[z] Respondents were queried as to which factor(s) unique to their overwintering method was most responsible for plant loss.
[y] Percent determined by dividing number of respondents reporting a particular loss factor divided by total respondents from the respective Hardiness Zone.

CONCLUSIONS

Overwintering systems must be tailored to the local climate, production system, and take into account the cold hardiness of species to be protected. Systems appropriate for U.S.D.A. Hardiness Zones 4 and 5 may be totally inappropriate for warmer zones. And even within a particular zone, several different winter protection systems may be necessary to protect an inventory of plants having varying degrees of cold hardiness and at various stages of development.

Plant loss can be minimized when plants are carefully matched to an appropriate overwintering system. Perennial species sensitive to excessive moisture should be protected within a well-ventilated overwintering environment. Cold-sensitive species should not be overwintered at the "edges" of polyhuts, polyhouses, or structureless systems. Protective measures must be taken to exclude, deter, or eradicate rodents and other destructive animals. And decisions about when to cover and uncover must be fluid and continually evaluated.

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Growing and Marketing Herbaceous Natives

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INTRODUCTION

The utilization of native plants, in the case of this paper, herbaceous forbs and grasses, has been very popular over the last several years. They are utilized in natural area restoration work; and highway, corporate, and residential landscape projects. Native plants should be considered as an addition to a nurseries production scheme. This paper discusses the methods that are used by the author to grow and subsequently market this type of plant material.

There is no denying that the perennial plant market is at this time, capturing a significant share of the wholesale and retail sales in the horticulture industry. The relative ease of perennial propagation, rapid turnaround in production time, and wide appeal in sales, make this product line worth investing in. With regards to native plants, or in the case of this paper, Midwestern woodland and grassland perennials, they are able to be utilized in various ways to achieve customer sales, and subsequent return sales. This type of plant material is excellent for where a low maintenance situation is to be incorporated. Some examples are: parking lot buffer areas, large-scale perennial plantings, and renaturalizing plantings in certain housing situations. These endemic plants offer nearly four seasons of usability for the landscape, they are in most cases, not hampered with significant disease or insect infestation, and they do not require extensive man hours of labor, once they become established.

PROPAGATION

Many of these plants can be readily grown from seed. They also can be propagated from stem and root cuttings, and by simple division. Their root systems will readily grow in the soilless container mixes that are standard in the industry today. Natives also will do well in many of the specialized tray and pot systems that are in use by growers. I, myself, utilize a variation of the popular pine bark and compost-based mix. I use a just-in-time system for obtaining my potting mix, and work with my local supplier to get a "fine tuned" mix for my production scheme. In some cases, plants are sold directly in the plug trays. Otherwise, I use either Anderson band pots or 1-gal plastic containers, after transplanting from plug trays, to grow plants to a finished product. So much for growing perfect plants, now that you have them, you have to sell them.

MARKETING

If you grow them, will they sell? So often people begin to grow particular plants, or want to get into what's trendy. In many cases, they later wonder what to do with their plants at the end of the season. The concept of marketing is not new, but what stymies people is how to market the service or product they have. In many cases, we rely upon existing customers to utilize our products. A recurring customer can be influenced easier into buying new products and services because they are already

familiar with your companies' product and service record. How then, do you reach out to new people, and thereby increase your market share, or reach out to those existing customers who may not have purchased from you in a while?

SELLING

First off, you should define what your goal in the market place is. Having plants that look good, does not mean that those plants will automatically sell for you. Why are you growing these plants, who will use them, what portion of you business do they account for? You should be asking yourself these questions along with another important point, what are your customers looking for. You must make it your point to know as much of your customers business as you can.

On a commercial level, the act of selling is not the end of a business dealing, but the beginning. With wholesale customers, they are looking for you, and you must be ready to deal with them. Retail consumers may never see you, or your product, and a retail sale is usually the end of the deal. When you enter into a wholesale relationship, you are hopefully beginning a long-term affair with your client. Buying habits in this business tend to be along seasonal lines, and in many cases, customers may project buying with regards to economic or contractual forecasts. Contractors may have a project which takes months or even longer to complete. Other growers who buy from you, may be projecting their crops on a yearly, or multiple-year schedule. You must be able to forecast this. (Sometimes we are guessing, and when we are right, we can claim to be successful).

ADVERTISING

When you want people to utilize your company and services tell them and make your message clear. If you're a specialist in growing a certain plant, make that point known. An example of native prairie plants would be their hardiness, or their ability to survive a drought. This is a key selling point. Customers don't need to be constantly dead heading, spraying for insects can be a minimal chore, and they are long-lived landscape or garden inhabitants. You can give examples of species adaptability to wet or dry conditions, report on their cold or heat tolerance. With regards to woodland species, they can be utilized along with early blooming bulbs to give color to the landscape in early and mid spring. In addition, you should remember, that these ephemerals go dormant by June, so that subsequent plantings of summer or even fall blooming plants, may be incorporated into the same garden area.

These are some key elements that will help sell this type of plant material. Remember, you are selling to people on a personal level, be armed with as much information as possible. The key to successful sales is not only what you know about the product you sell, but also what you know about the customer you are selling to. Many people hear the word native used in connection with plants, but they may be unfamiliar with what this really means. Can they use this type of plant material? To help you increase sales, you can host an informational seminar at your company. Provide visual and written aids to prospective buyers. Offer job-related facts for installing and maintaining this type of plant material. Provide either county or state guidelines for planting native plants. Do you have a demonstration planting area at your nursery? Are the plants there clearly marked? You can provide a sales person who can handle specific questions on native plants. You have to be accessible, return phone calls as soon as possible, and don't let that sale get away.

THE BEST MEDIA SOURCE

What can you put into your customers' hands that will help them keep you and your company in the front of their minds. With a printable format, the tradition has been the catalog. Followed up later in the year with mailings. In many cases, your mailing may get less than a second of time in someone's hands, before it's lost in the recycling bin. A quarterly report, in the form of newsletter, or brochure, has a better chance of staying around. You are looking at several weeks at best, of staying in people's minds, when you use printed materials. Direct contact has been, and still is one of the best tools for business-to-business sales. Utilize your fax machine to "direct mail" the people you need to reach. Include a coupon with the fax, or just with fax orders. This is another way to attract people who may not regularly trade with you. The newest tool is the internet. This can be your 24-h employee, with catalog lists, sales items, product availability, and the ability to take orders after normal business hours. Remember, product, quality, and service, all go hand in hand. Maintain a high level in each of these areas, and you will succeed, but you must be willing to work at it.

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Use of Growth Regulators in Production

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INTRODUCTION

This paper in no way promotes or recommends the use of chemical growth regulators, but rather offers an overview and insight into their potential uses and/or limitations. When considering growth regulators for plant production, the legal aspects (label restrictions, etc.) and environmental concerns must be taken into consideration.

The effect of any growth regulator is dependent on the method of application, health and vigor of the plant being treated, and the environmental influences during application as well as the cultural and environmental conditions after application. When we mention the term growth regulators, we are referring to chemical or environmental condition that will influence or modify the normal growth characteristics of a plant. The most important growth regulators currently employed at the nursery are cultural rather than chemical. They include:

- Watering (water can be a great growth inhibitor when employed by a skilled grower).
- Temperature (low temperature to reduce growth rates and or to keep certain plants dormant vs. higher temp to increase vegetative growth)
- Light (depending on the crop being grown day-length modifications can be used to induce or inhibit blooming, induce or inhibit dormancy, lengthen or shorten vegetative growth, etc.).
- Fertilizer modifications (increasing the ppm nitrogen can in some cases be used to increase vegetative growth and inhibit flowering, while reducing the ppm of phosphates can be used to reduce internode length).

A word of caution, any of these environmental modifications when used to the excess can cause severe crop damage. Experience, observation, and the skills of a good grower are the keys to successful plant culture and plant growth modification through environmental and/or chemical means.

CHEMICAL GROWTH REGULATORS AND THEIR USE FOR MODIFYING PLANT GROWTH

Auxins (NAA, IBA, etc.). This is perhaps the most widely used group of chemical growth regulators in the nursery business. Auxins are commonly used in either a liquid or powder form to induce or promote root development on vegetative shoots and rapid cell growth in tissue culture. In nature, auxins also influence or help to maintain apical dominance. To increase lateral bud break, we need to reduce or inhibit the effects of the naturally occurring auxins. This can be accomplished through; pinching, cutting back, and chemical applications. Atrinal and Atrimmec promote lateral shoot development in some crops, but whether they actually inhibit or compete with the naturally occurring auxins is questionable.

Cytokinins (Zeatin, PBA, and BAP). A group of plant hormones which promote lateral shoot development and to some extent cell division. Though they are rarely used in "normal" plant production they are widely used in tissue culture, and certain specialized methods of daylily, hosta, and orchid propagation. Cytokinins can also be used to promote branching in plants, but to my knowledge, cytokinins are only registered for research and not commercial greenhouse production.

Gibberellins (GA). A group of naturally occurring plant hormones produced by both plants and disease/symbiotic fungi. The primary mode of action of gibberellins is through the stimulation of cell elongation and to a lesser extent cell division resulting in increased internode length, leaf size, and in certain cases, flower size. The use of gibberellins for the production of a finished crop is limited by the weakened stems (increased internode length), yellowing, and occasional deformation of the foliage. However, gibberellins can be used in the production of standards, stimulation of a spring-like flush of growth for cutting production, to help break winter dormancy in certain plants, and as a germination aid for certain cactus and woodland wildflowers. Low doses applied at 2-week intervals to test blocks appears to work the best for us until a proper dosage for the entire group can be determined. The effects of GA varies according to the crop, time of year, and dosage. Thus, the proper dosage and number of applications must be determined individually for your crop and conditions. A word of caution, too much GA may result in a weak plant and during GA-induced growth spurts, the plants typically exhibit an increased need for nitrogen and to a lesser extent iron (if these needs are not met, yellowish plants will result). At the nursery, we have found that GA can be used to bring certain plants out of dormancy earlier without increasing day length or temperature (*Campsis*, *Coreopsis*, etc., particularly those plants whose dormancy is day-length dependent). GA can also be used to induce a spring-like flush of growth on such plants as, *Phlox, Scabiosa, Buddleja, Heuchera*, and just about anything we have ever tried it on. Care must be taken when working with plants with normally long internodes and things like *Ajuga*. GA can be lethal if too much is used.

Ethylene (Ethephon/Florel). Ethylene has long been known to have profound effects on certain plants, such as the induction of flowering in certain bromeliads, inhibition or damage to flowers in other plants, stunted and/or yellowish growth, etc. When used properly, ethylene or Ethephon (a liquid acid that produces ethylene when absorbed by the plant) can be used to inhibit flowering in certain plants (*Impatiens*, *Scabiosa*, *Pelagonium*, certain begonias, etc.), reduce internode length, and increase branching. With some on-site research specific to your conditions and crop it appears that Ethephon might be very useful in the maintenance of stock plants, increased branching, and flower inhibition and/or stimulation. A word of caution, ethylene tends to magnify the negative effects of environmental conditions such as water stress, cool temperatures, etc. The use of Florel is currently restricted by its label.

Other chemical growth regulators such as B-Nine (daminozide), Cycocel (chlormequat choride), A-rest (ancymidol), Bonzi (paclobutrazol), Sumagic (uniconazole), are very crop specific in their actions and great care must be used when applying (mixing, application method, uniformity, etc.) or more damage will result than benefits obtained.

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NEW PLANT FORUM

Compiled and Moderated by Jack Alexander

PRESENTERS:

Jack Alexander, The Arnold Arboretum, Jamaica Plain, MA 02130
Cladrastis kentukea 'Perkins Pink'

Darrel Apps, Woodside Nursery, Bridgeton, NJ 08302
Hemerocallis 'Jen Melon'

David Bakker, J.C.Bakker & Sons Ltd., St. Caterines, Ontario, N0M IG0 Canada
Spiraea thunbergii 'Fujoni'

Bill Barnes, Lorax Farms, Warrington, PA 18976
Sinocalycanthus chinensis

Dick Bir, N.C. State Univ. Research and Extension Ctr., Fletcher, NC 28732
Solidago roanensis var. *monticola*
S. rugosa 'Fireworks'
S. sphacelata 'Golden Fleece'

Don Brennan, Chicago Botanic Garden, Glencoe, IL 60022
Euonymus alatus 'Timbercreek', Chicago Fire™ euonymus
Fraxinus americana 'Tures', Windy City™ white ash

Dan Meier, Briggs Nursery, Olympia, WA 98501
Rhododendron 'Elvira'
R. 'Haaga'
R. 'Hellikki'
R. 'Mikkeli'
R. 'Peter Tigerstedt'
Rosa 'Golden Wings'
R. 'Jan's Wedding'

Charles Tubesing, The Holden Arboretum, Kirtland, OH 44094-5172
Aster linariifolius
Delphinium exaltatum
Liriope platyphylla
Silene regia

Ken Twombly, Twombly Nursery, 163 Barn Hill Road, Monroe, CT 06468
Cornus kousa 'Variegata'

Aster linariifolius

Stiff aster is an August to October blooming perennial from dry acid open areas. This accession was collected in southern Ohio but the species ranges to Maine. It will grow in average to dry soils amended with peat and sand. Plant height is 1 to 2 ft. Easy to propagate from seed when given a 90-day cold moist stratification. Stiff aster can be propagated from new growth cuttings taken in June. Seed is available upon request from The Holden Arboretum.

Cladrastis kentukea 'Perkins Pink'

The Perkins pink yellowwood, *C. kentukea* 'Perkins Pink', is a new name proposed for a plant that had been known as *C. kentukea* 'Rosea' (syn. *C. lutea* 'Rosea'). This cultivar was discovered growing at the Perkins Institute for the Blind in Watertown, Massachusetts. The pink form was noted by Dr. Wyman in his 1951 *Trees for American Gardens*, but the cultivar name 'Rosea' was not published until 1961 [*Arnoldia* 21(3):20 by B. L. Wagenknecht]. The International Code of Botanical Nomenclature had by that time outlawed the use of Latin form epithets as cultivar names, making the name 'Rosea' illegitimate. Additionally, this new cultivar name should distinguish the Perkins clone from others also having pink flowers. Anyone that has received scions of this plant from the Arnold Arboretum should note this name change. As all scions would have come from Arnold trees that are of the Perkins Institute lineage.

Hardy to U.S.D.A. Zone 4, Perkins pink yellowwood becomes a medium-sized tree with a height of 30 to 50 ft and about the same width. It has a gray, beech-like bark and bright yellow autumn leaf color. The light pink flowers appear in pendulous, terminal panicles that are about 10 to 15 in. long and, in the Boston area, appear in early June. It is propagated by grafting onto seedlings of the species.

The flowers of this cultivar are noticeably pink, but are a light pink. Seeking a plant of darker coloration, Gary Koller and I collected seeds from the Perkins tree in 1979 and distributed them at the Eastern Region I.P.P.S. convention that year. I am told that some of the seedlings resulting from that distribution have had pink flowers.

Cornus kousa 'Variegata'

Although not a new cultivar, 'Variegata' is not in widespread use today. It will grow with the same vigor as *C. kousa*, with good variegation in sun or shade, and excellent fall color, when the white margins of the leaves turn a rosy-pink color.

Delphinium exaltatum

Tall larkspur is a July to August blooming native perennial of dry prairie openings—our material was collected from southern Ohio. It is very easy to grow in dry to average soils, but prefers sites amended with limestone gravel, and it will grow in fill sun to partial shade. Plant height is 2 to 4 ft. Tall larkspur can be propagated by seed given 60 days warm-moist stratification followed by 90 days cold moist stratification. Seed is available from Jelitto Seeds in 1997 or by request to The Holden Arboretum.

Euonymus alatus 'Timber Creek' Chicago Fire® euonymus

This selection was made by Scott Lindemann, Timber Creek Nursery, Woodstock, Illinois, in 1979. Selected for excellent ornamental character, fine-textured branching, and cold hardiness. Midwest evaluation plantings have proven to be dependably hardy through U.S.D.A. Zone 4. The plant has a dense, uniform habit and reaches a height of 8 to 10 ft with a spread of 6 to 8 ft at 15 years. Young twigs and branches are an attractive mahogany-red. Corky wings, typical of the species, become less prominent as the plant matures, creating a more refined appearance. Dark green foliage turns rich crimson-red in fall. Established landscape specimens often produce abundant quantities of red-orange fruit, remaining ornamentally effective into early winter. Propagates easily from softwood cuttings. The selection carries a 10¢ per unit royalty and licensing is available.

Fraxinus americana 'Tures' Windy City™ white ash

This clone was selected for evaluation in 1988 from a block of plants at Matt Tures Sons Nursery, Huntley, Illinois. Prior to its release in 1996, this selection was evaluated for its adaptability and performance under a broad spectrum of nursery conditions, as well as in public and private landscapes. Hardiness is rated to U.S.D.A. Zone 4. This selection exhibits excellent uniformity, strong upright branching, good growth rate, and attractive semiglossy foliage. Fall color is an impressive blend of bronze and burgundy, highlighted by copper, orange, gold, and yellow accents. The narrow, upright-oval habit provides for a greater range of landscape applications due to reduced branch spread. Propagation is by standard budding techniques for the species. The selection carries a 50¢ per unit royalty and licensing is available.

Hemerocallis 'Jen Melon'

In August when most *Hemerocallis* cultivars have stopped blooming 'Jen Melon' is at its peak. When well grown the gold-melon, fragrant, green-throated blossoms are 6-1/2 in. wide on plants that are up to 34 in. tall. Often scapes have 30 or more buds so the heavy bloom season extends from late July through August. Rebloom scapes start appearing in mid August and produce flowers well into September. Plant increase is moderate to fast (4 to 1 or more per year) The qualities listed above make this cultivar one of the most outstanding late-blooming daylilies.

'Jen Melon' was introduced by William S. Oakes Rt. 4 Corryton, TN 37721 in 1987.

Liriope platyphylla

Wide-leaved lilyturf was originally picked out from a group of seedling plants collected in the wild in Korea in 1984. It was selected for its showy 8-in. spikes of amethyst flowers borne well above the foliage. Most cultivars of lilyturf are used for groundcovers or edging and their floral effect is considered negligible. This selection is worth growing as a flowering plant. The flower spikes appear in mid-August, and flowering continues for a month.

Originally collected in a pine forest, this lilyturf will grow in full sun, but will maintain its jade-green leaf color better if shaded during the heat of the day. It will grow satisfactorily in various soils, as long as the drainage is good. It is propagated readily by division at any time during the growing season.

Rhododendrons For Very Cold Climates

New breakthroughs in rhododendron breeding have produced rhododendrons to survive temperatures well below freezing. The new Marjatta hybrids survive -31F. Finland is situated between 60° and 70° north latitude and shares borders with Sweden, Norway, and Russia. The lowest recorded winter temperatures vary from -30 to 48F from south to north, though winters are normally somewhat milder. Since many imported landscape plants do not survive the cold winters, they have developed their own breeding programs.

Hybridization of broad-leaf evergreen rhododendrons was started in 1972 by Dr. P.M.A. Tigerstedt and Marjatta Uosukainen at the University of Helsinki. The program was based on the extremely hardy material that had been naturally selected at the Arboretum Mustilia. The goal was to create winter hardy cultivars that could tolerate temperatures below -31F.

Totally, 148 different cross combinations were made between species, species and hybrids, and between hybrids. Over 20,000 seedlings were obtained and 13,752

plants were planted for trial on eight different test sites. After two extremely cold winters, 1984-85 and 1986-87, only 40% of the plants survived. The progenies of the crosses between earlier mentioned species seemed to carry the best genetic material for better climatic adaptation. The first six cultivars were released for commercial propagation in 1986-87.

***Rhododendron* 'Elviira'** (*R. brachycarpum* ssp. *tigerstedii* × *R. forrestli*). Very low and densely branched hybrid. A spreading plant under 24 in. covered with bright red flowers.

***Rhododendron* 'Mikkeli'**
A plant of truly wonderful habit. Lush and vigorous foliage. New growth is covered with coarse textured hairs. A well branched, compact plant with white flowers, tinted with pink and a small blotch with green spots. Buds hardy to -31F. *Rhododendron brachycarpum* ssp. *tigerstedii* × *R. smirnowii* hybrid.

***Rhododendron* 'Haaga'**
Was selected from seedlings of a cross *R. brachycarpum* ssp. *tigerstedtii* × *R.* 'H.C. Dresselhuys'. Growth habit is upright to a mature height of 5 to 7 ft. Attractive dark green, coarse foliage. Flowers are dark pink. Buds hardy to about -31F.

***Rhododendron* 'Hellikki'**
Dark violet-red flowers. Plant has a dense habit to 5 ft. New leaves are indumented, aging to dark green. Buds hardy to -29F. Worthy of trials in colder climates. A selection from an open-pollinated *R. smirnowii.*

***Rhododendron* 'Peter Tigerstedt'**
One of the hardiest of all rhododendrons. Upright spreading habit to 6 ft. Dark green leaves. Flowers are white with strong violet-red flecks in the upper part of the corolla. *Rhododendron brachycarpum* ssp. *tigerstedtii* × *R. catawbiense* var. *album* 'Glass' hybrid.

***Rosa* 'Golden Wings'** is a very hardy shrub rose with single (five petaled) golden-yellow blossoms with prominent, attractive mahogany-colored stamens. Very long pointed flower buds open into blooms that are sweetly scented and produced freely all summer long. Flowers are large, usually 4 to 5 in. across. Large orange hips ripen in the fall. The size is perhaps 4 to 5 ft tall × 5 ft wide. 'Golden Wings' is tough and vigorous, but the flowers are delicate and beautiful. There are very few shrub roses with the virtues of 'Golden Wings'. It truly is a rare, first-class shrub rose that is hardy and repeat blooming with golden-yellow flowers. It is hardy to U.S.D.A. Zone 4 (7.9 Amer. Rose Soc. rating). Introduced in 1956 by Bosley Nursery of Mentor, Ohio, and hybridized by Roy Shepherd a noted rosarian and talented rose hybridizer. National Gold Medal Certificate 1958 (A.R.S.). The parentage is *R.* 'Soeur Therese' × (*R. spinosissima altaica* × 'Ormiston Roy').

***Rosa* 'Jan's Wedding'** is a new, colorful shrub rose with blooms of yellow, pink, and apricot borne in large clusters. Flowers are 2 to 3 in. wide, well formed (like a hybrid tea), and repeat blooming occurs throughout the summer. Plants are healthy, bushy, and tall (to 6 ft). An exciting new shrub that is colorful, floriferous, and hardy. Plants are very vigorous and perform extremely well on their own roots. 'Jan's Wedding' is an outstanding rose from Dr. Neil Adams, an amateur hybridizer. The hybridizer's first daughter is named Jan. Neil brought five flower arrangements of roses for her

wedding taken from just one bush of this rose in early July! 'Jan's Wedding' has been tested in Wisconsin and is fully winter hardy to U.S.D.A. Zone 4b. The parentage is *R.* 'Dornroschen' × *R.* 'Lichtkonigin Lucia'

Silene regia

Royal catchfly is a July to August blooming perennial from the tall grass prairie region of central Ohio. It grows well in average soils with average moisture. It is very useful as a hummingbird-attracting plant. Plant height is 3 to 4 ft. Royal catchfly is easy to grow from seed when given a 90-day cold moist stratification. Seed is available upon request from The Holden Arboretum.

Sinocalycanthus chinensis

This is a relatively new plant introduced into Europe during the mid 1980s. Dr. J. C. Raultson at North Carolina State University Arboretum has spent some time working with it and he finds it to be a promising ornamental. It is a medium size shrub, 3 m, with large glossy green leaves that turn yellow in fall. It blooms on new wood with the flowers being born singly on the ends of the new shoots. They are white and are about 7 cm across with two whorls of tepals of about 10 each. Flower color can vary from pink to white to pale yellow depending upon the variations in color of the two sets of tepals. There are maroon markings at the base of the tepals. Dr. Raultson has had an opportunity to cross this plant with it American cousin, *Calycanthus floridus*, and he reports the hybrids are quite interesting. The plant itself does have many of the same characteristics of *Calycanthus*. It is thought to be hardy to Zone 6.

***Solidage rugosa* 'Fireworks'.** Many wild plants when brought into the more fertile conditions found in perennial borders grow larger than in the wild. Such has been my experience with *Solidage rugosa*, which grows to 5 ft tall and flops over in my garden. However, folks at the North Carolina Botanical Garden obtained a plant via plant rescue that did not get tall and fall over plus was highly floriferous with long yellow flower panicles. After about 20 years of observing this plant, NCBG Assistant Director Ken Moore worked with Kim Hawks of Niche Gardens, Chapel Hill, North Carolina to jointly introduce this plant as *S. rugosa* 'Fireworks'. In my garden it has been spectacular for flower show as well as attracting insect pollinators like bumblebees and butterflies. The cultivar name is apt since the flowers look like the tracers in the night sky as part of a fireworks display.

Solidago roanensis* var. *monticola. This plant was discovered by Kim Hawks and Dick Bir while hiking in the southern Blue Ridge mountains of North Carolina at an elevation of about 5800 ft. It was about a foot tall, blooming in an exposed, difficult situation. Seeds were collected and sent to the North Carolina Botanical Garden as well as Niche Gardens. The plant, *Solidago roanensis* var. *monticola* or the Roan Mountain goldenrod, has been grown in a variety of gardens but has not exceeded 18 in. in height with an upright flowering pattern and a long period of bloom. It was introduced in the fall 1996 Niche Gardens catalog.

***Solidago sphacelata* 'Golden Fleece'**. This culitvar was introduced by Dr. Richard Lighty of the Mt. Cuba Center in Delaware but I am told he first saw this floriferous 15- to 18-in.-tall goldenrod in a local garden the morning after speaking to the Rockingham Co. North Carolina Horticultural Society near Eden, North Carolina. The cultivar name is apt since the flower heads look like recently dyed fuzzy natural wool.

Spiraea thunbergii 'Fujino'

This cultivar originated in Japan and flowers a week before forsythia in most areas. It is hardy to U.S.D.A. Zone 4. The buds appear very early and give the shrub a reddish glow; the open flowers change from an apple blossom pink to whitish-pink. Summer foliage is light green, turning yellowish-orange in fall. 'Fujino' has a medium growth rate with a bushy upright branching habit and reaches 3 to 5 ft at maturity. It does not like wet soils and is drought resistant. In the landscape it is valued as a hardy, early flowering shrub and would have sales appeal as a tool to bring in early spring customers. No major pest and disease problems have been observed.

QUESTION BOX

Moderated by Ralph Shugert and Bruce Briggs

QUESTION: Is there a safe, labeled herbicide I can use with container-grown *Phlox paniculata*? I have used Rout, OH II, Regal 0-0, etc. and experienced phytotoxicity.

HARLAN HAMERNIK: We do not use it but Ohio state University recommends Treflan as the only one.

BILL BARNES: In previous work at a nursery I worked at they used a mixture of Treflan and Pennant.

BRIAN GILSON: We have used Ronstar G and Snapshot PG.

QUESTION FOR KEN ROE: What, if any, herbicide program do you have for the grasses, *Hemerocallis*, and *Hosta* we saw on the tour?

KEN ROE: We use Snapshot TG.

QUESTION: Are there plants other than rye grass useful for allelopathic weed control in liners?

BILL BARNES: At Rodale they are using dwarf rape that has been grown and tilled in three times. It resulted in reduced growth of the corn that was planted in it and also eliminated weed seed germination.

JEFF ILES: Corn gluten meal has suppressive properties from work done at Iowa State University.

QUESTION: Does anyone have a chemical control for liverwort and mosses?

BILL BARNES: The use of Manzate fungicide will inhibit them. It is the presence of the manganese ion that will inhibit spore growth; it will not inhibit growth once they have germinated. Ronstar G will work on plants that are growing.

DAVE BAKKER: Treflan G will work. We never use it at greater than 1 lb a.i. $acre^{-1}$.

CHARLES TUBESING: When I was in British Columbia there was a product called Demoss (produced by Mycogen formally Safers) that was used to remove moss.

QUESTION: I have had sporadic results with softwood cuttings of *Prunus* ×*cistena*. If I go to hardwood propagation this year what do I have to look for? Is callus, hormone, length or caliper of wood important?

GARY MEIVOGAL: I have had varying results. I take the cuttings in mid December cut to 6 in., wound on one side, dipping them in 5000 ppm IBA, placing them in a flat, bottom up, and covering them with a moist sphagnum moss. Precallus

in warm moist heat for 4 weeks and sticking them in a pine bark and peat mix (2 : 1, v/v) which has proven best.

DAVE BAKKER: We have done it according to the method described by Howard at East Malling in England and presented to this Society. After precallusing at close to 32F we treat the bases with a gel containing a fungicide and plant in the field. We now are doing softwood because of losses.

QUESTION FOR ROGER COGGESHALL: Do you root white flowering French hybrid *Syringa* cultivars differently? I have failed badly the past 5 years with white cultivars.

ROGER COGGESHALL: No we do not treat them any differently. There may be cultivar differences and I would suggest that you select them first and from the youngest growth.

QUESTION FOR DR. STOLTZ: Can you propagate ginseng asexually?

LEN STOLTZ: No.

QUESTION: Is anyone growing (and pleased with) any clones of *Hydrangea arborescens* other than 'Annabelle'?

CHARLES TUBESING: *Hydrangea arborescens* ssp. *radiata* has been grown and has the ray flowers like the species.

BILL BARNES: At Winterthur Garden I have seen 'Grandiflora' with flower clusters white and containing numerous sterile florets. The plant tends to spread by suckers but the flowers do not flop like 'Annablelle'.

QUESTION: Does anyone have problems growing on softwood cuttings of *Acer palmatum* cultivars and pink dogwood? I have experienced losses of 1- and 2-gal containers over the winter even though the plants are protected with an inflated double-layer polyhouse. Could this be herbicide damage from OH II applied in fall 2 to 3 weeks before covering for the winter?

BRUCE BRIGGS: Research has indicated that it is a lack of stored food. Withhold nitrogen fertilizer after they have rooted. You might also try to store rooted cuttings in a cooler until spring.

POSTER SESSION

Practical Ideas and Solutions to Common Problems

H. William Barnes
Lorax Farms, 2319 Evergreen Ave., Warrington, Pennsylvania 18976

Resourcefulness and innovation are two sides to the same coin.

- One grower in the southern part of the U. S. uses plastic soft drink crates as deep flats for the rooting of cuttings.
- The wounding of cuttings can be troublesome. One solution is a hacksaw blade mounted with the teeth upright so that a cutting can be drawn across it , thereby inducing a wound.
- An elevated box with a gap along the bottom perimeter mounted onto a farm wagon can easily be converted into an effective mobile potting operation.
- Stratifying seeds can be a problem. The media, usually, peat or sand, is either too wet or too dry or too sticky and not enough air can get to the seeds. Moist perlite does a lot to eliminate these problems and the seeds come out cleaner and easier to handle. Also it is easy to see if they have germinated in the bag.
- Lights should be an integral part of mist propagation. Low-wattage incandescent lights mounted 3 ft above the rooting area and set to come on from 10 PM to 2 AM are very effective at extending photoperiod of many plants. An alternative set up is to have the lights flash during the 4 h interval at about 10 sec every 10 min.
- PVC pipe is a very versatile component of most greenhouse and propagation operations. It can be made even more useful by modifying a toaster oven so that a length of pipe can be inserted into the oven through the sides and heated till soft, the softened pipe can be withdrawn and bent into any curve or angle needed.
- Getting more cuttings from a rare or unusual one of a kind plant can be frustrating. Try planting the stock plant at a 45° angle so it is forced to break apical dominance and grow sideways. Many lateral buds will break into growth and become usable cuttings.
- Fuel costs are escalating daily and the winter heat bills can be substantial . A mini-greenhouse within a larger house will do much to contain heat where it is needed the most (around the cuttings or seedlings) and it will cut down on the overall heat bill.
- Fertilizer injectors are becoming more and more common. It is always prudent to check the reliability of the injector each time it is used. One convenient method is to use nitrogen test strips that give a clear color indication of the level of nitrogen in a diluted sample. It is quick and easy and allows for instant verification of the amount of fertilizer present in the water.
- Pesticide dusts and vapors can be most troubling when quantities are being measured out. One solution is to mount a fan to blow out

of the area so that dust particles and vapors can be drawn out and away from the user much like the fume hoods found in many laboratories.

- Slugs are especially fond of small seedlings and many chemicals and treatments harsh enough to eliminate the slugs might be enough to eliminate the seedlings as well. Granulated garlic powder offers a quick slug proof barrier and can be applied directly onto the seedlings. Slugs can not stand the smell of garlic and will quickly leave the area. Caution, do not use garlic salt, that is not a good product to apply to seedlings.
- Cleaning seed is an arduous task that can be speeded up by using a cement mixer with appropriate abrasive such as lava rock or golf balls. The recipe is simple, 1 bucket of fruit to be cleaned, two or more buckets of water and four to five stones or golf balls. Turn machine on and let it run until the pulp is macerated, usually 1/2 to 1 h. Drain, flush with clear water several times . The clean seed should be in the bottom of your container with the pulp and pieces floating off. This works best if the pulp has been allowed to ferment and breakdown prior to being put into the machine.

Winter Propagation of *Ulmus* 'Regal'

Dan Moore and Bernard Fourrier
McKay Nursery, P.O. Box 185 Waterloo Wisconsin 53594

Though elms can be propagated from softwood in the summer time or from shoot cuttings taken from pieces of roots stuck in flats in the winter months, we have found that taking "micro cuttings" from canned stock plants forced in a heated plastic house in the middle of the winter to be more reliable and economical.

Preparation of the Stock Plants. The canned stock plants are put in a plastic house in early December. On 1 Jan. the furnace is turned on and the temperature set at about 50 to 60F. On 15 Jan. the stock plants are trimmed on top lightly and re-canned if necessary. These are elms that are 1 to 5 years old. Then they are topdressed with 3-4 month Nutricote 14N-14P_2O_5-14K_2O at medium rate. On 30 Jan. each can is given Sequestrene 138 Fe at 1 tsp gal^{-1} and the temperature is raised to 65F.

Preparation and Treatment of the Cuttings. February 15th, the first cuttings are about ready to be harvested. We take the tips from the slower-growing side shoots; they are the best. We remove the lower leaves being careful not to tear the base of the cuttings to reduce rotting. If possible we leave a node at the base. The cuttings are then dipped in a solution of Dip 'n Grow for 5 sec. They are stuck in flats in Fafard #2 and drenched with 1 1/2 tsp of Banrot and 1 tsp of Sequestrene gal^{-1}. The flats are covered with a sheet of glass and put on a light shelf unit. We used cool white tubes with a light intensity between 500 and 750 fc. The temperature of the medium is about 70F.

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Care of the Cuttings. The cuttings are misted once a day until rooted which varies between 1 to 3 weeks depending on the type of cutting and the time the cuttings are taken. The flats are watered once after about 2 weeks with 100 ppm of 20N-10P_2O_5-20K_2O general purpose Peters fertilizer.

Once an acceptable percentage of cuttings are rooted, the glass is lifted slightly for about 3 days, a little more for 3 more days, and then taken off. The flats are then shifted to a growing house until they have put on some new growth and potted for field planting.

Note. For whatever reason, we had a lot of trouble with leaf drop during the period preceding the rooting. After trying many alternatives, the addition of iron (Sequestrene 138 Fe) to the stock plants seemed to halt much of the leaf dropping problems. Also by adding iron to the rooting medium it is readily available for the first emerging roots while at the same time we are giving a foliar application of iron to the cuttings.

The elms seem to enjoy having a lot of iron. When the stock plants show a little iron deficiency they are re-treated with Sequestrene at 1 tsp gal^{-1}.

The rooting percentage varies with timing of cuttings, but 50% to 90% is typical.

Softwood Cutting Propagation of *Eucommia ulmoides*

David Schmidt
Royal Botanical Gardens, Hamilton, Ontario, L8N 3H8 Canada

INTRODUCTION

The name *Eucommia* (*eu*, well and *kommi*, gum) is an illusion to the quality of the rubber contained in all parts. *Eucommia ulmoides* better known as hardy rubber tree is interesting because it is about the only rubber tree that grows and overwinters outdoors this far north. When leaves are torn gently across, the threads of rubber remain and can be easily seen. At the Royal Botanical Gardens in Hamilton two hardy rubber trees have been diligently guarding our east driveway entrance to our center since 1956.

The bark of *Eucommia* when first discovered in China around 1900 was being used in a medicinal tonic by the Chinese people. Today, rubber yields are found to be too low and difficult to extract compared to the great tropical rubber tree *Hevea brasiliensis*, thus eliminating it from commercial rubber production. In appearance the tree resembles a 40 ft elm showing off 3-in. long, glossy, alternate, sharply toothed, pest- and disease-free leaves. The plant is dioecious and exhibits no fall colour. *Eucommia ulmoides* is definitely a worthy candidate for street or lawn specimen plantings!

OBJECTIVE

To compare the success rate of rooting softwood cuttings of *E. ulmoides* taken at different time periods of the growing season using 5000 ppm IBA quick-dip solution.

A review of the literature shows very little work recorded on the propagation of *Eucommia*. Al Fordham talks about hardy rubber tree having a poor reputation for germinating, about 40% in 10 days after a 2-month cold period. Various horticulture encyclopedias mention that the plant can be propagated from seed or cuttings but give

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no further statistics. Michael Dirr also mentions that seed production of *Eucommia* is possible after using 2 to 3 months of moist stratification, and that cuttings are 57% successful using choromonel-napthyl-acetamine when new growth is forming.

MATERIALS AND METHODS

One hundred cuttings were taken on two separate occasions (12 June and 27 June 1996) and stuck into plug trays each cell (1 1/2 in. wide × 6 in. deep) containing sand and screened peat moss (4 : 1, v/v). The trays were set under intermittent mist with bottom heat set at 75F and 45% shade cover.

Where possible each cutting included three nodes, a fresh cut just below the node, a wound ° in. long above the node to encourage root development and a 5-sec quick-dip into Stim Root 5000 (0.5 % indole-3-butyric acid). The cuttings were checked daily and pulled on 11 Sept. 1996 to be examined and potted.

RESULTS

The cuttings were grouped into three different categories by percentage that died, callused only, and rooted.

Table 1. Rooting of *Eucommia ulmoides* cuttings.

	Cuttings taken on	
Rooting category	12 June 1996	27 June 1996
Dead	14%	8%
Callused only (still green)	29%	52%
Rooted	57%	40%

DISCUSSION

The cuttings taken on the earlier date of 12 June rooted the best; 57% compared to 42% rooted on 27 June. The rooted cuttings of the earlier date seemed slightly better in quality and numbers of roots. Whether the (callused only) cuttings would root if left in the trays for a longer period of time is hard to say. Different strengths of IBA rooting hormone may make a difference; although preliminary findings from past experiences trying to root *Eucommia* at Royal Botanical Gardens refute this idea.

There is a possibility that increased rooting percentages could be attained by using other types of rooting hormones such as α-naphthaleneacetic acid (NAA) or indole-3-acetic acid (IAA). Higher percentages might also be acquired if the cuttings were taken earlier than 12 June. They would be very small only one or two nodes at most. *Eucommia ulmoides* is not used in our landscape setting and should be given some serious consideration.

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Use of Sulfentrazone (F6285) for Preemergence Weed Management in Field-Grown Ornamentals

Kimberly Collins, Leslie Weston, and Robert McNiel
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The nursery industry currently has limited options for effective season-long weed control, because relatively few soil-persistent broad spectrum herbicides are registered for use in ornamentals. Sulfentrazone (F6285), a newly developed herbicide from the FMC Corporation, has shown promising results for preemergence weed control in field trials with ornamentals. Sulfentrazone provides selective control of yellow nutsedge (*Cyperus esculentus*) and morning glory (*Convolvulus*) species, as well as broadleaf and annual grass weeds (Weston et al., 1995). When applied at low rates in combination with other efficacious materials, the spectrum and longevity of weed suppression is enhanced (Crotser and Weston, 1995). Additional trials are needed to further evaluate the potential for registration of sulfentrazone for use in ornamentals.

Research was conducted to evaluate preemergence application of sulfentrazone and currently labeled products at different rates in ornamentals. The 17 treatments (replicated three times) included rates of sulfentrazone alone and in combinations with Gallery, Treflan, and Pennant. Within each treatment, 10 tree and shrub species were planted, using three plants of each species per treatment. The plant materials included: *Hemerocallis*, *Liriope muscari*, *Euonymus alatus* 'Compacta', *Abies concolor*, *Viburnum trilobum* 'Hahs', *Syringa vulgaris*, *Cercis canadensis*, *Crataegus viridis* 'Winter King', *Fraxinus americana* 'Skyline', and *Quercus rubra*. Plots were sprayed in June 1996, and herbicide efficacy was evaluated at 4 and 8 weeks after treatment (WAT), while phytotoxicity was evaluated at 5 and 10 WAT.

Major weeds encountered in this experiment at 4 WAT included annual grasses, yellow nutsedge, morning glory species., honeyvine milkweed, and velvetleaf. The best overall control was provided by sulfentrazone (0.426 kg a.i. ha^{-1}) plus Pennant (3.409 kg a.i. ha^{-1}), with a 90% overall weed control rating. Also providing excellent control was sulfentrazone at 0.568 kg a.i. ha^{-1} (86% overall control). Sulfentrazone alone at 0.142 kg a.i. ha^{-1} and Gallery alone at 0.568 kg a.i. ha^{-1} provided the poorest overall control (32 and 55%, respectively). Sulfentrazone at higher rates and all sulfentrazone combinations provided moderate control (~80%). Major weeds encountered at 8 WAT included annual grass, morning glory species, honeyvine milkweed, and velvetleaf. Yellow nutsedge was not apparent at 8 WAT, since it was non competitive with the vining weeds. The best overall control was obtained by sulfentrazone at 0.568 kg a.i. ha^{-1}, with a rating of 83%. Sulfentrazone (0.426 kg a.i. ha^{-1}) plus Pennant (3.409 kg a.i. ha^{-1}) also maintained good control with a 78% overall weed rating. Treatments providing the poorest control were the same at 4 and 8 WAT.

Limited phytotoxicity was observed at 5 WAT with sulfentrazone and sulfentrazone combinations. *Liriope* and *Hemerocallis* were most sensitive to sulfentrazone, exhibiting chlorosis and bleaching of the foliage. The highest levels of phytotoxicity in these species were observed where sulfentrazone was applied at 0.568 kg a.i.

ha^{-1} and at 0.426 kg a.i. ha^{-1} with Pennant (3.409 kg a.i. ha^{-1}). *Syringa vulgaris* exhibited slight herbicide damage due to initial foliar contact. At 10 WAT, injury to *Hemerocallis* and *Liriope* was still evident, with chlorosis of tissue greatest when high rates of sulfentrazone were applied (> 0.426 kg a.i. ha^{-1}) or when sulfentrazone at 0.426 kg a.i. ha^{-1} was applied with Pennant. Necrosis in *Syringa* was not apparent by 10 WAT and injury due to initial leaf contact was temporal. However, injury to *Abies* was highly visible at 10 WAT and was greater where higher rates of sulfentrazone were applied and in all sulfentrazone combinations. Chlorosis and necrosis of the foliage was likely due to postemergence contact, as evidenced by enhanced injury within the spray pattern at 10 WAT. It is not clear whether injury would be overcome with time.

In conclusion, sulfentrazone (>0.426 kg a.i. ha^{-1}) provided consistent and long-term weed suppression of difficult-to-control weeds. Combinations of sulfentrazone plus Pennant or Treflan also provided consistent control. Use of shielded applicators to prevent postemergence contact of sulfentrazone with ornamental foliage could minimize injury.

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Hemerocallis (Daylily) Propagation

Winston C. Dunwell
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INTRODUCTION

Numerous *Hemerocallis* (daylily) cultivars are introduced each year that never make it to the consumer market because of limited supplies. The dramatic increase in the number of daylily cultivars and the preference for named cultivars has resulted in daylily propagation being limited to vegetative propagation, except in the case of hybridizers use of seed propagation to grow-out and evaluate the plants produced from their crosses. It has been stated that it can take 20 years for an outstanding cultivar to move from the enthusiast (connoisseur) market to the mass market (Pounders and Garton, 1996). The shortage and subsequent rapid nursery production of 'Happy Returns' introduced in 1986 indicated that even if the cultivar forms a relatively large number of divisions per year, it can take 10 years or more to have adequate plants to meet market demand.

Hybridizers have often been caught short of plants when a new introduction proves popular leading some to postpone introductions for several years (Schott, 1995). The recent introduction of patented daylily cultivars and the continuing efforts by hybridizers to breed cultivars for use by the landscape industry has resulted in the

ha^{-1} and at 0.426 kg a.i. ha^{-1} with Pennant (3.409 kg a.i. ha^{-1}). *Syringa vulgaris* exhibited slight herbicide damage due to initial foliar contact. At 10 WAT, injury to *Hemerocallis* and *Liriope* was still evident, with chlorosis of tissue greatest when high rates of sulfentrazone were applied (> 0.426 kg a.i. ha^{-1}) or when sulfentrazone at 0.426 kg a.i. ha^{-1} was applied with Pennant. Necrosis in *Syringa* was not apparent by 10 WAT and injury due to initial leaf contact was temporal. However, injury to *Abies* was highly visible at 10 WAT and was greater where higher rates of sulfentrazone were applied and in all sulfentrazone combinations. Chlorosis and necrosis of the foliage was likely due to postemergence contact, as evidenced by enhanced injury within the spray pattern at 10 WAT. It is not clear whether injury would be overcome with time.

In conclusion, sulfentrazone (>0.426 kg a.i. ha^{-1}) provided consistent and long-term weed suppression of difficult-to-control weeds. Combinations of sulfentrazone plus Pennant or Treflan also provided consistent control. Use of shielded applicators to prevent postemergence contact of sulfentrazone with ornamental foliage could minimize injury.

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Hemerocallis (Daylily) Propagation

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INTRODUCTION

Numerous *Hemerocallis* (daylily) cultivars are introduced each year that never make it to the consumer market because of limited supplies. The dramatic increase in the number of daylily cultivars and the preference for named cultivars has resulted in daylily propagation being limited to vegetative propagation, except in the case of hybridizers use of seed propagation to grow-out and evaluate the plants produced from their crosses. It has been stated that it can take 20 years for an outstanding cultivar to move from the enthusiast (connoisseur) market to the mass market (Pounders and Garton, 1996). The shortage and subsequent rapid nursery production of 'Happy Returns' introduced in 1986 indicated that even if the cultivar forms a relatively large number of divisions per year, it can take 10 years or more to have adequate plants to meet market demand.

Hybridizers have often been caught short of plants when a new introduction proves popular leading some to postpone introductions for several years (Schott, 1995). The recent introduction of patented daylily cultivars and the continuing efforts by hybridizers to breed cultivars for use by the landscape industry has resulted in the

need for rapid build-up of stocks in order to have sufficient supplies available. Current demand for daylilies for use in mass plantings, some containing tens of thousands daylilies, has further strained already limited supplies of desirable cultivars. The use of all available propagation techniques will be needed to provide adequate supplies of desirable cultivars.

SEED PROPAGATION

Seed propagation can start with seed collected from the capsules found on the scapes or from seed produced from selected crosses that can be purchased from daylily hybridizers/propagators. Seed is collected as the capsule matures, drys, and is beginning to split at the distil end (Munson, 1989). Seed collected from dormant daylilies benefits from cold stratification at 32 to 45F; following stratification the seed can be dried and stored at room temperature until sown (Griesbach, 1956). Seeds resulting from evergreen parents can be directly sown or, handled, and stored the same as described above for seeds from dormant parents (Benzinger, 1968; Munson, 1989).

DIVISION

Dividing the daylily clumps by pulling or cutting apart is the most common form of daylily propagation. Division is relatively easy to do, plant survival is excellent and the resulting plants are identical. It is recommended that division be done during early spring or late summer with harvest season defined by the area. In Kentucky daylilies are commonly divided from February through April and late July through the mid-September with Autumn Equinox considered the latest possible day for dividing and transplanting. Fall is the dominant harvest season in Kentucky, but numerous small growers field divide from February to October in order to make retail and mailorder sales.

While division is the most popular form of propagation, some limitations do exist. The most common limitation is the slow progress in producing adequate numbers of plants of a popular cultivar to satisfy the market demand. A very high increase ratio would be 25 : 1, new plants : original, the average might be closer to eight, with a minimum ratio for commercial production being 3 : 1 (Apps, 1995). There are cultivars that take a year to produce a single division and therefore cannot be introduced even if it has many desirable characteristics (Dunwell et al., 1995).

PROLIFERATIONS

Proliferations are small plants that grow on the scapes of daylilies. Proliferations can be cut from the scape and if a multiple proliferation can be further divided by cutting before being stuck in a well-drained media. The proliferations will expand roots out into the media in approximately a week. Daylily growers frequently miss the opportunity to produce plants from proliferations because summer shearing and late summer division remove the scapes with proliferations and remove some scapes on which proliferations would have formed. I have had success producing plants from proliferations (Table 1). Considering the value of each plant of a recently introduced cultivar propagation by rooting proliferations can increase the number of plants produced from a single mother plant and, ultimately, increase the income from that plant. Unfortunately, a single plant of 'Lisa My Joy' that had four scapes which produced a total of 14 proliferations in 1996 might not produce any proliferations in 1997.

TISSUE CULTURE

Scientists have successfully grown daylilies from tissue culture (Apps and Heuser, 1975; Heuser and Apps, 1976; Heuser and Harker, 1976; Krikorian and Kann, 1979a, 1979b, 1980; Krikorian et al., 1981; Meyer, 1976, 1979; Pounders and Garton 1996; Smith and Krikorian 1991; Stoutemyer 1976a, 1976b) but it has not become a favored method of propagation because some propagators had difficulty producing identical plants from a single source in early attempts to tissue culture daylilies and to some extent the demand for new daylily cultivars was not at levels that would justify changing propagation techniques. Krikorian and Kann (1980) and Krikorian et al. (1981) showed they could produce identical plants from aseptically cultured tissues. The demand for new cultivars and large numbers of a single cultivar for mass planting now has several growers propagating plantlets by tissue culture.

Basic procedures for tissue culturing daylilies are illustrated in the publications of Krikorian and Kann (1979a) and Meyer (1976, 1979). Once the plantlets are produced in tissue culture they can be rooted relatively easily using standard conditions provided for daylily proliferation rooting.

OTHER TECHNIQUES

There are other techniques that can be used to propagate daylilies. Individual ramets can be cut into pieces that have some shoot and some root tissue. If handled in a sanitary manner these ramet cuttings will grow and after approximately 6-months growth can be made into cuttings (Foret and Nelson, 1967). Traub (1936) reported that the ramets should not be cut into "divisions" or "cuttings" smaller than 1/4 the original ramet.

Another technique is to cut the top off crowns and apply growth regulator compounds to force production of offshoots that can be excised and rooted. Apps and Heuser (1975) and Kirby-Smith and Kasha (1981) experimented with applying kinetin and kinetin-auxin mixtures respectively. They both had success, but care is

Table 1. Cultivars produced by rooting proliferations.

Best of Friends	My Son Bob
Cantique	Octavian Exotic Marble
Coral Crab	Octavian Marble Model
Evening Bell	Open Hearth
Fairy Tale Pink	Prairie Blue Eyes
Granite City Toehead	Purple Oddity
Jambalaya	Ruffled Magic
Janice Wendell	Siloam Sunburst
Lavender Patina	Siloam Red Toy
Lisa My Joy	Siloam Toddler
Lullaby Baby	Spectacular
Mad Max	Stella de Oro
Mary Shadow	Sun Flare
Milady Greensleeves	White Temptation
Milano Maraschino	Winds of Peace
Milano Violet Mark	

required in carrying out the procedure and the method has not found favor with commercial propagators.

It should be noted that the standard "Ditch Lily", *Hemerocallis fulva* and its cultivars are stoloniferous. Those wishing to propagate *H. fulva*, or any of its relatives, can cut the rooted offshoots that occur at the end of the roots.

While division will continue to be the most popular form of propagation for daylilies, tissue culture will make a significant contribution in the future by ensuring that deserving new cultivars get to the marketplace and the large numbers of plants used by the landscape industry are available.

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Cutting Propagation of Grafted Mature and Juvenile Northern Red Oak

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A rooting trial evaluated the rooting success of cuttings from mature and juvenile, grafted and ungrafted northern red oak (NRO). Buds from seedlings and from 4 mature NRO trees were grafted onto juvenile and mature rootstock. Shoot cuttings were collected from the grafts and directly from seedling and mature trees and subjected to a rooting trial. Of all treatments, cuttings from juvenile material rooted best. However, the rooting of cuttings from mature trees was also relatively successful. Percentage rooting of cuttings was significantly related to ortet genotype and ontogeny and was not directly influenced by grafting. The number of roots per cutting and post-rooting flushing behavior was significantly related to ortet ontogeny. Juvenile rootstock had little effect on the rooting, number of roots per cutting, flushing behavior, and overwintering success of cuttings from mature NRO. Mature rootstock negatively influenced the number of roots per cutting, flushing behavior, and overwintering success of shoots from grafted juvenile buds.

INTRODUCTION

Northern red oak (*Quercus rubra* L.) is a widespread and abundant species important in both traditional and urban forestry. It is a genetically diverse species and therefore offers great potential for tree improvement. Vegetative propagation, especially from mature individuals, is difficult and a severe hinderance to research and to the full utilization of the genetic variation within this species. The objective of this research was to identify techniques for the successful vegetative propagation of ontogenetically mature northern red oak (NRO).

MATERIALS AND METHODS

Mature Plant Material. Four seed-producing NRO trees provided sources of mature plant material for grafting and cuttings. In June 1991, the trees were 12, 13, 19, and 22 m tall and 29, 39, 68, 73 cm in dbh for ortets 1, 2, 3, and 4, respectively. Cuttings developed *in situ* from the mature ortets were designated M1, M2, M3, and M4.

Grafting Treatments. In April of 1990, dormant scion wood was collected from the lower 1/3 of the crown of the mature trees. One hundred dormant buds from each ortet were bud-grafted (spring T-budded) onto 1-year-old potted NRO rootstock.

These 1990 grafts are referred to as 90Xs (X = genotypes 1, 2, 3, 4). The successful 1990 grafts (47%) were maintained throughout the growing season and overwintered in an unheated greenhouse. In 1991, these grafts were used as a source of dormant buds for grafting and as a source of cuttings for the 1991 rooting trial.

In April 1991, ca. 100 dormant buds were collected from the 1990 grafts and budded onto 1-year-old potted NRO rootstock. Cuttings from these serial-grafted plants are referred to as 9190Xs, (X = genotype number 1, 2, 3, or 4). In addition, approximately 100 dormant buds collected directly from each of the four mature trees (genotypes 1, 2, 3, 4) and from 1-year-old potted seedlings (J) were grafted onto 1-year-old potted NRO rootstock. Cuttings from these single series grafted plants are referred to as 91Xs (X = 1, 2, 3, 4, and J).

In April and May 1991, additional grafts using approximately 100 buds from each of 1-year-old seedlings and mature tree #2 were made onto the lower 1/3 of the crown of mature tree #1. Cuttings for these treatments are referred to as J-M1 and M2-M1, respectively.

In May 1991, grafted rootstocks were decapitated just above the grafts to stimulate the grafted buds to break dormancy. Decapitation at this time provided synchrony of budbreak for both the indoor grafts and outdoor *in situ* ortets. At the same time, the 1990 grafts (90Xs) were brought into the heated greenhouse to stimulate budbreak.

Juvenile Plant Material. Pre-stratified acorns were sown in pots during April 1991 in a greenhouse and grown to provide 2nd-flush cuttings (J2) for use in the rooting trial. In May 1991, acorns from the same seedlot were similarly sown in pots in a greenhouse to provide 1st-flush cuttings (J1) for use in the rooting trial. Additionally, cuttings were collected from shoots that arose from along the 1st flush of decapitated 1-year-old seedlings (JDs).

Rooting Procedures. Mature tree cuttings (MXs) were collected from the lower 1/3 of the crown. Cuttings were collected daily and kept cool and moist until processing during the same day. All leaves were removed from cuttings, except three at the apex. The basal end of each cutting was freshly trimmed and dipped in 1.2% w/w IBA and ethanol for 5 sec and allowed to dry for 1 min. While drying, the remaining leaves were trimmed perpendicular to the midvein to about 1/2 of their original size. Cuttings were inserted into predibbled holes in moist media (1 perlite : 1 peat : 1 coarse white sand) in 115 cc Ray Leach Super Stubby Cells™ and lightly watered prior to placement in the rooting chamber. The rooting chamber was a polyethylene tent located in a greenhouse. Intermittent fog was provided by four ultrasonic humidifiers (Sunbeam model 667).

In both years, benomyl (Benlate at 2.4 g $liter^{-1}$) was sprayed on the leaves every month during the rooting period. Cuttings were checked for rooting and number of roots per cutting 80 days after sticking. Rooting success was defined as the presence of at least one root at least 5 mm in length. The number of roots per cutting reflects the number of roots >5 mm in length originating from the stem or callus of a cutting. Cuttings that had not rooted after 80 days were placed back into the high humidity chamber and checked again 40 days later. Data summaries reflect the total cuttings rooted over 120 days.

In 1991, 80 days after sticking, those cuttings that had rooted were potted into 6.5-cm^2 pots by 23-cm-tall pots filled with Pro-Mix BX and set into a shaded acclimation

tent. For the next 50 days, daylength was supplemented with 18 h day^{-1} of artificial light from sodium vapor lamps. Humidity was initially maintained at 100% and gradually decreased over 20 days to ambient greenhouse levels, at which time the shade was removed. Late-rooting cuttings were acclimated for 10 days. The rooted cuttings were transferred to an unheated greenhouse for overwintering.

RESULTS

Percentage Rooting. Rooting averaged 72.2% over all treatments but there were large differences among the treatments ranging from 96% for J1 to 20% for M3 cuttings (Table 1). Significant genotypic and ontogenetic effects were present but grafting was not significantly related to rooting.

Genotypic Effects. Rooting was dependent on genotype for mature ungrafted cuttings (chi-square, $P<0.001$). Logit analysis indicated that there was a significant relationship between scion genotype and rooting ($P=0.491$).

Grafting Effects. Cuttings from grafts of the mature genotypes rooted more often than their ungrafted counterparts (69% vs 59%). However, when considering genotypes, logit analysis revealed that rooting success was not significantly related to the main effects of grafting or genotype ($P<0.05$). Averaged over genotypes, percent rooting was 56, 59, 70, and 79 for 91Xs, mature, 9190Xs, and 90Xs, respectively. Grafting did decrease the differences between genotypes but not significantly so. Only for #3, the ortet with the poorest rooting performance, did every grafting treatment increase rooting compared to ungrafted controls (from 20 to 58%). Grafting treatments variably affected the other genotypes.

Ontogenetic Effects. Chi-square analysis revealed a significant relationship between rooting success and cutting maturity when comparing all mature cuttings as a group versus all juvenile cuttings ($P<0.001$). Rooting of 2-month-old J1 cuttings (96%) was considerably greater than mature cuttings (59%). Interestingly, rooting of only slightly older 3-month-old seedlings (J2) dropped significantly to 82% (chi-square, $P=0.05$) and was less than one of the four mature genotypes. Therefore, chronological age of the plant was not the determining factor of rooting success. This was further evidenced by the 94% rooting success of the 1-year-old JD cuttings.

Number of Roots Per Rooted Cutting. There were significant differences among the treatments for the number of roots per cutting ($P<0.0001$). Rooted cuttings from juvenile seedlings had significantly more roots per cutting than those from mature trees (Table 1). Grafting treatments using juvenile rootstock did not significantly influence the number of roots per cutting. Based on the number of roots per rooted cutting, there is no evidence of grafting-induced rejuvenation.

Cuttings from juvenile buds that were grafted onto a mature tree (J-M1) had significantly fewer roots (3.0) compared to cuttings from juvenile seedlings (23.3, 14.9, 14.3 for JD, J2 and J1, respectively) and to cuttings from juvenile buds grafted onto juvenile rootstock (13.5 for 91J). There apparently was an influence of the mature rootstock on the number of roots per rooted cutting but not on rooting success, suggesting that these measures of juvenility were independently controlled.

Overwinter Survival. By June 1992, 63% of the 1991 rooted cuttings were alive. Differences in overwinter survival closely mirrored rooting success (Table 1). For the

Table 1. Percentage rooting, roots/cutting, and overwinter survival by treatment for northern red oak cuttings.

Cutting type	Number of cuttings (n)	Rooting (%)	No. Roots per cutting	Overwinter survival (%)
M1	50	56.0	2.0	40.7
M2	50	86.0	4.1	79.4
M3	50	20.0	1.4	20.0
M4	50	74.0	5.8	47.2
J1	50	96.0	14.3	95.8
J2	49	81.6	14.9	80.0
JD	51	94.1	23.4	93.6
901	28	71.4	3.8	60.0
902	76	89.5	6.8	70.3
903	35	71.4	3.2	80.0
904	38	81.6	6.8	77.4
911	39	51.3	3.0	45.0
912	41	70.7	4.9	51.7
913	15	46.7	1.6	28.6
914	37	54.1	4.6	57.9
91J	42	90.5	13.5	70.3
91901	27	81.5	2.8	50.0
91902	44	72.7	4.5	65.6
91903	30	43.3	7.3	54.5
91904	30	83.3	3.6	52.2
J-M1	15	93.3	3.0	50.0
M2-M1	11	81.8	5.7	44.4

MXs = mature trees, genotypes 1,2,3,4.
J1, J2 = one- and two-flush seedlings, approximately 2 and 3 months old, respectively.
JD = 1st flush of one-year-old formerly multiflush but decapitated (clipped off) seedlings.
90Xs = 1990 grafts, 1-year-old rootstock, X=genotypes 1,2,3,4.
91Xs = 1991 grafts, 1-year-old rootstock, X=genotypes 1,2,3,4 and J (juvenile).
9190Xs = serial grafted on 1-year-old rootstock (1991 and 1990).
J-M1 = juvenile buds grafted on mature tree #1.
M2-M1 = mature genotype #2 buds grafted on mature tree #1.

most part, those treatments that had high rooting success (Js), overwintered well (90% survival) and those that had poor rooting success (M3), had poor overwinter survival (20%).

Overwinter survival was related to rooting date. For cuttings that had rooted by 80 days, 70% survived, compared to those that rooted after 80 days, only 25% survived. Of all juvenile treatments that had rooted, 97% had done so within 80 days. Only 62% of all treatments using ortet #3 had rooted by that time. Perhaps the cuttings that were early rooters were able to store more photosynthate and harden-off more completely than the late rooters. Post-rooting flushing behavior and the number of roots per cutting did not appear to directly influence overwinter survival as within-treatment averages for dead and surviving rooted cuttings were similar. Although the actual cause(s) of overwinter mortality was not certain, the roots of many of the dead rooted cuttings were infected with *Phytophthora*.

DISCUSSION

Cuttings of mature NRO are difficult to vegetatively propagate. However, in this study, rooting success of cuttings from mature NRO was 59%. The high level of rooting success does not appear to be an anomaly as additional rooting experiments performed in the same chamber in subsequent years achieved similar high rooting success. Even with relatively high rooting success, large differences in responses were apparent among treatments. For cuttings from mature trees, significant genotypic effects were found for rooting and overwintering success. Even after grafting, which decreased the differences in rooting, significant genotypic effects persisted.

Rooting and overwintering survival decreased significantly in a relatively short time when comparing 2-month-old (J1) and 3-month-old (J2) seedlings. However, chronological age was not a good predictor of success as the first flush of older (1-year-old) JD seedlings that were decapitated did not further decline but rooted and survived at levels similar to J1 seedlings. Ontogenetic effects are somewhat obscured by the ease of rooting and high overwintering percentages of cuttings from the much older and much larger M2 tree. The number of roots per rooted cutting was strongly related to donor plant ontogeny regardless of whether or not it had been grafted onto juvenile rootstock.

Juvenile rootstock had no significant main effect on rooting success, the number of roots per rooted cutting, or overwinter survival. For these responses, shoot system differences (genotypic and ontogenetic) were maintained. Cuttings from juvenile buds grafted onto mature rootstock rooted in percentages similar to those grafted onto juvenile rootstock but had fewer roots per cutting, and lower overwintering success. Mature rootstocks were apparently inhibitory for two of the measured characteristics, but not all three. There were also differences between J1 and J2 cuttings in rooting, flushing, and overwintering success but not for the numbers of roots per rooted cutting. This suggests that the responses are under relatively independent control.

The relatively small influence of juvenile rootstock on mature meristems does not appear to be due to ontogenetic rejuvenation but possibly physiological invigoration of the resulting shoots. For the most part, meristems appear to have predetermined rooting responses regardless of grafting. Assuming the differences between juvenile and mature shoots for rooting success are predetermined in buds, then expansion

of preformed buds originally set on a mature tree, whether it occurs *in situ* or grafted onto juvenile rootstock, should result in shoots that perform similarly. It follows that if ontogenetic rejuvenation of a meristem were to occur as influenced by juvenile rootstock, it must happen during the time of bud formation when the primordia for the next flush are formed. In our study, the corresponding treatments would be the 90Xs and the 9190Xs for which cuttings came from buds that formed on juvenile rootstock. The different environment provided by the juvenile rootstock during bud formation apparently did not change the mature character of the meristems and, for the most part, the cuttings responded similarly to their grafted (91Xs) or ungrafted counterparts.

The presence of significant interactive effects suggest that if ontogenetic rejuvenation is possible, it may be genotypically dependent. It is also possible that it may take additional grafting phases for more definitive indications of rejuvenation to be manifested.

Is Kiek Another Mugwort?

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Common Name.

In U.S.A.: creeping field cress
In Holland: Kiek

Scientific Name.

Rorippa silvestris
Brassicaceae family (mustard)

Where Did Kiek Come from?

Europe
Introduced into U.S.A. 1818.

Native habitat.

Stream edges and wet areas
Ideally suited to nursery/container culture.
Very winter hardy.

How in the Weed Spread?

Rhizomes in and on bareroot herbaceous perennials shipped to the U.S.A. from Holland or on U.S.A.-grown bareroot and potted perennials.

Examples of Plant Vigor.

Shoots emerge from 2 to 4 cm depths in 3 to 4 days.
After 1 month in a greenhouse, as many as three new shoots and more than 80 root shoots were produced.
A 3-cm long rhizome segment grew 28 cm from the bottom of a pot.

Herbicide Control.

No cleared herbicides in U.S.A.
Repeated Roundup application does not kill.

Post Emergence Control.

Dutch nurserymen control Kiek with mixture 2,4-D and MCPA.
Not been cleared for U.S.A.

Other Control Methods.

Cultivation exacerbates problem.
Chopping rhizome rapidly propagates new plants.
Plants are drought-sensitive.

Pest Resistant Landscape Plants

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Reducing pesticide usage while utilizing attractive landscape plants has been the goal of many research programs. At the Mountain Horticultural Crops Research and Extension Center, we have been evaluating landscape plants for pest resistance under the high pest pressure conditions of the southern Blue Ridge Mountains. Resistance to Japanese beetle foliar feeding and depredations from eastern tent caterpillar on flowering trees plus disease resistance on *Cornus kousa* and allegedly pest-resistant shrub roses revealed plants displaying a wide range of pest resistance.

Eighty-five different taxa of woody plants were included in these tests. Tables shown here include a representative sample of those plants. For a complete listing of these plants as well as experimental methods, please consult the research papers referenced. The relative terms: poor, fair, good, and excellent were developed for ease of comparison. Poor resistance to disease indicates that the test plant became infested with the disease. Poor resistance to an insect indicates that the insect ate significant portions of foliage, caterpillars grew and developed both normally and rapidly, or the plant was a preferred site for egg deposition. Excellent resistance indicates that little or no problem from the pest evaluated occurred on the cultivar or species listed. Excellent and good ratings for resistance to a particular pest are those that should result in reduced pesticide application by the landscape and nursery industries.

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Table 1. Crabapple (*Malus*) resistance to Japanese beetle foliar feeding as well as eastern tent caterpillar growth and egg deposition.

	Eastern tent caterpillar		
Species/cultivar	Japanese beetle	Growth	Egg deposition
'Baskatong'	Excellent	Poor	Excellent
'Callaway'	Good	Poor	Excellent
'Donald Wyman'	Good	Poor	Fair
floribunda	Excellent	Fair	Excellent
'Golden Raindrops'	Excellent	Excellent	Excellent
hupehensis	Excellent	Poor	Poor
'Molazam', Molten Lava® crabapple	Excellent	Fair	Excellent
'Naragansett'	Excellent	Good	Good
'Radiant'	Poor	Poor	Fair
'Snowdrift'	Fair	Poor	Fair
Sutyzam', Sugar Tyme® crabapple	Good	Poor	Poor

Table 2. *Prunus* species and cultivars resistance to Japanese beetle foliar feeding as well as eastern tent caterpillar growth and egg deposition.

	Eastern tent caterpillar		
Cultivar	Japanese beetle	Growth	Egg deposition
'Hally Jolivette'	Fair	Poor	Excellent
'Kwanzan'	Good	Fair	Excellent
'Okame'	Poor	Poor	Excellent
sargentii	Poor	Good	Excellent
'Snofozam', Snow Fountains® cherry	Fair	Poor	Excellent
'Snow Goose'	Fair	Fair	Excellent
'Spire'	Poor	Poor	Excellent
subhirtella 'Autumn Rosea'	Fair	Poor	Excellent
virginiana 'Canada Red'	Excellent	Poor	Good
×*yedoensis* 'Afterglow'	Good	Fair	Good
×*yedoensis* 'Akebono'	Good	Fair	Good

Germination and Seedling Development in Pawpaw *Asimina triloba*

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Pawpaw [*Asimina triloba* (L.) Dunal] is a small, deciduous fruit tree indigenous to most of the eastern United States. It is the only temperate member of the tropical Annonaceae or Custard Apple family. As a member of this primitive family, its large seeds have a characteristic ruminate endosperm and underdeveloped embryo.

Seed anatomy and seedling development have been outlined for a limited number in the Annonaceae family (Corner, 1948, Hayat and Canright, 1968). Ovule and seed development as well as seed morphology have been described in pawpaw (Mohana Rao, 1982, Lampton, 1957), but there are no descriptions of morphological changes during seed germination or seedling development. This study was designed to describe important developmental stages during germination and seedling development of pawpaw.

Seeds were extracted from ripe fruit (Keedysville Orchard, University of Maryland, Keedysville, MD), packed in moist sphagnum moss and stored in plastic bags at 4C until planting. Cold-stratified pawpaw seeds were sown in vermiculite and placed in a growth chamber (25C, 16 h of 25 μmol sec^{-1} m^{-2} light, 8 h of dark, and watered every 2 days).

Ten seedlings were randomly chosen and destructively harvested for length measurements (mm) and fresh and dry weight (mg) determinations. To obtain length measurements prior to radicle protrusion, the testa was removed and a 4-mm × 4-mm portion of endosperm containing the embryo was excised from the hilar end of the germinating seed. Paraffin-embedded tissue samples were sectioned using a rotary microtome and stained with safranin-fast green.

Pawpaw has an underdeveloped embryo surrounded by ruminant endosperm tissue. The embryo measured less than 2 mm at 9 days after planting. Extending from the cotyledon tips were two parallel channels of cells which stained differently than embryo or endosperm tissues. These growth channels have not been previously described. The cotyledons grow through these channels and it is possible that this facilitates absorption and translocation of materials to the developing axis.

Recognizable stages of seedling development include radicle protrusion, hypocotyl emergence, epicotyl elongation, and seed coat abscission. Prior to radicle protrusion, the cotyledons and radicle grow concurrently at approximately the same rate. Cotyledons reached a maximum length after 40 days, well after hypocotyl emergence (27 days).

As the seedling developed, a reallocation of fresh and dry matter occurred. Initially, the largest proportion of fresh weight and dry weight was in endosperm tissue. This gradually decreased as storage material in the endosperm was mobilized and the seedling became autotrophic (45 days).

Pawpaw exhibits an epigeal pattern of seedling emergence. The cotyledons remain encased within the seed and are shed as one unit (Day 50). Pawpaw seeds may remain subterranean, but are most often raised above the soil surface as the

hypocotyl elongates. This unusual pattern may explain why pawpaw germination has been reported as hypogeal.

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Mohana Rao, P.R. 1982. Seed and fruit anatomy in *Asimina triloba*, with a discussion on the affinities of Annonaceae. Bot. Jahrb. Syst. 103(1):47-57.

Capillary Mats Modify Media Moisture During Mist Propagation of Chrysanthemum Cuttings

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INTRODUCTION

A central feature of the propagation of leafy cuttings is that lacking roots they readily develop water deficits. Slight water deficits, even though insufficient to cause any visual symptoms of distress, can result in considerable delay or reduction in the rooting response (Davis et al., 1988). With the use of intermittent mist, a film of water remains on the leaf surface lowering the vapor pressure deficit and reducing transpirational water loss (Synder and Hess, 1953). However, misting, either applied too frequently or too long at each interval, can result in excessive wetness leading to restricted aeration and reductions in root development (Grange and Loach, 1983b).

Capillary mats can be used to add or reduce the water content of growing media in containers (Buxton and Jia, 1991). In the present study, Vatex capillary mats added or removed water from Smithers-Oasis 1-in. Rootcubes® during mist propagation. The objective of the current study was to evaluate the efficacy of using capillary mats to maintain uniform moisture in the medium during mist propagation.

MATERIALS AND METHODS

Mats placed on the surface of the propagation bench extended over the edge of the bench and downward into a water reservoir located a distance of 0, 5, or 10 cm below bench level. The water table established at bench level was determined by the location of the water reservoir. Oasis blocks with *Dendranthema* 'Boaldi' and 'Salmon Charm' were placed on the mats under intermittent mist (10 sec every 5 min) between 5 AM. and 8 PM. Leaf relative water content and quantity of water in the growing medium (ml of water per gram oasis) were measured every 3 days for 15 days. After 21 days, the number of roots per cutting was evaluated.

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Mats placed on the surface of the propagation bench extended over the edge of the bench and downward into a water reservoir located a distance of 0, 5, or 10 cm below bench level. The water table established at bench level was determined by the location of the water reservoir. Oasis blocks with *Dendranthema* 'Boaldi' and 'Salmon Charm' were placed on the mats under intermittent mist (10 sec every 5 min) between 5 AM. and 8 PM. Leaf relative water content and quantity of water in the growing medium (ml of water per gram oasis) were measured every 3 days for 15 days. After 21 days, the number of roots per cutting was evaluated.

RESULTS AND DISCUSSION

Water content in the oasis propagation cube was significantly reduced by 47.5%, 17.9%, and 2.3% for the 10-, 5-, and 0-cm mat treatments, respectively. This change in water content remained uniform over time for all treatments and both cultivars. Leaf relative water content of the cuttings was not significantly different between capillary mat treatments for both cultivars. This suggests that the water status of the cuttings varied due to the environment (light levels and temperature) and that mist frequency and duration could be changed to meet this demand; capillary mats could then be used to prevent oversaturating of the medium.

Root number per cutting was greater at the 5-cm mat treatment for both cultivars compared to the 0 cm and 10 cm treatments. This suggests that a capillary mat extending 5 cm below the bench can maintain moisture content in the propagation medium for improved rooting of the two cultivars of chrysanthemums used in the study.

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Changes in Root Length and Diameter in Plants Grown in Copper-Treated Containers

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INTRODUCTION

Copper products have been successfully used to control root growth and development in container grown woody landscape plants for several years. Nurseries apply a solution of copper in latex paint to inner surfaces of containers for increased root control enabling improved field establishment and performance of woody landscape plants (Struve, 1993). Copper products control roots by eliminating circling in containers, forcing roots to branch to the center of the container (Arnold and Struve, 1989). The resulting root system is more compact and evenly distributed throughout the container. Increased shoot growth and development after transplanting has also been reported in several plant species produced in copper-treated containers (Arnold and Struve, 1989). In the past, researchers have relied upon gravimetric measurements to evaluate root systems. Observation of roots exclusively by root dry weight can provide misleading information due to differences in allocation of root biomass in production of large and small roots. Observation of root systems with the aid of computer imaging and analysis software (MacRhizo^{TM}, Regent Inc.) provides an improved method of observing and evaluating root systems. The objective of this study is to determine how copper treatment modifies total root length and root diameter of plants grown in containers.

MATERIALS AND METHODS

A fine-rooted species, redbud (*Cercis canadensis*), and a greenhouse species utilized for rapid growth, marigold (*Tagetes patula* 'Little Devil Flame') were grown in 12 cm containers. Container walls were untreated or treated with Spin Out^{TM} (Griffen Corp., Valdosta, GA, USA) a form of cupric hydroxide in latex paint. Marigold seeds were sown directly into containers and redbud were sown into Metro Mix 360 (Scott's) in large flats (60 cm × 30 cm × 10 cm), and transplanted to containers once seedlings reached 2 in. Overhead irrigation was applied as needed with Peter's 15N-$5P_2O_5$-$15K_2O$ fertilizer in solution at 200 ppm. Plants were grown under standard greenhouse conditions.

Root length and root diameter classes were obtained from a random 2.5 cm × 2.5 cm × 6.5 cm section of the root system. Marigold plants were evaluated after 38 days, once four to five flower buds were visible and beginning to open. Redbud were evaluated after 114 days, once treatment effects were observed in the root system. This experiment was repeated as a time course with marigold and was evaluated on 30, 35, and 40 days.

RESULTS AND DISCUSSION

No differences in root biomass were observed between treatments of copper and no copper, however, copper treatment effectively increased total root length in the

Table 1. Leaf area, shoot and root dry weight, and root length per root class of redbud and marigold 'Little Devil Flame' plants grown in 12-cm containers treated and untreated with copper hydroxide.

Species	Leaf area (cm^2)	Shoot dry wt (g)	Root dry wt (g)	Root length per root class treatment		
				0 - 0.5 mm	0.5 - 1 mm	>1 mm
Redbud						
Control	793.7	7.3	2.4	269.29	108.63	63.49
Copper	925.3	9.0	2.5	388.44	146.78	79.30
Marigold						
Control	490.15	2.5	0.8	348.30	312.99	259.53
Copper	517.99	2.8	0.8	426.32	361.02	246.94

sampled wedge of redbud and marigold by 28% and 11%, respectively. There was a significant increase in root length in the smallest diameter root class (0 - 0.50 mm) and the subsequent root diameter classes (0.50 - 1 mm and >1 mm) in both redbud and marigold when grown in copper-treated containers. MacRhizo™ enabled us to observe differences in roots from treated and nontreated copper containers that were not detected by measuring root dry weight. Shoot dry weight and leaf area of redbud and marigold were larger when subjected to copper treatments. In redbud, the leaf area and shoot dry weight increased by 14%. The results were less dramatic in marigold with only 5% and 13% increases in leaf area and shoot dry weight. These results suggest increased shoot development occurs as a result of better root development. A root system comprised of a greater proportion of small diameter roots results in increased water and nutrient uptake (Atkinson, 1980). Similar results were obtained when this experiment was repeated as a time course, evaluated at 30, 35 and 40 days for marigold. Again, no differences were observed in root dry weight but an increased amount of 0 - 0.50 mm diameter roots were observed in the copper treatment.

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Stock Plant Shading to Increase Rooting of Paperbark Maple Cuttings

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INTRODUCTION

Acer griseum, the paperbark maple, is a lovely small tree with year-round interest but is relatively scarce in the nursery trade because of slow growth and difficulties in propagation. Propagation is mostly from seed, though seed production is often poor or unpredictable due to problems with poor seed fill and sterility. Grafting paperbark maple is difficult and generally impractical. In 1985, Dixon Hoogendoorn recounted to the I.P.P.S. membership his experiences with propagating paperbark maple from cuttings (Hoogendoorn, 1985). Using stock plants, of seedling origin, that had been cut back (hedged) for many years, he was able to obtain, predictably, 60% rooting of softwood cuttings taken in late June (Rhode Island).

It would be commercially important to be able to root paperbark maple in high percentages. The objective of this study was to use stock plant shading, in a commercial setting, to increase rooting success of this hard-to-propagate species.

MATERIALS AND METHODS

A 35-year-old hedge of paperbark maple at Hoogendoorn Nurseries (Middletown, RI), measuring ~6 ft high, 5 ft wide, and 60 ft long was heavily pruned in March 1996. On 5 May, as buds began to flush, 10 ft of hedge was covered with two layers of 50% saran shade cloth, and another 10 ft was covered with one layer of 50% saran. The remainder of the hedge was left uncovered. The double saran layer produced an 80% shade, and the single layer produced 60% shade. Shading was left in place until cuttings were taken on 21 June 1996. Nursery workers harvested and prepared cuttings as described by Hoogendoorn (1985). Briefly, cuttings were taken early in the morning and chilled overnight. Prior to sticking, cuttings were trimmed to an 8 in. length with two sets of leaves, soft terminal tips removed. Unwounded cuttings were treated with Hormodin #3 (0.8% IBA in talc) and stuck to a depth of 3 in. in coarse sand. The number of cuttings prepared was: 3900, control; 700, 60% shade; and 450, 80% shade. Overhead mist was applied from 8:30 AM to 6:00 PM, for 12 sec every 10 min. Fungicides were used on a regular schedule. Percent rooting, root number, and length of the longest root were assessed on 1 Oct. 1996.

RESULTS AND DISCUSSION

The rooting of light-grown (control) cuttings was similar to that reported by Hoogendoorn in 1985. Stock plant shading dramatically improved rooting percentages. The number and length of roots also improved somewhat with shading (Fig.

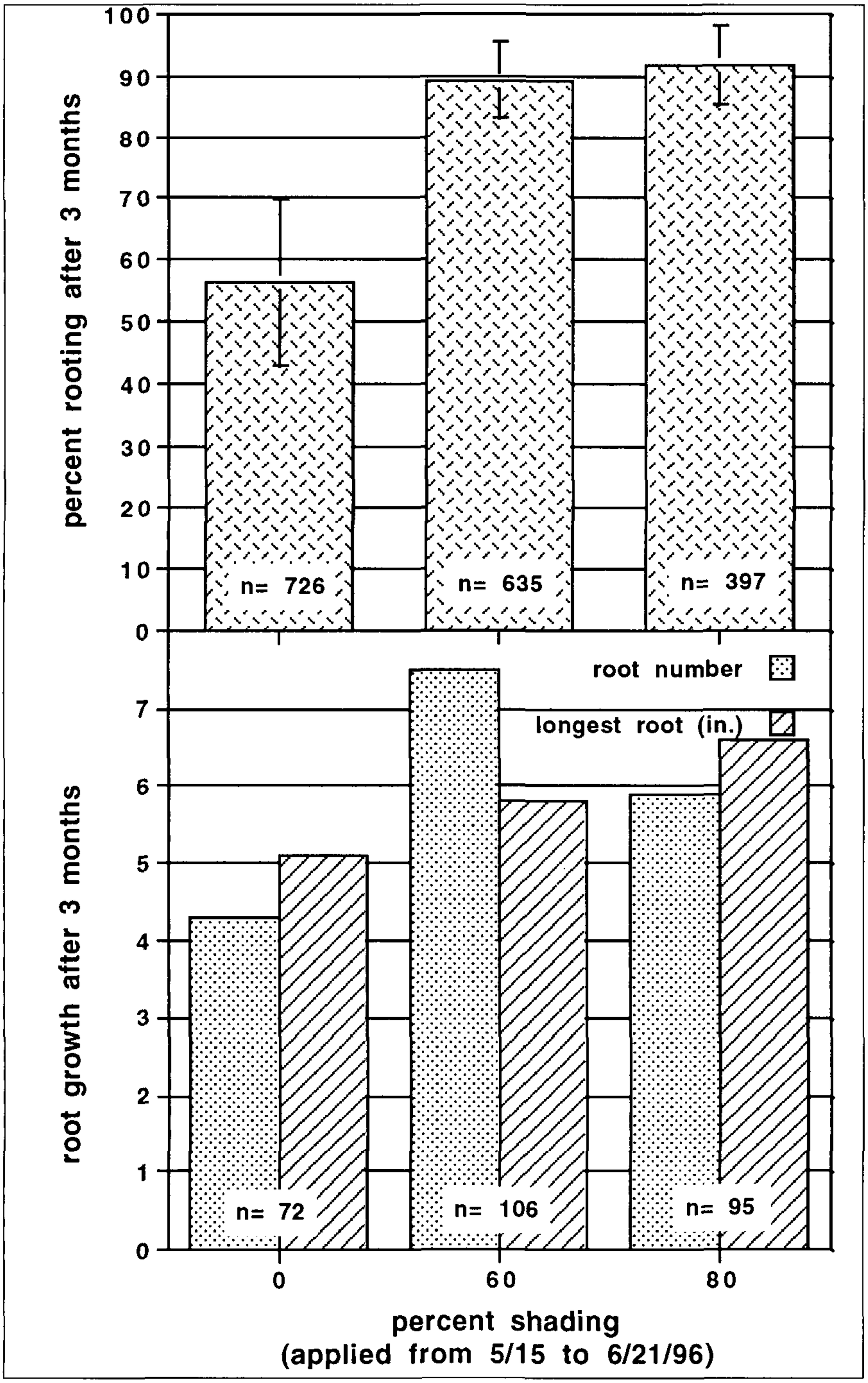

Figure 1. Rooting of paperbark maple cuttings in relation to stock plant shading.

1). High rooting percentages were apparent with shading of 60% or higher, similar to the results Maynard and Bassuk (1991) obtained with cuttings of shaded hornbeam stock plants. On the stock plant, shaded cuttings were nearly indistinguishable from full-light-grown cuttings; shaded shoots possessed somewhat longer internodes (data not presented). In the rooting bench, shaded cuttings retained more leaves, possibly because of increased rooting, as virtually all unrooted cuttings lost their leaves. Shaded cuttings also produced fuller, better branched root systems than full-light cuttings. Using a double layer of saran (80% shade) was not a significant improvement over a single layer (60% shade).

CONCLUSION

The high rooting percentages obtained using cuttings harvested from shaded stock plants has great implications for the nursery production of own-rooted paperbark maples. At such high rooting percentages, cuttings are less costly to produce and might even be stuck to root directly in the production container, reducing transplant shock and losses, and decreasing production time. The increase in root number and length seen on shaded cuttings might also improve transplant success, reduce production losses, and yield better quality liner material.

Placing a single layer of saran shade cloth over an existing stock block is an inexpensive addition to the propagation system that can dramatically improve propagation success.

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Enhancement of Undergraduate Education in Plants, Propagation, and Production Using Regional, National, and International Tours

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Education of undergraduate majors in horticulture can be enhanced by touring the industry related to their profession. Classroom activities of textbook, lecture, and lab are limited activities when it comes to opening the eyes of a new student to the profession. The plant material classes are limited to covering 200 to 300 plants per semester and may be limited to a single specimen on campus. A diverse industry works with thousands of plants and each plant has its own personality at each stage of life and season of the year. Textbooks in a way may be limited to the basics. At best, texts are revised on a 5- to 10-year basis. How do students keep abreast of the current technologies and changes? Labs can continue to expand the knowledge put forth in the lecture. However, equipment and plants may be the limiting factors in developing laboratory activities which would cover the breadth of this industry. Local tours during labs may be limited to a single day or a single firm. Texts, lectures, and labs are important parts of the education process, but each may be limited.

During the 1980s we started incorporating 2- to 3-days tours into the system to present more exposure. In 1990 we incorporated the first week-long tour, when we toured the industry centered around Portland, OR. This event brought significant encouragement that it should be repeated and the decision was made to place this tour on a 3-year cycle. Each student in the program should have a chance to participate while working on their degree. Next we added international exposure with a tour to Europe to visit gardens and industry. This also is now on a 3-year cycle. The other year in the 3-year cycle was initiated in 1995 as a garden tour of the Northeast United States and Southeast Canada. Participation has been between 10 and 16 students for each one of these events. During the 28-month period from May 1994 to August 1995, undergraduate students at the University of Kentucky participated in five tours which were of regional, national, or international scope.

Funding for the tours has come from several sources other than from students' pockets. The Portland, OR tour is now partially funded by the nursery industry. In 1994 the Robert R. Scott, Laverne Scott & Elmira Scott Trust was established in the Department of Horticulture and Landscape Architecture and its funds were specified for travel. Our regional tours are now supported with a grant from the Scott Trust. A very active Horticulture Club has instituted fund raising activities which have been very instrumental. Other grants and gifts have also been supportive.

A 2-week tour is like a semester course. It takes education beyond the classroom. Tours alter a student's scope of the industry on the regional, national, and

international levels and offers new information and technologies not available on campus. Thus, students have a better understanding or working knowledge of what they are exposed to in class.

UK HORT CLUB TOUR OF NETHERLANDS AND FRANCE 9 - 21 MAY 1994

Netherlands.
Aalsmeer Floral Auction
Aalsmeer Flori. Res. Station
Beebee Bulb Co.
Boskoop Area nurseries
Boskoop-Nursery Res. Station
Goldsmith Seed Europe
Het Loo Palace
Keukenhof Gardens
Terra Nigra bv
U. of Leiden Botanic Garden

France.
Azay-le-Rideau
Bois de Boulogne - Bagatelle
Andre Briant Plants
Chenonceau Chateau
I.N.R.A. Experimental Station
LePage Perennial Nursery
Metz, France Green Space
Monet's Garden
Vaux-le-Vitcomte
Versailles
Villandry Gardens

UK HORT CLUB TOUR OF NORTHEAST U.S. AND S.E. CANADA 6 - 19 MAY 1995

Angelica Nursery
Arnold Arboretum
J. C. Bakker & Sons Nurseries
Bartrum Garden
Butler's Orchard
Centerton Nursery
Chapel Valley Landscape Co.
Conard-Pyle Co.
Dunbarton Oaks
Fairmont Park Japanese Garden
Jeffery's Greenhouse
Kendall Sculpture Garden
Kingwood Garden
Lavall Univ. Res. Gardens
Longwood Garden
Monticello
Montreal Botanic Gardens
Morris Arboretum
Mt. Cuba Center
National Arboretum
Niagara Hort. School Garden
Planting Fields
Royal Botanic Garden
Rutgers Univ. Garden
Univ. of Delaware Garden
UCONN Conifer Collection
Univ. of Maine Arboretum
URI Rhododendron Garden
John Vermeulen & Son Nursery
Wade & Gatton Nurseries
Waterloo Gardens
Wave Hill Garden
Western Maine Nursery
White Flower Farm

Figure 2. Andre Briant Plants, May 1994.

Figure 1. Mt. Cuba Center, May 1995.

SCOTT GRANT TOUR OF N Y, ONTARIO, AND OHIO
13 - 15 OCT. 1995

Baker Farms
J.C. Bakker & Sons Limited
Brotzman's Nursery
Herman Losley & Son
Niagara Parks Greenhouse
Schenk Farm & Greenhouse
Stokes Seeds
Sunleaf Nursery
Vineland Experiment Station
Westbrook Greenhouses

UK HORT CLUB TOUR OF OREGON AND CALIFORNIA
9 - 25 MARCH 1996

Oregon
Bailey's Nursery
Buchholtz & Buchholtz
Caprice Farm
Crystal Gardens
Femrite Nursery
Fisher Nursery
Gutmann Nursery
Heritage Seeds
Iseli Nursery
Japanese Garden
Klupenger's Nursery
McConkey Manuf.
A. McGill Nursery
Microplant Propagation
Moller Nursery
Monrovia Nursery
Nat'l Germ. Repos.
Northwoods Nursery
Panzer Greenhouse
Portland Rose Garden
J. F. Schmidt Nursery
SEBECO
Weeks Berry Nursery
TREECO Rootstocks
Van Bloem
Van Veen Nursery
Windflower Farm
Woodburn Nursery

California
Deigaard Nurseries
Goldsmith Seed
J&P Roses
La Samida Garden Center
Monrovia Nursery
Sequoia National Park
Stewart's Orchids
Styrbling Arboretum
Yoder Bros. Greenhouse
Yosemite Nat'l Park

SCOTT GRANT TOUR OF CHICAGO/MILWAUKEE
29 AUG. - 2 SEPT. 1996

Alfred L. Boerner Bot. Garden
Ball Seed Trail Garden
Growing Systems
Hahlbeck Greenhouse
Kennicott Brothers Co.
Leider Greenhouse
Leid's Nursery Co.
Midwest Ground Covers
Midwest Trading
Mitchell Park Conservatory
Morton Arboretum
Pan American Seed
Platt Hill Garden Center
Radte Perennial Nursery
Stein's Garden Center
Tom's Farm Market
Val-Al Greenhouse

Rooting Rhododendron Without Mist: Subirrigation and Medium pH

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INTRODUCTION

Mist systems have been widely used in the rooting of cuttings. They enable propagators to root cuttings with both ease and flexibility. However, mist is not without its problems. Some of these problems include leaf chlorosis, nutrient leaching, salt build-up, leaf rot, algal growth, water quality, clogging of nozzles, and other maintenance tasks. A method of rooting cuttings using subirrigation instead of mist was reported by Zhang and Graves (1995). It was recently reported that rhododendrons are difficult to propagate in subirrigation systems (Cuny, 1996). Tissue culture research shows that the optimum pH for root embryogenesis is between pH 4.0 to 5.0 (Smith and Krikorian, 1990). However, little research has been conducted on the effects of pH on the rooting of stem cuttings. We report on the use of a subirrigation system to root cuttings of Rhododendron 'PJM' without mist and to determine the role of the pH on rooting.

MATERIALS AND METHODS

Five-inch terminal stem cuttings of Rhododendron 'PJM' were collected on 2 August 1996 from a single plant and trimmed to 6 or 7 leaves. They were wounded on one side and treated with in a 1 : 10 dilution of Dip 'n Grow (1.0% IBA, 0.5% NAA) for 5 sec. The cuttings were propagated in a greenhouse under 80% shade. The propagation system consisted of 1-gal nursery containers (15 cm × 18 cm) placed in a flat (50 cm × 35 cm) that was lined with 6-mil plastic and filled with 5 cm of water. There were two treatments, each with four reps of 10 cuttings. The first treatment consisted of a perlite medium in the pots and tap water (pH=7.5) in the lined flat. The second treatment consisted of acid-washed perlite medium in the pots and tap water adjusted to pH 4.5 with 1 N sulfuric acid. Water was added to each system to account for evaporation on a weekly basis. In the pH 4.5 treatment the pH of the water was adjusted to a pH of 4.5. On 18 September 1996 the cuttings were harvested and percent rooting was recorded. The rooted cuttings were gently washed to dislodge loose perlite, and submerged in a 100 ml graduated cylinder to record volume displacement.

RESULTS

The pH of the subirrigation system had a dramatic effect on root development and growth of Rhododendron 'PJM' (Table 1). The pH 4.5 treatment had 100% rooting with an average root ball water displacement of 7.6 ml. The pH 7.5 treatment had 52.5% rooting with an average root ball water displacement of 0.8 ml. The pH 7.5 treatment produced no commercially acceptable cuttings, while in the pH 4.5 treatment 90% of the cuttings were commercially acceptable.

Table 1. Rooting percent and root volume of *Rhododendron* 'PJM' after 6 weeks in subirrigation at two pH levels.

Volume displacement of *Rhododendron* 'P.J.M.' cuttings (ml)							
pH 4.5 subirrigation treatment				pH 7.5 subirrigation treatment			
Rep 1	Rep 2	Rep 3	Rep 4	Rep 1	Rep 2	Rep 3	Rep 4
0.3	0.1	9.5	10.6	NR	NR	NR	NR
8.1	0.3	11.7	4.5	NR	NR	NR	NR
6.4	0.3	10.9	9.2	NR	NR	NR	NR
7.8	7.9	10.6	12.8	NR	NR	0.2	NR
6.9	9.0	9.7	5.5	0.1	NR	0.5	NR
10.3	6.8	7.3	6.8	0.2	NR	0.6	NR
6.6	7.0	12.8	9.2	0.2	0.1	0.7	0.1
7.3	5.4	8.4	11.8	1.8	0.4	1.1	0.2
3.2	9.2	11.9	12.6	1.6	2.3	0.6	0.1
10.7	4.5	7.5	3.2	2.4	2.1	2.1	0.6
		Column means				Column means	
6.8	5.1	10.0	8.6	1.0	1.3	0.8	0.3
		Grand mean 7.6 ± 1.9				Grand mean 0.8 ± 0.4	
			Percent rooting of *Rhododendron* 'PJM' cuttings				
100	100	100	100	60	40	70	40
		Mean % rooting 100 ± 0				Mean % rooting 53 ± 13	

The cuttings in the pH 4.5 treatment showed no visible sign of wilting stress throughout the experiment. Cuttings in the pH 7.5 treatment showed signs of wilting stress after the 2nd week. This is likely due to increased resistance to water uptake at the base of the stem. It was observed that roots started to emerge from the cuttings in the pH 4.5 treatment after 10 days. Roots did not emerged from the pH 7.5 treatment until 20 days after the cuttings were stuck.

DISCUSSION

The success of the subirrigation system is due partly to the use of perlite as a rooting medium. In subirrigation the water flows from the reservoir to the base of the stem cutting by capillary action. Perlite is unique in that its water is loosely held and readily available to the plant roots. Peat and vermiculite hold water tighter and make it less available (Grange and Loach 1983). Preliminary studies showed that perlite and peat or perlite and vermiculite combinations were unsatisfactory media in subirrigation (data not presented).

In addition to the *Rhododendron* 'PJM' we have been successful in rooting *Ilex* ×*meserveae, Cotoneaster adpressus, R.* 'Catawbiense Album', along with other taxa in this subirrigation system. All of the plants rooted with acceptable percentages and showed little or no water stress. We are currently working on the effects of different levels of irradiance, pH, and particle size to fine tune the subirrigation system. It should be possible to root many kinds of softwood cuttings with equally well or better rooting percentages than under mist.

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Propagation of Birch by Softwood Cuttings

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INTRODUCTION

Birch is one of the most commonly used trees in America's landscapes. For many years the primary propagation method was by seed. Selection for superior landscape characteristics created a need for clonal propagation. The two methods most widely used in the industry are micropropagation and softwood cuttings.

LaPorte County Nursery propagates the following birch cultivars by softwood cuttings: *Betula nigra*, *B. nigra* 'Cully', Heritage™ river birch, *B. nigra* 'Little King', Fox Valley™ river birch, and *B. platyphylla* var. *japonica* 'Whitespire Sr'.

MATERIAL AND METHODS

Plant Material. Softwood tip cuttings are taken from field or stock plants in early June. Cuttings are then recut to a length of 4 to 6 in. The bottom leaves are then stripped off so there is 2 in. of stem to place in the rooting medium. A two-node cutting may also be used instead of tip cuttings. The cuttings are then placed into bundles for treatment.

Bundles of cuttings are completely dipped in a Green-Shield® solution. This is a soapy disinfectant for sanitation. Cutting bundles are allowed to dry off some before the hormone treatment. Bundles are dipped in a solution of Woods rooting hormone of 2500 ppm IBA for 10 sec. Cuttings are kept moist at all times prior to sticking.

Medium. The medium consists of peat and perlite mix (1 : 1, v/v). All parts are thoroughly blended and run through a shredder.

Propagation House. Polyhouses are covered with double-layer poly with the outer layer being white. The floor of the house has a fabric with 1 in. of pea gravel underneath. Before the cuttings are stuck, the whole house is treated with Green Shield®.

Anderson band pots are placed on the floor and filled with medium. Two sizes of pots are used — 2-3/8 in. and 3-5/8 in. A single cutting is stuck in the 2-3/8 in. and 4 to 5 cuttings in the 3-5/8 in. Cuttings are direct stuck into the pots on the floor.

Mist is supplied using Eddie Mist nozzles. Misting is controlled by a Phytotronics controller and a 24-h timer. Misting begins at 6:00 AM and shuts off at 8:00 PM No bottom heat is used and the air temperature is controlled by ventilation.

Post Rooting. Root initials begin to appear in about 3 weeks. On an average year 90% rooting can be obtained. Once root initials are visible, the mist is gradually decreased. If the cuttings are taken early in the propagating season, an additional 4 to 6 in. in growth can be obtained by fall. All cuttings are overwintered in polyhouses with minimum heat.

Marigold Growth Following Transplanting at Several Stages of Development

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There are several studies investigating the relationship between plug size and subsequent growth. These studies involve large plugs (>7 cm^3). Marr and Jirak (1990) showed that tomato transplant size decreased with smaller root volumes and length of time held in plugs. Total tomato fruit yield after transplanting to the field, however, was not negatively affected. In marigold, transplants with smaller root volumes had decreased height for up to 7 weeks after transplanting into the landscape (Latimer, 1991). There are no reports on the influence of the smaller plug sizes (<7 cm^3) typical of bedding plant production on subsequent transplant development. The objective of this study was to examine marigold seedling growth and development after transplanting as affected by root restriction, canopy competition, and transplant shock.

In the first of these experiments marigold (*Tagetes patula* 'Little Devil Flame') was seeded into each cell of a 392-count plug trays (4 cm^3 per cell). Twelve seedlings were transplanted into 6-packs (42 cm^3 per cell) on Days 0, 5, 10, 15, 20, and 25. On Day 25 leaf area, shoot dry weight, root dry weight, and total root length (via analysis with computer software MacRhizo^{TM}) were measured. In the second experiment, marigold seeds were sown in both 392-count plug trays and community flats (512 cm^3) at three densities (20.8 plants m^{-2}, 29.5 plants m^{-2}, and 38.1 plants m^{-2}). On days 0, 10, 20, and 25, 12 seedlings from each planting density were transplanted into 6-packs. Plants were evaluated after 25 days. Twelve plug seedlings, 12 transplanted seedlings, and 12 seedlings directly sown into 6-packs were harvested on days 10, 20, and 25 and the above-mentioned measurements taken.

In the first experiment, shoot biomass of plug seedlings transplanted on Day 10 was significantly lower than Day 5 transplants. Root biomass of day 15 transplants was significantly lower than Day 10 transplants. Leaf area growth, shoot dry weight, root dry weight, and total root length of seedlings 25 days in plugs was significantly lower than those seedlings 25 days in 6 packs. These data suggest seedling development is negatively affected as roots become restricted. The second experiment revealed that seedlings sown directly into 6-packs had significantly more biomass than either plug or community flat seedlings. Plant density, or canopy competition, affects seedling biomass, however, root restriction has the greater effect on reducing seedling size. In the third experiment after 20 days, leaf area, shoot dry weight, and total root length were significantly lower than seedlings grown in 6-packs. Seedlings transplanted from plugs to 6-packs at Day 20 had lower total biomass than seedlings grown in 6-packs. Although the rate of growth post transplanting was higher than seedlings remaining in plugs, the rate was lower than the rate of growth for seedlings grown in 6-packs. These results suggest a minimal effect of transplant shock in the reduction of growth of plug transplants.

The results of this study suggest that transplant shock, shoot competition, and root restriction in the plug are all factors in the reduction of seedling growth following

transplanting. Root restriction, however, appears to be the most critical factor in affecting transplant growth in 6-packs.

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Commercial Micropropagation Laboratories in the United States

Richard H. Zimmerman
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To determine the current status of commercial micropropagation in the U.S., an extensive survey of laboratories was made in March and April, 1996, by doing telephone interviews with the manager or owner of each laboratory. All laboratories contacted and currently doing commercial production provided data.

Commercial micropropagation laboratories are located in at least 26 states and most are situated near important production areas of the horticultural industries that they service. Florida leads in plants produced, followed by California, Washington, and Oregon. California and Florida each have more than 15 laboratories; all other states have fewer than 10 each. Within states, the laboratories are often clustered in certain areas. In Florida, the heaviest concentration is near Apopka, where much of the foliage plant production is located. California labs are clustered mainly in coastal areas near San Francisco, Los Angeles, and San Diego. The Pacific Northwest labs of Washington and Oregon are located west of the Cascade Range stretching from near the Canadian border to the south of Portland.

Production of individual laboratories varies from a few thousand to tens of millions of plants per year. Small laboratories (<500,000 units per year) account for about 60% of the slightly more than 110 laboratories identified; 24 of these small labs produce only 50,000 units per year or fewer. About 30% are medium-size laboratories (500,000-2,500,000 units per year); large laboratories (2,500,000-6,000,000 units) and very large laboratories (> 6,000,000 per year) account for the remaining 10%.

Total production of micropropagated plants is now more than 120 million plants per year, considerably higher than earlier estimates of 61 to 75 million plants (Hartman, 1995; Jones, 1985; Zimmerman and Jones 1991), but a much broader range of crops is now being micropropagated than 5 to 10 years ago. Also, more laboratories were identified and contacted to obtain the figures reported here. Plants now being micropropagated can be grouped according to their uses or area of horticulture as shown in Table 1.

Foliage plants, the largest category, have as the main crops ferns, *Spathiphyllum, Syngonium, Dieffenbachia, Ficus, Calathea,* and *Philodendron.* Orchids are about

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Table 1. Production of micropropagated plants in the United States by geographic region and type of crop. Numbers are thousands of plants.

Crops	Eastern U.S.[1]	Florida	West Central	Pacific Northwest	California & Hawaii	Total
Foliage plants	1200	47,975	0	0	14,520	63,695
GH flowers	278	5,178	495	0	5,346	11,297
Perennials	4,388	1,030	1,320	2,080	630	9,448
Trees and shrubs	1,434	2,480	1,400	7,850	2,130	15,294
Vegetables	3,692	0	4,849	1,130	3,191	12,862
Fruits	1431	10	50	1,970	260	3,721
Miscellaneous	25	975	1,715	1,270	560	4,545
Total	12,448	57,648	9,829	14,300	26,637	120,862

[1] Eastern U.S.—states east of the Mississippi River; West Central U.S.—states west of the Mississippi River except for Pacific coastal states; Pacific Northwest—Washington and Oregon.

one-third of the greenhouse flower crop production and other major crops are *Gerbera, Anthurium*, and bromeliads. Herbaceous perennials are a rapidly increasing segment of the production; major genera are *Hosta, Hemerocallis, Stokesia, Gypsophila, Heuchera, Leucanthemum*, and *Rudbeckia.*

Ericaceous plants (*Rhododendron, Kalmia, Pieris, Leucothoe*) account for more than 23 % of the trees and shrubs now micropropagated; another 22% are trees including *Acer, Amelanchier, Betula, Eucalyptus, Magnolia, Malus, Populus, Prunus,* and *Ulmus.* Shrubs include *Nandina, Syringa, Fothergilla, Hydrangea, Photinia,* and *Viburnum*, among others.

Potatoes are about 90% of the micropropagated vegetable crops with other crops including asparagus, garlic, and sweet potato. Fruit crops are primarily blueberry (*Vaccinium*) and raspberry (*Rubus*) with limited production of fruit tree rootstocks. Miscellaneous crops are a wide assortment of ornamental and tropical fruit crops and specialty crops including *Lilium, Gladiolus,* banana (*Musa*), *Citrus* rootstock, peppermint *(Mentha ×piperita)*, spearmint (*M. spicata*), wasabi (*Wasabia japonica,* Japanese horseradish), and sugarcane (*Saccharum officinarum*).

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The Effect of Transplanting Date on the Growth of Three Evergreen Shrubs in Containers

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INTRODUCTION

Producers of woody plant material have consistently worked toward finishing stock in the shortest possible time while maintaining high quality. In the South Jersey area, container growers have noted the combination of a large vigorous liner, early transplanting date, and high fertility contribute to the profitable production of such stock.

Appleton and Whitcomb (1983) indicated that an early transplanting date has a positive effect on the growth of deciduous tree seedlings, but it was less important on evergreen tree seedlings as suggested by Whitcomb, et al.(1977).

This study was conducted to determine the effect on growth over five transplant dates.

MATERIALS AND METHODS

Rooted cuttings of *Rhododendron* 'Hino-crimson' (hino crimson azalea), *Juniperus conferta* 'Blue Pacific', and *Taxus ×media* 'Densiformis' were potted at approximately 15-day intervals from 18 May through 14 July in #2 nursery containers. Each of the five treatments was replicated 20 times.

The medium was a peat, vermiculite, and sand mix (45 : 45 : 10, by volume) and was amended with 2.97 kg m^{-3} (5 lb yd^{-3}) of dolomitic lime and 0.15 kg m^{-3} (4 oz yd^{-3}) of a fritted trace element material containing 5% manganese, 14% iron, 1.5% copper, 5% zinc, 0.8% boron, and 0.07% molybdenum. The major nutrients were supplied as a 20-20-20 soluble fertilizer containing micronutrients applied at the rate of 200 ppm nitrogen twice a week. The plants were grown in an open 14 ft × 100 ft nursery storage house and later overwintered in the same house with a single-layer white polyethylene cover.

All plants were measured on 26 April of the following year using the formula: width+width+height/3=overall size. The results were then evaluated to determine the least significant difference at the 5% level. Where mortality existed, average values were inserted and treatments were then further evaluated to determine if there was significance for mortality in the treatments.

RESULTS

Azaleas potted after mid May showed a significant reduction in overall growth when compared with all other treatments. Growth was also reduced with each subsequent planting date, which supports the position that azaleas should be transplanted at the earliest possible date (Table 1, Figure 1).

The influence of the earliest transplanting of juniper showed less positive effect than with azalea, although when transplanted later than early June growth of juniper was significantly reduced. Like the azalea, each subsequent date after the initial significant reduction in growth resulted in further reductions in growth.

Table 1. Top growth of plants transplanted at various dates.

Transplant date	*Rhododendron* 'Hino-crimson'	*Juniperus conferta* 'Blue Pacific'	*Taxus ×media* 'Densiformis'
18 May	35.05 (13.80)[z] a[y]	22.25 (8.76) a[y]	15.49 (6.10) a[y] a[x]
2 June	33.68 (13.26) ab	22.30 (8.78) a	15.34 (6.04) a a
16 June	32.89 (12.95) b	16.00 (6.30) b	13.92 (5.48) b a
31 June	31.37 (12.35) c	12.78 (5.03) c	14.50 (5.71) ab a
4 July	29.46 (11.60) d	10.80 (4.25) c	14.99 (5.90) ab b

[z] Centimeters (inches).
[y] Means within columns followed by the same letter are not significantly different at the 5% level.
[x] Significance at the 5% level for increased mortality.

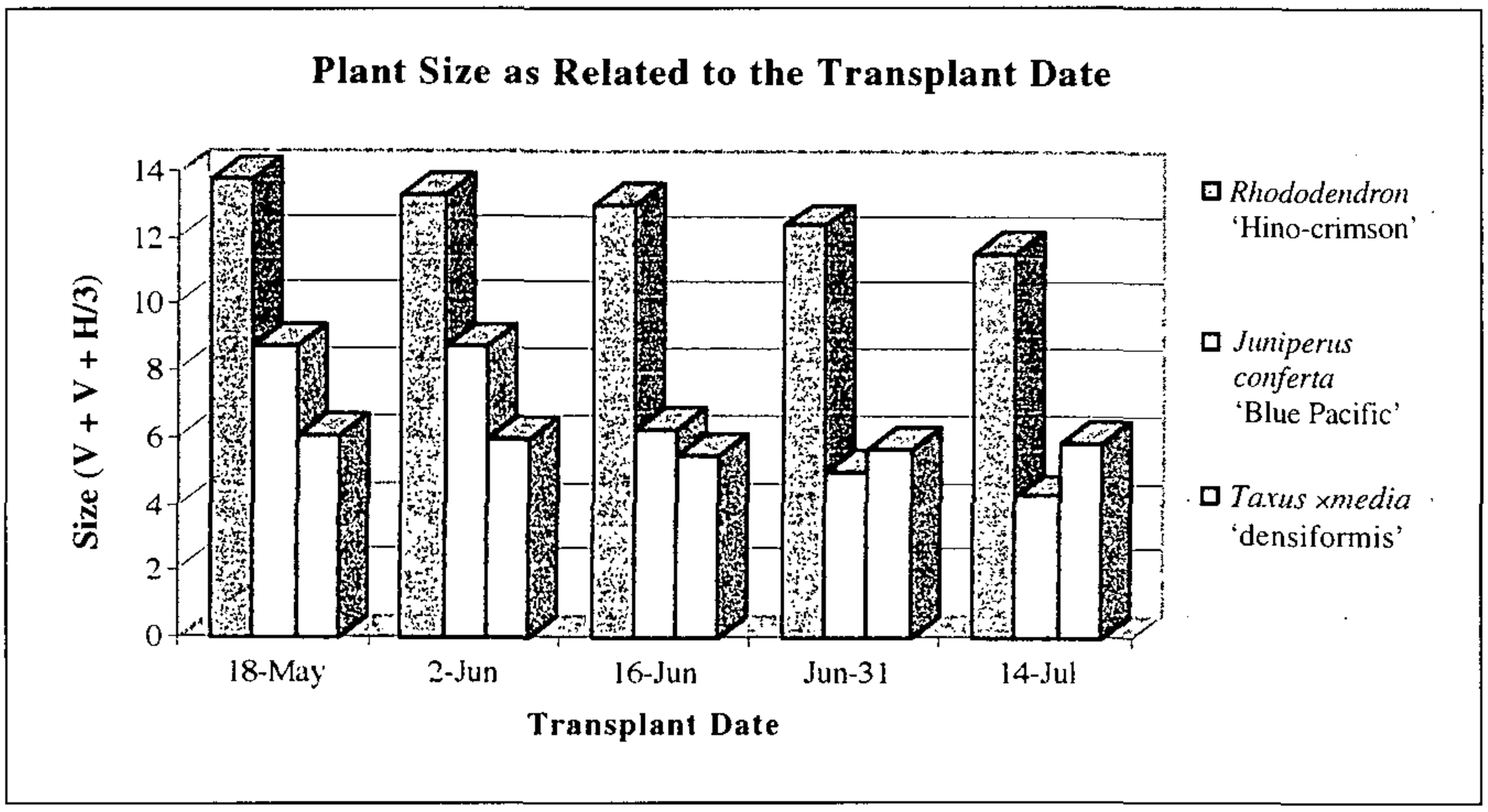

Figure 1. Plant size as related to the transplant date.

Taxus performed similarly to the juniper with respect to early transplanting but differently from either the azalea or the juniper on later dates. There was no benefit from a mid May transplant date over the early June date. Transplanting after early June resulted in a significant reduction of growth from the earlier transplant dates, but growth did not continue to decline on later transplant dates. While maintaining a plateau of growth during later dates, there was a significant increase in mortality by mid July.

DISCUSSION

It was noted that the two narrow-leaved evergreen species showed a significant decrease in growth after an early June transplant date, while the broad-leaved evergreen species reacted positively to an earlier transplant date. It is possible that the azalea may exhibit continued positive response to a transplant date earlier than that of 18 May. The cause of the later decrease in growth response for the narrow-leaved evergreens can only be speculated. It is possible that high root temperatures may have caused the growth inhibition. Narrow-leaved evergreens are generally accepted to be more heat tolerant than broad-leaved evergreens, and the early decline in azalea growth based on transplant date appears to support that concept. In *Petunia hybrida*, high temperature inhibition occurred at medium temperatures above 24C (75F) (Merritt and Kohl Jr., 1982). The sun readily warms a peat-lite medium because of its dark surface, and temperatures exceeding 43.3C (110F) have been recorded by area growers.

SIGNIFICANCE TO THE NURSERY INDUSTRY

This study indicates the importance of transplanting rooted cuttings early for best vegetative growth of the species tested. These results also indicate the need for further research observing the effect of root temperatures on the overall growth of woody ornamentals. Optimum transplanting dates for other plant genera and species should be developed as well. In a time when profitability is strongly related to the crop cycle time, maximum vegetative growth and therefore an early transplant date is a key to profitability.

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Propagating *Sassafras albidum* from Root Shoots

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Sassafras albidum is an attractive native tree in the Northeastern U.S. not commonly available in the trade. It can be trained to a single stem, often forming thickets when growing in the wild. While it can be propagated both from seed and cuttings, we have found this root-shoot method simple and efficient, as well as effective in clonal production of selected individuals.

When an established sassafras thicket is cut down and mowed, shoots continue to come up in profusion for many years from the dense root system. Gently tugging on the 6- to 10-in.-long shoots in June separates them from their roots. At the bottom of the shoot is a white to pink area of the stem from which new roots have proven to generate quickly, given the proper conditions. This rooted "cutting", transplanted to a container, rapidly grows to become a uniform, vigorous, 2-ft-tall plant within about 3 years.

We dip the bottom inch of the just-pulled shoot in a 1 : 20 (v/v) solution of Dip 'n Gro and water for about 5 sec. These are direct stuck in plug trays or pots. Trays are placed for several weeks in a fog propagation house until they are well rooted and can be held in a cold house for the winter to be potted the next spring. Our Mee Fog Generating System is set at 1 min every 6 min and adjusted for weather changes.

Rooting Medium:

- 6 ft^3 pine bark mulch
- 6 ft^3 sphagnum peatmoss
- 12 ft^3 horticultural perlite
- 2 lbs ground limestone
- 1 lbs AquaGro 2000 G

In the spring of the next year rooted plants from the plug trays are planted into #2 pots. Most growth this year occurs in the roots, with the tops growing slowly. During the second year in #2 pots the top growth becomes vigorous; the plants are about 2 ft tall by mid summer, and the roots have filled the container. This plant can then be sold, shifted to a larger container or used as a liner for field production to produce a mature tree.

Medium for #2 Pots:

- 2 parts composted bark
- 1 part sharp sand
- 1 part leaf compost
- 8 lbs per yard Sierra High N 24N-4P_2O_5-8K_2O

Camellia Propagation and Production

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INTRODUCTION

Camellias are relatively easy to propagate and to grow. At Overlook Nurseries camellia cultivars of *C. japonica*, *C. sasanqua*, *C. ×hiemalis*, and selected hybrids are propagated and grown in containers. The rate of growth of camellias compared to hollies and azaleas is slower, but the majestic beauty and grandeur of its flowers more than compensate for their slower growth rate.

PROPAGATION

Camellias are propagated by seeds, cuttings, and graftage. Camellia cultivars are heterozygous and do not breed true from seed. If seedlings are not worthy of selection for production for resale they are used for rootstock in grafting. Cuttings are the most common form of propagation and guarantees cultivars remain true. Grafting is used on camellia cultivars that are difficult to root by cuttings and/or have a poor root system.

Collection of Cuttings. Cutting wood for propagation is collected from a maintained stock block during September and October. We do not take any cuttings from containerized plants we plan to sell in the fall. Ideally terminal cuttings are recommended since they produce plants which branch more freely and grow faster than leaf bud cuttings. A semihardwood cutting approximately 8 to 10 cm (3 to 4 in.) in length, firm with the wood green to light brown is desired. Cuttings collected from the stock block are gathered and prepared within a period of 1 h. Clippers are disinfected with Consan when collecting and preparing cuttings to help reduce potential disease problems.

Cutting Preparation. Cuttings are prepared under a covered shed on top of a polycoated table to reduce transmission of diseases. All cuttings are first soaked in a fungicide dip of Captan. The lower leaves are removed leaving at least three leaves on the top of the cutting. The remaining leaves are not reduced in size to avoid entry of pathogens and the terminal bud is pinched off. The cuttings are grouped into bundles of 25 and the ends are trimmed off.

Rooting Compounds. The bundled cuttings are dipped into a 10,000 ppm solution of IBA for 3 sec. The cuttings are then stuck in 6-cm (2 1/4-in.) rose pots one cutting per pot. Cuttings are stuck at a depth of 3 cm (1 in.). It is important not to stick cuttings too deep.

Medium. A medium of fine pine bark [1-cm (3/8-in.) screen size] with a trace of washed sand is used and provides good drainage and better control of water requirements. Amendments incorporated into the medium include the slow-release fertilizer — Nutricote 20N-7P_2O_5-10K_2O/Type 360 at 3.6 kg m^{-3} (6 lb yd^{-3}), 7.1 kg m^{-3} (12 lb yd^{-3}) of pelletized dolomitic lime, and 1.2 kg m^{-3} (2 lbs yd^{-3}) of Gro & Sho Micro-ment (minor element package, Tri-State Plant Food, Dothan, Alabama).

Propagation Structures. Cuttings are rooted in greenhouses with 55% shade on raised benches under intermittent mist. Cuttings are misted for 30 sec at 20-min intervals between 3 h after sunrise and 3 h prior to sunset. This mist frequency is maintained for 2 weeks, and then reduced as the weather cools. All propagating houses are covered with polyethylene for winter protection and propane gas heaters are used in severe conditions.

Rooting. Most camellia cultivars are easy to root with a few exceptions. It is not unusual for us to have better than 90% rooting. Most cultivars take 3 to 5 months to develop adventitious roots — so patience is paramount.

Maintenance. After the cuttings are rooted, they are trimmed frequently with gasoline trimmers to increase lateral breaks. No herbicides are used, only hand weeding.

Problems. The major problem we experience in growing camellias is dieback which is caused by the fungus *Glomerella cingulata*. It is more prevalent in humid areas. We spray for dieback as needed and on the days we are pruning, the fungicides Cleary's 3336 or Dithane are applied. Some camellia cultivars are more susceptible to dieback than others and don't respond to treatment. Our most critical time for camellia dieback is the spring after liners have been transplanted to 3.8-liter (1-gal) containers. We do not transplant liners into larger containers than 3.8-liter (1-gal) because of dieback problems. Camellias are also susceptible to tea scale which produces unsightly white webs underneath the leaves and sometimes discoloration. Eradication and control is achieved with Oilicide and Supracide. Spider mites cause browning of camellias leaves. Control is maintained with Kelthane and Pentac.

Grafting. Grafting is used in the case of hard-to-propagate cultivars and ones that do not have good root systems. We graft in December and January and use rootstocks that we know are strong growing cultivars. For the purposes of grafting, plants that stay too wet do not callus well and usually disease problems occur at the graft union. Plants must be dried to be suitable for successful grafting. Hand select rootstock with a straight base. Prior to grafting, the rootstock is sprayed with Cleary's 3336 and Captan. Rootstocks are cut off 8 to 10 cm (3 to 4 in.) above the soil line. A vertical incision [no longer than 3 cm (1 in.)] is then made using a sharp grafting knife. The caliper of the rootstock should be 1 to 1.3 cm (3/8 to 1/2 in.) in diameter. Scion wood to be gathered needs to be 15 cm (6 in.) in length. Lower leaves are stripped away leaving at least three leaves at the top of the rootstock. Leaves are not reduced in size. After a Captan dip, scionwood is stored in plastic bags at 4C (40F) until used. They will store well for a number of weeks. Two incisions are to be made on the scionwood at the base. The first incision is 1.3 cm (1/2 in.) in length angling the incision toward the center of the scion. The second incision is just like the first, but on the opposite side. If done properly a wedge or a V-shape should be produced. The scion is then placed into the rootstock incision forming a cleft graft. Two scions are inserted matching the vascular cambium areas on the outside edges of the rootstock. The graft is not wrapped nor do they require any sealing. After grafting, the plants are sprayed again with Cleary's 3336 and Captan. The last step involves a Physan-dipped wax-coated paper cup [9 cm (3.5 in.) wide and 17 cm (6.5 in.) in length] used to cover the grafted area. A small quantity of sand is placed outside, around the base of the cup, to secure it. This provides the graft union area with a controlled disease

free greenhouse environment and high humidity. Within 3 to 4 weeks, callusing and graft union formation should occur. We like to keep the cup on the graft until a flush of growth is produced from the scionwood. When signs of new growth appear the cupis tilted (but not removed) to allow for air circulation and to aid in hardening off the graft. The cup will remain an additional week before removal. Producing a plant of suitable size for resale using the grafting technique will take from 2 to 2.5 years from the time of taking scionwood. But, the results are well worth the wait.

PRODUCTION

Medium. The container medium we use is 100% pine bark [2- to 5-cm (3/4- to 2-in.) screen size] which provides needed air to the roots and good drainage. With this medium we have totally eliminated root rot caused by *Phytophthora cinnamomi*. Camellias like a lot of irrigation water, but not to the point of drowning the root system. A soil mix with little to no air space is not recommended as it will cause root rot. Peat moss likewise is not recommended as it fills in the air spaces in the soil mix and reduces root aeration.

Growing Structures. Newly potted containerized plants are placed pot to pot in greenhouses under 55% shade on top of ground covers. Camellias usually can not tolerate full sun in the summer and are subject to scalding. All greenhouses are covered with polyethylene for winter protection and propane gas heaters are used in severe conditions. Older plants are spaced as needed.

Transplanting. All potting is done by hand under sheds. No potting machines are used as better control can be achieved with hand potting . We concentrate on potting all plants straight and not too deep as the roots need air. Our schedule for transplanting is shifting liners into 3.8-liter (1-gallon) containers after 1 year. We will grow the 3.8-liter (1-gal) containers for 2 years before transplanting into 11-liter (3-gal) containers. We do not sell 3.8-liter (1-gal) container plants and use them only for transplanting. We wait 2 years to transplant from a 3.8-liter (1-gal) to 11-liter (3-gal) container, as we want a well established plant with a good root system to improve its chances of surviving and thriving. A majority of the 11-liter (3-gal) container plants will be salable after 1 year and the others after a flush of growth the following spring. The 11-liter (3-gal) container plants are transplanted into 27-liter (7-gal) and 57-liter (15-gal) containers. The 27-liter (7-gal) containerized plants will be salable after one season and the 57-liter (15-gal) container plants after 2 years.

Fertilization. A medium rate of Nutricote 20N-7P_2O_5-10K_2O/Type 360 at 7.7 kg m^{-3} (13 lb yd^{-3}), 7.1 kg m^{-3} (12 lbs yd^{-3}) of pelletized dolomitic limestone, 1.2 kg m^{-3}(2 lb yd^{-3}) of Gro & Sho Micro-ment (minor element package, Tri-State Plant Food, Dothan, Alabama), and 2.9 kg m^{-3} (4.8 lbs yd^{-3}) of Talstar (fire ant control) are incorporated into the soil mix of all containers upon transplanting. A pH of 6.0 is desired. After transplanting all plants are topdressed in the spring with a medium rate of Gro & Sho 18N-6P_2O_5-10K_2O, then in the summer with a medium rate of Woodace 18N-5P_2O_5-10K_2O, and fertilized again in the fall with a low rate of Gro & Sho 18N-6P_2O_5-10K_2O.

Maintenance. Camellias are trimmed frequently (3 to 4 times a season) with gasoline trimmers and shears producing flushes of growth. Herbicides are used for weed control.

Problems. The problems remain the same as discussed under propagation. Dieback is the primary fungal problem, and scale and spider mites are the principal pests. All are chemically treated on an-as-needed basis.

Heat-Tolerant Perennials

Bill Hall
Carolina Nurseries, 739 Gaillard Road, Monks Corner, South Carolina 29461

INTRODUCTION

Carolina Nurseries has been producing container-grown nursery stock since Sept. 1984. At that time, most of the plant materials we grew were woody ornamentals. This included cultivars of azaleas, camellias, holly, and junipers found at most Southern U.S. nurseries. The one perennial item that we listed in our first sales catalog was *Hemerocallis* 'Aztec Gold'.

As one looks through our Fall 1996 Sales Catalog, it is evident that our product mix has changed considerably—particularly in regard to perennials. Perennials now make up 13% of our annual sales. Our current catalog lists over 400 cultivars of perennials.

INITIATING A PERENNIAL PROGRAM

Our perennial program was instituted partly as a reaction to customer demand, and partly as an attempt to diversify our product mix. It seemed that blooming plants had become increasingly popular with home gardeners, and our customers were looking to fulfill these needs. We saw this as an opportunity to capitalize on this demand, and to distinguish our nursery plant products.

The expansion of our perennial line did not happen overnight. Over the years, we added more cultivars of *Hemerocallis*, added an extensive line of *Hosta* cultivars, and several *Iris* cultivars. These items have proven to be very popular, and remain the cornerstone of our perennial program as it exists today.

We went to work researching everything we could find on perennials, and contacted various plug producers in and attempt to find herbaceous perennials that would work for us.

THREE CRITERIA IN OUR SELECTION OF PERENNIALS

When we select perennials, we ask ourselves three important questions:

- **Will They Thrive in our Growing Conditions?** In addition to the high heat and humidity of the Charleston, South Carolina region, plants have to be able to withstand heavy afternoon showers that accompany the late summer hurricane season. We specifically chose types that would tolerate lots of water, and deliberately avoided those that preferred a drier environment. However, we did roll the dice on some cultivars that we thought had some outstanding attributes — even if they did not meet all of our criteria.
- **Are They Cold Hardy?** Cold hardiness affects the marketability of a plant. We try to ship throughout the United States, and prefer plants that will work in all areas of the country.
- **Are They Rebloomers?** A plant that reblooms throughout the growing season allows us to extend our sales beyond the typical spring shipping window.

It is interesting to note that as we started selecting cultivars of perennials, we tended to gravitate towards those that would work in a 3.8-liter (1-gal) containers. Through our research, we found cultivars with very desirable characteristics, but tended to be taller growers. This helped contribute to the implementation of an 11-liter (3-gal) perennial line. Consequently, we were able to offer a larger selection of color and growth habit to our customers.

SCHEDULING PERENNIAL PRODUCTION

We strive to have two main perennial shifts at the nursery. One in the spring, just past our frost free date of 15 April. The other is in the fall, so that the material has an opportunity to root out completely before it goes dormant. Our propagation and the ordering of plugs is targeted toward these two times of the year. This system works well for us, as we are able to supply our customer's needs for early spring color, and continue on throughout the growing season without interruption.

This has been a learning process for us, with many surprises along the way. Some plants that we regarded as long shots have proven themselves to be real winners. Also, some cultivars have not lived up to our expectations.

SUCCESSFUL PERENNIAL CULTIVARS

I will share some perennials that have proven themselves as valuable additions to our product mix. These selections have distinguished themselves as being able to handle our growing conditions and are popular with our customers.

Hostas are the world champions of our perennial program. Although they require 50% shade, they are well suited to our growing environment. Most are hardy to Zone 4, so we are able to ship them anywhere in the country. Although they do not rebloom, their appeal lies in their unique foliage. There are so many cultivars with different color combinations and textures available. They offer great diversity for shady landscapes. As urban areas are becoming more crowded with trees and buildings — plants that thrive in the shade are becoming increasingly popular.

Hemerocallis cultivars are tough perennials that fit the bill on all three of our selection criteria. They stand up well to the heat, and most are cold hardy — so their potential marketability is nearly nationwide. We still grow 'Aztec Gold', but in addition our catalog lists 18 other cultivars. We specifically select rebloomers from the wide pallet of color that is available to us.

Iris are very tough and can take the heat and all the rain you can give them. Most are cold hardy to Zone 4, and therefore marketable throughout the country. Although not a rebloomer, it offers versatility as a water gardening plant. Foliar effect can be sensational as in the case of 'Kaempheir Variegated'. This is a large genus, and we grow several species including *I. kaempheri*, *I. pseudacorus*, I. *sibirica*, and the Louisiana hybrids.

Gaura lindheimeri is a tough plant that is the king of the rebloomers. This plant will literally bloom spring through fall. Pruning will encourage it to bloom repeatedly. It is hardy to Zone 6, so it has a fairly good marketing range in the U.S. *Gaura* will tolerate all the heat and drought that the south can meter out. It also handles the heavy afternoon rains of later summer quite capably. Sometimes a reddish leaf spot will develop on this plant, but when its foliage is covered by blooms this minor distraction goes unnoticed.

Black eyed susan (*Rudbeckia fulgida* var. *sullivantii* 'Goldstrum') is very well adapted to the southern U.S. This compact free-flowering cultivar blooms from June through September. It is characterized by deep gold blooms over deep green foliage. This cultivar never goes completely dormant at the nursery, forming a thick clump that just explodes with color as the weather warms. 'Goldstrum' is probably the most popular cultivar of *Rudbeckia* used in the trade, but there are other forms that merit some attention. *Rudbeckia* 'Goldquelle' is a lovely double-flowered form that does not exceed 1 m (3.3 ft). For those wanting to make a dramatic statement, consider *R.* 'Herbstonne' (syn. *R.* 'Autumn Sun'). This tall perennial is produced in 11-liter (3-gal) containers, where it can be pruned to maintain a height of 1.2 m (4 ft). It is an outstanding specimen in full flower, and a valuable addition for the back of a perennial border.

Purple cone flower (*Echinacea purpurea*) handles the summer heat and drought well. It has a good market range, and is extremely popular as a dried flower. The one drawback to this plant is that it can be sensitive to a wet environment, particularly at a juvenile stage — before it gets established. In an attempt to deal with this, we will transplant our plugs into a 10-cm (4-in.) pot for overwintering before shifting to a larger container in the spring. This allows the plant to get established before bedding it outside. There is also a white-flowering form called *Echinacea* 'White Swan.'

Fern leaf yarrows (*Achillea* spp.) are trouble-free plants that have no insect problems. They are touted as being very drought tolerant, and most hold up well in the constant afternoon rains of later summer. *Achillea millefolium* 'Oertel's Rose' is a sturdy red that blooms all summer long. It was still blooming when I left Charleston, SC for the Southern Region International Plant Propagators' meetings. *Achillea* 'Terracotta' is an Ernst Pagel introduction that sports unique coloring for which it is named. *Achillea* 'Snowsport' is a beautiful white cultivar that can reach 46 cm (18 in.).

***Dianthus gratianopolitanus* (cheddar pinks common name)** was one of the first lines of perennials we offered for sale. In addition to a large marketing range, these plants are low growing and lend themselves well to our 3.8-liter (1-gal) container production system. The foliage is very attractive, but with the visual impact of blooms which can last throughout the season — it is easy to declare this a winner. Two of our favorites are *D.* 'Spotti' (syn. *D. plumarius* 'Spotti'), and *D. gratianopolitanus* 'Feuerhexe' (syn. 'Firewitch'). Both of these cultivars bloom all season long — rather than being limited to spring blooming.

Crocosmia is an interesting plant that we buy in as bulbs. The market range is good, and they hold up well in the heat. The blooms last about 3 weeks in early summer. The one production problem is that the spider mites seem to be particularly fond of these plants.

Gay feathers (*Liatrus spicata*) are purchased as bulbs during the winter months and are planted outside in pots for very early spring sales. These cold-hardy perennials are finished and ready for marketing in 8 to 10 weeks. They only bloom once, so there is a tight window to get them shipped while still in color. There is a white-flowering form, *L. spicata* 'Alba'. A unique form of this plant is *L. microcephala*, a native collected from the U.S. Southern Appalachians. It boasts a good marketing range, has shiny green leaves, and an attractive purple spiked inflorescence.

Mexican hat (*Ratibida columnifera*) is one of the biggest surprises of our program. We never expected this plant to survive for us, assuming that it would drown in our afternoon rains. Surprisingly, it has performed very well and has held up remarkably — even through the wettest South Carolina summer on record. The plant has a good marketing range and we are very happy to offer it as part of our product mix.

***Stokesia* 'Klaus Jelitto'** is a very popular perennial with large pincushion-type blooms of lavender. It holds up well in the heat and has a good marketing range. A similar plant is *S. laevis* 'Omega Skyrocket', a native species that we propagate by seed. The blooms are similar to *S. klaus* 'Jellito', but the stems are much taller. These elongated stems give a completely different architectural aspect to the plant. This cultivar shows promise with the cut flower market.

***Belamcanda chinensis* 'Hello Yellow'** is a selection from Goodness Grows Inc., Lexington, Georgia, that is a great performer for us. It holds up well in the heat, has beautiful clear yellow blooms, and has a good marketing range. The attractive foliage does not require pruning or staking as long as adequate space is provided. All things considered, this is a relatively maintenance-free perennial.

***Scabiosa* 'Butterfly Blue'** and ***S.* 'Pink Mist'** have proven to be tremendously popular cultivars. These low growers work well in 3.8-liter (1-gal) container production. They never need pruning, and are almost always full of blooms — so they usually move quickly to our customers. Both of these cultivars are cold hardy to Zone 5, with a high tolerance for heat. Soil mix should provide for adequate drainage.

Ten-petaled sunflower (*Helianthus decapitalus*) is a very attractive and relatively low-growing *Helianthus*. This cultivar behaved itself quite nicely to produce a wonderful 11-liter (3-gal) crop.

Anise hyssop (*Agastache* 'Blue Fortune') is sometimes listed as an herb in seed catalogs. This is a wonderful perennial that puts on one of the most outstanding flower displays. It is a prolific rebloomer, and pruning stimulates flowering again and again. It performs well in the heat, and will take all the rain that mother nature can meter out. A very popular item, and deservedly so.

Veronicastrum virginicum is an elegant white bloomer for the shade garden. The plant is relatively trouble free, but can take a while to get established. It is certainly worth the wait, as it is an interesting and underused plant.

***Nepeta siberica* 'Souvenir d'Andre Chaudron' (catmint)** is a very hardy cultivar. Catmint 'D'Andre Choudron' does well for us, particularly with the abundance of heat and rainfall we experienced this past summer. The bloom is very interesting.

Hibiscus moscheutos from the tough Disco Series was one of our first successful perennials. These sturdy plants can overwinter in the container and emerge even stronger the next season. We offer an assortment of colors, all of which thrive in our environment and allows us to ship throughout the U.S.

Hibiscus coccineus offers stunning cut-leaf foliage and is an absolute show stopper when in bloom. Not quite as cold hardy is *H. mutabalis*, which is a staple of the southern U.S. garden. We market it for its unique landscape value.

Common joe pye weed (*Eupatorium fistulosum* and *E. maculatum*). These great performers need a place in every garden. Rather tall growers, which can exceed 1.8 m (6 ft), they do well in our 11-liter (3-gal) container perennial line. We have found that plant heights can be limited by judicious pruning early in the season. The main attraction is that they are at their best when the rest of the landscape looks tired and dull — around mid-August. Insect and disease-free, they handle all the heat and the humidity that the southern U.S. can offer.

***Ageratina altissima* 'Chocolate' (syn. *Eupatorium rugosum* 'Chocolate')** is an unusual cultivar recognizable by its chocolate brown foliage which is great in itself — but when it becomes covered with white blooms it is even more attractive!

***Perovskia* 'Filagran'** is a former perennial of the year winner. It is a tough, durable plant that sustains heat and drought remarkably well.

Vernonia angustifolia is a cold-hardy native plant that also offers a flower display in mid-August as a companion plant to the eupatoriums. While relatively trouble free, it does tend to get a bit weedy-looking after bloom.

Turtleheads (*Chelone* spp.) are wonderful shade-loving plants with blooms that resemble snapdragons. We offer two species — *C. lyonii*, a pink-flowering form, and *C. glabra*, a white-flowering form. The pink form is particularly attractive, as it is complemented by shiny bronze foliage.

***Euryops pectinatus* 'Viridis'** is an early founding member of our perennial program. This cultivar is not very cold hardy, but thrives in the heat. It propagates easily by cuttings.

Lantanas are generally grown as annuals. However, *Lantana camara* 'Miss Huff' is supposed to be fairly cold hardy. We have included this Goodness Grows introduction in our perennial program. Like other lantanas, it takes the heat well and blooms all summer long. We are anxious to see how this cultivar overwinters for us.

Cannas are relative newcomers for us. But they are old standards in the garden and are used frequently in highway plantings. Tough and durable, they can handle the heat, are cold hardy, and thrive in wet conditions. Cannas offer versatility as water gardening plants.

Stachys is another surprising survivor for us. When we first saw its pubescent silvery foliage we immediately discounted it as doomed by drowning. This plant is tougher than it appears, and has survived many a hot, wet summer in South Carolina.

***Artemisia* spp.** are another perennial that we thought would hate our growing conditions. Although very cold hardy, we suspected the afternoon showers would cause production problems with its delicate lacy foliage. Amazingly, this plant has endured and prospered.

Verbenas were grown at Carolina Nurseries before the days of a perennial program. Always a good performer in the heat, the main problem of this general is the lack of cold hardiness. Selections of *V.* 'Homestead Purple', and *V.* 'Homestead Pink' have improved cold hardiness.

Salvia uliginosa sports beautiful sky blue flowers and is well suited to soùthern U.S. growing conditions. *Salvia uliginosa* has a bad reputation as being very invasive, but works well in containers. Other salvias that work well for us are the coccineus hybrids, velvet sage (*S. leucantha*) and the *Salvia* ×*sylvestris* cultivars — particularly *S.* 'Mainacht' (syn. *S.* ×*superba* 'May Night') and the white-flowering form, 'Snow Hill'.

Veronicas are good tough summer flowering perennials. They are capable of enduring drought and hold up well in periods of heavy rain. There are many good cultivars available and *V.* 'Sunny Border Blue' is one of the best.

Rain lilies (*Zephyranthes* spp.) are very interesting perennials that we offer in a 10-cm (4-in.) pots as well as 3.8-liter (1-gal) containers. They are not very cold hardy (Zone 8), but they do have some outstanding characteristics. Their foliage is shiny, and fills the container well. Their delicate blooms are quite colorful. A special attribute is that once established, they will rebloom after a rain. Needless to say, we saw a lot of blooms this past year. *Zephyranthes candida* is a white-flowering form, *Z. rosea* is pink, and *Z. citrina* is the yellow-flowering form.

Asters were among the first incorporated into our perennials program in an attempt to include fall-blooming plants. One of the first cultivars we grew was *Aster* 'Purple Dome', a compact grower with lovely dark purple flowers. *Aster* 'Nesthäkchen' is a pink-flowering compact grower. We have also incorporated taller growing asters to compliment our mix.

Boltonia is a taller growing fall bloomer in the Aster family. It is heat and drought tolerant and make a stunning display when in flower. We grow a white cultivar, *B. asteroides* 'Snowbank', and a pink flowering cultivar, *B. asteroides* 'Pink Beauty'. Another unique cultivar is the dwarf-growing form, *B. asteroides* 'Nana'.

Solidagos or **goldenrods** round out our line of fall bloomers. Though some would discount these as nuisance weeds, improved selections are often spectacular in full flower. *Solidago rugosa* 'Fireworks' is a 1-m (3.3-ft) grower whose blooms are reminiscent of exploding fireworks. A dwarf selection is *S.* 'Golden Fleece', can be used as a groundcover. These plants are rugged and holdup well in the heat and through periods of heavy rainfall.

Improving Production Efficiency

Jeff Howell
Rocky Creek Nursery, 229 Crenshaw Road, Lucedale, Mississippi 39452

INTRODUCTION

Whenever you hear the word "efficiency", several things usually come to mind. Speed, automation, labor-saving, step-saving, time-saving, and money-saving are all common terms associated with efficiency. Unfortunately, the day of the push-button nursery is not yet here. However, there are probably some things that all of us can do to become more streamlined (another efficiency buzzword there).

Certainly the development of better chemicals has made all of us more efficient growers of nursery stock. Nurserymen of generations past could never have imagined the pre-emergent herbicides and slow-release fertilizers we now find commonplace. Although this is not an economics course, the biggest reason for the painfully slow rise in plant prices over the last two decades is that we have the ability to produce plants so much more efficiently than our predecessors did. But, there is still room for improvement, and it will come.

CONCENTRATE EFFORTS ON WHAT YOUR NURSERY DOES BEST

One way to become more efficient is to concentrate your efforts on doing what you do best. One genus of plants maybe, or perhaps only one cultivar. If all you did was grow thousands and thousands of Helleri holly, for example, odds are you'd figure out how to grow them very efficiently. The obvious downside to this technique is that you are at the mercy of a very fickle market.

So, if you're like most of the rest of us, you're left trying to figure out how to grow the most plants on the least space in the shortest time for the lowest cost. While I certainly don't pretend to have all the answers, I would like to share a few ideas with you that you might implement in your business.

IRRIGATION EFFICIENCY

One of the most important aspects of nursery production is irrigation. As with all other cultural practices, every nurseryman I have ever met has different ideas and techniques regarding irrigation. But, whether it is in propagation or production, there are quite likely some things you can do to irrigate more efficiently.

At our nursery, we rely quite extensively on 24-volt solenoid valves. In our propagation houses, these valves are controlled by an electronic timer. In our fields, we use toggle switches on a centrally located panel to operate them. While solenoid valves generally cost about twice as much as brass ball valves, they more than pay for themselves in labor savings. Whoever invented electronic timers and solenoid valves should have been awarded a Congressional Medal of Honor.

Like a lot of other folks, I had always imagined that the only way to water large, container-grown trees was with a drip system. Twin Oaks Nursery in Wilmer, Alabama uses very large overhead sprinklers to irrigate their trees. While this system is far less efficient in terms of water usage than a drip system, it increases production efficiency in that you don't have all those drip tubes to tend to. This is not

a water-usage seminar anyway. Incidentally, even though these sprinkler heads are enormous, the water is so finely broken that it falls as softly as rain. So softly, in fact, that liners can be grown under them.

EASIER WAYS TO COVER GREENHOUSES WITH POLY

The nursery business, like any other business, I suppose, has its share of unpleasant tasks. In my opinion, no regular chore at our nursery is any less fun than covering greenhouses with poly. At Flowerwood Nursery in Loxley, Alabama somebody figured out a way to make this job easier, if not more fun. They have taken an old school bus and built a platform atop it. This puts the workers right up there even with the tops of the greenhouses. Inside the bus are all the supplies needed to put up plastic.

CHEMICAL SPRAYERS

Earlier, I mentioned that improvements in chemicals had helped all of us to become more efficient. Fortunately, sprayers have come a long way, too. Blower-type sprayers are quite popular now and in many operations, so are electrostatic sprayers (ES sprayers). At our nursery, we use blower sprayers almost exclusively and we love them. While they may not be perfect, they save us a lot of time and money. As for the ES sprayers, they are great in many cases, but the slightest breeze makes them difficult to use.

One simple but effective spray rig I have seen recently was used to apply liquid pre-emergent herbicide. It was simply a 4.9-m (16-ft) piece of pipe with holes drilled and tapped for spray nozzles about every 46 cm (18 in.). One end was capped and the other had a hose attachment. This device was attached to the sprayer hose and carried by two men over two rows of container-grown plants at a time. Although this spray boom was inexpensive to construct, it worked like a charm.

RECYCLING MEDIA FROM DISCARDED PLANTS

None of us really likes to throw plants away as this practice makes profit difficult at best. But, if you have to trash some plants, and at times it seems we all do, you can learn a little something from Flowerwood. They dump dead plants onto a conveyor which runs into a dump truck. The waste soil is then incorporated, in small part, into a new potting mix. Since this operation takes place under a shed, dead plants are placed there in advance so they can be dumped during rainy weather.

POTTING SYSTEMS AND CONVEYORS

In our neck of the woods, a lot of time, thought, and money has been spent on making our potting systems more efficient. Speaking from my own experience, the ability to pot in the field has vastly increased our production efficiency. We spent a good bit of money distributing electricity all over the nursery, but it was money well spent. With our potting machine and conveyors, we can pot almost three times as many plants per day as we could when we potted under a shed and hauled the filled wagons out to the fields to be unloaded.

As for the conveyors, not only are they indispensable in our potting set up, they are also very handy for loading trucks and for filling or emptying greenhouses. Like any other piece of equipment, conveyors are quite expensive. But, for us at least, they have been well worth the cost.

MECHANIZED PRUNING

A quick, simple and less back-breaking method of pruning is a good way to increase production efficiency. Flowerwood Nursery uses a nifty pruning apparatus made of three mower decks mounted on a cart-like frame. The cutting height is easily adjusted by means of a small pulley which raises or lowers the cutting deck within the frame. About the only requirement for a pruning device like this is that all your rows must be of equal width.

A simpler pruning device, from Overlook Nursery, is nothing more than a pair of gasoline trimmers attached to a wheelbarrow frame. The cutting height is adjusted simply by raising or lowering the handles. This in not rocket science — you know!

At our nursery, we are quite fond of our gasoline-powered trimmers. They are great for anything that needs a flat top and, while they may not be as impressive as a cart-type pruner, they are a vast improvement over human-powered hand trimmers.

IMPROVING ROADS AND DITCHES

Believe it or not, there are some things you can do to make your nursery more efficient that aren't chemical or mechanical. Paved or gravel roads and ditches give your nursery a neater appearance and reduce weeds.

OTHER PRODUCTION PRACTICES

Potting small liners into large containers was virtually unheard of 15 years ago, but is commonplace today. Obviously, cutting out even one potting operation in the production of any crop increases production efficiency.

One efficient cultural practice we have employed at Rocky Creek Nursery is the potting of our young azaleas into very narrow rows. This enables us to space our azaleas where they were potted rather than having to move and space them elsewhere. An added benefit of this practice is that weeding and pruning are considerably easier than with wider rows. Incidentally, we can grow roses in the gaps between the rows. By the time the azaleas need to be spaced, the roses are gone.

Obviously, I have only scratched the surface of all the possibilities that exist in increasing production efficiency. If I can make only one impression on you from these ramblings, it should be that nurseries that are efficient will prosper when all the others simply survive.

Relocation of 100-Year-Old Dogwood — Cooperation Between Public and Private Entities

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INTRODUCTION

This is a story about the physical act and skill required to move a massive one hundred year old dogwood out of season. The successive transplanting of this specimen dogwood was the result of the cooperation and collaboration between several public and private entities. Equally important was the tremendous public relations that was generated from the effort which greatly benefited the nursery industry and the Huntsville Botanical Garden.

BACKGROUND

On March 27, 1995, a local citizen called the Mayor's office of the City of Huntsville with a complaint. She wanted to know why the City was not going to try and save the beautiful flowering dogwood (*Cornus florida*) from the path of bulldozers as they were widening an existing roadway. The Mayor gave her a very candid answer — he did not know why and he would look into this matter. Mayor Hettinger contacted the City Arborist, Chuck Weber, and asked Mr. Weber to investigate the situation. Weber visited the construction site and indeed found a magnificent dogwood standing 6.7 meter (22 ft) tall with a wingspan of 18 meter (45 ft) about to burst into full bloom. Also, he saw the bulldozers from the construction crew about to make firewood of this beautiful tree. Immediately three problems were apparent:

- The road construction was a state of Alabama project, not a city of Huntsville.
- The time to act was very short.
- The city did not have the equipment or expertise to successfully handle the relocation.

Weber reported back to the mayor his findings and called me at the Huntsville Botanical Garden for a second opinion. I serve with Weber on the Huntsville Tree Commission, a committee established by the city council to promote urban forestry in our community. I concurred with Weber's observation that we were unable to handle the relocation without outside consultation and expertise. Weber recommended to the Mayor that he bring in a consulting arborist he knew from Tennessee who had vast experience in the process of moving such a tree. Steve Clark of Brentwood, Tennessee, agreed to visit the site and develop the process of how such a project could be done if deemed feasible. Clark's arrival on site found the tree in full bloom and he was impressed with the beauty and grace of this old dogwood. Clark has been involved with many large-scale tree moving projects across the country, primarily with the Wal-Mart corporation after they have purchased a site for constructing a new store. He stated that the tree was worthy of saving, that there was a 90% to 95% possibility that it could be transplanted successfully. He estimated that the cost might be up to $30,000, depending upon the level of local cooperation. With this report in hand, the Mayor chose to proceed and announced at a press conference the intent to save the dogwood.

PREPARATION

As consulting arborist and project manager, Clark began to layout the resources needed to undertake the move. He contracted the company, Environmental Design of Houston, Texas, to actually transplant the tree. Environmental Design has expertise in the field of transplanting large trees and Clark had worked with them in the past. The Tree Commission and the division of landscape management of the city of Huntsville developed a plan to raise money through local elementary schools for the project. Flyers were prepared for distribution to every classroom in K-5th grade. The city of Huntsville was able to persuade the state of Alabama to give us some time to move the tree and 30 days was granted. The week of 10-13 May was chosen as the target. This fit the work schedule of Environmental Design and also allowed the tree to finish flowering and to harden off the new foliage. A list of additional resources was compiled by Clark and we set about to line up the needed equipment to complete the move. This included dump trucks, track hoes, a crane, a house-moving trailer, bucket trucks, and a gas-line tunneler. Publicity went out to the local schools, and the school children gathered there coins in each classroom. Meanwhile, Clark and Weber developed the plan of action which had to be implemented in a very short window of opportunity.

PROCESS

As 10 May 1995 arrived a meeting was called for all individuals participating in the project to meet and plan the following 2 days. Clark outlined the process and made sure everyone understood the plan. To make matters worse, the weather was beginning to turn inclement. Severe storms were predicted for the following day. To combat this, we immediately sent heavy equipment out to the site to remove topsoil from the area to use at the new site and to cover the area around the tree to keep it as dry as possible. The following day, the first order was to lift up the arching branches of the dogwood. We did not want to remove these branches for they added so much architecturally. The branches were pulled up off the ground with rigging. Next a backhoe began removing soil outside of the drip line to a depth of 1.2 m (4 ft). The digging was done completely around the tree, creating an island on which the tree was still resting. The digging crew then shaped the root ball by hand and wrapped the prepared ball with burlap and hog wire. The next step was to drive 4-in. steel pipe under the root ball, spaced 2 ft apart. This was done with a pneumatic gas line mole. One had to be very careful to drive these pipes in level in order that they did not destroy the root ball. The pipes were necessary to take the weight off of the root ball when lifting with the crane. After all the pipes were in place, a steel cable was placed under the pipes and pulled across the root ball to slice the roots below the pipes. Cables were attached to the steel pipes and hooked to a 72,727-kg (80-ton) crane. The crane was able to lift the tree quite easily and place it onto the bed of a house moving trailer. The height from the road bed was critical at this juncture for we had numerous traffic lights and power lines to cross on our 5- mile trek from the digging site to the transplanting site at the Botanical Garden. The tree on the flat bed was 7.6 meters (25 ft), which was too tall to drive under most electrical power lines. The Transportation Department was able to push up most of the traffic wires without having to disconnect them at each pole. With a police escort the tree set off on its journey at a speed of 5 km (three miles) per h.

At the Garden, we had selected an appropriate site for planting — one where the dogwood tree would be seen by all our visitors. Also, we were very sensitive to the

cultural needs of the tree. We literally planted the dogwood on top of the ground and placed the topsoil from the original site around the root ball. This insured adequate drainage in our clay soils. We mulched the whole root zone area out to the drip line with wood chips and installed a drip irrigation system. This whole process from initial digging of the root ball to final mulching took 30 h.

AFTERCARE

Since we moved the tree on 13 May 1995 we were very sensitive to the moisture requirements of the newly transplanted tree. We discussed placing a mist system in the tree to syringe the foliage intermittently. Due to the fungal leaf problems associated with dogwoods we did not do this procedure. As an afterthought, we added two soil moisture meters to monitor the root zone. This proved to be the smartest thing we did in taking care of the tree. The ensuing summer proved to be the hottest and driest in many years. I am convinced we would have drowned the tree if we did not have the soil tensiometers present to accurately tell us the moisture of the root zone. Due to the mulch layer and shading of the root zone by the canopy, we did not add additional water after the initial planting throughout the summer. New growth initiated in June and a heavy bud set was initiated in September. The Winter of 1995-96 was one of our coldest in years, but the tree was not affected. Easter week of 1996 brought out the blossoms and the whole community trekked to the Garden to see the tree which was saved from the bulldozers.

SIGNIFICANCE TO THE INDUSTRY

The moving of a tree this size is not something that is unique. Larger trees have been moved successfully. The real significance of this project was in allying oneself within the community. The media exposure was phenomenal. Everywhere I went, I was asked about the tree and how it was managing. It offered a platform in which to promote horticulture, gardening, tree planting, and care — without paying for it or sounding like a commercial. This offered a wonderful opportunity to educate the public about dogwood anthracnose without sounding defensive and protective of future sales. It exposed future gardeners, the school children, to the importance of trees and tree planting. I believe all who participated reaped much greater benefits than the level of their in-kind contribution. It is important that we be inventive in *our promotion of the nursery industry, landscape horticulture, and gardening.*

Sanitation and Disease Control in the Propagation Area

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INTRODUCTION

Many disease problems that occur in propagation are due to poor sanitation management. This results in increased diseases and a reduction in plant quality. Once a pathogen has penetrated into cutting, it is generally not economically feasible to exterminate it with chemical treatments. Hence, proper management of a sanitation program is an essential part of disease control.

SANITATION

The first part of a good sanitation program is to clean and disinfect the greenhouse when it is totally empty. This entails removal of any plant debris or media/soil left from the previous crop. Cleaning also includes removal of weeds that can also harbor insects. Next, the area is disinfected with bleach or a quaternary ammonium compound, i.e. Physan 20, Green Shield, or Consan Triple Action 20.

There are different types of greenhouse structures and different procedures to clean them. Cuttings are propagated in greenhouses covered with glass, polyethylene greenhouse film, or a polycarbonate structured sheet. Some of these greenhouses are built with wood or aluminum framing with concrete floors and/or raised benches. This type of house can be cleaned by sweeping or using a water hose to remove leftover debris. A pressure washer can be used to remove any algae buildup left on the walkways, benches, walls, or purlins. The greenhouse can then be disinfected with bleach or quaternary ammonium compound. Other types of greenhouses may have a floor made of gravel or another type of ground cover with no raised benches. A greenhouse with gravel can be cleaned with a rake. A blower can be used to remove small debris that is left behind after using a rake. Greenhouse floors with nongravel-type materials can then be cleaned with a push broom. A blower can also be used on the floor to remove any debris that is left behind. Disinfecting the floors can be done with quaternary ammonium compounds.

Cleaning equipment used in propagation is essential when producing a disease-free crop. If you propagate in previously used flats and trays, start by soaking them in a quaternary ammonium compound solution. One of the quickest ways to spread disease from one cutting to another is with the shears or knives used to take cuttings. Disease can be transmitted to thousands of cuttings before they are stuck if the cutting tools are not disinfected. This can be done by periodically soaking the cutting tools in a quaternary ammonium compound. An efficient way to do this is for each person to have two pair of shears and use one pair while the other is soaking. Flat fillers should also be cleaned in between long periods of use by spraying with a quaternary ammonium compound or bleach. Be sure to let the bleach dry before placing soil in the flat filler. Some nurseries place a wet burlap cloth over a batch of cuttings before they are stuck to prevent their drying out. The burlap can be disinfected using a quaternary ammonium compound and should be hung up to dry out overnight.

AVOIDING POOR MANAGEMENT IN PROPAGATION

Poor management of a propagation area can destroy a sound sanitation program. This includes unsound irrigation practices. Over watering, leaking valves, or poor drainage can cause root rot diseases to spread rapidly. Placing flats or pots in a low area that holds water can destroy a crop before the cuttings are rooted. Water hoses left on the ground will allow pathogens to enter the nozzle and then be spread on young cuttings.

SELECTING CUTTINGS

When selecting an area to gather cuttings, use only plants that are free of diseases and insects. Some nurseries use plants that are in early stages of production. These must be healthy plants in order to sell them in the future. Other nurseries maintain stock plant blocks that they keep extremely clean. Whether cuttings are gathered from a production area or a stock block, it is very important to use clean plant material. It is wasteful to disinfect a greenhouse and fill it with unhealthy cuttings.

PROPER CARE OF UNROOTED CUTTINGS

Proper care of young, unrooted cuttings, before and after they are stuck, is essential to producing a quality crop. When cuttings are being gathered they should be placed in a clean container and kept moist. After the cuttings are gathered they should be soaked in a mild fungicide, such as Captan. The cuttings should be placed in the propagation area as soon as possible. The cutting material can be covered with a moist, disinfected burlap cloth before they are stuck. Cuttings should not be left under the burlap cloth for an extended period of time. As they are being stuck it is important to make sure that cuttings are not inserted too deeply. After the cuttings are stuck, it is important to monitor the humidity levels in the propagation house, before the cuttings develop roots. If the foliage on an unrooted cutting gets dry and begins to wilt, the leaves will burn. Disease will thrive on decaying plant material in a propagation house with high relative humidity. It is impossible to manage diseases in a propagation house of unrooted cuttings, just by chemical applications—without also regulating temperature, light, and relative humidity level conditions.

PROPER CARE OF ROOTED CUTTINGS

In some situations, the first application of fertilizer and pinch are made in the propagation houses. Some nurseries grow cuttings in the propagation houses after they are rooted. It is important to continue a sanitation program after the cuttings are rooted. The greenhouse should be free of weeds. Weeds harbor insects that can transport diseases. Fungal gnats that thrive on greenhouses with an abundance of algae are a perfect example. Adult fungal gnats can spread diseases as they move from contaminated areas onto plants. To deduce the risk of diseases damaging your crop, a fungicide can be tank-mixed into a spray rotation. A general list of some common diseases, and a few of the chemicals that control them, are listed in Table 1.

Realistically, there are often times when all of us have too many projects going at one time. Often sanitation is one aspect of nursery management that can be overlooked. It is amazing how rapidly diseases can spread from one contamination point that was not properly cleaned or disinfected. Therefore, it is important to train all of your employees to follow a sanitation program. It should start in propagation

and be carried throughout the entire production cycle in the entire nursery.

Table 1. Management of common diseases — most common root rot and/or damping-off diseases and their chemical control.

Rhizoctonia	*Pythium*	*Phytophthora*
Banrot	Aliette	Aliette
Chipco 26019	Banrot	Captan
Cleary's 3336	Captan	Subdue
Domain	Subdue	
Terraclor		
Terraguard		
Cylindrocladium	*Fusarium*	*Thielaviopsis*
Chipco 26019	Banrot	Banrot
Cleary's 3336	Chipco 26019	Captan
Domain		Cleary's 3336
Terraguard		Domain
		Terraguard
Alternaria	*Botrytis*	*Anthracnose*
Daconil 2787	Captan	Cleary's 3336
Domain	Chipco 26019	Daconcil 2787
Terraguard	Cleary's 3336	Domain
	Daconil 2787	Duosan
	Domain	
	Duosan	
	Terraclor	

Tree Seedling Production

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Seed Pretreatment. Of the approximate 70 taxa of trees we grow, 80% are started from seed. Seventy-five percent of the seed we propagate requires some form of stratification. A few varieties must be scarified before their stratification. We use warm moist, cold, and cold moist types of treatment for varying time periods—from 30 days to 6 months. Those seeds requiring warm-moist or cold-moist stratification are placed on newspaper and dusted lightly with the fungicide—Thiram WP, and agricultural streptomycin, Agri-Strep, for bacterial control. The seeds are then placed loosely in a fabric netting and packed in a bag containing damp sphagnum moss. We use the netting to eliminate the need to search for loose seeds when it is time to plant. The bags are then labeled and placed either in the office for warm stratification or the cool room for cold stratification.

Seed Propagation Houses, Trays, Containers, and Media. All our propagation houses have ground covers on the floor for weed control. We wash the floors and spray with a dormant oil to control insects prior to placing freshly planted seeds on the floor.

Since seed germination percentages vary and our space is limited, we pregerminate about 25% of the taxa we grow in small plug trays. We use a variety of these trays ranging from 68 to 288 cells per tray. We usually get good seed germination. Oak acorns are planted directly into Rootmaker propagation containers (Lacebark, Inc., Stillwater, Oklahoma) or Ropak Mullet-Pot #3 – 96 cells or #6 – 45 cell plug trays (Stuewe & Sons, Inc., Corvallis, Oregon).

We have a 1.5 m^3 (2.0 yd^3) mixer which also becomes a flat filler with the conveyor belt under it. The conveyor was designed to handle seed trays up to 19-liter (5-gal) containers. This mixer had a dead spot inside its center which did not allow for proper mixing, and we added a V-shaped piece of metal at that spot to help eliminate the problem.

Rootmaker propagation containers are put in an 46 cm (18 in.) square carry-all flat and placed on a conveyor belt. Once the containers are filled they are taken to the planting tables and prepared for planting. We lift the carry-all trays off the table and gently drop them back on the table to settle the media mix. The excess media on the tops of the trays is removed and we are ready to plant.

Our planting mix starts with peat moss, course perlite, and extra course vermiculite, to which we add 8.9 kg m^{-3} (15 lb yd^{-3}) of Osmocote 16-6-12 slow-release fertilizer, 3.6 kg m^{-3} (6 lb yd^{-3}) of dolomite, and 1.2 kg m^{-3} (2 lb yd^{-3}) of Micromax trace element mix. All seeds are planted in this mix regardless of whether they go into a pregermination tray, a Rootmaker, or a plug tray.

Positioning Seeds in Containers. Since all the oaks are directly planted into Rootmaker propagation containers or plug trays—it is extremely important that the seeds be placed properly in these containers. We try to center the seed in the container and at the same time position that seed in a way that when the root radical emerges it goes directly down toward the bottom of the container. We do not want

that root to emerge in an upward or sideways position. Anything other than a straight root will create a weak point as the seedling grows, and it will not be able to stand on its own. We never cover our oak seeds or push them deeply into the container. This gives the maximum space for root development.

The seeds that are planted into the pregermination trays have to be transplanted into either Rootmakers or plugs to become a salable liner. This procedure is time consuming and can create major problems in root development. Plants are carefully selected from the seed trays. Any seeding with a crooked root is immediately discarded and not planted. Seedlings that are to be transplanted have their roots pinched off. This is necessary because roots will spiral in these trays. A dibble is made with the finger in the container and the seedling is carefully placed in that container so as not to create a "J" root. It is vital that the roots are placed straight up and down and the seedling is not "pushed" down into the medium.

The planted seeds or transplanted seedlings are then taken to houses to grow on. Our benches are quite simple. They consist of 2.5 cm × 5.0 cm (1 in. × 2 in.) welded wire set on upright 3.8-liter (1-gal.) containers. This provides air pruning for the bottom of the container.

Most of our propagation houses are 3.7 m × 29 m (12 ft × 96 ft). We like this smaller size house because it is easier to heat and easier to separate water loving seedlings from those that require less water. The majority of our houses no longer have shade cloth on them. We have learned that full sun prevents "stretching" of the stems, increases caliper, and prevents many fungus problems by allowing leaves to dry. Those seedlings that do require shade are grown under 30% shade cloth.

Irrigation Regimes. All watering is done without the help of timers. Each crop of seedlings has different water demands at so many different times during its growing season that we feel it important to water only when necessary—and this cannot be done with a timer. Therefore, all houses have manual water valves. Each sprinkler head can be opened or closed manually. This is nice if you have only half a house to water.

Production of Tree Seedlings. We feel strongly about good root development in our production of tree seedlings—and are always searching for ways to improve. A large part of our program is producing 3.8- and 11.4-liter (1 and 3 gal) lining-out stock. Our planting mix for these larger containers consists of—2.5 cm (1 in.) screened aged pine bark, sand, and peat (7.5 : 1 : 1.5, by volume), to which we added 8.9 kg m^{-3} (15 lb yd^{-3}) of Osmocote 17-7-12, 3.6 kg m^{-3} (6 lb yd^{-3}) of dolomitic limestone, and 1.2 kg m^{-3} (2 lb yd^{-3}) of Micromax trace element mix.

When potting liners into 1- and 3-gal containers we make every effort to use a seedling produced in the Rootmaker propagation pot. This gives us the greatest number of root tips and will fill the 1- or 3-gal container from top to bottom with roots. The liners produced from these containers give us a faster growing 1- or 3-gal tree than seedlings produced in plug trays. If we have to use seedlings produced in plug trays we cut off the bottom 1/4th of the roots before planting into 1- or 3-gal containers. By doing this we can at least fill up half the container with roots, the top half will be loose soil.

We like to grow in the Rootmaker 1 or 3 gallon containers. We have compared the cooper coated containers to the Rootmaker and still prefer the root system of the Rootmaker. The root development in the conventional containers makes one wonder

why they are still in use for tree seedlings. There is no way to deter root spiraling or encourage secondary root development in conventional containers.

Preventing Wind Blow Over of Containerized Plants. In producing large numbers of 3.8- and 11.4-liter (1- and 3-gal) liners, we have the problem of wind blow over when they become large and top heavy. For our 3.8-liter (1 gal) containers, we use remesh wire and T-post hooks. The containers are placed in the wire, skipping a space for better air circulation. The wire is pulled to the top edge of the pots and T-post hooks are attached under the remesh wire and over the top edge of the pots and T-post hooks are attached under the remesh wire and over the top of the pot, holding the wire up to within 1 cm (0.5 in.) from the top of the pot. To prevent blow over on our 11.4-liter (3 gal) containers, we used an idea from Ed and Barbara Ricks, Bushman Plant Farm, Cleveland, Texas. That is, we take 1-cm (3/8-in.) rebar in lengths of 6.1 m (20 ft), crisscross the rebar through the drain holds at the bottom of a 15 and 19 liter (4- or 5-gal) containers and place the 11.4-liter (3 gal) Rootmaker inside. There is no blow over, the roots stay cooler and get less damage from the summer heat. We call this an above-ground pot-in-a-pot system.

Overwintering Systems. Because of our overwintering problems with larger containers, we are currently experimenting with containers in the ground. We have placed 11.4-liter (3-gal) containers in the ground and in those containers we have planted seedlings in 23-cm (9-in.) knit fabric. We have also experimented with the 18.9-liter (5-gal) Rootmaker in the ground. This pot is designed to be used in the ground and has already shown us more top growth and better root development in a shorter period of time than with liners positioned on top of the ground. This will allow us to overwinter the slower species outside instead of in taking up space in our larger propagation houses.

How pH affects Pesticide Effectiveness

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HYDROLYSIS OF PESTICIDES

Many commonly used organophosphate and carbamate pesticides are known to degrade rapidly under mildly alkaline conditions as are found in some natural waters throughout the U.S. Buffering adjuvants can extend the effective life of alkaline-sensitive chemicals when properly mixed in the spray tank at time of spraying. Alkaline hydrolysis, the breakdown of chemicals due to the high pH of the water carrier, is one of the leading problems in obtaining effective pesticide control. The amount of acidity or alkalinity (pH) of the spray water can greatly influence how pesticides and other products perform in the spray tank. The pH of most well and stream waters fall within the range of 4 to 9. Most waters are slightly basic because of the presence of dissolved carbonate and bicarbonate salts. Alkaline hydrolysis may also occur—clogging sprayer nozzles, causing plant phytotoxicity, and/or poor pesticide control.

The breakdown or hydrolysis of pesticides is measured in terms of half-life. If a product is 100% effective when first added to water and has a half-life of 4 h—its effectiveness is reduced 50% during this 4-h period. During the next 4 h, its effectiveness is halved again. The shorter the half-life, the greater the effect of alkaline water. Hydrolysis is affected by water pH, the chemistry of the pesticide, length of time the mixture is in the spray tank, the pH of leaf surface, and temperature of spray solution. The source of the irrigation water will determine how often one must check for compatibility with the pesticide to be mixed. Well water would be a water source less likely to change over a short period of time. Conversely, municipal water should be sampled and tested before each spray application.

ADJUVANTS

Adjuvants are materials that are added to a pesticide mixture in the spray tank to improve chemical mixing, application, or otherwise enhance pesticide performance. While pesticides are formulated to be suitable for many types of application conditions, they cannot be formulated for all possible situations. Adjuvants are used to customize the formulation to specific needs and compensate for local water conditions, etc. Adjuvants are used for many things, including adjusting the pH of the spray solution. Most pesticide labels will provide instructions and precautions for mixing adjuvants. Be sure to read and follow label directions.

OPTIMUM PH

The term pH is a measure of the acidity or alkalinity of a solution. Many pesticides are unstable in alkaline solutions, but quite stable if the solution is slightly acid. The optimum pH for most pesticide spray solutions is around 6.0. Some pesticides are most effective when the solution is acidified to a pH of 3.0 - 3.5. A high pH normally causes accelerated breakdown of the pesticide. Many growers know the pH of their soil, but few know the pH of their water supply.

COMPATIBILITY TEST

A simple test to check pesticide compatibility is given below.

1) Measure 473 ml (1 pt) of the intended spray water into a clear 946 ml (1 qt) glass jar.

2) Adjust the pH of the water if necessary.

3) Add ingredients as listed below. Be sure to stir each time an ingredient is added.

- Surfactants, compatibility agents, and activators are added to water at the rate of 5 ml (1 tsp) for each 473 ml (16 oz) of pesticide per 379 liters (100 gal) of planned final spray mixture.
- Wettable powders and dry flowable formulations are added at the rate of 15 ml (1 tsp) for each 0.5 kg (1 lb) pound per 379 liters (100 gal) of planned final spray mixture.
- Water- soluble concentrates or solutions are added at the rate of 5 ml (1 tsp) for each 473 ml (16 oz) of pesticide per 379 liters (100 gal) of planned final spray mixture.
- Emulsifiable concentrate and flowable formulations should be added at the rate of 5 ml (1 tsp) for each 473 ml (16 oz) of pesticide per 379 liters (100 gal) of planned final spray mixture.
- Soluble powder formulations are added at the rate of 5 ml (1 tsp) for each 473 ml (16 oz) of pesticide per 379 liters (100 gal) of planned final spray mixture.
- If required, additional adjuvant is added at the rate of 5 ml (1 tsp) for each 473 ml (16 oz) of pesticide per 379 liters (100 gal) of planned final spray mixture.
- After mixing, stir and let the solution stand for 15 min before observing the mixture.

If the mixture is compatible, it will be of one consistency and combine well after stirring. However, incompatible mixtures will exhibit clumps, layering, graininess, or particle separation. Incompatible emulsifiable concentrate (EC) mixtures will not have the desired milky formation, but may have an insoluble sludge or contain layers of pesticide within the mixture. Wettable powders (WP) are usually lumpy indicating that the material did not go into suspension. If a pesticide mixture is incompatible after initial mixing, an additional compatibility agent should be added at the rate of 6 drops and the solution allowed to sit for 1 h. If, at the end of the hour, the material still doesn't seem compatible, add an additional 6 drops and wait 1 h. If problems persist, dispose of the mixture and start over by adding compatibility agent first.

BUFFERS AND ACIDIFIERS

Buffers are substances capable of changing the pH of a water solution to a certain level and maintaining a relatively constant pH, even if water alkalinity changes. On the other hand, acidifiers (acidulaters) are acids that can be added to spray mixtures to neutralize alkaline solutions and lower the pH. Acidifiers do not have buffering action, therefore acidic or alkaline materials added to the spray solution later will change the pH of the solution.

Always read the pesticide label before mixing or combining with another pesticide or fertilizer. Usually, a statement can be found on the label regarding compatibility at various pH and precautions about mixing with other pesticides.

Several companies, including W. A. Cleary, Terra International, Riverside, Miller, DuPont, Valent, and others make adjuvants for use in obtaining compatibility with pesticide mixtures. If your spray solution isn't doing as well as you think it should, check the water pH.

Propagating Woody Ornamentals With Bottom Heat

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INTRODUCTION

Bennett's Creek Nursery is located in the southeastern corner of Virginia. During the cooler months our climate requires supplemental heat to maintain 21C (70F) root zone temperatures. This paper will describe our recently installed heating system. Crops produced, propagation technique, and overall benefits of the system are discussed.

THE HEATING SYSTEM

In 1994, we added 743 m^2 (8000 ft^2) of hot-water tube mats, which were placed on the floors of nine free-standing greenhouses. The dimensions of each greenhouse were 5.2 m × 19.5 m (17 ft × 64 ft). The mats are coupled to a one million BTU cast iron boiler. The fuel for the boiler is natural gas. In order to protect our investment, the majority of the system is located in an adjacent shed. All piping was insulated and placed below ground. The following equipment is housed in the boiler shed:

- Electronic ignition, double burner boiler
- Main circulator pump
- Air separator
- Expansion tank
- Pressure relief valve
- Pressure reduction valve
- Low water emergency cut-off
- Primary aquastat
- Secondary aquastat
- Two isolation valves

Each greenhouse contains the following:

- Two 2.2 m × 19.2 m (7 ft × 63 ft) grow mats (with 0.6-cm (0.25-in.) diameter rubber tubes spaced 10.2 cm (4 in.) on center
- Supply headers
- Return headers
- Mechanical flow control valve
- Circulator pump
- Thermostat and remote soil temperature sensor (root zone)
- 61-cm (24-in.) vent fan
- Thermostat (air temperature control)
- Two isolation valve

MAIN LOOP CONNECTION BETWEEN THE BOILER AND GREENHOUSES

The components in the boiler shed are linked to the greenhouses via a 6.4-cm (2.5-in.) diameter piping system. The copper pipe inside the boiler shed is connected to hot water plastic pipe (CPVC) outside the boiler shed. The supply and return piping exit the boiler through the floor. All CPVC pipe is insulated with a rubber material

and placed 46 cm (18 in.) below ground. The supply and return pipes run the length of the greenhouse range along one end. Just beyond the farthest house from the boiler shed, the supply and return pipes are connected to form a loop system. This design supplies evenly heated water to all greenhouses regardless of distance from boiler. Each greenhouse is coupled to the main loop with 4 cm (1.5 in.) diameter supply and return piping.

HOW THE SYSTEM REALLY WORKS

As previously mentioned, the boiler has two burners. Each burner is equipped with an aquastat (water temperature sensitive thermostat). The primary aquastat, which controls the primary burner, is set at 54C (130F). The primary burner will burn until this temperature is reached in the boiler. The secondary aquastat is set at 52C (125F) and is located on the supply pipe boiler shed. If the primary burner can't maintain at least 52C (125F) at the boiler, then the secondary burner is activated to obtain this temperature. This design greatly increases the efficiency of the system. Only during the coldest winter nights is the secondary burner needed.

In each greenhouse a thermostat connected to a soil probe monitors the root zone temperature. If the soil temperature drops below the desired level, the thermostat signals the main circulator pump and the small circulator pump in the greenhouse simultaneously and they are energized. The main circulator pump is located on the supply line exiting the boiler. The small circulator pump is located on the return line inside the greenhouse. Hot water circulates in the main loop via the main circulator and is drawn into the greenhouse via the small circulator. The mechanical flow control valve is located on the supply leg entering the greenhouse. It is just inside the greenhouse. This valve automatically opens as the small circulator comes on. Hot water is then allowed to flow through the tube mats via supply and return headers connected to the tubing. Once the desired root zone temperature is reached, the small circulator pump shuts off. In turn the mechanical flow control valve automatically shuts off and the greenhouse is again isolated from the main loop. If the root zone temperatures are satisfied in all greenhouses then the main circulator pump shuts off. The boiler will continue to maintain 54C (130F) regardless of flow.

The pressure in the system is reduced to 12 psi before entering at the boiler. Very little additional water enters once the system is initially filled. The water is also chemically treated to prevent corrosion of any system components. The level of treatment must be monitored periodically to make sure that it is still at the correct level. If found to be low, an additional chemical treatment is added. Chemical is pumped into the system at the boiler via a boiler drain on the return line.

NURSERY CROPS PROPAGATED

The system was installed primarily for conifer cutting propagation during the winter. However many other crops are currently produced using this system. Selected cultivars of hollies, camellias, barberries, and gardenias root particularly well at the onset of cooler weather. Each greenhouse usually roots a fall crop of one of the aforementioned genera, which are then moved to a minimum-heat holding house in early winter. Then a crop of conifers (mostly junipers) are rooted in the same house.

CUTTING PROPAGATION

Cuttings are collected from young container-grown plants in the nursery. The lower foliage is stripped and the cutting is quick dipped in a liquid rooting compound. Most cuttings are about 10 cm (4 in.) long. On most plants, tops are removed to promote early bushy growth.

After preparation the cuttings are direct stuck in 7.6-cm (3- in.) pots in trays containing 36 individual cells. The media is a very porous mix of composted pine bark, perlite, and sphagnum peat moss (16 : 8 : 1, by volume). Fertilizer incorporated into the propagation media includes: 2.4 kg m^{-3} (4 lb yd^{-3}) of Osmocote 18-6-12, 3.0 kg m^{-3} (5 lb yd^{-3}) of dolomite, and 0.9 kg m^{-3}(1.5 lb yd^{-3}) of micronutrients. The trays of cuttings are placed on the tube mats on the graveled floor of the greenhouses.

Intermittent mist is applied sparingly. During cool season propagation in covered greenhouses very little mist is needed in comparison to warm season propagation. More emphasis is placed upon hand syringing than frequent misting. Conifers seem to respond well to this technique. Syringing also helps correct dry spots associated with bottom heat systems.

CONCLUSION

We like the results from the two seasons we've used our boiler system. Overall crop quality is up and we've gained a 5% increase in overall rooting percentage. We also like the flexibility in regard to production timing. No matter what the weather conditions we're able to maintain warm root zone temperatures.

If there is anything we would change in the system design, it would be the flow control valves. An electronically operated valve coupled with the thermostat in each house would probably be worth the extra expense. This would better isolate the greenhouse if that greenhouse wasn't calling for heat. Overall we are very pleased with the system performance.

Weed Management Strategies for Container Production

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INTRODUCTION

Weed control in the production of container-grown landscape crops is essential if the plants are to be successfully marketed. Container nurseries provide an optimal environment for weed growth with frequent overhead irrigation and fertilizer applications necessary for maximum growth of landscape plants. Weeds in container-grown plants are unsightly, reduce growth of the landscape plant, and contribute to the spread of weeds into the landscape. As a result, weed control strategies are an important component in the overall production of container nursery crops. In this paper, I will attempt to address some of the common questions related to weed control in containers.

COMMON QUESTIONS RELATED TO WEED CONTROL

Improving Weed Control. One of the first questions normally asked is, "How can I improve my weed control program?" There are numerous factors that influence weed control in containers. Most basic is an understanding of the weeds that must be controlled, including the weed species, the source of weed seed for that species, the weed life cycle, and control measures that adequately address the particular weed. Additional information concerning weed life cycles, seed production and a listing of common weeds was reported last year by Dr. Stu Warren (1995). Movement of weed seed into production areas may occur by wind, water, animals, humans, and infested crop seed. Major weed infestations in close proximity to a nursery generally result in greater weed problems and may explain why two nurseries with the same herbicide program have different levels of weed control. In addition to the adjacent areas near container production beds, roadways, aisles, and ditches in a nursery should be kept clean or mowed to prevent weeds from going to seed. Growers should give weed control in the immediate area around the container production blocks high priority. Another consideration is not allowing weeds to go to seed and germinating in containers. Many of the weed species common in container production are high seed producers and have specialized structures for dissemination. Once they get established and are allowed to seed, it is difficult to break the weed cycle. Finally, while research has shown that growing media are not a major source of weeds, growers should make an effort to keep media piles weed-free, as well as the immediate area around the media.

When to Apply Herbicides. Another question frequently asked is, "When should herbicides be applied?" For most growers, the weed control program begins at potting. A preemergence herbicide should be applied at potting after the plants have been watered and the medium has settled. Many growers water their plants as they are moved to the container block and the herbicide(s) is applied after the first watering in the field. For most of the herbicides used in container production, reapplication should occur about every 90 days. During periods of high temperature

and heavy rainfall, the reapplication interval may be shortened to 60 days. A survey of Alabama growers has shown that most container producers applied herbicides three times annually; however, some of the growers with excellent weed control programs made up to five applications annually. Preemergence herbicides should be applied 2 to 4 weeks prior to covering for winter protection or any other type of enclosure because of potential injury from volatilization. Most granular herbicide labels state that the herbicide should not be applied to wet foliage. Also, many of the herbicides containing oxyfluorfen (Goal) should not be applied when plants are breaking dormancy or when the growth flush is soft.

Which Herbicide to Use. Another basic question is, "Which herbicide should I use?" Growers should always read and follow the label of the herbicides used. For landscape crops, plant tolerance is the most important factor in selecting a herbicide. Each herbicide labels list the landscape crops that have been tested under actual growing conditions and found tolerant at the recommend application rate. Another major factor in selecting which herbicide to use is the weed species controlled. Again, each label lists the weed species controlled and the rate required. Thus, it is extremely important for the growers to identify the major weed species before selecting the appropriate herbicide; not all herbicides control all weeds. Formulation of a herbicide is also a consideration; however, most container producers apply granular herbicides. There is a growing trend for container growers to use spray-applied herbicides. In a survey of Alabama growers, about 99% of the growers were using granular herbicides. Spray-applied herbicides that can be applied over-the-top of labeled container-grown landscape crops include: Factor 65 WDG, Surflan 4AS, Pendulum 60 WG, Pennant 7.8E, and Gallery 75 DF. Finally, the cost of the herbicide should be considered. In cases where herbicides have similar activity and chemistry, herbicide cost may determine which herbicide a grower selects.

Why Herbicides May Not Work. Growers frequently question, "Why do herbicides not work (sometimes)?" Correct timing of herbicide application is one of the most common reasons that herbicides do not work. It is important for growers to understand that we are dealing with preemergence-applied herbicides. With most of these herbicides, weed control is ineffective if the weed seed has already germinated. As previously mentioned, basic knowledge of the weed life cycle is critical in the total weed management strategy. Also, for applications during the growing season the container should be weed-free prior to herbicide application. A poor job of hand weeding cannot be overcome with an application of a preemergence-applied herbicide. Improper application rate also contributes to poor weed control. The person applying the herbicide should calibrate frequently to know the application rate. Calibration should occur under field conditions. Label instructions should be followed with respect to the rate required to control the problem weed at your nursery. Some herbicides (Snapshot 2.5 TG) have different rates for different weed species. Selecting the wrong herbicide also results in poor weed control. The herbicide label should list the weed species that is a problem in your nursery, otherwise a lack of control may occur.

Rotation of Herbicides. Another question frequently asked is, "Should I rotate herbicides during the production cycle?" Little research has been conducted in this area, but recent evidence suggests herbicide rotation could be beneficial. Most of the

herbicides registered for landscape crops contain a dinitroanaline (DNA) herbicide. Root inhibition is the mode of action of these herbicides. Some landscape crops are more sensitive to DNA herbicides than others, and some DNA herbicides have more activity than others. Growers should consider using nonDNA herbicides (Ronstar or Regal O-O) at potting and switching to DNA-containing herbicides with subsequent applications.

Control of Weeds Underneath and Around Containers. Weed control beneath containers is often a problem. In the past, this area was often treated with Princep at the noncropland rate of 10 to 20 lbs a.i. per acre. With a greater awareness of our environmental responsibility, this practice of applying high rates of Princep has generally been discontinued. Most growers use some type of ground cover, either landscape fabric or black plastic. In general, a good weed control program for the container crop combined with a ground cover will provide the desired weed control. If it is necessary to treat the ground beneath the containers with a preemergence-applied herbicide, the water solubility of the herbicides should be a strong factor in determining which herbicide to select.

Herbicides for Recycled Water Systems. Since many growers are now recycling their water, a question frequently ask is, "Will it matter which herbicide I use if I recycle my water? The herbicide choice can make a difference if recycling of the irrigation runoff water occurs; however, with most herbicides registered for woody landscape plants the likelihood of injury is remote. Dr. Ted Whitwell at Clemson University has shown in greenhouse studies with three herbicides (Surflan, Gallery, and Goal) that herbicide residue levels detected in the irrigation water were 100 times lower than the level that would cause measurable landscape plant damage. While limited research has been conducted in this area, herbaceous plants are more likely to be injured from herbicides in the runoff irrigation water. Key considerations to avoiding problems with herbicide accumulation in recycled irrigation runoff water are using the correct rate of application, selecting herbicides based on water solubility (with less than 3 ppm being a ballpark guideline), developing grassed waterways and vegetated filter strips to filter the irrigation runoff before it enters the collection pond, staggering herbicide application over a period of time, and applying herbicides to jammed (can tight) containers when possible to avoid nontarget herbicide loss.

Nonchemical Options for Weed Control. Many growers are interested in nonchemical alternatives for weed control in containers. There are several options available that provide varying degrees of success. Geotextile disks are available and have been shown to provide good weed control. These disk are easy to install, U-V resistant, and permeable to solid fertilizers. One problem with these disk is that weeds occasionally emerge in the slit around the base of the plant or around the edge of the pot. Newer disks are designed to reduce this problem. Another nonchemical weed control alternative is mulch. A recycled newspaper product is now available that provides good weed control throughout the growing season. Recycled newspaper pellets are applied about one inch deep after potting, and in many areas of the country provide weed control and moisture conservation throughout the growing season. Other mulch materials are available locally throughout the country. Growers should test these material on a limited basis prior to wide-scale use.

CONCLUSION

In summary, there are many components to developing a successful weed management program for container-grown landscape crops. Through proper management, container-grown crops can be produced and marketed weed-free.

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A New Approach to Irrigation

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INTRODUCTION

I am changing the title of my talk from a "High Tech Irrigation" to "A New Approach To Irrigation." For those of you who don't know me, I am the production manager of Saunders Bros., Inc., Piney River, Virginia. I have worked in this capacity for the past 15 years, since graduating from Virginia Tech University in the field of ornamental horticulture. Piney River is nestled in the scenic Blue Ridge Mountains in central Virginia between the cities of Lynchburg and Charlottesville. It was the final touchdown site of Hurricane Camille in 1969. Camille (a category 5 hurricane) killed 125 individuals in our county when rainfall fell at a rate believed to be unmatched in recorded history. Rainfall was in excess of 76 cm (30 in.) during a 6-h period. Meteorologists reported approximately 630 million tons of water falling over the county's 471 square miles, which would have the energy value equivalent of a 40,000 megaton nuclear bomb. Incidentally, it was this natural disaster which converted us from being primarily field stock growers to container producers.

In addition to some of the finest Gala and Fuji apples, Saunders Bros. produces peaches, registered Black Angus cattle, and over 1 million plants annually in our 45-acre container nursery. Azaleas, rhododendrons, and boxwood are our specialty; however, we also produce flowering shrubs, hollies, spring annuals, a large line of perennials, dwarf Alberta spruces, and fall pansies.

The Irrigation Person. The most important position in a nursery is that of the irrigation person. Once a pot is filled, it must be irrigated to reduce stress on the transplanted liner plant.

When plant is stepped-up or upcanned, it must be irrigated immediately to reduce transplant shock. Water is crucial during the summer months for evaporative cooling of the plants. In the winter months, prior to a big freeze, the amount of water in the soil system determines whether we will have plants to sell in the coming spring months or not. Through proper irrigation management, we can reduce disease, improve flower bud set on certain crops, and reduce the total amount of fertilizer needed. Now, ask yourself, "Who's watering your plants?" And "Do they really know what they're doing?" The real question is "Can you relax at home if it is 38C (100F) at your nursery with your irrigator making decisions to water?"

When I finished college in 1981, we had a 5-acre nursery and four greenhouses. At the time, we did all the irrigation by hand. Valves were manually opened 24 h per day. Many nights I would leave my wife behind in a cozy bed to open a valve only to return 2 h later to close it and open another. The days of manually opening valves are hopefully long gone for all of us who hope to remain competitive in the nursery industry. These antiquated systems have been replaced with electric solenoids and corresponding control panels designed to irrigate plants for the desired amount of time. Even these newer systems can be greatly improved.

Modernizing our Irrigation System. As our nursery grew from four greenhouses to over 230, we too put in electric solenoids and control panels to facilitate irrigating plants. However, production changes such as direct planting (upcanning) and piece work to increase output created new irrigation obstacles.

Again, we realized our method of irrigation had to change. Initially, I decided to irrigate at night to reduce interference with production activities during the day. Night irrigation improved water efficiency by providing the water at a time when evaporation is lowest. In establishing a schedule, I would run the corresponding number of controllers based on the capacity of the pump. When a controller was to turn off, I would have another programmed to come on. Making this program work was a piece of cake. The problem arose when new plants were potted (which happens often with some of the faster maturing crops such as chrysanthemums, annuals, and perennials) and also when a crop was sold and a large area was emptied and the corresponding zone's time had to be zeroed to stop irrigation. With our multiple cropping areas and crop production periods from 3 weeks to 2 years — the irrigation person has to be on his toes. If you're selling plant material throughout the growing season, these kind of problems happen often. Of course, weather changes and differences in certain media create other changes in our irrigation schedule — sometimes taking hours of calculating.

Computerized Irrigation Scheduling. Knowing the importance of correct irrigation, I sat down with a friend who is a computer programmer. He was able to write a program that has saved me an enormous amount of time in irrigation scheduling.

How does it work? First of all, we try to place all plants that are similar in type, soil mix, and container size in an area that is to be irrigated by a common controller. If possible, different plants would go in an another area irrigated by a different controller. Unlike some nurseries, we grow plants in different container media ranging from 15 to 33% pore space. It is very important to know the production requirements of the different soil mixes being used.

One of the secrets to the whole system is the timer which acts as the clock for the controller. It can be programmed to start and stop up to 4 times a day, which enables us to run both the regular irrigation schedule and a summer cool-down (syringe) with only one program. Unlike most controllers, it doesn't have to start and stop "on the hour."

The Irrigation Controller. A controller box may be able to irrigate or handle up to 12 solenoids (or zones) of plant material. The program allows for a brief description of the controller and allows the person to enable or disable the box (or to run the box or not) simply by inserting a T (for True) or an F (for False). If the plants in an entire area need to be sprayed the controller box can be disabled (cut off) on one day and enabled (cut on) the following. In addition, it has the ability to make multiple replications or provide cyclic irrigation to a zone of plants. This is important in water conservation as well as for plants requiring more time than the controller will allow. For example, if the plants in a given area needs 80 min of water and the box only allows a maximum of 60 min, then two replications can be made of 40 min, or four replications can be made of 20 min each (see Tables 1, 2, and 3).

Table 1. Irrigation controllers.

ID	Description
CONTROLLER: D1	Gray box at injector
ENABLED: T	(True or false)
REPLICATIONS: 2	(1, 2 or 4) = # times to run back to back
PASSES: 1	(1-99) = # times to run all replications with delay between
PRIORITY: 1	(0-99, lower numbers go first)
FLAG:	Cool down: t (true or false)
NOTES: memo	Hold control and press home to open notes window
START TIME	0 minutes since midnight, one pass
END TIME	408
TOTAL TIME	408 minutes with replications, one pass

Table 2. Irrigation controller zones.

ID	Description
CONTROLLER: D1	Gray box at injector
ZONE: 1	1 HH 1-4 hollies
MINUTES:	20 per replication inch/REP
SQUARE FEET:	17472 zone total W 8448S
# SPRINKLERS:	16 square ft/sprinkler:
GPM/SPRINKLER:	4.0 gpm zone total:
INCHES MEASURED:	0.00 In 30 minutes
INCHES PROJECTED:	0.18 in 30 minutes
MINUTES TO .25":	43 minutes
FLAG:	NOTES: Memo hold CTRL and press HOME to open notes window

The Priority Feature. One feature that I particularly like is that the program can be set to prioritize the irrigation of selected areas (see Table 4). The lower numbered boxes run first. This feature enables us to start a controller box at the beginning or end of the schedule depending on the plants within the controller area. If selected plants are more susceptible to disease by staying wet all night, then the box will receive a higher number so that the irrigation section is irrigated later (closer to the end of the night irrigation schedule). In addition, if an area is to be sprayed with pesticides or fungicides and then watered the same day, its priority can be changed to delay irrigation until so desired. This feature is great for plant species that should not stay wet for long periods at night.

Syringing Cycles. A cool-down irrigation cycle (evaporative cooling) is available for each controller box if weather dictates. The cool-down cycle is created by allowing each desired box to make one complete replication. The start time for the cool down is then set to coincide with the hottest part of the day.

Table 3. Irrigation schedule.

Time	Task	Controller description	Total time	Controller on
11:20 AM	ON:	Gray box at injector	6 hr, 48 min	1
11:20 AM	ON:	Lower field	2 hr, 35 min	2
11:20 AM	ON:	Box front of 506		3
11:20 AM	ON:	Box at front of 101		4
11:20 AM	ON:	Box At HH 34		5
11:20 AM	ON:	New area - left box @ rear of		6
11:20 AM	ON:	Green box at injector		7
40 HP	Pump	ON		
1:55 PM	OFF:	Lower field	2 hr, 35 min	6
1:55 PM	ON:	Box wood hollow	2 hr, 14 min	7
2:30 PM	OFF:	New area - left box @ rear of	3 hr, 10 min	6
2:30 PM	ON:	Top hill	1 hr, 04 min	7
3:34 PM	OFF:	Top hill	1 hr, 04 min	6
3:34 PM	ON:	Box at front of 515	1 hr, 52 min	7
3:44 PM	OFF:	Box front of 506	4 hr, 24 min	6
3:44 PM	ON:	Box at front of House 909	3 hr, 00 min	7
4:06 PM	OFF:	Green Box At Injector	4 hr, 46 min	6
4:06 PM	ON:	Rhododendron terrace	1 hr, 42 min	7
4:09 PM	OFF:	Boxwood hollow	2 hr, 14 min	6
4:09 PM	ON:	New area lower - right box @ r	2 hr, 30 min	7
4:28 PM	OFF:	Box at HH 34	5 hr, 08 min	6
4:28 PM	ON:	Box at back of house 909	3 hr, 02 min	7
5:26 PM	OFF:	Box at front of 515	1 hr, 52 min	6
5:48 PM	OFF:	Rhododendron terrace	1 hr, 42 min	5
6:08 PM	OFF:	Gray box at injector	6 hr, 48 min	4
6:39 PM	OFF:	New area lower - right box @ r	2 hr, 30 min	3
6:44 PM	OFF:	Box at front of house 99	3 hr, 00 min	2
40 HP Pump	OFF			
10 HP Pump	ON			
6:48 PM	OFF:	Box at Front of 101	7 hr, 28 min	1
7:30 PM	OFF:	Box at back of house 909	3 hr, 02 min	0
10 HP Pump	OFF			

Schedule start = 11:20 AM
Schedule end = 7:30 PM
Total schedule time = 8 hr, 10 min

Zone File. The next file is the "zone file." This is really a working file where all solenoid zones are listed within a controller box. In a particular zone, we enter the number of minutes we want to irrigate the area. We also enter the square feet within that zone for the summer and winter irrigation periods. Most of our houses are built so growing can take place in the greenhouse middles, and then we jam the houses can-tight as our overwintering process begins. Consequently when the houses are covered for winter, the sprinklers are irrigating a smaller area than in the summer. The irrigation time is reduced to apply water to the reduced square footage.

Calculating Vertical Inches of Irrigation Water. In each zone, we also list the total number of sprinkler heads and the flow rate of gallons per minute (gpm) for the particular sprinkler head. We then determine square feet per sprinkler, total gpm in the zone, total gallons of water applied per zone, and most importantly — the amount of water applied in vertical inches. This latter figure is the one I use most when determining the amount of water to apply in a particular zone. Because our nursery was built over a period of 15 years, our houses are not a standard size, nor are the middles a standard width. This variance makes the amount of water applied in vertical inches that much more important because it allows the comparison of zones using a similar format. In other words, a house that has middles up to 3.7 m (12 ft) will require 25% more water than will a house that has a 1.8-m (6-ft) middle (assuming uniform house widths).

The Task File. The task file helps generate the irrigation schedule. This schedule tells what time our irrigation schedule starts and ends, and the time each controller is on and off. It reports the total amount of time a particular controller is on. It helps the irrigation person know what time a particular irrigation pump(s) needs to be on, and when they should be shut off.

The Change Settings File. A second task is the change settings file that allows us to set a particular schedule start time and cool-down start time. This enables us to spray pesticides in the evening after work, and change the irrigation time to accommodate it. It also allows us to facilitate turning irrigation pumps on and off.

Because most control panels will not let you irrigate longer than 60 min, we can set this parameter in the task file. Finally, once we determine a pump's irrigation capacity, we enter that number so irrigation pressure will not be a problem. With this number entered, only the corresponding number of controllers will run, based on the priority of the particular controller. Once a controller has run for the total amount of time desired, the next highest priority controller number will come on to fulfill the pump capacity.

Printout Reports. Once a schedule has been printed, the report is followed by the irrigation person in setting the amount of time to irrigate each particular zone. Using the printed report, all controller boxes can be set to accommodate planned field work. Furthermore, a hard copy is available which gives data on total gallons of water applied during the schedule, and the amount of water applied per zone in vertical inches. From a managerial standpoint, it is this later figure which is most important.

Table 4. Irrigation controllers and zones.

A. Lower field (11:20 AM - 1:55 PM) priority = 2

1 repl. Min/repl	Zone#	Description	Vertical in. of water	Gallons of water
18	1	T terrace 1 gal azaleas	0.21	1152
22	2	A terrace various, far end	0.21	1408
10	3	L7 & L8 houses boxwoods 1G	0.11	640
10	4	L5 & L6 houses boxwoods 1G	0.10	640
40	5	L3 & L4 Houses Junip.& Spruce	0.31	2880
40	6	L1 & L2 Leyland cypress	0.28	1600
15	7	Poplar tree & L. Main (P. Shed)	******	0

Total time per replication = 2 h, 35 min

Total gal = 8320

Total time with replications = 2 h, 35 min

B. Boxwood hollow (1:55 PM - 4:09 PM) priority = 8

1 repl.	Min/repl	Zone#	Description	Vertical in. of water	Gallons of water
	16	1	301-303, 201 - (Propagation)	0.21	832
	16	2	202-204	0.17	768
	16	3	205-207	0.18	768
	16	4	304-306	0.18	768
	16	5	307-309	0.20	768
	18	6	New area top	******	1584
	18	7	New area middle	******	1728
	18	8	New area bottom	******	1368

Total time per replication = 2 h, 14 min — Total gals = 8584
Total time with replication = 2 h, 14 min

C. Top hill (2:30 PM - 3:34 PM) priority = 9

1 repl.	Min/repl	Zone#	Description	Vertical in. of water	Gallons of water
	0	1	Gravel terrace @ pack shed	******	0
	16	2	Behind reserv. & Below prop.	******	832
	16	3	Top hill facing pack shed	******	1408
	16	4	Top hill - field rd. - Hemlock	******	896
	0	5	Field rd. Near hollow	******	0
	16	6	Propagation areas	******	1024

Total time per replication = 1 hr, 04 min — Total gals = 4160
Total time with replications = 1 hr, 04 min

D1 - Gray box at injector (11:20 am - 6:08 PM) priority = 1

1 repl.	Min/repl	Zone#	Description	Vertical in. of water	Gallons of water
	20	1	HH 1-4 hollies	0.24	2560
	18	2	HH 5-7 hollies	0.28	2304
	30	3	HH 8, 10, 12, 14, azaleas 3G	0.36	3840
	30	4	9, 11, 13, azaleas 3G	0.36	2880
	20	5	HH 14A-14D azaleas 3G	0.33	2560
	28	6	HH 15-18 azaleas 3G	0.34	3584
	28	7	HH 19-21 azaleas 3G	0.34	2688
	20	8	21A-21D azaleas 3G	0.33	2560
	10	9	27A-27D azaleas 3G	0.33	1600
					Total gals = 24576

Total time per replication = 1 hr, 04 min
Total time with replications = 6 hr, 48 min

D2 - Green box at injector (11:20 AM - 4:06 PM) priority = 7

1 repl.	Min/repl	Zone#	Description	Vertical in. of water	Gallons of water
	8	1	Y terrace	******	0
	15	2	Z terrace azaleas 1G & can hems	******	2160
	12	3	AA near	0.23	1536
	12	4	AA far	0.22	1536
	24	5	BB lower	0.48	3264

CONCLUSION

In summary, this system has saved our nursery valuable management time — some days up to 3 to 4 h. It also has earned us money by reducing fertilizer usage by 33% on selected crops. It provides a management tool to oversee that the irrigation person is providing the amount of water experience has taught me to give the plants. A plus over other systems is that this one doesn't require any additional wiring. It allows flexibility in setting start and/or stop times. It has the flexibility to quickly increase or decrease irrigation times, depending on weather conditions. This systems eliminates the need for years of experience generally needed of a field employee to carry out the irrigation planned. However, the system maintains enough hands-on operational requirements to catch mistakes. Finally, it allows me extra time to do other important things.

Horticultural Opportunities

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INTRODUCTION

There are numerous production opportunities in the nursery industry. Some opportunities for producing nursery crops include: specialty floriculture items, specialty nurseries, mitigation and restoration, specialized propagation nurseries for seed production and rooted liners, and site preservation.

Specialty Floriculture. This includes — fresh, dried or preserved foliage, flowers, twigs, branches, or seed pods. It is difficult to develop a new business in this industry since established companies are quite protective of their interests. At trade shows company booths may be walled-off and it is understood that competitors enter only on invitation.

Herein is where the opportunity lies. A grower of floral materials has the options of selling to the local retail market, or selling larger quantities to the wholesale market at reduced prices.Growers have confided in me that they can grow these products, but that there is no market for them. I suggest the formation of a nationwide growers co-op. The Association of Specialty Flower Growers may be of help to potential producers.

Even though dried or preserved floral products have extended shelf life and storage advantages, I believe the greatest market potential is with producing fresh floral material. Access to a good airport is imperative for shipping.

Specialty Nurseries. These nurseries have the greatest market potential in today's industry. While dwarf youpon, Chinese hollies, kurume azaleas etc., are still the staple crops for larger nurseries, more new plant introductions occur. There is greater diversity of product assortment offered by larger nurseries for one-stop shopping. While these nurseries sell significantly more bread and butter plants than specialty items — the production capabilities of large-scale nurseries may indirectly create market demand for specialty items produced by smaller specialty nurseries.

The specialty producer invests considerable time in selecting, evaluating, and building stock of the product to market. For small growers considering entering the specialty nursery niche, it is important to develop a good relationship with more progressive mail order nursery companies. Generally they are willing to pay a premium price for unique plants. They might mark-up specialty items as high as 500%. Plant patents and trademarking should also be considered when developing and marketing specialty products.

Mitigation or Restoration. There are great opportunities for specialty nurseries which produce plants for sand dunes and wetland areas. Native plant nurseries in Florida can not keep up with the demand for plants which aid in the restoration of sand dunes destroyed by recent hurricanes. I am greatly concerned about rapid development of condominiums, etc. in sand dune and wetland areas. The lack of regulation on construction encroaching the dune lines is unfortunate. Typically, these areas are paved with asphalt and planted with oleanders and pampas grass.

A more ecological friendly plant mix could be utilized if more dune plants such as beach golden rod, conredina, sea oats, dwarfed oaks, and magnolias were commercially available.

Constructed Wetlands. Coastal areas of the U.S. continue to be encroached upon by urban sprawl and development. In coastal Alabama, entire compounds on docks are being built over wetlands, neglecting environmental protection laws. There will be increased demands for native plant materials for wetland restoration and mitigation. Some of these native species come from nurseries, but most are dug from ditches. Hence, there is ample opportunity for nurseries to produce these fast turnover wetland plant species (Street, 1994).

Specialized Propagation Nurseries. Various speakers have commented on plant selections which should be grown, but are not available in the nursery industry. Propagation and production problems may limit the commercial availability of new material. Some seed propagated species are limited by insufficient seed availability. Selected plants grown as seed orchard plantings for seed production may be profitable. Two such plants are *Stewartia malacadendron* and *Magnolia ashei*. Specialty propagation nurseries producing liners from rooted cuttings is another option.

Site Preservation. This might, at first glance, seem counterproductive to the nursery industry, since preserved plants are not replaced with new ones. However similar principles which apply to container production or field production apply to full site preservation. Some of our native habitats must be preserved for plant diversification.

My company, Coastal Woodland, currently focuses on opportunities which lead towards preservation. These projects are large in scope and we anticipate that the utilization of nursery-grown container plants will compliment these native landscapes. One of the most difficult tasks we have is minimizing bulldozer damage of sites. The architect Frank Lloyd Wright was famous for designing homes which nested into the landscape. In one case after we pruned and shaped a wooded area surrounding a planned homesite, the architect aborted and redid his plans. This greatly enhanced the aesthetic aspect of the home fitting in with the native landscape site.

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The Internet and How It Applies to the Nursery Industry

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BoShanCee Nursery, New Market, Alabama 37361

THE WEB

The backbone of the world wide WEB is the Web Page which is constructed using hypertext markup language (HTML). The words, graphics, and sound that are transmitted on the WEB is defined using HTML. One of the keys in making this easy to use is the ability of the user to move from one page to another by "pointing and clicking" with the computer cursor. This hypertext link allows the user to move from one document to another without knowing where that next document resides. Therefore, a user could be reading a growers catalogue written by a nursery in Oregon and reference an article on Plant Trial Tests published by the Auburn University in Alabama. The illustration below is the home page for the BoShanCee Nursery WEB site. Presently, our site contains nine pages of text. We have taken 35 mm pictures of our plant material for sale this season and are adding them to our site so that our customers can see a picture of the plant they are considering purchasing.

The BoShanCee Homepage
Welcome to BoShanCee Nursery
"Wholesale growers of field grown, broadleaf evergreens'
214 County Lake Road
New Market, Alabama 35761
Fax: 205-536-6913
Phone: 205-379-3826
E-mail: boshancee@compuserve.com
Web:http://ourworld.compuserve.com/homepages/BOSHANCEE
1996/97 Wholesale Price List

-barberry	-boxwood
-hinoki false cypress	-dogwood
-euonymus	-holly
-magnolia	-nandina
-laurel	-hemlock

Company History
Growing Philosophy for Specimen Plant Material
Terms and Conditions
Order Placement

BROWSERS

The software program that resides on your computer and establishes the interface with the WEB is called a "browser". Netscape and the Microsoft's Internet Explorer are the two most common WEB browsers. Actually, there are over 26 different browsers available on the market today. Using a browser, one can access the WEB

and visit many different WEB sites around the world. This is known a "surfing the WEB".

Individual users are not connected directly to the Internet. Instead, they are connected to an Internet Service Provider (ISP) via telephone lines which are connected to the Internet. The ISP charges for the time that an individual is connected. This charge usually runs from $9.95 to $30.00 per month. I recommend selecting a local ISP in your city which offers unlimited access to the Internet. The monthly charge is around $20. Except for this monthly expense and your personal time, there are usually no additional costs for being on the WEB.

HOW CAN YOU USE THE WEB

There are three things that are needed in order to use the WEB:

- Equipment
- Internet service provider (ISP)
- The name of a webpage to access

The equipment needed is a computer, a modem, a telephone line, and browser software. Any computer will do so long as it can run the browser software. In order to minimize problems, I recommend a computer with an Intel 486 chip or better. There are many modems to chose from, but select a modem with a minimum speed of 28.8 baud. Slower modems will take minutes not seconds to display many webpages and are very ineffective in utilizing the WEB. WEB usage on your existing telephone line can interfere with incoming business phone calls. A second telephone line is desirable, but the cost must be considered. I recommend staying with your existing line but installing a second line if it can be justified. Either Netscape Navigator or the Internet Explorer browser software are excellent and can be purchased from your local computer store.

In selecting a Internet Service Provider (ISP), you can choose a local company which can be accessed by a local phone number (thus eliminating long distance charges) or a national service provider who can be accessed by an "800" phone number. Costs between the two are about the same. I use CompuServe (American On-Line is also available) because for $9.95 a month it offers many additional services and provides a **free** home for the BoShanCee Nursery Website.

Once you are connected, you need to point your browser to a homepage. Homepage names are showing up everywhere — magazines, brochures, advertisements, television programs, etc., see the attached list. Start building a library of names ("bookmarking") for those whom you do business with. The WEB offers a very powerful search capability which helps you find homepages for subjects of interest. This software, known as search engines, is available free of charge on the WEB. In response to your defined keywords, it will provide you the Web Page names that contain information about the subject material.

HOW DOES BOSHANCEE NURSERY USE THE WEB?

The nursery publishes its product brochure along with plant photographs and current availability. We also include technical information about our plants and our own personal observations learned while growing the plants. The information is updated monthly. An advantage of the WEB is its accessability 24 h a day: i.e., a landscape contractor client can reference our plant availability via the WEB at home or in the office during the evening. A landscape design can then be developed in the

evening and presented to their customer in the morning with detailed technical information and pictures of the actual plants. Our landscape contractor and retail nursery clients can also place orders while they are looking at the brochure. This order is sent by e-mail and a confirmation is returned the same way.

Twoway communication with the chemical manufacturers enable our nursery to obtain current information on chemicals we use. Any queries of chemical usage problems we may encounter are sent directly to the manufacturer — and they quickly respond to us.

The quantity of horticultural information available from educational and research institutes is significant. Access to this information will be an important benefit to our nursery in the future.

THE FUTURE OF THE WEB

In just a few years the cellular telephone became an integral part of our daily lives. The use of the WEB will take a little longer. It involves computers, which is still a stumbling block for many potential users. Based on the present usage of computers by our customer base, our nursery can not justify spending much more in time and dollars than we currently do. I believe this will change in the near future. Televisions are now being sold with an internet channel. The user will sit in his arm chair and communicate with the WEB through the TV screen — without the hassle of working a computer or dealing with a telephone line. As the technology becomes easier and cheaper to use, more of our customers will come on-line. Someday you will be able to vote, engage in interactive entertainment and education, receive customized news, buy products, talk to others with real-time pictures—all from the comfort of your home or office.

URL ADDRESSES

Some selected URL addresses which are useful and interesting to view are listed below:

- http://www.cstone.net/plants/
- http://ourworld.compuserve.com/homepages/BOSHANCEE
- http://www.agr.state.tx.us/tame/fxg/1342.htm
- http://www.hardie.com/homepage.html
- http://www.vngw.com/
- http://www.hort.purdue.edu/ext/conhort.html
- http://www.teleport.com/confir/
- http://www.ahandyguide.com/catl/n/n17.html
- http://www.growzone.org/
- http://aggie-horticulture.tamu.edu

For looking up nurseries, the best index I've found to date is: http://www.ahandyguide.com/catl/n/n17.html. Generally it is hard to locate nursery growers, since so few have submitted their URLs to the popular search engines. I have stumbled onto most of my contacts by surfing the Net, which can take a lot of time. Easier and faster ways to search for specific information need to be devised.

GETTING INFORMED

Now is a good time to become informed. There are many magazines and books available on the subject. Get with friends who can show you the capabilities

available. Become comfortable with the idea. Then you can decide for yourself if and when this technology will benefit your company. A quick way to find and purchase publications about the WWW and other related subject areas is to get on line and search the homepage of Amazon.com books — i.e. http://www.amazon.com.

SOME SELECTED REFERENCES TO CONSIDER

Levine, J.R and **C. Barodui.** 1996. The internet for dummies. IDG Books, Inc. (very technical and detailed, but thorough; this book is for those who want to know how the internet works).

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Hahn, H. and **R. Stout**. 1995. The internet yellow pages. McGraw-Hill, Inc. (an index of web pages, URL's, descriptions, etc.; good for those who want to find something particular on the WEB).

Adventitious Rooting of Stem Cuttings of Loblolly Pine as Influenced by Carbohydrate and Mineral Nutrient Content of Hedged Stock Plants

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Hedged stock plants of four full-sib families (B, G, R, and W) of loblolly pine (*Pinus taeda* L.) were fertilized daily with a complete nutrient solution containing either 10, 25, 40, 55, or 70 ppm N. In May 1995 (spring softwood), July 1995 (summer softwood), and Jan. 1996 (winter hardwood) terminal stem cuttings were taken for tissue analysis and rooting studies. Spring cuttings rooted in the highest percentages (59.5%), followed by winter (40.5%), and summer (34.7%). Maximum rooting for spring (70.0%), summer (48.6%), and winter (55.6%) occurred with cuttings taken from hedges that received 55 ppm N. Winter values of total nonstructural carbohydrates (TNC) were twice levels present in spring or summer (32.8% vs. 17.1% and 16.3%), but levels remained relatively constant with increasing applied N. In contrast, average N concentrations were lower in winter (1.29% vs. 1.79% and 1.69%) and increased linearly with increasing applied N levels. Genetic differences among families were evident as families B, G, and W exhibited a quadratic response with maximum rooting of 61.1% at 70 ppm applied N, 62.4% at 55 ppm N, and 63.0% at 40 ppm N, respectively. The TNC : N ratio was not correlated with rooting and an optimal TNC : N ratio for rooting success was not found. However, optimal rooting occurred at concentrations ranging from 1.8% to 2.0% N for spring and summer softwood cuttings and at approximately 1.5% N for winter hardwood cuttings. Also, low tissue B concentrations, which were not detrimental for plant growth, may have severely inhibited adventitious root formation.

INTRODUCTION

When focusing on the stock plant in relation to adventitious rooting of stem cuttings, one must consider the effects of both the environment and genetics on the physiological processes within the stock plant, which in turn influence subsequent rooting. Two measures of physiological status which are influenced by stock plant environmental history are carbohydrate content and nitrogen content (Andersen, 1986; Moe and Andersen, 1988). Changes in the relative amounts of either within cuttings influence rooting (Haissig, 1986).

Total nonstructrual carbohydrates (TNC) influence rooting by providing energy reserves and carbon skeletons to support root initiation and growth (Haissig, 1986; Veierskov, 1988). On the other hand, slight deficiencies of N (not stress) within the stock plant generally promote root formation in cuttings, presumably due to restricted metabolism of stock plant carbohydrates (Moe and Andersen, 1988). When photosynthetically fixed CO_2 enters the carbohydrate pools, it is normally

available to be metabolized further. However, if N is deficient, carbon cannot be metabolized since most organic compounds contain N. In this situation, surplus carbohydrates would then be available to support root formation in stem cuttings (Veierskov, 1988). Thus, the aforementioned serves as a hypothesis that low N status relative to available carbohydrates (high TNC : N ratio) results in a tendency for stored carbohydrates and current photosynthate to be directed into adventitious root formation.

In addition to environmental effects, correlations between TNC : N ratios and rooting have been shown to have a genetic component. Hyun and Hong (1968) studied the seasonal variation in TNC : N ratios of both easy- and difficult-to-root clones of pitch pine (*Pinus rigida* Mill) and reported that clones which rooted in high percentages had higher TNC : N ratios than clones which were difficult-to-root. Although precise endogenous and exogenous relations between N and adventitious rooting have not been established, carbohydrate to N ratios can be manipulated by varying N fertilization provided to the stock plants. Henry et al. (1992a and 1992b) reported optimal growth of eastern redcedar (*Juniperus virginiana* L.) when stock plants were fertilized weekly with 180 ppm N. However, optimal rooting occurred at only 20 ppm N. This work also demonstrated that external N availability may have influenced rooting via its effects on uptake and utilization of other mineral nutrients. Therefore, the objective of this research was to determine whether selected levels of applied N supplied to hedged stock plants of loblolly pine (*Pinus taeda*) influence adventitious rooting with respect to the carbohydrate and N content of the cuttings.

MATERIALS AND METHODS

Hedged stock plants with varying carbohydrate and N status were established by growing plants outdoors on a gravel container pad at a range of applied N levels. The experimental design on the container pad was a randomized complete block design with four blocks each containing four full-sib families (controlled pollinations where both parents are known) and six N treatments (including an Osmocote control) arranged in a complete factorial, and with a four tree row plot within each block-family-N combination. A group of four-trees represented an experimental unit. There were a total of 24 treatments and 384 trees.

Trees for the five N treatments were grown in a medium of perlite and sand (6 : 4, v/v), while controls were grown in a medium of peat, coarse vermiculite, and perlite (2 : 2 : 1, by volume) amended with 2.1, 0.24, and 1.0 kg m^{-3} (3.6, 0.4, and 1.7 lb yd^{-3}) Osmocote 18N-6P_2O_5-12K_2O, Micromax, and dolomitic lime, respectively. The six N treatments consisted of the peat culture control and five levels of N (10, 25, 40, 55, and 70 ppm N) supplied at optimum levels. The four families (designated B, G, R, and W) were included to compare genetic effects. From previous work it was determined that families B and R were poor rooting families (<10%) and families G and W were good rooters (>50%).

During May 1995 (spring softwood), July 1995 (summer softwood), and January 1996 (hardwood), 9-cm-long (3.5-in) terminal stem cuttings were taken from the hedged stock plants for tissue analysis and rooting experiments. These dates also coincided with rehedging of stock plants to maintain juvenility (Hackett, 1988). Tissue collected for carbohydrate and mineral nutrient analysis were lyophilized, ground to pass a 20-mesh (1.3-mm openings) screen, and extracted four times in 80%

ethanol. The decanted supernatant used to determine soluble carbohydrates was evaporated, resolubulized in deionized distilled H_2O, and centrifuged through microfilter columns packed with anion and cation exchange resins and polyvinylpolypyrrolidone (PVPP) to remove phenolic compounds. Samples were then analyzed for glucose, fructose, sucrose, raffinose, and the sugar alcohols, myoinisitol, and pinitol utilizing high performance liquid chromatography. The remaining insoluble pellet from the extraction process was utilized for enzymatic determination of starch. The samples were incubated with the enzymes amyloglucosidase, hexokinase, and glucose-6-phosphate dehydrogenase, and absorbance at 340 nm was measured on a spectrophotometer to determine starch content. In addition, tissue samples were analyzed with a CHN elemental analyzer to determine total C and N and by plasma emission spectrometer to determine P, K, Ca, S, Mg, Mn, Fe, Zn, B, and Cu. Cuttings utilized for rooting experiments were inserted into flats containing a medium of perlite and coarse vermiculite (1 : 1, v/v) and placed in a greenhouse under intermittent mist. They were not treated with auxin. After 12 weeks, cuttings were evaluated for percent rooting. A cutting having at least one root > 1 mm (0.04 in.) in length was considered rooted. Means were subjected to analysis of variance procedure and regression analysis (SAS Institute, 1990).

RESULTS AND DISCUSSION

There were significant differences among seasons, families, and N treatments, as well as a family × N interaction in regards to rooting percentages. When averaged over families and N treatments, significantly greater rooting percentages occurred for spring softwood cuttings (59.5%) than summer softwood (34.7%) or winter hardwood cuttings (40.5%). Maximum rooting for spring (70.0%), summer (48.6%), and winter (55.6%) occurred with cuttings taken from hedges that received 55 ppm N (Fig. 1A). Likewise, differences were evident in the percentage of total nonstructural carbohydrates (TNC) and percent N concentrations of the cutting tissue. Winter values of TNC were twice levels present in spring or summer (32.8% vs. 17.1% and 16.3%), but levels remained relatively constant with increasing applied N (Fig. 1B). In contrast, average N concentrations were lower in winter (1.29% vs. 1.79% and 1.69%) and increased linearly with increasing applied N levels (Fig. 1C).

When averaged over seasons, families B, G, and W exhibited a quadratic response with maximum rooting of 61.1% at 70 ppm applied N, 62.4% at 55 ppm N, and 63.0% at 40 ppm N, respectively (Fig. 2A). Overall, family R was the poorest rooting family. However, rooting increased linearly with higher applied N suggesting that additional N may have improved rooting further. Families G and W were the best rooting families at the lower applied N levels, whereas family B was extremely poor (8.3% at 10 ppm N). However, family B was the best rooting family at the highest applied N level (61.1% at 70 ppm N). These results emphasize that differences in rooting response are partially genetic, even within the same species.

Levels of applied N showed similar linear and quadratic responses for TNC (Fig. 2B). Families B and W contained the highest levels of TNC and were both good rooting families, whereas family R contained the lowest TNC levels and was the poorest rooting family. Family G was an exception. Although it was generally a good rooter, it contained low TNC levels, which suggests that it may be more efficient in metabolizing carbohydrates. Contrary, to our hypothesis, TNC : N ratio was not

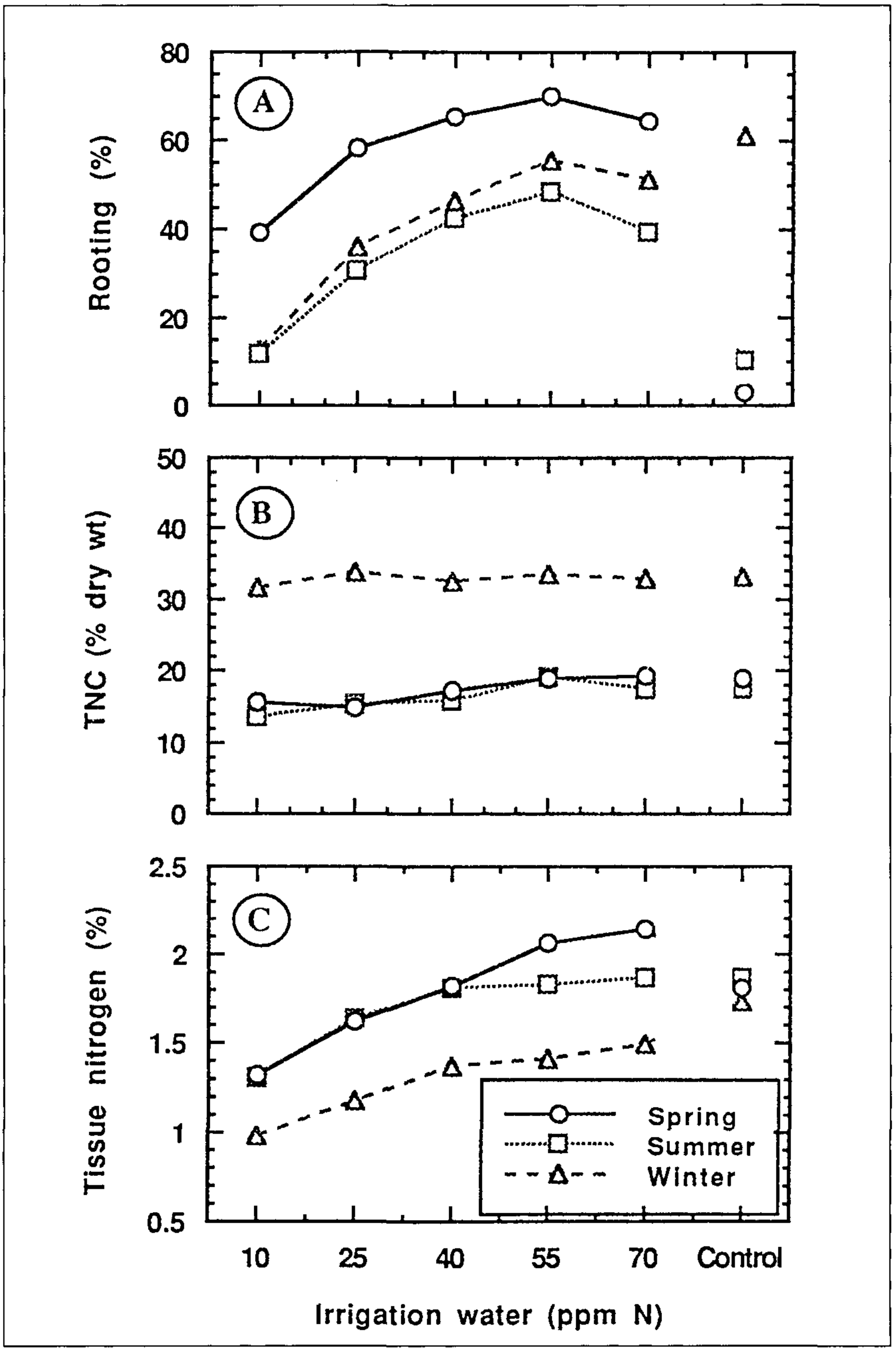

Figure 1. Effect of stock plant nitrogen fertilization on (A) rooting, (B) total nonstructural carbohydrates (TNC), and (C) tissue N concentrations of stem cuttings of loblolly pine taken from hedged stock plants. In (A), each symbol is based on 96 observations. In (B) and (C), each symbol is based on 16 observations. Data are averaged over families.

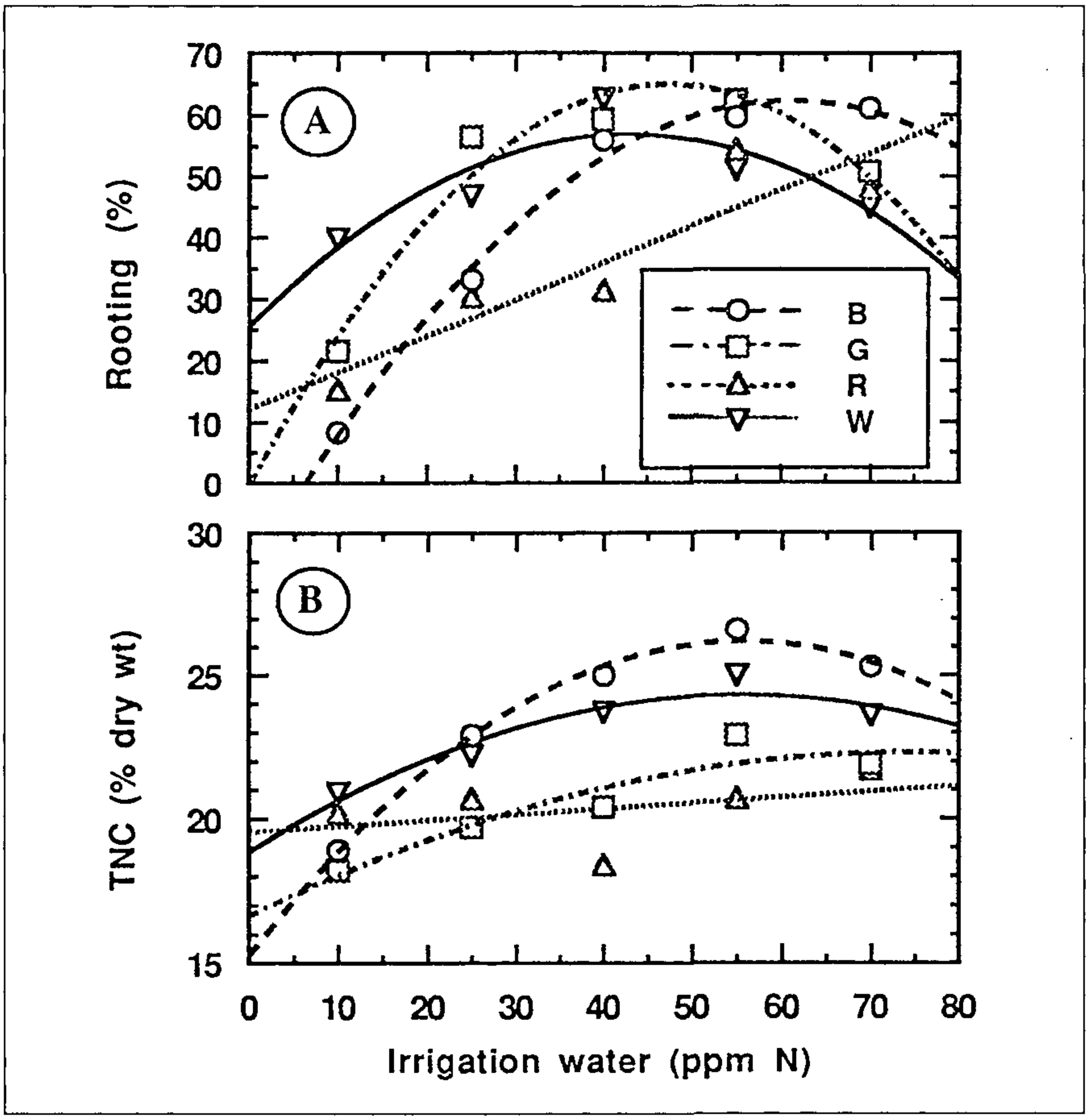

Figure. 2. Effect of stock plant nitrogen fertilization on (A) rooting and (B) total nonstructrual carbohydrate concentration (TNC) of stem cuttings of loblolly pine taken from four families (Fam. B, G, R, or W) of hedged stock plants. In (A), each symbol is based on 72 observations. In (B), each symbol is based on 12 observations. Data are averaged over seasons.

correlated with rooting and an optimal TNC : N ratio for rooting success was not found. As TNC for each family exhibited a quadratic or positive linear response to applied N, TNC : N ratio decreased with increases in applied N for all families (Fig. 3). At the lower applied N levels, tissue N concentrations were depressed (Fig.1C), which in turn inflated the TNC : N ratios. Even so, determining this ratio would be too time consuming and costly to be practical for a propagator. A more reasonable test would be tissue N concentration. For all treatments studied, a range of tissue N concentrations from 0.92% to 2.24% was observed. However, optimal rooting occurred at concentrations ranging from 1.8% to 2.0% N for spring and summer softwood cuttings and at approximately 1.5% N for winter hardwood cuttings.

Of the other mineral nutrients, B may have had the greatest impact on rooting. There were no significant differences among families or applied N levels, but a B

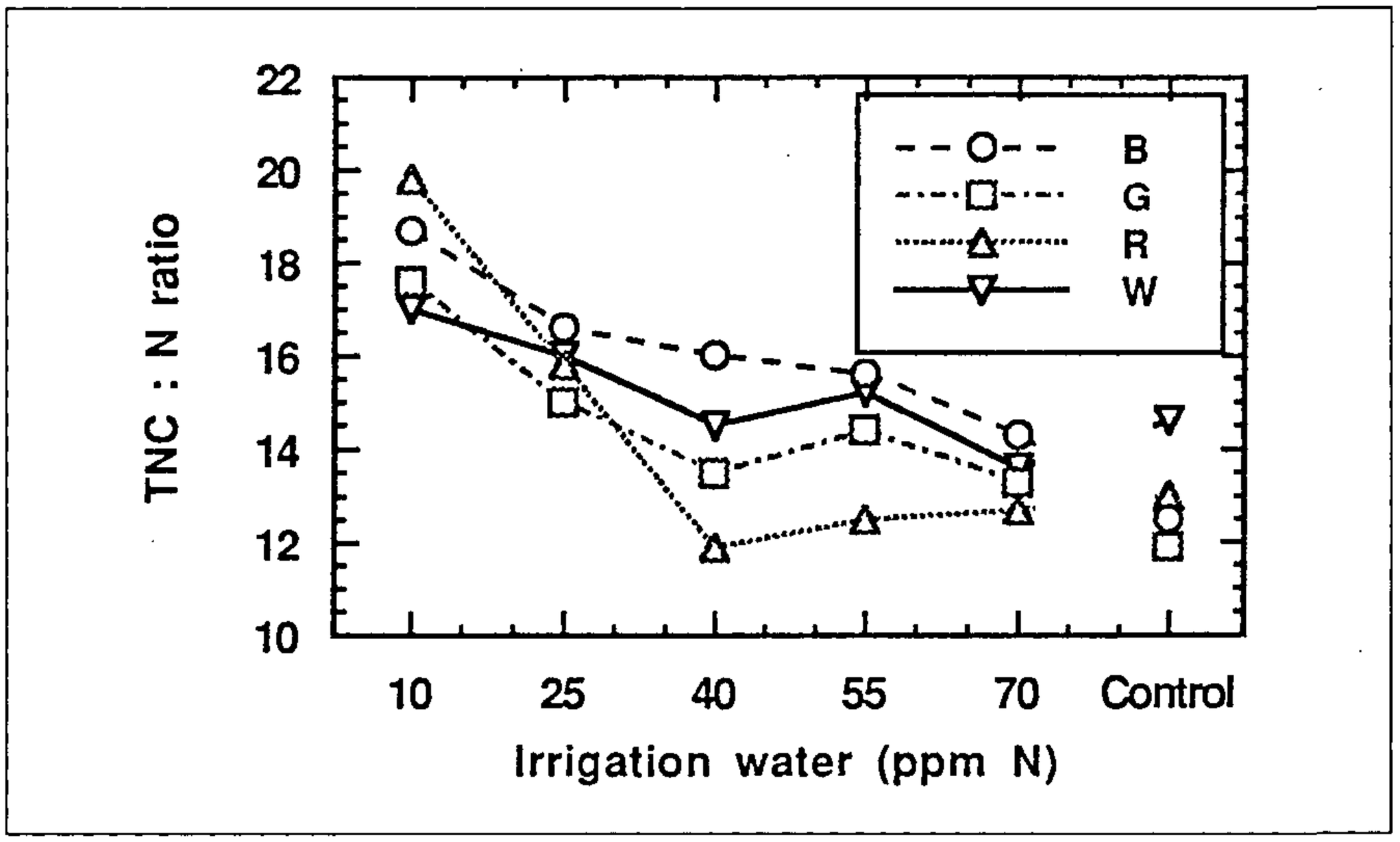

Figure. 3. Effect of stock plant nitrogen fertilization on total nonstructural carbohydrate : nitrogen (TNC : N) ratio of stem cuttings of loblolly pine taken from four families (Fam. B, G, R, or W) of hedged stock plants. Each symbol is based on 12 observations. Data are averaged over seasons.

deficiency in the spring (7.0 ppm) and summer (8.7 ppm) control treatments compared to the other 5 N treatments (21.7 ppm B), could have reduced rooting dramatically (Table 1). Rooting percentages for the controls were only 0.83% in spring and 10.4% during summer, but increased to 61.1% for winter cuttings when tissue levels were restored to 15.9 ppm B. This occurred despite the fact that spring and summer control hedges produced the greatest number of shoots, contained high TNC levels, and exhibited no visible symptoms of mineral nutrient deficiency (data not presented). Even though 7.0 ppm B is adequate for plant growth, it appears that higher amounts may be required for adventitious rooting. Thus, further stimulation of rooting also may be possible by manipulating stock plant B concentrations.

Table 1. Internal boron concentration (ppm) in tissue of stem cuttings.

Applied N (ppm)	Spring	Summer	Winter
10	23.5	21.1	18.5
25	21.5	23.2	16.4
40	21.6	23.0	15.9
55	21.0	21.6	14.7
70	22.0	19.7	14.8
Control	7.0	8.7	15.9

In conclusion, the time of year in which woody stem cuttings are taken from stock plants (actually the growth stage), mineral nutrient status of stock plants, and

genetic variation all have a major influence on adventitious rooting of loblolly pine. Spring softwood cuttings rooted in the highest percentages, followed by winter hardwood, and summer softwood cuttings. Also, genetics plays an important role in adventitious rooting as not all families responded the same to varying applied N levels. Manipulating stock plant nutrition influences adventitious rooting in loblolly pine, and probably in other difficult-to-root species as well. However, specific fertility regimes will need to be determined for each species and even for families or clones within a species.

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Sequential Benzyladenine (BA) Applications Enhance Offset Formation in *Hosta*

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A study was conducted to determine the effects of repeated benzyladenine (BA) applications and subsequent repeated offset removals on offset yields from hosta stock plants. Two hosta cultivars, 'Francee' and 'Frances Williams', received either 0, 1, 2, 3, or 4 foliar applications of 3000 ppm BA. Plants receiving multiple applications were retreated at 30-day intervals following offset removal from all plants. BA application stimulated offset formation in both cultivars, but repeated applications were necessary for a continued response following offset removal. Offset removal did not inhibit a subsequent response to BA, and total offset yield increased with an increasing number of BA applications. Over the 120-day study, plants of 'Francee' receiving four applications formed 124% more offsets than controls, while plants of 'Frances Williams' receiving four applications formed an average of 18 offsets over the 120-day study, compared to none for controls.

INTRODUCTION

Hostas are herbaceous perennials in the lily family. They are the most popular of all herbaceous perennials (Rhodus, 1995), and are well suited for use in the shaded landscape. Hostas are conventionally propagated by crown division or tissue culture, but there are limitations to these methods. Division yields relatively few plants per clump, and is typically accomplished only annually (Walters, 1981). Tissue-cultured explants are costly to produce and may not come true to type (Meyer, 1980). Moreover, propagation of plants by tissue culture requires skilled technicians, specialized materials, and facilities unavailable to most growers. Rapid increases in plant numbers and the introduction of new cultivars may be impeded because of these limitations. Increasing the number of propagules available may reduce production costs and facilitate accelerated production. In hosta this can be accomplished by promoting the outgrowth of lateral buds, a process which is under phytohormone control.

Vegetative buds and roots of hosta grow from rhizomes (Schmid, 1991), but the rhizomic or shoot apex appears to suppress outgrowth of lateral axillary and rhizomic buds by apical dominance. A primary factor in the mechanism of apical dominance is a hormonal interaction between auxins and cytokinins (Cline, 1988), and exogenous application of cytokinin can release lateral buds from inhibition in many plants (Mok and Mok, 1994). Previous studies have demonstrated that application of the synthetic cytokinin, benzyladenine (BA), induces the outgrowth of rhizomic and axillary buds in hosta (Keever, 1994), and that offsets formed from BA-induced buds can be removed from the mother plant within 30 days of BA application and rooted under intermittent mist (Keever et al., 1995). These findings

suggest that production of BA-stimulated offsets can provide an effective alternative to conventional propagation methods by increasing the number of offset cuttings available. BA application has been shown to enhance offset cutting production of *Gerbera jamesonii* Hook. stock plants when BA is reapplied after each cutting harvest (Kaminek, et al., 1987). A successful strategy for propagating hosta in this manner may require the use of hosta stock plants which could be treated with BA at 30-day intervals and serve as a source for BA-stimulated offset cuttings throughout the growing season. The objective of this study was to determine the effects of multiple BA applications and subsequent repeated removal of BA-induced offsets on offset yield from hosta stock plants.

MATERIALS AND METHODS

On 20 Feb. 1995, dormant, bareroot divisions of hosta cultivars 'Francee', which forms offsets readily, and 'Frances Williams', which does not (Garner et al., 1996), were potted in 3.7-liter (1-gal) containers in a pine bark and sand medium (6:1, v/v). The medium was amended with 4.8 kg m^{-3} (8 lb yd^{-3}) dolomitic lime, 3.0 kg (5 lb yd^{-3}) Micromax (The Scotts Co., Marysville, Ohio), and 7.4 kg m^{-3} (12.5 lb yd^{-3}) 24N-$1.8P_2O_5$-$10K_2O$ (Polyon 24-4-14, 12-month formulation, Pursell Industries, Sylacauga, Ala.). Plants were grown under 47% shade and irrigated by overhead rotary nozzles twice daily for 30 min per application, for a total of 3 cm (1.2 in) per day.

On 7 July 1995, 50 single-eye (no offsets) plants of each cultivar were selected for uniformity, and 10 plants of each cultivar were randomly assigned to each of five treatments, 0, 1, 2, 3, or 4 foliar applications of 3000 ppm BA (Abbott Laboratories, N. Chicago, Ill.). Buffer-X (Kalo Agr. Chemicals, Inc., Overland Park, Kan.) at 0.2% was added to all BA solutions as a surfactant prior to foliar application at 0.5 gal per 100 ft^{-2} (0.2 liter m^{-2}). Application was made with a CO_2 sprayer fitted with a cone nozzle at 30 psi (207 kPa). At commencement of the study, 40 plants of each cultivar received BA treatment and 10 untreated controls of each cultivar did not. Plants were completely randomized within cultivar following initial treatment. At 30-day intervals thereafter, all offsets were removed from each plant. The number of treated plants was then reduced each time by 10, and BA was reapplied to the remaining plants, resulting at 90 days after initial treatment (DAT) in a total of five treatments.

At 30, 60, 90, and 120 DAT, visible offset counts and a growth index [(height + width at widest point + width 90° to first width)/3] were determined for each plant. Offsets present were removed from each plant, and offset stage of development, based on number of unfurled leaves, was determined for each offset. Data were tested by analysis of variance, using SAS General Linear Model procedure, and single degree of freedom contrasts were used to make specific planned comparisons (SAS Institute, 1988).

RESULTS AND DISCUSSION

As in previous studies (Keever, 1994), BA application promoted formation of offsets in hosta. At 30 DAT, offset counts were higher in treated plants of both cultivars compared to untreated controls (Table 1). At 60 DAT, plants of 'Frances Williams' that received two BA applications had more offsets than controls or plants that received only one BA application. In 'Francee' at 60 DAT, sufficient offsets had

formed in controls such that offset counts in plants that received one or two BA applications were similar to controls. At 90 and 120 DAT, plants of both cultivars that were retreated following offset removal had higher offset counts than controls or plants not retreated. Repeated BA application was required to achieve a continued response in offset production, but removal of offsets prior to reapplication of BA did not appear to affect subsequent response to BA. Total offset yield over the 120-day duration of the study increased with an increasing number of BA applications. Total yield of offsets with 0, 1, 2, 3, or 4 BA applications was 9.8, 9.5, 13.9, 17.4, or 22.0 for 'Francee' and 0, 6.3, 8.6, 14.0, or 18.2 for 'Frances Williams', respectively. Compared to controls, there was a 124% increase in offset counts for plants of 'Francee' that received four BA applications. With four BA applications, 'Frances Williams' averaged 18 offsets per plant, while no offsets formed in controls over the 120-day period. Growth index or offset stage of development were generally not affected by BA treatment (data not shown).

SUMMARY

These data indicate that hosta stock plants can be treated with BA at 30-day intervals throughout the growing season to provide greater numbers of offset cuttings than could otherwise be obtained by conventional division. Offset formation in response to BA application was cultivar-dependent, but in either cultivar, repeated application was required for a continued response, and offset removal did not prevent subsequent response to BA. BA application can promote offset formation in cultivars that readily form offsets and those that do not. By increasing the number of propagules available, introduction and multiplication of cultivars, including those which do not readily form offsets, may be accelerated. A practical system for the accelerated multiplication of hosta may increase propagation efficiency and decrease production costs. These findings are a significant step toward the development of such a system.

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Table 1. Offset counts, 1995, at 30, 60, 90, and 120 days after initial treatment (DAT) in two hosta cultivars treated with 0, 1, 2, 3, or 4 applications of 3000 ppm BA.

	Offset number									
	Application number					Application number				
DAT	0	1	2	3	4	0	1	2	3	4
	'Francee'					'Frances Williams'				
30	3.7	4.5	-	-	-	0.0	3.9	-	-	-
60	4.9	3.6	5.9	-	-	0.0	2.4	3.7	-	-
90	1.2	1.4	3.5	6.0	-	0.0	0.0	1.0	5.4	-
120	0.0	0.0	0.0	1.0	5.6	0.0	0.0	0.0	1.0	5.2

Significant contrast:[z]

DAT	Application number	
	'Francee'	'Frances Williams'
30	0 v. 1	0 v. 1
60	-	0 v. 2, 1 v. 2.
90	0 v. 3, 1 v. 3, 2 v. 3	0 v. 3, 1 v. 3, 2 v. 3
120	0 v. 4, 1 v. 4, 2 v. 4, 3 v. 4	0 v. 4, 1 v. 4, 2 v. 4, 3 v. 4

[z] Single degree of freedom contrast. $P \leq 0.05$.

Azaleas For the 21st Century

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INTRODUCTION

When my father and I began our liner nursery in 1990, we produced a broad line of woody ornamentals and azaleas in 7.6-cm (3-in.) pots and rooted cuttings. As our business developed, we began to look for market alternatives to the general ornamental line. We began our search with the question of "What can we produce in this area which would fill a unique, marketable need in the industry?" Since Mobile County, Alabama produces more azaleas per square mile than anywhere in the United States, azaleas seemed like a reasonable starting point to look for an answer.

Quickly we found that we were dealing with a plant group which have been actively hybridized for the past fifty years with few commercial outlets in the market. While the wholesale industry at large was producing greater and greater quantities of azaleas, backyard enthusiasts were producing better and better quality plants. Typically, these new azaleas were traded among enthusiasts or released to specialty growers with limited markets.

If indeed we had found a unique product within our industry, then we needed to address the "marketable"aspect of our original question; "Will the public buy them?" This was simple enough to test. We set out our current "test"azaleas with the rest of our crop and paid attention to the reactions of our customers—typically wholesale growers and retail nurserymen. The results were surprising. The average retail customer was overwhelmingly enthusiastic. They were excited by the prospect of a unique and markedly better azalea. The wholesale grower on the other hand would inquire about the plants, what they were and where we found them, then proceed to buy the standard varieties.

Public reaction has reinforced our beliefs that a strong potential market exists for unique azaleas; much greater than for roses, particularly with the high cultural care required of roses. Marketing of new azalea selections has been lacking.

WORKING WITH AZALEA HYBRIDIZERS

My company has worked closely with three modern Azalea breeders: Ronald "Pete" Vines, and Charles and Wanda Hanners. We have intentionally chosen to introduce and propagate plants which are not easily available to the market. Several of these breeders' selections have just been released this year. In the remainder of this paper, I summarize the methodology and objectives of these breeders — and describe some of their selections.

RONALD VINES

Ronald "Pete" Vines, a retired Army Colonel who began breeding 'Holly Springs' hybrids in 1978 in the Washington, D.C. area. He currently resides in Amelia Island, Florida. From 491 crosses and 46,000 seedlings he has named 90 cultivars. These were closed-pollination crosses designed to produce azaleas with: (1) larger blooms,

(2) the sharp clean colors found in the Satsuki azaleas, (3) a dwarf to mid-size growth habit, and (4) increased cold hardiness [typically -20C (-5F) or below]. In making his selections, Col. Vines developed a matrix of azalea characteristics (i.e., color, habit, flower form) and chose the best representative from his extensive collection to epitomize each combination in his matrix. If a seedling was not significantly superior to his standard, it was discarded.

What follows is a selection and short description of his hybrids extracted from his 1990 catalog. Bloom times are for the Washington, D.C. area. Plant hardiness is -20C (-5F) unless otherwise indicated.

'White Peacock' (Glacier × Mother of Pearl). Flowers have a 6-cm (2.5-in.) white feathered hose in hose with light green blush, long tapered petals with space between sets. Blooms 5 May. Hardy to -23C (-10F).

'Rebecca Lynn' (RH Frosty × Easter Parade). Flowers have a 6- to 8-cm (2.5- to 3-in) soft peachy-pink semidouble with yellow-green blotch and lighter margins, white marbling, frilled lobes, and very floriferous. Blooms 10 May.

'Shenandoah' (Hotshot × Gloria Kessel). Flowers have 6-cm (2.5-in.) deep red hose in hose, frilled lobes, 2 to 3 per head and very floriferous. Blooms 29 April. Hardy to -23C (-10F).

'Peggy Vines' (Nancy of RH × Shinnyo no Tsuki). Flowers have 8- to 10-cm (3- to 4-in.) light pink variegated double with very dark red variegation, tips, and marbling, two to head with a flat face and ruffled lobes. Blooms 15 May.

'Doctor Fred Vines' (Chiyoda Nishiki × Juko). Flowers have 6- to 8-cm (2.5- to 3-in.) white single with green blush and very heavy red sanding, two to head. Blooms 5 June.

'Jeffrey Alan' (Nancy of RH × Shinnyo no Tsuki). Flowers have 8- to 10-cm (3- to 3.75-in.) strong reddish coral double with dark red blotch, beautiful urn shaped buds and frilled lobes. Blooms 18 May.

'Astronaut' (Amaghasa × Sekai no Hikari). Flowers have 10- to 13-cm (4- to 5-in.) variable white single with light green blotch and light pink wash, few pink to rosy red lines and dashes, six ruffled and imbricated lobes. Blooms 1 June.

'Becky's Blush' (Glacier × Mother of Pearl). Flowers have 6-cm (2.25-in.) light pink hose in hose with rosy red blotch and white throat, darker margins, very showy in bud form. Blooms 10 May.

HS 86-48-36 (Achievement × Winedrop). Flowers have 6-cm (2.5-in.) variable white single with very heavy lavender sectors, lines, sanding, and selfs. Blooms 5 May.

'Painted Lips' (Kamino yama Kirin × Dorothy Clark). Flowers have 6- to 8-cm (2.5- to 3-in.) very light pink bi-color single with strong red to hot pink margins, star shaped bloom of very heavy substance. Blooms 28 May.

HS 85-39-6 (Kotobukihime × Variegated Dogwood). Flowers have 6-cm (2.5-in.) variable white single with red lines, dashes, sectors and sanding, larger and stronger colors than Germanique. Blooms 1 May.

'Jill McDowell' (Kotobukihime × Crimson Queen). Flowers have 6-cm (2.5-in.) variable single. blooms include: coral with narrow white margin, coral with red sectors, white with red and coral pink sectors and sanding, red and white selfs, two to head, rounded lobes. Blooms 22 May.

HS 85-62-3 (Opal × Presto). Flowers have 6- to 9-cm (2.5- to 3.5-in.) variable white double/semidouble with purplish pink sanding, lines, sectors, and a light green blush, some purplish pink and white selfs, excellent fall bloomer. Blooms 5 May.

'Saint Moritz' (Nancy of Robin Hill × Shinnyo no Tsuki). Flowers have 6- to 8-cm (2.5- to 3-in.) formal white double with strong green blotch, rosebud form with 15 - 20 petals, two - three per head and very floriferous. Blooms 26 May.

HS 86-60-8 (Gyoko × Festive). Flowers have 6-cm (2.5-in.) variable white single with coral pink and strong red sectors, lines, sanding, blooms 2 weeks later than 'Festive' with strong Satsuki colors in the early Spring. Blooms 24 April.

CHARLES AND WANDA HANNERS

Charles and Wanda Hanners of Azalea Trace Nursery in Huntington, Maryland began their breeding program in 1982 "for fun". They germinated seed from over 200 open-pollinated crosses each year until 1990 — selecting out the strongest, most viable seedlings.

Additionally, some seed from the American Rhododendron Society and Azalea Society of America seed exchange programs were used. Seedlings were transplanted into 3.8 liter (1 gal) containers, and re-evaluated after 1 year. Approximately 3500 1-gal plants were planted at the nursery from over 10,000 original seedlings. From this group the Hanners anticipate they will register "probably no more than six or so". Their baseline for evaluation is their collection of more than 1700 cultivars.

The following are short descriptions from selections of their hybrids.

All plants are hardy in Zone 7 to 6. Bloom dates are for the Washington, D.C. area.

83-S-27, 99-01. Flowers have 6-cm (2.5 in.) deep rose red double, very low and floriferous. Blooms 18 May.

83-S-20, 03-56. Flowers have 5-cm (2-in.) light pink double with strap-like petals. Blooms 5 June.

NO ID, 99-419. Flowers have 6-cm (2.5-in.) light pink petaloid with rose pink margins, heavily ruffled and washed with white. Blooms 13 May.

83-S-1, 02-064. Flowers have 4- to 5-cm (1.5- to 1.75-in.) white single with crimson blotch and yellow-green throat edged in crimson, very floriferous. Blooms 12 May.

82-S-2, 99-470. Flowers have 9-cm (3.5-in.) dusty rose single, dark red-orange blotch, two to head, ruffled. Blooms 17 May.

82-S-2, 4-13. Flowers have 5-cm (2-in.) old rose single with pointed lobes, tyrolian blotch in a pink to white center. Blooms 12 May.

82-S-008, 99-272. Flowers have 5-cm (2-in.) blood red single, two - four per head, heavy substance. Blooms 10 May.

82-S-26, 99-353. Flowers have 5- to 6-cm (2- to 2.5-in.) single white with pink tints, prominent red blotch, light yellow throat, very heavy bloomer. Blooms 14 May.

82-S-28, 99-548. Flowers have 4-cm (1.8-in.) white single with strong lavender edges, cream throat, lobes pointed and long, very orchid-like effect. Blooms 18 May.

83-S-20, 99-551. Flowers have variable light pink single, occasional dark pink stripes, distinctive dark pink blotch, wavy. Blooms 18 May.

'Flat Face', 82-S-017, 99-242. Flowers have 6-cm (2.5-in.) strong red single, crinkly with flat face, short yellow stamens, very floriferous. Blooms 10 May.

83-S-30, 99-386. Flowers have 5- to 6-cm (2- to 2.5-in.) variable white single, deep red stripes and sectors, occasional white or red selfs, chartreuse blotch. Blooms 14 May.

84-S-35, 99-513. Flowers have 8-cm (3-in.) very light pink single, six rounded lobes, white picotee edges, dark red blotch. Blooms in August.

83-S-92, 99-285. Flowers have 3- to 4-cm (1- to 1.5-in.) pale pink single, pointed arched lobes with a very showy yellow blotch, three - four per head, long rose red stamens. Blooms 16 June

84-035, 99-512. Flowers have highly variable white, six rounded lobes, strong red and white selfs, light pink with strong red blotch, white with sectors and stripes of dusty rose red, stunning, Blooms in August.

SUMMARY

If any of my slide presentation captured your interest, then imagine the thousand-fold increased interest from your potential new customers. As the mass merchants continue to encroach on the retail nursery industry, the independent retailer will need to find and improve their niches. Two important options for the independent are service and variety.

Variety development in azaleas has been underexploited. As breeders across the country continue to improve the hybrids suitable to our climate, the stage is set for a commercial upheaval of the plants currently grown. We believe the time is now.

Dogwood Propagation from Cuttings

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Trail Ridge Nursery is located in northeast Florida, halfway between Gainesville and Jacksonville and about 50 miles south of the Florida-Georgia state line. We are on the southern edge of USDA Hardiness Zone 8b. We are a wholesale container tree nursery specializing in cultivar trees with an emphasis on flowering dogwood (*Cornus florida*) and southern and oriental magnolias (*Magnolia* spp.).

We initially grew our flowering dogwood from seed. However, we realized that seed propagation did not produce a uniform crop. We were ending up with a large number of unacceptable trees and the good trees would not flower for several years, if at all. We then decided to put our efforts into growing named cultivars only.

In evaluating several named dogwood cultivars, we found that most did not grow well for us. We felt that it was probably because they were selections from areas farther north and not well adapted to our area. We did, however, have one white-flowering form that was a much superior tree, both in vigor and flowering characteristics. It was a selection made by Dr. H. H. Hume in the mid-1940s. It is believed the parent tree was from Gainesville, Florida. He named it 'Weaver's White' for a University of Florida professor. The tree was put into commercial production by two nurseries (Glen St. Mary and Holmes Nurseries) and became well known and accepted. At that time the method of propagation was by field budding. However, as budders and grafters became harder to find, production fell off and finally ceased.

We have found the tree relatively easy to root and the following is the procedure we are currently using.

We take 15- to 20-cm (6- to 8-in.) terminal cuttings from the first flush of growth which is normally in late June or early July. Our criteria for when the cuttings are ready is when the tip is rigid enough to support itself. They will root at an earlier stage but if the tip bends over while in the mist a crooked tree is produced which is unacceptable for our standards. The cuttings are taken to the misthouse where the lower leaves are removed, leaving 4 to 6 leaves — depending on leaf size. The cuttings are then given a brief fungicidal bath of Tilt followed by a basal quick dip of 5000 ppm KIBA. The cuttings are then stuck in benches of pure horticultural perlite and misted. Our average mist cycle is 6 sec every 16 min, depending on weather conditions.

In 3 weeks we start looking for rooting. When we begin to get good rooting on some cuttings, we pull up all the cuttings and sort them into four groups: well rooted, lightly rooted, callused, and those showing no activity. The first three groups are potted into 6-cm (2.5-in.) rose pots and kept separate in the misthouse. The remaining cuttings are restuck in perlite media. This process continues until we determine there will be no more rooting, at which time the remaining cuttings are discarded.

We continually check the potted trees and individually remove them from the mist when they have an established root system. These are moved to a hardening-off house and placed on benches where they are watered twice a day and periodically fertilized with a liquid fertilizer. We have lights over the benches and use them to

extend the day length by 4 h. We have found that this helps to get the cuttings to flush out and begin growth before the winter. If no growth flush occurs before winter, the survival rate drops dramatically. When the trees are fully rooted out and have flushed out they are shifted up to 3.8-liter (1-gal) containers and moved out to ground beds under full sun with overhead rainbird-type irrigation. In areas farther north with shorter growing seasons, the finished liners would likely have to be held in a greenhouse over winter.

We have used these procedures for over 10 years and have found them to be successful for other cultivars as well as with 'Weaver's White'. Our initial rooting yield is around 80% and we normally lose another 10 to 20% of the trees between rooting and the potting up procedure. The 1-gal trees are shifted up to 11-liter (3-gal) containers the summer after propagation and we end up with trees that are 0.9 to 1.2 m (3 to 4 ft) by fall.

Variations in pH from Different Bark Sources

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Management of medium pH is an important consideration in commercial production of nursery crops. Bark source, fertilizer source, and dolomitic lime application rate are significant factors in pH management, while dolomitic lime source is not significant. Plant growth is influenced depending upon timing of fertilization and optimum pH for the species being grown.

INTRODUCTION

Growers in the southeastern United States are currently producing container-grown ornamental plants in a wide range of medium components. Pine bark has been the primary media component. In Louisiana, pine bark is widely used, but for the last several years limited availability of "high quality" pine bark has led several bark suppliers to initiate delivery of hardwood bark or bark sources having a combination of pine and hardwood. Wide pH fluctuations in bark that is currently being utilized has created problems with proper adjustment of dolomitic lime rates and selection of slow-release fertilizers. It is very important to recognize not only the influence of bark source on medium pH but also the role of fertilizer source (Table 1), fertilizer rate, fertilization frequency, water quality, and bark age in pH management. With these considerations, a study was conducted to determine the role of bark sources, fertilizer sources, dolomitic lime application rates, and dolomitic lime sources on leachate pH from container medium over a 12-month production period. Treatment effects on shoot growth of *Liriope muscari* 'Variegata' and *Juniperus horizontalis* 'Wiltoni' (syn. 'Blue Rug') were recorded.

MATERIALS AND METHODS

One 17 June 1994, a 3 (bark source) × 2 (fertilizer source) × 4 (dolomitic lime application rate) × 2 (dolomitic lime source) × 2 (plant species) factorial experiment was initiated. Each treatment was replicated four times in a randomized complete block design. Bark sources used were pine bark, blended hardwood bark, and a combination (1:1, v/v) of these two bark sources. Fertilizer sources were Nutricote 17-7-8 (Type 270) and SierraBlen 18-7-10 applied at experiment initiation at an incorporated rate of 1.2 kg m^{-3} (2 lb yd^{-3}). Plant species were *L. muscari* 'Variegata' and *J. horizontalis* 'Wiltoni'. All medium treatments contained an incorporated application of Micromax at 0.9 kg m^{-3} (1.5 lb yd^{-3}) applied at planting. Plants were grown in the gallon-container production area at Adams Nursery, Forest Hill, LA. Overhead irrigation and weed control were provided under the cultural practices typically employed by the nursery.

Leachate pH was determined at 3-month intervals for one year (18 June 1994, 10 Sept. 1994, 9 Dec 1994, 3 Mar. 1995, and 23 June 1995). These dates corresponded to 0, 3, 6, 9, and 12 months after initiation. Shoot dry weight of liriope and juniper

was determined on 23 June 1995 by harvesting the plant at the medium level and drying the resultant plant material at 70C (158F) for 72 h.

Table 1. Reaction and influence on pH of commonly used nutrient sources in container nursery crop production.

Nutrient source	Reaction speed	pH response
Dolomitic lime	medium	alkaline
Gypsum	medium	neutral
Epsom salt	rapid	neutral
Aluminum sulfate	rapid	acid
Elemental sulfur	slow	acid
Urea formaldehyde	slow	acid
Ammonium sulfate	rapid	acid
Sodium nitrate	rapid	alkaline
Calcium nitrate	rapid	alkaline
Potassium nitrate	rapid	acid
Urea	rapid	slightly acid
Superphosphate	medium	neutral

RESULTS AND DISCUSSION

Leachate pH. Leachate pH was influenced over the 1-year evaluation period by fertilizer source, bark source, and dolomitic lime application rate (Table 2). Dolomitic lime source was not a significant factor in adjustment of leachate pH.

Blended hardwood bark had an initial pH of 6.7 and remained stable for most of the evaluation period before gradually increasing to 7.0 by the end of the study. The largest change in leachate pH for the pine bark medium occurred during the first 3 months. SierraBlen 18-7-10 and Nutricote 17-7-8 had similar leachate pH until after the second fertilizer application in March 1995, 9 months after initiation. Sierra Blen has been shown to be more acid forming than other slow-release fertilizer sources.

While application rate of dolomitic lime influenced leachate pH, the addition of this material, regardless of rate, does not appear to influence leachate pH after 6 months. The differences in leachate pH due to dolomitic lime application rates were nonsignificant 9 and 12 months after application.

Plant Growth. Shoot dry weight of *L. muscari* 'Variegata' was influenced by bark source, fertilizer source, and dolomitic lime application rates, while *J. horizontalis* 'Wiltoni' had shoot dry weight differences attributed to bark source and dolomitic lime application rates (Table 3). Liriope had the highest shoot dry weight when grown in the pine bark medium. SierraBlen 18-7-10 produced greater shoot dry weights in liriope than Nutricote 17-7-8 at 12 months after treatment initiation. This was probably due to the increased "up front" release of nutrients from SierraBlen following the second fertilizer application several months prior to harvest. Nutricote-fertilized liriope had greater visual quality ratings at 9 months after treatment when compared to SierraBlen-fertilized plants (date not shown). Dolomitic lime application increased shoot dry weight of the liriope.

Wiltoni juniper had the greatest shoot dry weight when grown in the blended hardwood bark. Increases in the application rate of dolomitic lime decreased shoot dry weight from 42 to 39 grams.

Table 2. Average leachate pH of nursery media at 3-month intervals as influenced by bark source, fertilizer source, dolomitic lime source, and dolomitic lime applicator rate.

	6/18/94	9/10/94	12/9/94	3/3/95	6/23/95
Bark source					
Blended hardwood	6.74	6.49	6.67	6.75	6.99
Pinebark	4.30	5.90	6.07	6.40	6.32
Hardwood + pinebark	5.68	6.32	6.52	6.56	6.70
Fertilizer source					
Nutricote 17-7-8	5.64	6.26	6.45	6.60	6.77
Sierrablen 18-7-10	5.50	6.20	6.39	6.60	6.57
Dolomitic lime source					
Micro-encapsulated	5.70	6.29	6.47	6.56	6.68
Pulverized	5.57	6.28	6.47	6.57	6.68
Dolomitic lime application rate					
0 kg m^{-3} (0 lb yd^{-3})	5.18	5.88	6.14	6.60	6.62
3 kg m^{-3} (5 lb yd^{-3})	5.51	6.15	6.37	6.59	6.60
6 kg m^{-3} (10 lb yd^{-3})	5.88	6.31	6.48	6.54	6.71
9 kg m^{-3} (15 lb yd^{-3})	5.72	6.39	6.55	6.57	6.73

Table 3. Shoot dry weight (grams) of *Liriope muscari* 'Variegata' and *Juniperus horizontalis* 'Wiltoni' as influenced by bark source, fertilizer source, dolomitic lime source, and dolomitic lime application rate.

	Liriope muscari ' Variegata'	*Juniperus horizontals* 'Wiltoni'
Bark source		
Blended hardwood	23.89	42.82
Pinebark	28.72	37.32
Hardwood + pinebark	24.87	39.22
Fertilizer source		
Nutricote 17-7-8	23.25	39.22
Sierrablen 18-7-10	28.40	40.35
Dolomitic lime source		
Micro-encapsulated	26.48	40.22
Pulverized	25.84	38.71
Dolomitic lime application rate		
0 kg m^{-3} (0 lb yd^{-3})	23.82	41.72
3 kg m^{-3} (5 lb yd^{-3})	27.03	41.65
6 kg m^{-3} (10 lb yd^{-3})	25.13	38.38
9 kg m^{-3} (15 lb yd^{-3})	26.33	38.35

CONCLUSION

Monitoring leachate pH in container production of nursery crops is an important factor that needs to be considered. Bark pH is very important in determining plant growth performance and nutrient management. Dolomitic lime plays an important role in nutrient management and bark pH during the first 3 to 6 months of production, but is not a significant factor after 6 months. Reapplication of dolomitic lime may need to be considered depending on the plant species being grown, water quality, fertilization practices, and other production factors.

Short History of the International Plant Propagators' Society

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History is important – what has happened in the past can guide us in the future.

I.P.P.S. is based on the sharing of ideas and experiences that can help us all in our work in the future.

Mr. Jim Wells of New Jersey, U.S.A. was responsible for the early development of I.P.P.S. Jim, now 82, was the first President and it was his enthusiasm that saw new Regions develop in England, New Zealand, and Australia.

1951. The first meeting of the Plant Propagators' Society was held in Cleveland, Ohio, U.S.A. About 80 people attended and a number of interesting papers were presented, including the first written paper on rhododendron propagation. Rules and guidelines were set down—many are still with us today. The most important is not "where you work or where you come from; it is you the propagator who is important. It is what you do, what your knowledge is, and how much you are willing to share your knowledge that counts". The motto is important, "Seek and Share". We can all learn from and share with each other.

DEVELOPMENTS OF I.P.P.S.

1960. Western Region formed for West Coast of U.S.A.

1961. Name changed to "International" Plant Propagators' Society.

1968. Region of Great Britain and Ireland formed.

1972. New Zealand Region formed.

1973. Australian Region formed.

1976. Southern Region of U.S.A. formed.

1992. Danish Region formed.

1993. Potential Regions of Japan and South America initiated.

1997. Japan gains regional status, Potential Region of Southern Africa formed.

The last decade of this century is an exciting time for I.P.P.S. and we are becoming truly international with the acceptance of non English speaking regions. We can all benefit from the exchange of ideas.

Although the secretariat for I.P.P.S. is in the U.S.A., annual meetings of the Board of Directors are held in a different region each year. Each region has a director on the Board, usually a past-president of a region. The Japanese Region will host the Board meeting in 2004.

Vegetative Propagation of Apricot (*Prunus armeniaca* L.) by Softwood Cuttings

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Apricot (*Prunus armeniaca* L.) cultivars were propagated by softwood cuttings in order to evaluate rooting ability. 'Heiwa' cuttings with IBA (indolebutyric acid) treatment inserted in June gave the highest rooting rate, while rooting did not occur in August or later. 'Heiwa' cuttings without IBA treatment did not root, regardless of the timing of cutting collection. Optimal IBA treatment for rooting of 'Heiwa' was investigated. The highest rooting rate and the largest number of roots per rooted cutting were obtained when the cuttings were soaked in 80 ppm IBA solution for 20 h. Cultivar difference in rooting ability was evaluated using five cultivars. Rooting rate varied from 63.3% for 'Shinshuohmi' to 96.7% for 'Alfred'. Larger numbers of roots were associated with the cultivars that had the higher rooting rates.

INTRODUCTION

Apricot cultivars are difficult-to-root from cuttings. Therefore, they have been propagated by grafting onto non-uniform seedling rootstocks. Propagation through cuttings is the most convenient, easy, rapid, and least expensive method. In addition, the problem of incompatibility due to poor graft union formation does not arise with the cutting method. In our previous study, apricot cultivars had very poor rooting ability as hardwood cuttings (Murai et al., 1994). However, propagation through softwood or semihardwood cuttings was often found to be successful with other difficult-to-root species, using mist and auxin treatments (Couvillon, 1982; Hartmann and Hansen, 1955a; 1958b; Sharma and Aier, 1989). However, there is only limited information on rooting softwood cuttings of apricot.

In the present study, we evaluated the rooting ability of softwood cuttings of apricot cultivars.

MATERIALS AND METHODS

Plant Materials. Donor plants of six cultivars ('Heiwa', 'Shinshuohmi', 'Niigataohmi', 'Bakuohjunkyou', 'Yamagata-3', and 'Alfred') were used and grown in an experimental field at Shizuoka University. They were healthy, uniform, and moderately vigorous trees.

Seasonal Changes in Rooting Response. 'Heiwa' cuttings were collected from 2 June to 3 Sept., 1994. Subterminal cuttings 12 cm long were collected from the

upper parts of long shoots. All but the terminal three leaves were removed. All cuttings were soaked in distilled water for 20 h. The bases of half of them were dipped into 4000 ppm IBA (indolebutyric acid) solution for 10 sec, while the rest were left untreated. All cuttings were then inserted into coarse vermiculite under intermittent mist for 20 sec every 40 min. They were removed from the vermiculite after 40 days, and rooting was scored based on survival, rooting rate, and number of roots per rooted cutting.

Optimal IBA Treatment for Rooting. 'Heiwa' cuttings were collected from the upper parts of long shoots in early June and prepared as described above. The bases were soaked in 0, 20, or 80 ppm IBA solution for 20 h, or dipped into 4000 ppm for 10 sec. All cuttings were inserted into vermiculite, and rooting response was recorded as described above after 40 days.

Cultivar Difference in Rooting Ability. Cuttings were collected from the upper parts of long shoots of five cultivars ('Shinshuohmi', 'Niigataohmi', 'Bakuohjunkyou', 'Yamagata–3' and 'Alfred') on 3 June 1995. Cuttings for each cultivar were prepared as described above, and soaked in distilled water for 20 h. Then, the bases were dipped into 4000 ppm IBA solution for 10 sec, and inserted into vermiculite. After 40 days, rooting response was evaluated as described above.

RESULTS AND DISCUSSION

Table 1 shows changes in rooting response of 'Heiwa' apricot. Survival rates of cuttings ranged from 60% to 100% during this experiment. Cuttings collected in June (30.0%) and July (16.7%) rooted with the IBA treatment. Cuttings collected in August or later did not root. Without IBA treatment, cuttings did not root, regardless of the timing of collection. A larger number of roots occurred with the higher rooting rates. The rooting rates of deciduous trees increase from spring to summer, and then decrease from autumn to winter. It has been suggested that rooting is closely related to bud dormancy (Genma,1987; Fadl and Hartmann, 1967), therefore, rooting ability might reasonably be poor after August.

Table 1. Seasonal changes in rooting ability of 'Heiwa' apricot cuttings.

Date cuttings collected (month/day)	IBA treatment	Survival rate(%)	Rooting rate(%)	No. of roots per rooted cutting
6/2	+	80.0	30.0	15.6±2.0[y]
	-	70.0	0	-
7/3	+	60.0	16.7	4.2±1.0
8/2	+	63.3	0	-
	-	80.0	0	-
9/2	+	100	0	-
	-	90.0	0	-

[z]The bases of each cutting were dipped into 4000 ppm IBA solution for 10 sec
[y]Each value represents mean ± standard error.

Optimal IBA treatment for rooting was investigated. Table 2 shows the rooting response to various IBA treatments with 'Heiwa' apricot. The survival rate varied from 53.3% when soaked in 80 ppm IBA solution to 86.7% when dipped in 4000 ppm solution. The highest rooting rate was obtained with cuttings soaked in 80 ppm IBA solution, followed by 20 ppm IBA solution and then dipping in 4000 ppm solution. However, cuttings without IBA treatment did not root. Larger numbers of roots were associated with the treatment having the higher rooting rate. Based on the results in Table 1 and 2, it is evident that 'Heiwa' has a poor rooting ability. In addition, timing of cutting collection and IBA treatment are very important factors in rooting softwood cuttings.

Table 2. Rooting of 'Heiwa' apricot cuttings as affected by IBA concentration

IBA concentration (ppm)	Survival rate(%)	Rooting rate(%)	No.of roots per rooted cutting
0	83.3	0	-
20[Z]	73.3	30.0	6.2±1.0[X]
80[Z]	53.3	43.3	14.1±1.5
4000[Y]	86.7	33.3	12.0±1.2

[Z]Soaking in 20 ppm or 80 ppm IBA solution for 20 h.
[Y]Dipping into 4000 ppm IBA solution for 10 sec.
[X]Each value represents mean ± standard error.

Table 3. Cultivar difference in rooting ability of apricot cuttings[z].

Cultivar	Survival rate (%)	Rooting rate (%)	No.of roots per rooted cutting
Bakuohjunkyou	93.3	16.7	4.6±1.4[Y]
Shinshuohmi	63.3	6.7	3.5±2.5
Niigataohmi	100	23.3	6.0±1.0
Yamagata-3	83.3	43.3	12.3±1.6
Alfred	96.7	86.7	10.4±1.4

[Z]The base of each cutting for all cultivars was dipped into 4000 ppm IBA solution for 10 sec.
[Y]Each value represents mean ± standard error.

The differences in rooting ability among five cultivars is shown in Table 3. Survival rates varied from 63.3% for 'Shinshuohmi' to 100% for 'Alfred'. 'Alfred' had a rooting rate of more than 80%, while, 'Niigataohmi', 'Bakuohjunkyou', and 'Shinshuohmi' had a rooting rate of less than 30%. Larger numbers of roots were associated with the better rooting rates as described above. Nemeth (1986) reported that rooting depended on genotype in many woody species in the Rosaceae. Therefore, similar results might occur in this experiment.

Based on the above results, further experiments are necessary to clarify the optimal conditions for the rooting of cuttings.

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Vegetative Propagation of Japanese Plum (*Prunus salicina* Lindl.) by Softwood Cuttings

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Seasonal changes in rooting ability, effect of IBA treatment, and cultivar difference in rooting ability of softwood cuttings of Japanese plum cultivars were investigated. When treated with IBA, the cuttings stuck in June gave the highest rooting rate. The rooting rate gradually decreased and plants did not root in September. Without IBA treatment, the highest rooting rate was obtained in May and rooting did not occur later than July. Soaking the basal portions of the cuttings in 20 or 80 ppm IBA solution for 20 h and dipping the basal portions of the cuttings into 4000 ppm IBA solution for 10 sec gave similar rooting rates. The number of roots per rooted cutting was greater with the IBA treatment at 20 or 80 ppm than the 4000 ppm dipping treatment. There was a great variability in the rooting ability among Japanese plum cultivars. Rooting rates varied from 24% for 'King' to 100% for 'Methley'.

INTRODUCTION

Japanese plum (*Prunus salicina* Lindl.) has been propagated by grafting onto rootstocks. Recently, interest in own-rooted plants has increased. High-density planting using own-rooted plants requires a large number of trees at low cost (Couvillon and Erez, 1980). Inexpensive plum trees can be produced using softwood cuttings. In this study, we investigated the seasonal changes in rooting ability, the effect of IBA treatments, and cultivar differences on the rooting ability of Japanese plum cultivars.

MATERIALS AND METHODS

Seasonal Changes in Rooting Ability. Softwood cuttings were collected monthly from May until September from field-grown 'Oishi-wase' Japanese plum trees. At each date the cuttings were prepared from long shoots. Cutting length was about 12 cm and had three distal leaves. After treating the basal ends of the cuttings with IBA at 4000 ppm for 10 sec, the cuttings were stuck in the rooting medium under mist. The rooting medium was coarse vermiculite. The beds were situated in a glasshouse with a natural ambient temperature, and natural daylight and daylength. Intermittent mist was applied for 10 sec every 30 min. The rooting percentage and number of roots per rooted cutting were recorded after the rooting period (30 days).

Effects of IBA Concentration on Rooting. In July, the cuttings of 'Oishi-wase' were collected and prepared as described above. The basal portions of the cuttings were immersed in IBA solution at 0, 20, 80 ppm for 20 h or dipped in 4000 ppm IBA solution (50% EtOH solution) for 10 sec. The cuttings were planted in vermiculite under mist as previously described. The cuttings were evaluated after 30 days for the number of cuttings that survived, the number that rooted and the number of

roots per rooted shoot.

Cultivar Difference in Rooting Ability. The difference in rooting ability of five cultivars ('King', 'Sordum', 'Methley', 'Santa Rosa', 'Taiyo') was evaluated. Cuttings of each cultivar were collected and prepared in July. The cuttings were treated by dipping the basal portion in an IBA 4000 ppm solution for 10 sec. The cuttings were planted in vermiculite under mist as previously described. They were evaluated after 30 days for the number of cuttings that survived, the number that rooted, and the number of roots per rooted shoot.

RESULTS AND DISCUSSION

Seasonal changes in the rooting ability of 'Oishi-wase' plum from May to September are shown in Table 1. When treated with IBA, the cuttings stuck in June gave the highest rooting rate (93.5%), the rooting rate gradually decreased and cuttings stuck in September failed to root. Without IBA treatment, the highest rooting rate (33.3%) was obtained in May and rooting did not occur later than July.

Table 1. Seasonal changes in rooting ability of 'Ooishi–Wase' plum cuttings.

Date of cutting collection (month/day)	IBA treatment[z]	Survival rate (%)	Rooting rate (%)	No.of roots per rooted cutting
5/17	+	93.3	76.6	11.8
	-	100	33.3	2.7
6/3	+	100	93.5	12.8
	-	93.1	18.5	4.0
7/6	+	66.7	66.7	9.9
	-	68.0	0	-
8/1	+	75.9	20.7	6.5
	-	92.9	0	-
9/2	+	92.0	0	-
	-	100	0	-

[z]The IBA treatment was applied by dipping the base 1 cm of each cutting into a 4000 ppm IBA solution for 10 sec.

The time of cutting collection has an important influence on rooting (Couvillon, 1988). For softwood cuttings of deciduous species, the best rooting is generally obtained if the cuttings are taken when the leaves are fully expanded and the shoot have attained some degree of maturity (Hartmann and Kester, 1975). Many cultivars of peach root best when the cuttings are taken in July rather than any other time of year (Couvillon et al., 1975). Sharmar and Aier (1989) reported that plum cuttings stuck during summer under mist gave better rooting than autumn cuttings. The results in this paper were in accordance with other reports. However, in this experiment, environmental factors such as temperature and daylength were not controlled. It was not clear whether the decline in rooting percentages in August and September could be related to the physiological state of the cuttings or was merely

a reflection of the existing environmental conditions.

Table 2 shows the effect of IBA on rooting. IBA increased the rooting percentages of Japanese plum cuttings. Soaking the basal portions of cuttings in 20 or 80 ppm IBA solution for 20 h and dipping the basal portions of cuttings into 4000 ppm IBA solution for 10 sec gave similar rooting rates. The number of roots per rooted cutting was greater in the IBA treatments of 20 and 80 ppm than with the 4000 ppm dipping treatment.

Table 2. Rooting of 'Ooishi–Wase' plum cuttings as affected by IBA concentration.

IBA conc. (ppm)	Survival rate (%)	Rooting rate (%)	No.of roots per rooted cutting
0	100	10.0	1.7
20[Z]	86.7	86.7	12.6
80[Z]	80.0	80.0	16.7
4000[Y]	80.6	80.6	8.0

[Z]Soaking the basal 1 cm of each cutting into 20 or 80 ppm IBA solution for 20 h.
[Y]Dipping into 4000 ppm IBA solution for 10 sec.

Table 3 shows the cultivar differences of rooting ability among five Japanese plum cultivars ('King', 'Sordum', 'Methley', 'Santa Rosa', 'Taiyo'). There was a great degree of variability in the rooting ability of the plum cultivars. Rooting rates varied from 24% for 'King' to 100% for 'Methley'.

Table 3. Cultivar difference in rooting ability of plum cuttings.

Cultivar	Survival rate (%)	Rooting rate (%)	No.of roots per rooted cutting
King[1]	64.0	24.0	2.2
Sordum	84.0	72.0	4.3
Methley	100	100	17.4
Santa Rosa	84.6	61.5	10.1
Taiyo	90.5	76.2	8.1

[1]The basal 1 cm of each cutting was dipped into 4000 ppm IBA solution for 10 sec.

Most Japanese plums grown in Japan are grown on rootstocks of *Prunus cerasifera*. There has been a recent increase in trials using micropropagated own-rooted trees (Zimmerman and Miller, 1991). However, vegetative propagation by softwood cuttings is more convenient and less expensive than micropropagation. There have been many reports on the rooting of plum rootstocks, such as *Prunus insititia* and *P. cerasifera*, however, very few reports have been available on Japanese plum

cultivars. Sharmar and Aier (1989) reported the seasonal rooting behavior of plum cultivars and the effect of IBA treatment on rooting. They also reported that the Japanese plum cultivars showed better rooting percentages than the European plum cultivars. In this paper, we showed that the rooting ability varied markedly among Japanese plum cultivars. However, it remains unknown what physiological or morphological factors are involved in cultivar differences in rooting success.

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The Commercial Production of Japanese Persimmon 'Fuyu' (*Diospyros kaki* 'Fuyu')

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A HISTORY OF THE PRODUCTION OF FUYU–GAKI.

The First Stage (–1963). During this stage a cold-store was established, and a start was made on a specialized 3-ha orchard of kaki (*Diospyros kaki*).

The Second Stage (1964–1971). During this stage, part-time workers were employed and in order to provide a longer period of employment for the staff, the production farm was doubled in size (6 ha). Production and management staff took over the day to day running of the farms whilst production was increased through our technical direction.

The Third Stage (1972–1980). This period saw the establishment of a sales strategy for kaki and a new cultivation system. The Marukin-Seika Co. was founded in 1978 (initial capital: 10 million yen). By means of strict quality control and reliable supply our brand became established in the market.

The Fourth Stage (1981–1990). This stage saw the expansion of storage facilities with five new cold-stores (total 825 m^2) added and expanding sales. Two lines of automatic packing machines were installed bringing savings in labour and costs. Direct sales to home consumers were started (15,000 families in 1995) and exports to North America and south-eastern Asia were increased.

The Fifth Stage (1991– future). Trials started of container culture of 800 8-year-old plants. Sales of frozen kaki began, wrapped in special sheets for off-season sales, from April. A joint venture has been set up with Taiwan for the production of kaki. In 1995 tourism on kaki orchards began.

IN FUTURE

By concentrating on the production of kaki, it is my aim to distribute high quality *Fuyugaki all year round in Japan, supplemented by imports from abroad.*

Cultivars and Breeding of *Gloriosa*

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Gloriosa is a bulbous climber of the Liliaceae that grows wild in tropical regions and Africa. Recently, cut flowers and potted plant have become commercially available in Japan. Over 10 cultivars including one major cultivar, *G. superba* 'Rothschildiana', are grown. The following are cultivars that are grown in Japan. The characteristics of each cultivar are briefly described below.

CULTIVARS

Red Flower Types.

- 'Rothschildiana': the largest acreage in Japan, leading cultivar in Kochi pref.
- 'Rose Queen': the leading cultivar in Atsumi, Aichi pref., easy to grow, but many faults.
- 'Summer Red': selected in Atsumi for summer cropping, lower flowering rate in winter.
- 'Misato Red': selected in Misato, Kochi pref., excellent flower colour, expanding acreage in Misato.
- 'Royal': a brand name when shipped from Atsumi, originally introduced from Kochi.
- 'Rothschildiana Mini': the shortest culitvar, used for breeding purposes because of the poor keeping quality of the flower.

Orange Flower Types.

- 'Africana': in production over 5 years, three clones exist and are still under selection.
- 'Superba': mostly grown in the south of Thailand and India, only a summer crop in Japan.
- 'Carsonii': mainly grown in India, a less vivid colour but very popular. Seedling propagation has been tried to eliminate virus, but the flower colour varies, needs to be selected.

Yellow Flower Type.

- 'Lutea': a mid-sized flower with narrow petals, hard to grow, propagated from seed.
- Yellow Hybrid: a selection of the Sakata Seed Co., it has big flowers of excellent colour, flowering better in winter.
- 'Lutea Rie': selected in Atsumi, a short culitvar with small flowers, suitable for high temperatures.

Pink Flower Types. Current cultivars are not good. Having poor flower colour

through viral infection.

New hybrids.

- 'Jipang Sasayo': The outside and inside of the petals are gold and red respectively. It has short internodes and a compact habit.
- 'Mrs. Sasayo': The outside and inside of petals are white and pink respectively, brand new.
- Mini 95: high yielding and the shortest cultivar derived from 'Rothschildiana Mini'.

White Flower Type. Under micropropagation for release in 2 years time.

BREEDING

Plant breeding is a long-term project and a lot of work is required before any profits can be expected. Since gloriosa's grow fast for bulbous plants, one might expect quick results from a breeding programme. However, even with modern technology it is only possible to obtain a four-fold increase per year with vegetative propagation. Since it takes many years to obtain 10,000 bulbs from the multiplication of one bulb, plants are often infected by virus during that time. Therefore, the mass propagation of healthy bulbs is difficult. Producing an F1 hybrid cultivars is one of the ways of solving this problem, but no wild species suitable for such a breeding programme are available. It would certainly take longer to repeat selfing, create atavism, and fix lines. Gloriosa is a gorgeous flower, but without a large quantity of cut flowers, a new cultivar will not make an impact in the markets, and will not be commercially successful. It is also important to be able to forecast new trends. The new variety 'Jipang Sasayo' has been micropropagated by Verde Co., Ltd. using tissue-culture technology, and shipped to markets in large quantities as cut flowers. This cultivar is now under field trial in Holland. In various production areas of Japan, the problem of virus infection has arisen. However, this can be overcome by establishing meristem culture.

Horticultural Improvement of the Native Azalea, *Rhododendron tosaense*

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INTRODUCTION

Japan has many native azaleas scattered throughout the country, and people have appreciated their beautiful flowers since ancient times. In the Edo era, people were especially keen about horticultural plants, such as azalea, chrysanthemum, camellia, primrose, hydrangea, gardenia, dianthus, flowering cherry, mume, willow, etc. With regard to azaleas, several groups, such as Kurume, Satsuki, Hirado, and Miyama, were developed from the native species on Kyushu Island. They were taken to western countries and bred to produce many horticultural evergreen azaleas, such as Belgian forcing azalea, Glendale, etc.

I would like to introduce one promising native azalea, *Rhododendron tosaense*, 'Fuji-Tsutsuji' (meaning mauve-coloured azalea) from Shikoku Island.

THE HORTICULTURAL MERITS OF *RHODODENDRON TOSAENSE*

- Very slender and soft twigs.
- Medium-sized flowers of mauve to lavender colour.
- Very early spring flowering, with a mass of blossom covering the entire plant.
- Forcing ability is very high, and equal to that of Kurume azaleas. To save energy, heavy shading during summer promotes pre-Christmas flowering in an unheated glasshouse.
- Rapid growth from seed to maturity in 1 year.

RESULTS OF SURVEY

- Many of the wild populations have disappeared recently owing to the rapid growth of the urban area of Ehime Prefecture. Genetic conservation is now urgently needed to prevent the extinction of this native azalea.
- A new population was discovered growing on the recently cleared slopes near paddy fields and along a newly constructed road. This demonstrates the pioneering habit of this species.
- Two distinct flower sizes have been observed in the wild. The northern population has a rather large flower, and the southern population in Ehime Pref. has a smaller one. A larger flowered type would be the aim of a breeding programme.
- Several colour variants have been collected. They are temporarily named as "Violet", "Purple", "Apricot", "Cherry", "Snow" and "Mauve" and have been transferred to the cutting-propagation programme.

Care of Stock Plants and Cutting Production of Kalanchoe

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MAINTENANCE OF STOCK PLANTS

The practical life of a kalanchoe stock plant is usually 1 year. To obtain suitable cutting material, the stock plant is potted on three times in the course of a year. As it grows taller the stock plant becomes unstable and falls over easily so it needs frequent thinning. The maintenance of the stock plant is very important, but is labour-intensive.

I learned about the container culture of kalanchoe stock plants in Denmark, and applied a modified version of this technique to my present cultivation system. A styrol box (70 cm × 43 cm × 14 cm) equipped with four watering wicks at the bottom was used for the cultivation of the stock plants. Eight to ten stock plants were planted in this box with a kalanchoe compost [unconditioned peat, conditioned peat, perlite, manure (6 : 7 : 4 : 3, by volume) pH 5.5-6.0, EC 1.2 mmho]. On average, five to six cuttings were harvested from each stock plant per month. In winter, the number of harvestable cuttings decreased. In general, the average number of harvestable cuttings is two to three 1 month after planting, and ten to twelve 12 months later. In the container, the stock plants grow vigorously, and remain stable. At first, disease epidemics were feared. However, the occurrence of disease was similar in both the normal pot culture and container culture. The container is recycled after sterilization with a fungicide (Sunfume). The container culture of stock plants produced good results with the following features:

- Healthy growth
- Freedom from soil-borne diseases
- Good growth of cuttings
- Increased labour savings
- Stability of container system

In the future, I plan to examine rockwool culture, hydroball culture, etc. I must improve the fixing technique of the stock plants in rockwool culture, and the recycling method in hydroball culture.

For success in propagation, the cutting should be 5 to 6 cm in length, with 2 to 3 leaves attached; young, soft growth is recommended. Suberized shoots are not good for cutting propagation. Young cuttings produce many branches and grow uniformly. During winter cover the cutting bed with vinyl sheeting and during summer mist to keep cuttings turgid. Rooting begins in 7 days during summer, and 10 to 12 days during winter.

As mentioned above, the container culture of the stock plants of kalanchoe achieved a constant harvest of young soft shoots.

Controlling Root Systems with Slit Containers

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In the container production of many horticultural plants, root circling is a serious problem. It is especially important in the production of large trees to prevent root circling as it has a deleterious effect on the growth after planting out. In many nurseries, however, trees are often grown without any treatment to prevent root circling. As a result, root distortion and aging can be observed at an early stage of growth. In addition, street trees with weak root systems are uprooted easily by strong winds such as typhoons. Therefore, we investigated the combination of soil media in the container, the amount of watering, and the material and structure of the container in order to avoid root circling.

The soil medium used in the experiment was mainly composed of a mixture of red earth or weathered granite as the basal medium and peat moss. The mixture was adjusted by adding kanumatsuchi, hyugatsuchi, perlite, and charcoal to improve the physical condition of the medium. Attention was paid to supplying the plants with adequate water to enable good growth, that is, a large amount of water was supplied to the plants whilst in active growth and reduced when growth ceased. The plants were spaced far apart to prevent disease by allowing good air movement, which also allowed for good soil aeration.

It was considered that the structure and material of the container affected the moisture content of the medium which in turn affected plant growth. A large proportion of the water supplied to the medium drained from the container. Some water remained at the bottom of the container through surface tension. Moreover, condensation formed on the inside surface of the container because of the difference in day and night temperatures. Therefore, the soil medium in the bottom of the container became wet and lacked oxygen. Then, the root cells became deformed, and the lateral roots grew spirally downward along the inside surface of the container without branching. This is the first sign of circling, eventually resulting in deformed roots. Accordingly, we devised a container with an overflow slit which is easily able to drain the water remaining at the bottom. Using the slit container, the circling of roots is prevented, and similar results were observed in slit containers made of other materials, such as paper, cloth, and china. A plug tray of this type was also developed.

When plants are grown in the slit container, root tips cease growing once they come into contact with the container wall, and new roots are formed from the base of the plant, not from the growing tip of the root. By this method, production of well-shaped large trees became possible with a limited amount of soil media in a short time. The improved root system, without circling, produced a better plant. The same benefits of the slit container were also observed with some fruiting vegetables such as sweet pepper and egg plant, and made a marked difference in annual seedlings.

The phenomenon might be explained by the physiological relationship between roots and leaves as described below. With a sufficient supply of oxygen, the root tips cease growth, and synthesis of cytokinins commences. The hormones are translocated to the leaves, contributing to an active synthesis of protein, development of buds, and expansion of leaves. Consequently, photosynthetic products and auxins synthesized in the leaves are translocated to the roots and promote differentiation and development of lateral roots from the base of the plant.

Production of Large Evergreen Landscape Trees and Their Typhoon Protection in the Nursery

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INTRODUCTION

Even though the economic bubble has burst in Japan, the price of land is still extremely high in the cities. There is a trend toward the planting of large landscape trees around new commercial buildings as a status symbol. Urban renewal is also taking place in large cities from Osaka to Tokyo.

These large buildings affect the microclimate of the surrounding area. To soften the effects of these changes, various regulations have been adopted to control spacing, and landscaping of buildings to blend with their surroundings. Along with the increase in land values, large-grade landscaping trees are in demand by the owners of large buildings.

In order to meet these demands, my company is run with the following points in mind.

ECONOMIC FACTORS AFFECTING THE PRODUCTION OF LARGE-GRADE LANDSCAPE TREES.

Owing to the economic decline in recent years after several natural disasters in Japan, the demand for large trees will decrease. So, the competition will become more intense among large-tree growers. High quality will become the most important factor. This is the chance to apply the know-how to produce high quality trees which my company has acquired over 20 years in this business.

Trees Which Meet the Demands of the Landscaping Industry. My company sells well-shaped, good quality trees which are easy to establish and easy to deal with at the planting site. These qualities are produced by proper training of stems and branches, sturdy root systems, good management, and strong, healthy growth without pests and diseases.

Typhoon Protection. Miyazaki Prefecture, where my company is located, gets one or two typhoons every year. So, my company endeavours to produce strong trees to withstand typhoons. The most essential point is to produce a tree of a tidy form and habit, combined with the removal of extra branches. The trees in the nursery prior to despatch are supported by many poles to secure them against the strong typhoon winds.

Production Planning and Sales. Each year, my company increases tree planting 20% on the number sold the previous year. Once the trees are planted, the yearly sales planning is done and prices are set. Accurate sales figures are kept every year and 95% of our sales are of products grown by my company.

Staff Education. In the past, it was rather difficult to get good staff in our business. It costs at least 10 million yen and several years to educate new staff to become

skilled workers. However, this education is most important. By having many skilled workers, and good production techniques and sales staff, my company will become more competitive with our rivals.

Seedling Propagation of *Sophora microphylla*

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INTRODUCTION

The planting of indigenous tree species is continuing to increase and public interest in their use is in three broad categories:

1) Home gardens
2) Landscaping of recreational areas, riparian zones, and highway plantings
3) Regeneration of native forests

Seedling propagation of New Zealand indigenous plants is a common form of propagation for a number of reasons.

1) Where seed is readily available, large numbers can be grown economically
2) Root systems are superior to cutting-grown plants and can result in more successful establishment
3) Seed can be stored for long periods of time owing to the very hard seed coat
4) Genetic diversity through cross pollination is insured, very important when propagating small and isolated populations

BACKGROUND

The genus *Sophora* contains fifty species of trees and shrubs found in subtropical and temperate parts of North and South America, Asia, Australia, and New Zealand. Two of the three New Zealand species are endemic and are known locally as Kowhai.

The Kowhai is New Zealand's most beautiful flowering tree. Its feathery leaves and pendulous flowers borne in great profusion make a striking contrast against the many shades of green in the New Zealand landscape.

The flower colour ranges from a pale lemon-yellow in *S.* 'Little Baby' (syn. *S. prostata*) to the golden yellow of *S. microphylla*. Flower colour, leaf shape, and tree form depend on locality and the genetic content of individual trees. This allows the plants person the opportunity to collect and select forms suitable for a wide range of situations.

One or more species are found in most parts of New Zealand from the coast to mountain districts, in forests, on open hill sides, and along streams and rivers. They grow in most soil types and situations, all are hardy throughout New Zealand, with *S. microphylla* well adapted for planting in exposed sites.

Sophora microphylla is a 5- to 7-m tree with a spreading and drooping habit. The pinnate leaves are up to 15 cm long with 20 to 40 pairs of oblong leaflets. The two varieties of *S. microphylla*, var. *fulvida* and var. *longicarinata,* avoid the densely tangled juvenile stage which can persist for up to 7 years before the plant assumes its adult form and flowers. *Sophora microphylla* var. *longicarinata* has a very

distinct slender habit and smaller size making it ideal for home gardens. It flowers within 6 to 7 years from seed, in the month of October.

GENERAL PRINCIPLES FOR SEEDLING PRODUCTION

Seed Collection. Collection by the grower is usually the preferred option as specific locations and forms can be selected. Garden seed collection can result in a hybrid swarm of different form types. By choosing individuals with superior form from a uniform population of the species in an area and keeping careful collection records the propagator can produce true-to-type tree stocks.

Certain individual trees produce large quantities of seed each year, following heavy flowering in October. The seed is yellow in colour, slightly oval to round, 6 to 8 mm in diameter. The pods are green when young, 75 to 150 mm long, containing 3 to 8 seeds. The pods dry to dark brown and remain attached to the tree for 12 to 24 months. They are collected from the branch ends into a collecting bucket.

Seed Treatment. The seed pod is dry and removal of seed is slow, hence we soak the pods for 20 days in water. The soft and slightly decomposing pods can then be forcefully rubbed over a course sieve breaking open the pods. The seed is then screened from the seed pod residue.

The seed has a very hard seed coat which is not easily damaged and requires some form of scarification to allow the seed to imbibe and swell.

TECHNIQUES TO OVERCOME HARD SEED COAT DORMANCY

Mechanical Scarification. This involves the cracking, puncturing or reduction of the thickness of the dry seed coat allowing it to be permeable to moisture and air. Small quantities can be filed or rubbed with sanding blocks or in a rotating sanding drum.

Hot Water Soak. Seed is soaked in hot water which has been off the boil for 30 sec. The water is allowed to cool for 24 h and the swollen seed is twice the size of the nonimbibed seed.

Acid Scarification. Concentrated sulphuric acid is an efficient technique to reduce the thickness of the seed coat. Sulphuric acid is a very corrosive and potentially dangerous liquid and should be handled with full protective clothing and acid resistant glass. Water should never be added to acid. A sample of the seed is divided into sample batches and each is treated for a set period of time. The seed batch with the highest proportion of undamaged swollen seed indicates the optimum time period. The following acid scarification treatment is successfully used at Appletons' Tree Nursery:

- The first acid treatment of 60 min is followed by a 48 h water soak with water changed every 8 h to drain off leachates. The swollen seed is sieved off and stored in sealed plastic bags in a cool room at 4C prior to sowing.
- Unswollen seed is retreated with acid for 30 min and repeated treatments are necessary until all seed has swollen.

OPEN-GROUND SEED BED PRODUCTION

Seed Bed Formation. Appletons' Tree Nursery Ltd. practices a fixed seed bed production system. Once a seed bed is established, all subsequent operations are undertaken from the tractor alleyways and after the crop is harvested, the seedbed is ripped and reformed. The incorporation of organic compost allows the improvement of the seed bed soil structure.

Correct seed bed preparation involves forming raised seed beds which aid drainage and encourage successful germination and healthy root systems. A modified Howard rotary hoe with a bed-former forms 200-mm high seed beds.

Seed Sowing and Growing On. A five-row roller is used to form 20-mm-deep grooves in which the seed is hand sown. An inter drill spacing of 25 mm allows sturdy 35- to 50-cm plants to develop. A basal fertiliser of a slow-release type is used and side dressings of a balanced NPK are made during the growing season.

A sawdust covering of 10-mm covers the seed. A shade cloth cloche or a brushwood arch is used to protect the freshly germinating seedlings.

A reciprocating-blade under-cutter is used to cut the long tap root in December. This aids the formation of a branched and fibrous root system, which greatly enhances the ability of the seedlings to successfully transplant during the winter planting season.

During the plants' dormant period in winter, seedlings are lifted carefully so as not to damage the roots, graded and fully enclosed in plastic bags with peat moss around the root system, before dispatch.

As with all bare-rooted evergreen seedlings, they should be transported promptly and potted or planted in the ground with minimum delay.

SUMMARY

Sophora microphylla has the potential to be used in temperate parts of the world, where its attractive flowers and form would complement existing garden plants. The potential to select from its very wide genetic base, offers a real challenge to plants people and propagators.

Miniature Rose Production in Gifu Prefecture

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Our company, Bromellia-Gifu Ltd., situated in the towns of Yoro and Kaizu in the warmer southern region of Gifu Prefecture, was founded in 1990 by a group of growers for the production of bromeliads. Initially the company concentrated on growing bromeliads, however, in 1992, miniature rose production began.

THE MANAGEMENT AND PRODUCTION OF MINIATURE ROSES

Nursery stocks are produced from cuttings. To save labour costs the cuttings are stuck directly into pots under a polyethylene sheet. Plant growth retardants are applied to improve the quality.

We always trial new products and evaluate the efficiency of mass production in relation to auction prices. We are always endeavouring to improve techniques and management. We developed our original system for sales of 500,000 pots per year.

SALES

We have two methods of marketing. One is an arrangement of different sized pots in a basket. The other is single potted plants at an economical price. There are ten different patterns of baskets. The price of the basket varies with the design of the arrangement.

FUTURE PROBLEMS

Nursery houses for overwintering are scattered in various places. This causes inefficient management during winter, loss of sales, and unchecked spread of diseases.

Rose Production in the Present and Future

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INTRODUCTION

Gifu Prefecture is home to the largest area of rose production in Japan. In this paper I will report on the present and future problems of rose production.

Table 1. Kind of stock produced.

Age	Propagation method	Usage
1 year	cutting	pot rose and cut rose (rockwool culture)
	grafting (bud)	cut rose and pot rose
	grafting (stem)	cut rose and pot rose
	grafting (soft stem)	cut rose
	graft-cutting	cut rose
	tissue culture	general
2 years	grafting (cleft)	gardening

PROBLEMS

1) Stock: Management of production, ensuring continuous production, retention of workers
2) Disease: Crown gall, etc.
3) Grafting: Incompatibility
4) Stock production: Adaptability to different production systems
5) Supply: Year-round availability

PRESENT AND FUTURE

As almost all production goes to the commercial sector, the selection and quality of cultivars greatly affects the yield and quality of cut roses. The constant supply of high quality roses is paramount. Because of the increase in numbers of cultivars and the different end uses, it is becoming very important to have methods of production which can be adapted to the various demands of the cut rose growers, by using additional methods such as stenting (graft-cutting) and micropropagation, etc.

Cut-flower Production of Roses in Goudo

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The decision of several cucumber farmers to change to rose cultivation in 1970 saw the start of cutflower production of roses in Goudo. Seven years later, the agricultural corporation, Rose Production Corporation of Goudo, was founded. In 1984, the rose was registered as the town flower of Goudo. Since then, rose production has been regionally promoted in Goudo. From 1986, direct sales to consumers by means of a house-to-house delivery system began with large sales made for Mother's Day and Father's Day.

ORGANIZATION (IN 1993)

- No. of farmers: 11 families
- Total cultivated area: 493 acres
- Yield: 5,240,000 stems.
- Production: ¥500,000,000

METHODS OF CULTIVATION

- Thorough disinfection before planting
- Sufficient fertiliser
- Ripping subsoil to the depth at 1.0 m before planting
- Adoption of rockwool culture to achieve best use of labour and uniform results
- Automated pest and disease control, and a flower sorting machine resulted in labour cost-savings and better worker conditions
- Soil analyses at regular intervals and proper maintenance of the soil condition
- Computer management of rose cultivation

MANAGEMENT STRATEGIES

- Year-round production allowing for seasonal variations
- Market research and expansion of business by direct sales through the house-to-house delivery system
- Hiring of a production manager
- Introduction of new cultivars suitable for the auction market and consumer

FUTURE PLANS

- Improvement of rose quality by means of new technology and facilities
- Publicity of the Goudo brand name
- Keeping high quality production through the year
- Promotion of cooperative despatch to market
- Joint production of potted roses with rose nurseries
- Promotion of tourism in rose growing
- Promote the image of Goudo as the Rose Town

Orchids in Thailand

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"A country of smiles" is the frequently used catch-phrase in guide books and pamphlets introducing Thailand.

In Thailand, the average temperature is 28C, there is abundant sunshine every day, and a plentiful supply of tropical fruits.

Because the Thai economy is increasing by 8% every year, Bangkok (Krung Thep), its capital, is a hive of construction of large skyscrapers and condominiums. Along with a rapid increase in population has come a number of environmental problems including world famous traffic congestion which produces dust and exhaust fumes that destroy the sweet tropical atmosphere.

Even in such a busy dusty city in the rainy season, they have heavy squalls in the afternoons, the city becomes calm. The time passes slowly like the Menam river (Chao Phraya) and people wait patiently until the rain stops. Thai people are patient by nature and visitors to Thailand should relax and appreciate the spirit of the Thai people.

At present, Thailand is facing a dangerous ecological imbalance because of the rapid changes to the environment. The serious flood of last year might have been caused, to some extent, by a severe reduction of the natural forest cover. The Government of Thailand, realizing the importance of natural forests, has instigated a conservation plan.

Our company, which is engaged in the production and export of Thai orchids, has been directed to cultivate wild and rare species under the control of the Thai government.

Effects of Media and Time of Seed Collection on Seed Germination of *Cypripedium macranthum* var. *rebunense*

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To obtain basic information for maximizing the *in vitro* seed germination of *Cypripedium macranthum* var. *rebunense* the suitability of media and the optimum time of seed collection were investigated. Seed capsules were collected at weekly intervals ranging from 5 to 8 weeks after pollination and inoculated on four tested media (Harvais, 1/2 MS, 1/2 Norstog, and T). Seeds collected at 6 weeks after pollination had the highest germination regardless of the medium components. Germinations and subsequent growth on both °Norstog and T medium were better than those on Harvais and ° MS medium. Eighty weeks after inoculation, seedlings were transplanted to soil-based media, and a preliminary investigation was made of the relation of cold treatment to sprouting (shoot elongation).

INTRODUCTION

Most terrestrial orchids have become increasingly rare owing to the destruction of their native habitat by human encroachment. In fact, *Cypripedium macranthum* var. *rebunense* has become the symbol for the conservation of endangered plant species in Japan (Japan Society of Plant Taxonomists, 1993). The propagation method that has received the most attention for *Cypripedium* species is *in vitro* seed germination (De Pauw and Remphrey, 1993), and many attempts have been made to germinate seeds of North American *Cypripedium* species (Arditti, 1982; Harvais, 1982; De Pauw and Remphrey, 1993). Immature seeds were often used for the propagation of 'hard-to-germinate' orchids (Arditti, 1982). However, little is known about the germination of Asiatic taxa (Hoshi et al., 1994; Takahashi and Tsutsui, 1992; Tomita and Kanbara, 1995). Nagashima (1995) only reported the germination ability of mature seeds of *C. macranthum* var. *rebunense*, but no other practical report, especially about the culture of immature seeds of this species, is known. For both conservation and commercial production, it is desirable to find practical, efficient methods of propagation.

To obtain basic information for maximizing the *in vitro* seed germination of *C. macranthum* var. *rebunense*, the suitability of media and the optimum time of seed collection were investigated. In addition, the relationship between cold treatment and sprouting (shoot elongation) of juvenile plantlets was preliminarily investigated.

MATERIALS AND METHODS

After pollination, seed capsules were collected at intervals ranging from 5 to 8 weeks during July and August, 1994. Capsules were rinsed with tap water, burned in flame after spraying with 70% ethanol, soaked in sodium hypochlorite solution (1% available chlorine) containing 2 to 3 drops of Tween 20 for 20 min, then rinsed in

sterile distilled water (Tomita and Kanbara, 1995). Capsules were cut open in a sterile Petri dish and seeds were transferred to culture media with an inoculation loop. Sowing density was approximately 100 to 180 seeds per test tube. Four to five replications of each treatment were seeded. The media used were Harvais (1982), 1/2 MS [the major inorganic elements of MS (Murashige and Skoog, 1962) were reduced by one-half], 1/2 Norstog [the major inorganic elements of Norstog medium (Norstog, 1973) were reduced by one-half], or T (Tsutsui and Tomita, 1990). All media were supplemented with 10 g litre^{-1} sucrose, adjusted to pH 5.5 and solidfied with 8 g litre^{-1} agar. Twenty milliliters of medium was distributed to each 25 × 150-mm test tube, and cooled in a slanted position after autoclaving. All test tubes were incubated in the dark at 20C. At 20 weeks after sowing, germination was assessed. After the assessment of germination, protocorms were subcultured onto fresh medium (30 ml of medium in 100-ml flasks, solidfied with 3 g litre^{-1} Gelan Gum) every 20 weeks for 80 weeks. After culturing, seedlings derived from seeds 6 weeks after pollination and cultured on 1/2 Norstog medium were thinned out. They were divided by bud size (5 mm <, 5 mm-10 mm,10 mm >), and transplanted to pots containing soil-based media [sand : volcanic ash soil : vermiculite (1 : 1 : 1, by volume)]. They were then treated for 12 weeks at 5C (cold treatment) for vernalization. Following cold treatment, potted plants were transferred to a greenhouse with 70% shading. After 16 weeks of culture, sprouting was investigated.

RESULTS AND DISCUSSION

Germination had occurred on both 1/2 Norstog and T media within 2 weeks after inoculation. On the other hand, germination on both Harvais and 1/2 MS medium

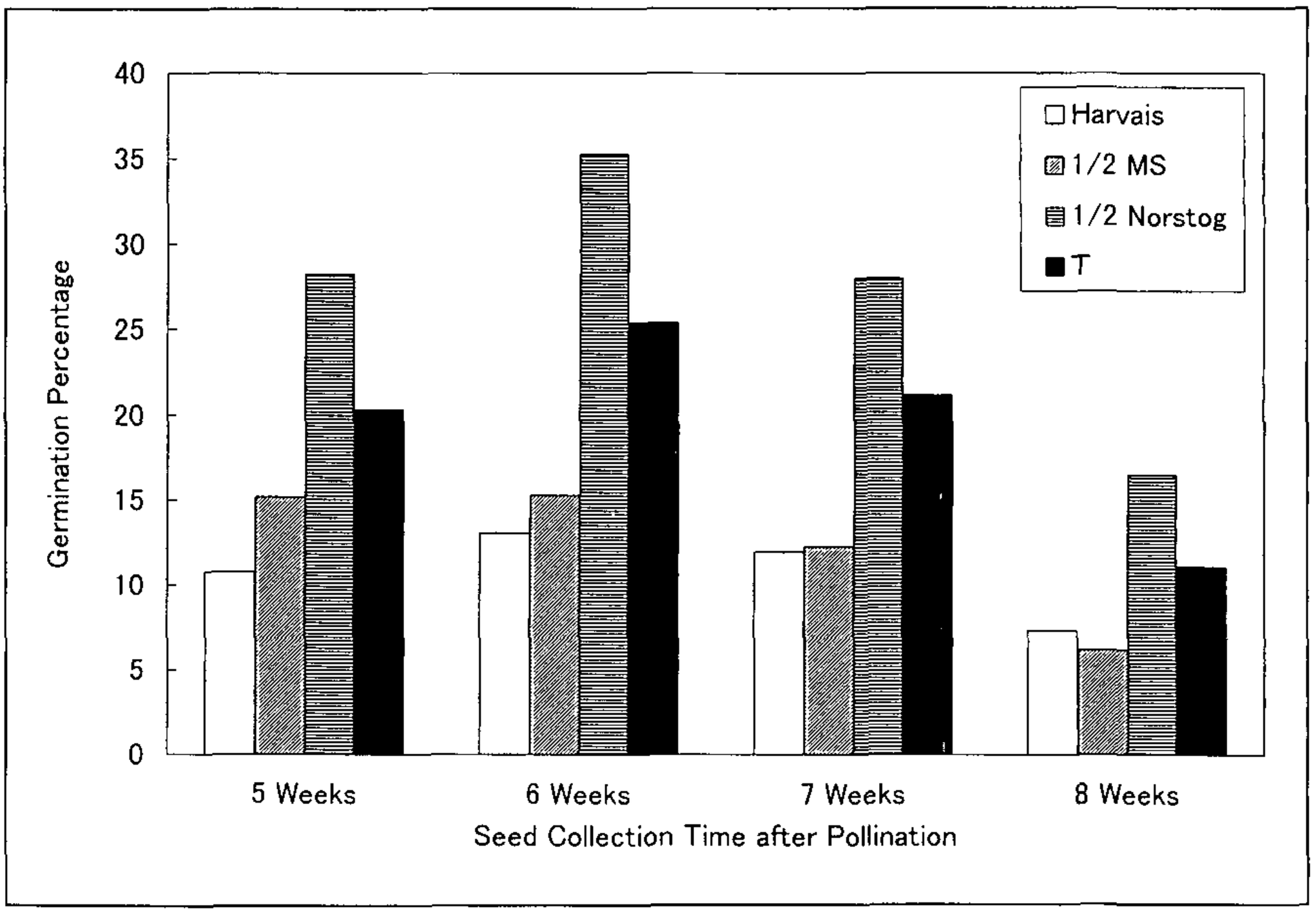

Figure 1. Effect of media and seed collection time on the germination of *Cypripedium macranthum* var. *rebunense*.

was very slow, with the first germination observed at 3 to 5 weeks after inoculation. The results of the initial germination of *C. macranthum* var. *rebunense* after 20 weeks of culture are summarized in Fig.1. The time of seed collection affected the initial germination of *C. macranthum* var. *rebunense*. Seeds collected at 6 weeks after pollination had the highest germination regardless of the medium components. Seeds collected after 7 weeks showed a decrease in germination for all media. Nagashima (1995) reported that the germination of mature seeds of *C. macranthum* var. *rebunense* was very poor (under 1%). The present study shows that the decrease in the germination ability of seeds, according to the seed maturation, starts 7 weeks after pollination. Many factors have been suggested as causing the poor germination ability of mature seeds (De Pauw and Remphrey, 1993). Further study of the physiological changes in the seed maturing process is needed. The germination on both 1/2 Norstog and T media was better than that of the other two media. Among four tested media, the germination was most successful on 1/2 Norstog medium. All germinated protocorms, 8 to 16 weeks after inoculation, were a bright maize colour. At the period of assessment (20 weeks after inoculation), protocorms which germinated on both Harvais and 1/2 MS media changed to a creamy brown, and some of them died. After the assessment of initial germination, all live protocorms were transplanted to fresh medium at 20 week intervals. All protocorms cultured on both Harvais and 1/2 MS medium were dead by 40 weeks after inoculation. On the other hand, most protocorms on both 1/2 Norstog and T media survived to reach seedling stage by 80 weeks after inoculation (Fig.2).

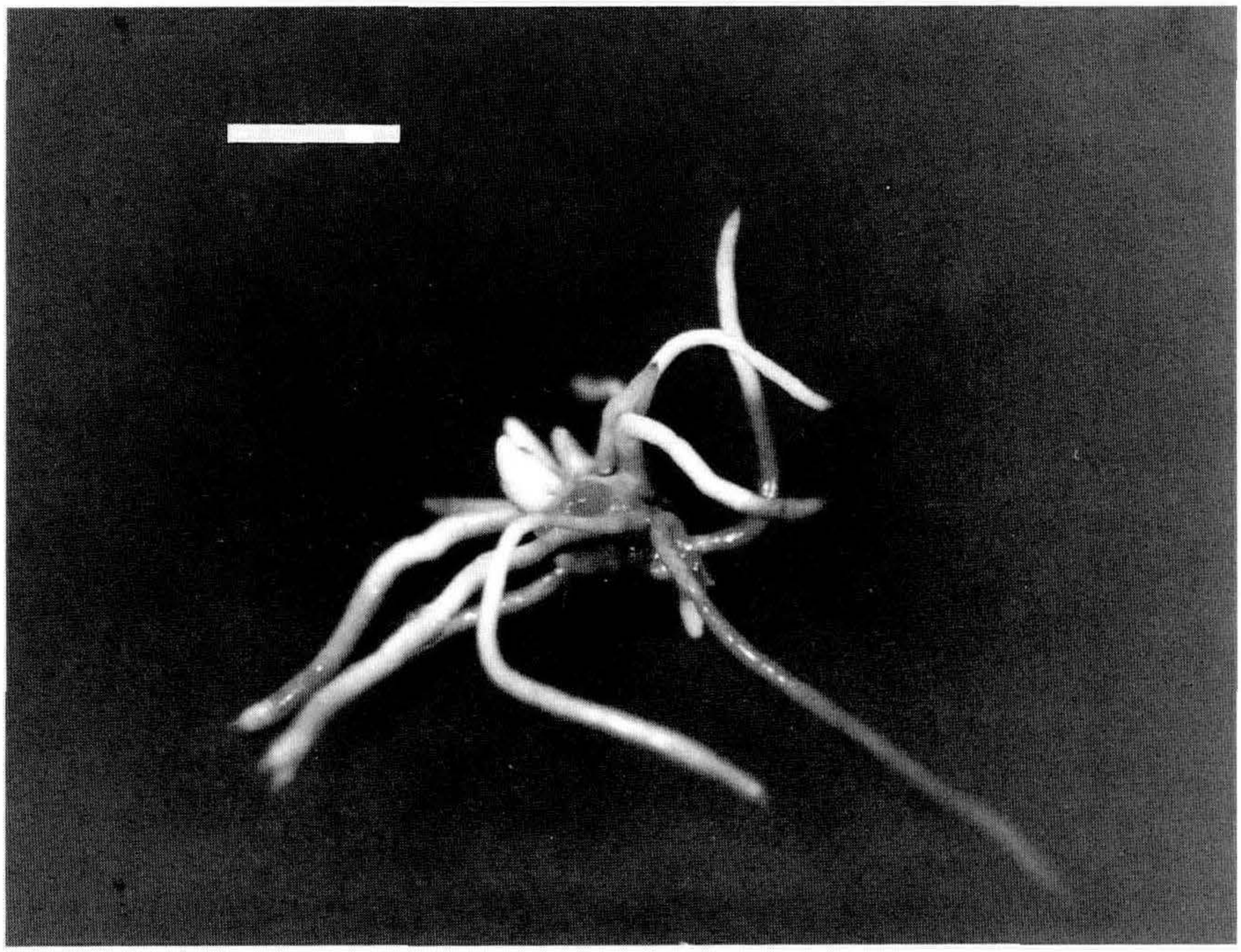

Figure 2. Plantlet of *Cypripedium macranthum* var. *rebunense* after 80 weeks of culture on 1/2 Norstog medium. Scale bar = 10 mm.

The latter two media were used for germination of some Asiatic *Cypripedium* species, and showed good results on *C. macranthum* var. *speciosum* (Takahashi and Tsutsui, 1992; Tomita and Kanbara, 1995) and *C. macranthum* var. *taiwanianum* (Tomita and Kanbara, 1995). It seems that these two media were also useful for initial germination and subsequent protocorm growth of *C. macranthum* var. *rebunense*. The 1/2 Norstog medium would be more suitable for research to determine the organic components essential for asymbiotic germination and seedling growth of *C. macranthum* var. *rebunense* because it is a completely defined medium.

After 60 weeks of culture, some plantlets were transferred to light conditions (16 h day regime under 1500 lux). However, no plantlets sprouted buds, and were dead by 80 weeks after inoculation (data not shown). It was suggested that the juvenile plantlets of *C. macranthum* var. *rebunense* had a kind of dormancy. In nature, dormancy ensures that seedlings do not sprout until climatic and temperature conditions are optimal for seedling survival. Takahashi and Tsutsui (1992) showed that asymbiotic seedlings of *C. macranthum* var. *hotei-atsumorianum* had epicotyl dormancy which requires low temperature for sprouting. They investigated the relationship between the bud size of juvenile plantlets of *C. macranthum* var. *hotei-atsumorianum* and their reaction to low temperature, and reported that shoot development following cold treatment affected bud size. Small buds (<5 mm), in turn, delayed both sprouting time and subsequent seedling growth. Then, for the purpose of overcoming dormancy, the effect of cold treatment on the sprouting time of *C. macranthum* var. *rebunense* as it relates to their bud size was preliminarily investigated. The results are summarized in Table 1 and Fig. 3. The present study agreed with the results of *C. macranthum* var. *hotei-atumorianum* (Takahashi and Tsutsui, 1992) that the plantlets of *C. macranthum* var. *rebunense* required cold

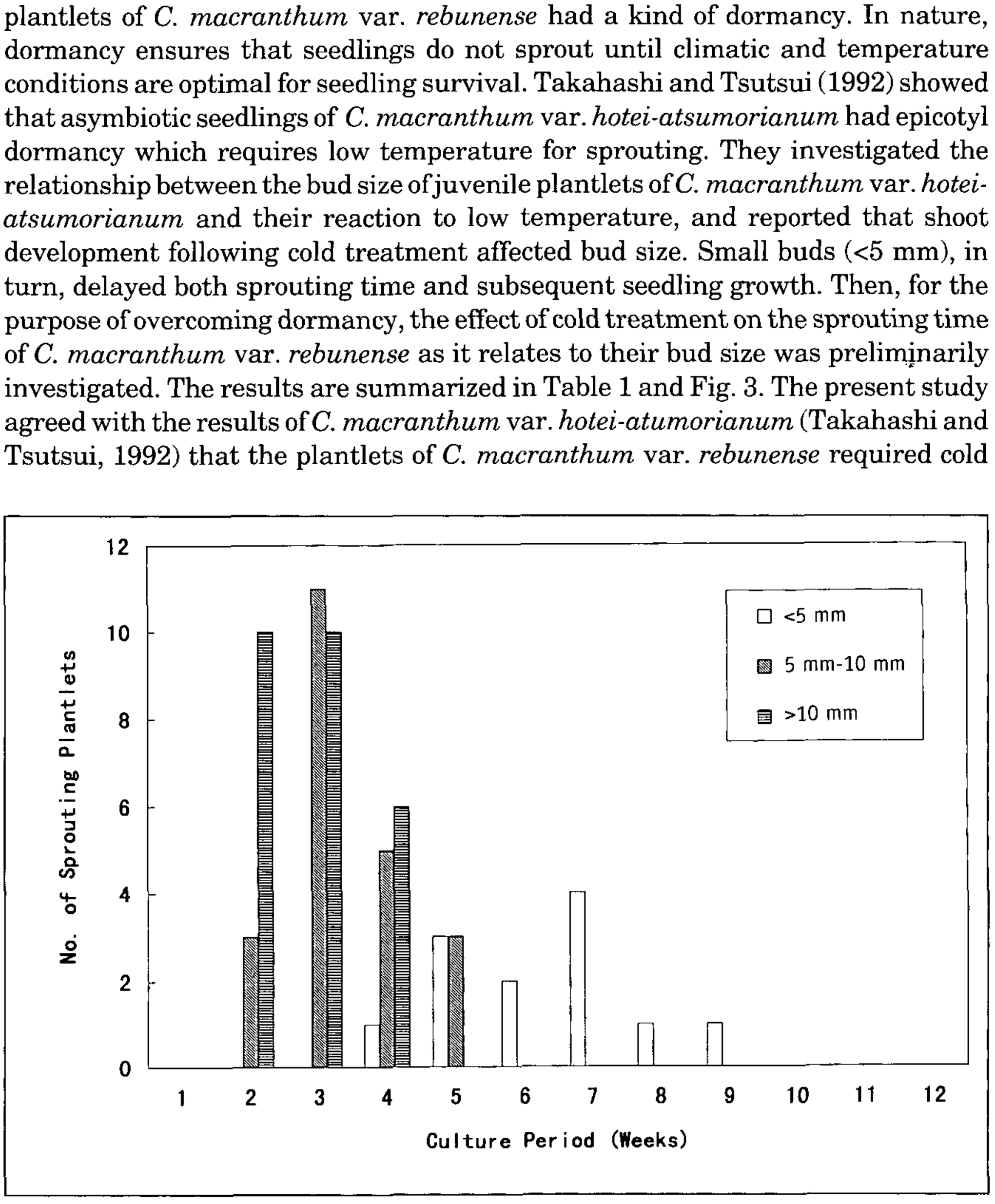

Figure 3. Effect of bud size on sprouting time after 12 weeks of cold treatment.

treatment to overcome dormancy (sprouting), and that the sprouting time was related to their bud size when exposed to cold treatment.

Table 1. Effect of bud size on sprouting time of *Cypripedium macranthum* var. *rebunense* after 16 weeks of culture in greenhouse following 12 weeks of cold treatment.

Bud size (mm)	No. of sprouting plantlets /no. of tested plantlets	Sprouting percentage	Mean sprouting time (weeks)
<5 mm	12/30	40	6.3
5 mm to 10 mm	22/30	73.3	3.4
>10 mm	26/30	86.7	2.8

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Sales Strategy for Cactus

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Thirty years have passed since the start of our retail cactus growing business. Such direct sales are limited with little chance to increase the business. Later we tried sending plants to the auction market. At the auction, we received prices equal to those from direct sales, and this changed the direction of our marketing in favour of the auction.

Production of cactus had to be increased which caused several problems, such as the difficulty of flower forcing, the spilling of sand-compost during transport, and other problems. A new product, "petit-cactus", targeted towards young girls as consumers, was introduced in 1983. They were decorated with small dry flowers and with sand solidified with special paste to prevent spillage. This unique product became a big hit, and set a record by selling a million units in 3 months. It will be difficult for anyone to break this record in the future.

At present, 80% of our business goes to the auction market and 20% to other outlets. These other outlets include Daiei Co. (one of the biggest supermarket companies in Japan), Takara Co. (a famous toy company in Japan), and several wholesale traders of confectionery, all non horticultural businesses. Daiei Co. purchases a cheaper grade of cactus for Takara Co., we produce original designs under a Micky Mouse brand for their shops in Tokyo's Disney Land, and a combination of chocolate and cactus for the confectionery traders.

The best opportunity to increase the sales of our cactus is to broaden our range of innovative products to appeal to various kinds of shoppers, instead of having limited sales of potted plants through florist shops. In the future, our company will advertise on the internet to increase business opportunities. I believe the cactus business still has a chance to increase further, so I try to keep the business vital by foreseeing future trends and creating new products to appeal to various age groups.

Effects of Cytokinins on Multiplication and Rooting of Micropropagated Shoots of *Spathiphyllum*

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Using micropropagated shoots of *Spathiphyllum*, the effects of cytokinins, including new types which were recently introduced into micropropagation, on shoot multiplication and rooting of multiplicated shoots were examined. Phenylurea-type cytokinins (CPPU and thidiazuron) markedly promoted shoot multiplication and inhibited rooting of multiplied shoots at more than 0.1 mg liter^{-1}. A water soluble BA (TG-19) showed a promotive effect on shoot multiplication similar to BA. The results showed that BA was the most effective cytokinin for micropropagation of *Spathiphyllum*.

INTRODUCTION

Recently, new types of cytokinins, such as, N-phenyl -N^1- (1,2,3 - thiadiazol-5- yl) urea (thidiazuron) and N-(2-chloro-4-pyridyl)-N^1-phenylurea (CPPU or forchlorofenuron) (Mok et al., 1987), and one of water soluble-BA (6-benzylaminopurine), N^6-[2-(N-methoxy-N-methylamino) ethyl] adenine (TG-19) (Sasaki et al., 1993), were introduced to plant tissue culture. *Spathiphyllum* is one of the typical ornamental plants propagated through tissue culture. In the micropropagation system for *Spathiphyllum*, BA is the most popular cytokinin to promote shoot multiplication (Hikosaka, 1988).

In this report, the effects of these new cytokinins on the growth and rooting of *Spathiphyllum* micropropagated shoots were examined and compared to those of BA.

MATERIALS AND METHODS

In the following experiments, micropropagated shoots of *S. wallisii* 'Merry' (syn. *S. clevelandii* 'Merry') were used. The shoots were obtained through shoot-tip culture and multiplied through subculture on Murashige and Skoog (1962) medium (MS) supplemented with 1 mg liter^{-1} BA (Hikosaka, 1988). All cultures were incubated in test tubes (ϕ26 × 120 mm) at 24C under 16-h light period (40 μmols^{-1}m^{-2} PPFD).

Experiment 1. Effects of Cytokinins on Shoot Multiplication. Shoots with two unfolded leaves (3 cm long, cat 50 mg FW) and without roots were prepared from the multiplied shoots. The shoots were cultured on MS supplemented with BA, kinetin (Kin), TG-19, CPPU, or thidiazuron (TDZ) at the concentrations of 0.1, 0.5, or 1.0 mg liter^{-1}. After culture for 2 months, the number and fresh weight (FW) of shoots (more than 6 mm long) and roots (more than 5 mm long) of respective test tubes were recorded.

Experiment 2. Carryover Effects of Cytokinins on Rooting and Shooting of Cultured Shoots. Shoots with two unfolded leaves and without roots were

prepared from each of the media supplemented with different cytokinins. All were subcultured to the cytokinin-free MS medium. At 4 weeks after subculture, percentages of rooting were recorded. After culture for 6 weeks on cytokinin-free medium, the cultured shoots were potted into plastic pots containing Metromix 360. At 4 weeks after potting, the number of shoots longer than 10 mm were recorded.

RESULTS

Experiment 1. Effects of Cytokinins on Shoot Multiplication. Total FW increased with the increased concentration of cytokinins (Fig. 1). The largest value of total FW, FW of shoots, and the number of multiplied shoots was obtained on the

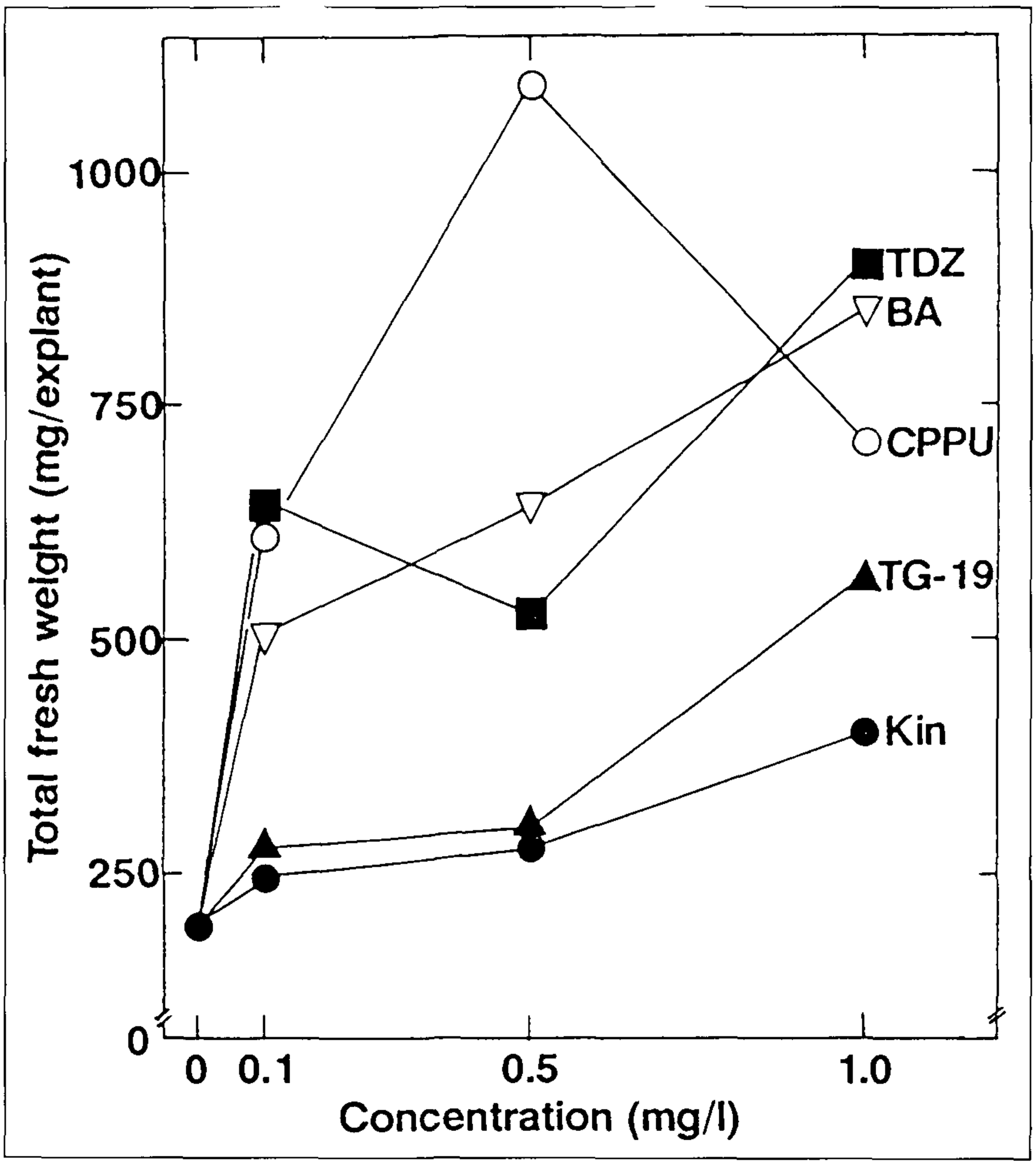

Figure 1. Total fresh weights of *Spathiphyllum* shoots after culture for 2 months on media supplemented with different cytokinins. Shoots with two unfolded leaves and without roots were used as explants. The average fresh weight of explants (initial shoot) was 50 mg.

medium supplemented with 0.5 mg liter^{-1} CPPU. On the other hand, shoots grew without shoot multiplication on media supplemented with 0.1 or 0.5 mg liter^{-1} KIN, and 0.1 mg liter^{-1} TDZ as in the control (cytokinin-free medium). The average FW per shoot, multiplied on the medium supplemented with 0.5 mg liter^{-1} BA, was 51.7 mg, the largest result on the media examined. The effects of TG-19 on shoot multiplication were almost the same as those of BA (Table 1).

Table 1. Effects of cytokinins on growth and multiplication of shoots during the multiplication stage in *Spathiphyllum wallisii* 'Merry'.

			Multiplied shoots per explant	
Cytokinin	Conc. (mg liter^{-1})	Total FW of shoots per explant (mg per explant)	Number	Average FW (mg per shoot)
Control	0	148.0±15.7	0	0
BA	0.1	288.8±29.4	1.5±0.6	11.4±3.31
	0.5	322.8±85.5	2.8±1.2	51.7±6.18
	1.0	350.0±56.4	7.5±1.7	23.6±3.42
TG-19	0.1	183.3±25.1	1.3±0.4	14.6±4.75
	0.5	197.3±25.5	2.3±1.1	26.7±10.5
	1.0	344.0±55.1	6.3±1.6	26.7±3.74
Kinetin	0.1	173.3±7.54	0	0
	0.5	171.8±13.0	0	0
	1.0	230.0±33.6	1.0±0	28.3±6.53
CPPU	0.1	253.5±20.4	3.8±1.6	23.3±10.7
	0.5	522.8±166	18.3±5.9	18.5±3.41
	1.0	179.3±53.3	3.3±1.7	22.2±7.30
TDZ	0.1	122.0±14.0	0	0
	0.5	168.8±25.8	1.0±0.6	22.8±17.2
	1.0	274.5±65.9	9.5±3.1	19.7±2.25

Experiment 2. Carryover Effects of Cytokinins on Rooting and Shooting of Cultured Shoots. BA and KIN showed a promotive effect on root formation, at 0.1-1.0 mg liter^{-1} and at 1.0 mg liter^{-1}, respectively. However, TDZ completely inhibited root formation (Fig. 2 and 3). CPPU also inhibited root formation at 1 mg liter^{-1}, but promoted it at 0.1 mg liter^{-1} (Fig. 2).

As shown in Table 2, the rooting of shoots multiplied on media supplemented with CPPU and TDZ at 0.5 and 1.0 mg liter^{-1} was obviously delayed. The number of shoots derived from media supplemented with CPPU and TDZ at 1 month after potting was more than those from other cytokinins. Shoots from media supplemented with 1.0 mg liter^{-1} of CPPU and TDZ showed strong after-effects on shoot multiplication even after potting (they produced 6.8 and 3.4 shoots, respectively).

Table 2. Effects of applied cytokinins during the multiplication stage on rooting after transplanting to a cytokinin-free medium and shooting after potting in *Spathiphyllum wallisii* 'Merry'.

Cytokinin	Conc. (mg liter^{-1})	Rooting (%) of multiplied shoot on cytokinin-free medium (after 1 month)	Number of shoots after 1 month from potting
Control	0	100	1.0±0
BA	0.1	66.7	1.0±0
	0.5	80.0	1.0±0
	1.0	100	1.1±0.1
TG-19	0.1	71.4	1.1±0.1
	0.5	100	1.1±0.1
	1.0	100	1.3±0.2
Kinetin	0.1	66.7	1.0±0
	0.5	75.0	1.0±0
	1.0	100	1.1±0.1
CPPU	0.1	100	1.4±0.2
	0.5	40.0	2.5±0.5
	1.0	30.0	3.4±0.4
TDZ	0.1	70.0	1.8±0.4
	0.5	0	3.3±0.6
	1.0	0	6.8±0.6

DISCUSSION

Since Fonnesbech and Fonnesbech (1979) showed the promotive effect of cytokinins on the micropropagation of *Spathipyllum* using PBA (a tetrahydropyranyl derivative of BA), commercial tissue-culture laboratories have generally utilized cytokinins to multiply *Spathiphyllum*. Chu and Kurtz (1990) described micropropagated *Spathiphyllum* as characterized by a greater degree of basal branching when the culture medium was supplemented with cytokinins, and they called the effect the "carryover effect". However, BA also showed an inhibitory effect on rooting at more than 2.5 mg liter^{-1} BA (Werbrouck and Debergh, 1995). Hikosaka (1988) pointed out that the optimal concentration of BA to multiply shoots and not to inhibit rooting in *Spathiphyllum* shoot-tip culture was 1.0 mg liter^{-1}.

TG-19 is characterized by its high solubility in water, while it has a comparable cytokinin activity to that of BA (Maruyama et al., 1993). In the present experiments, 1 mg liter^{-1} TG-19 also showed similar effects on shoot multiplication to that of BA and uninhibited rooting of plantlets after potting.

By contrast, TDZ, one of phenylurea type, showed a strong inhibitory effect on rooting during in vitro culture and even after transplanting to pots. CPPU also had an inhibitory effect on rooting, but to a lesser degree than TDZ. Henny (1995) reported that *Spathiphyllum* plants given a soil drench of TDZ at 4 to 10 mg liter^{-1} had more than double the number of shoots without inhibition of root growth in a glasshouse. At present, there is no known reason for the difference in response to TDZ between in vitro plantlets and intact plants. However, it is known that

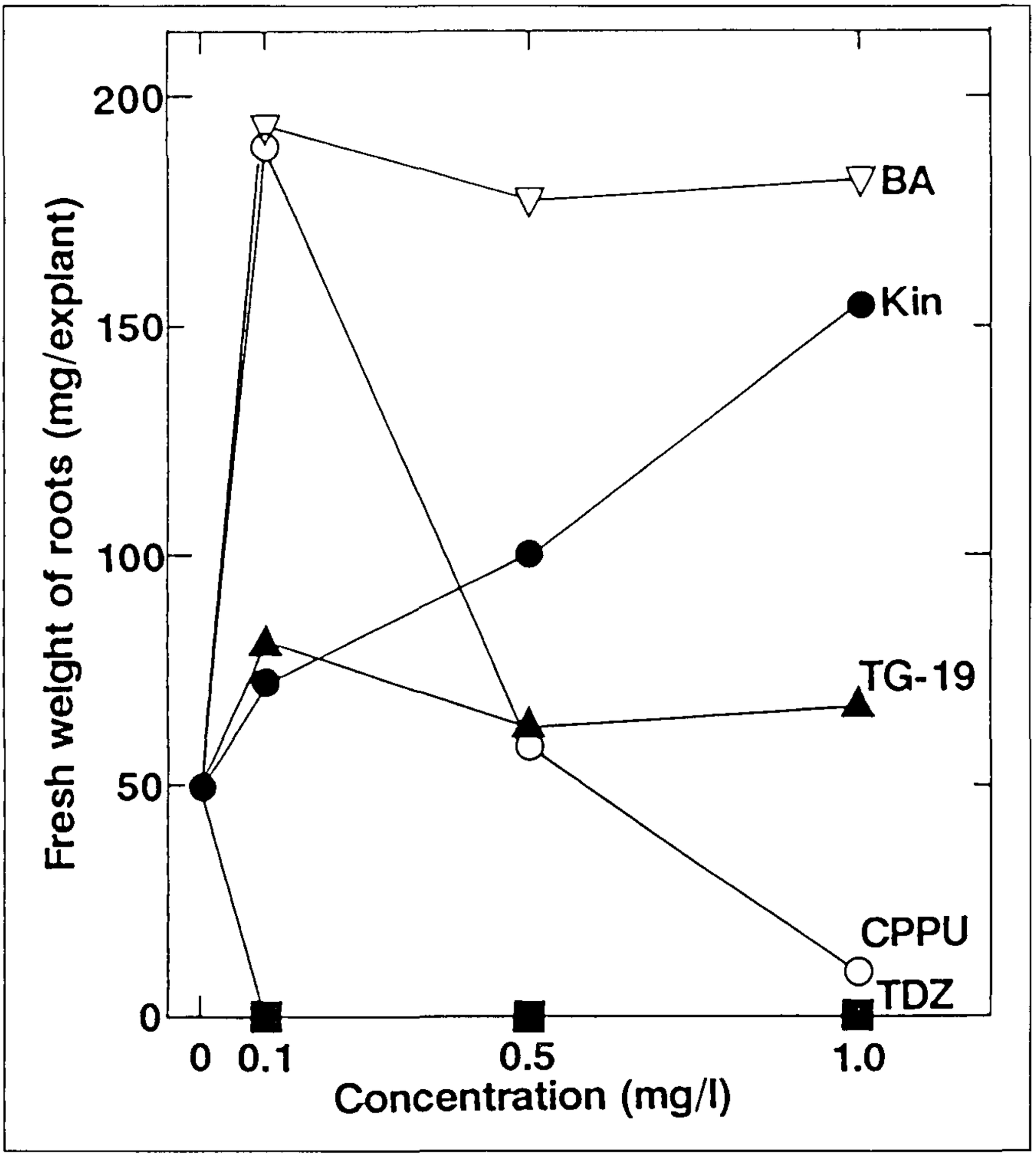

Figure 2. Root fresh weights of *Spathiphyllum* shoots after culture for 2 months on media supplemented with different cytokinins. Shoots with two unfolded leaves and without roots were used as explants.

Spathiphyllum plantlets take BA rapidly from the culture medium and accumulate large amounts of BA in the stem tissue when they are cultured on a medium containing 5 mg liter^{-1} BA (Werbrouck et al., 1995). It seems that TDZ is also accumulated in the *Spathiphyllum* plantlets at multiplication stage, and the accumulation could cause the carryover effect, that is, the strong inhibition of rooting after potting.

In conclusion, the effects of TG-19 on multiplication and rooting of multiplied shoots were similar to those of BA, and the carryover effect of the urea-type cytokinins inhibited rooting after potting. Such a carryover effect is undesirable for the practical production of potted *Spathiphyllum* plants.

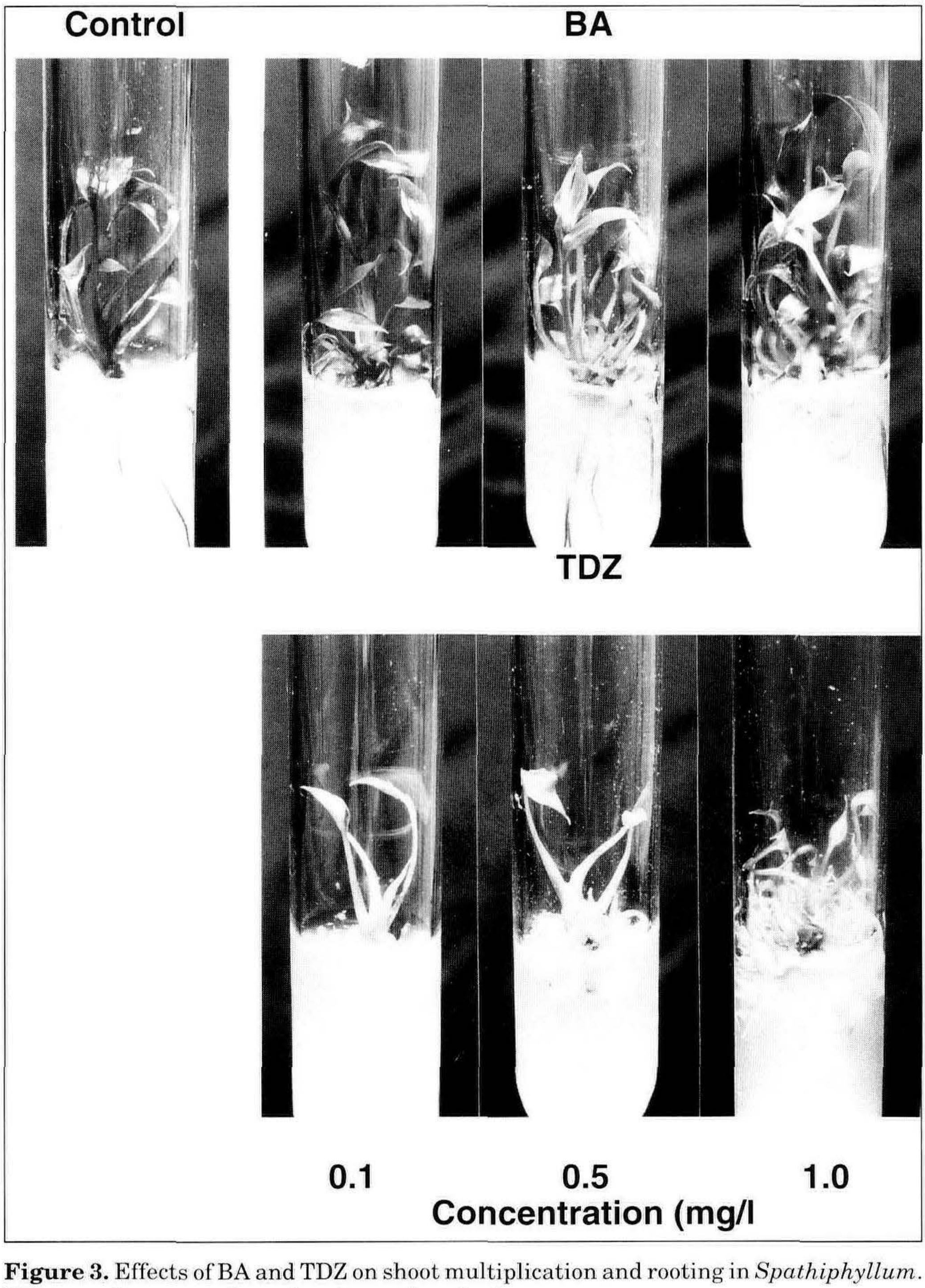

Figure 3. Effects of BA and TDZ on shoot multiplication and rooting in *Spathiphyllum*. Photographs were taken after 2 months of culture.

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Inducing Callus Formation from Leaf or Petiole Segments and Culture of Callus in Pelargonium

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INTRODUCTION

Pelargonium is an important source of perfume because of its strong fragrance.

The purpose of this study is to induce callus from the leaf or petiole segments of two taxa of *Pelargonium*, to examine the difference between the two taxa in the induction of callus, and to investigate the proliferation rate of callus during subculture.

MATERIALS AND METHOD

The two taxa, *P. inquinans* and *P.* 'Rouletta', were used as the source material. The leaf or petiole segments were cultured on Murashige and Skoog (MS) medium containing 3% sucrose, 2.5 g liter^{-1} Gellan Gum, 0.22 mg liter^{-1} NAA + 2.2 mg liter^{-1} BA (medium 1) or 0.2 mg liter^{-1} 2,4-D + 2 mg liter^{-1} 2ip (medium 2) at pH 5.6 to induce callus formation.

Young leaves with petioles, 3 to 6 nodes from the top, were collected and cleaned with running water, and then sterilized with 70% alcohol for 30 sec and 10% sodium hypochlorite for 15 min. Segments of leaf and petiole were cut into 5-mm lengths and placed on medium 1 or 2, in a vial (73 mm × 127 mm). The segments were cultured in an incubator (Nihonikakiki, EZ-022) under 16-h light (white fluorescent lamps), 130 μmol s^{-1} m^{-2} PPF(5000 lx), at 25C. Callus induced from the leaf or petiole segments was divided into about 5-mm squares and cultured on medium 2. Proliferation rates were obtained from the average of 22 replicates every 4th day by measuring callus size (length × breadth × height).

RESULTS

There was a difference between the two taxa in callus formation. The petiole segment produced more callus than the leaf segment in both taxa. Medium 2 (0.2 mg liter^{-1} 2.4-D + 2 mg liter^{-1} 2ip) induced better callus formation. The proliferation rate of callus with *P.* 'Rouletta' was about twice that of *P. inquinans*.

Growth Characteristics of Nursery Plants Regenerated Through in vitro Culture in Leek (*Allium porrum* L.)

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The growth characteristics of leek (*Allium porrum* L.), regenerated through in vitro culture, were investigated. Leaf sprouts emerged from the ground 2 to 4 weeks after planting in the field. Adult foliage followed, and four to five leaves were produced by December. The following April the foliage began to elongate and the plant height increased. By July the leaves had completely expanded and bolting and flowering followed. The number of bulbs per plant at harvest was 6.2 in the control. However, they varied from 2.9 to 9.7 among the 29 lines under investigation. The fresh weight of bulbs per plant also ranged from 3.8 to 25.3 g. The relationship of the fresh weight of the bulbs between planting in 1995 and harvesting in 1996 was shown to be significantly positive (r = 0.86) and was also consistently stable. These results provide significant information on growth characteristics of plants regenerated through in vitro culture, and indicate that an individual selection by numbers and fresh weight of bulbs as an index, will increase the efficiency of cultivation.

INTRODUCTION

Leek (*Allium porrum* L.) is a vegetable crop grown for its edible bulbs and belongs to the Allium family, i.e. onion (*A. cepa* L.) and garlic (*A. sativum* L.). Recently, in vitro culture has been considered to be a useful method for the improvement of crop characteristics in *Allium* (Keller, 1990; Nomura and Makara, 1993; Mohamed-Yasseen et al., 1994). Regeneration through in vitro culture has been described for leeks (Schavemaker and Jacobsen, 1995; Silvertand et al., 1995) and is a valuable new propagation method as well as the traditional seed and vegetative methods. Plants produced by tissue culture are useful for a breeding programme aimed at improving yield and quality. It is important to specify the desirable characteristics of plants for commercial cultivation.

In this report, the growth characteristics of leeks which were regenerated in vitro were investigated.

MATERIALS AND METHODS

The plants from which the material for in vitro culture was taken were used as the

control in this experiment. The tissue-cultured plants were divided into 29 groups and their fresh weight was individually measured. Five to seven bulbs of each group were transplanted into the field at the experimental farm of Iwate University in October 1995. After transplanting, all of the bulbs were observed to grow in the field. In August 1996, when the foliage began to die, the bulbs were collected. After harvesting, the number and fresh weight of bulbs were recorded for each group.

RESULTS AND DISCUSSION

Young leaves were observed to emerge above the ground 4 weeks after planting out. Adult foliage followed and gradually increased to between four or five leaves by December. However, after December no new leaves emerged. In the following April, leaves elongated and the height increased (Fig. 1). From June to July, the leaves expanded further and bolting commenced. The flower stalk with involucre began to elongate through the leaf sheaths. The involucre grew with the elongation of the flower stalk. Flowering occurred from top to bottom of the umbel-shaped inflorescence when the involucre was removed.

Leek seedlings grown from seed sown in spring do not produce bulbs until the seedlings have matured. The bulbs begin to grow once temperatures drop in winter (Yakuwa, 1963; Aoba, 1976). When the bulbs are transplanted, they can be propagated vegetatively. Therefore, it is necessary to find the best producing plants in the field for commercial purposes. In this experiment, all of the tissue-cultured bulbs and the mother plants sprouted and developed into plants. The leaf colour of both types of plants was similar.

Significant differences in the number of bulbs occurred among the 29 groups (Fig.

Figure 1. Development of leek plants regenerated through in vitro culture.

2). There were 6.2 bulbs harvested from the control. More than half of the groups had 5 to 8 bulbs but the numbers in groups 3, 17, and 18 were lower, 2.9-3.0., while groups 12, 23 and 26 had more than eight bulbs and were considered superior to the other groups. Thus, the numbers of bulbs varied from 2.9 to 9.7 among the 29 groups of plants.

The fresh weight of bulbs per plant was closely related to the number produced

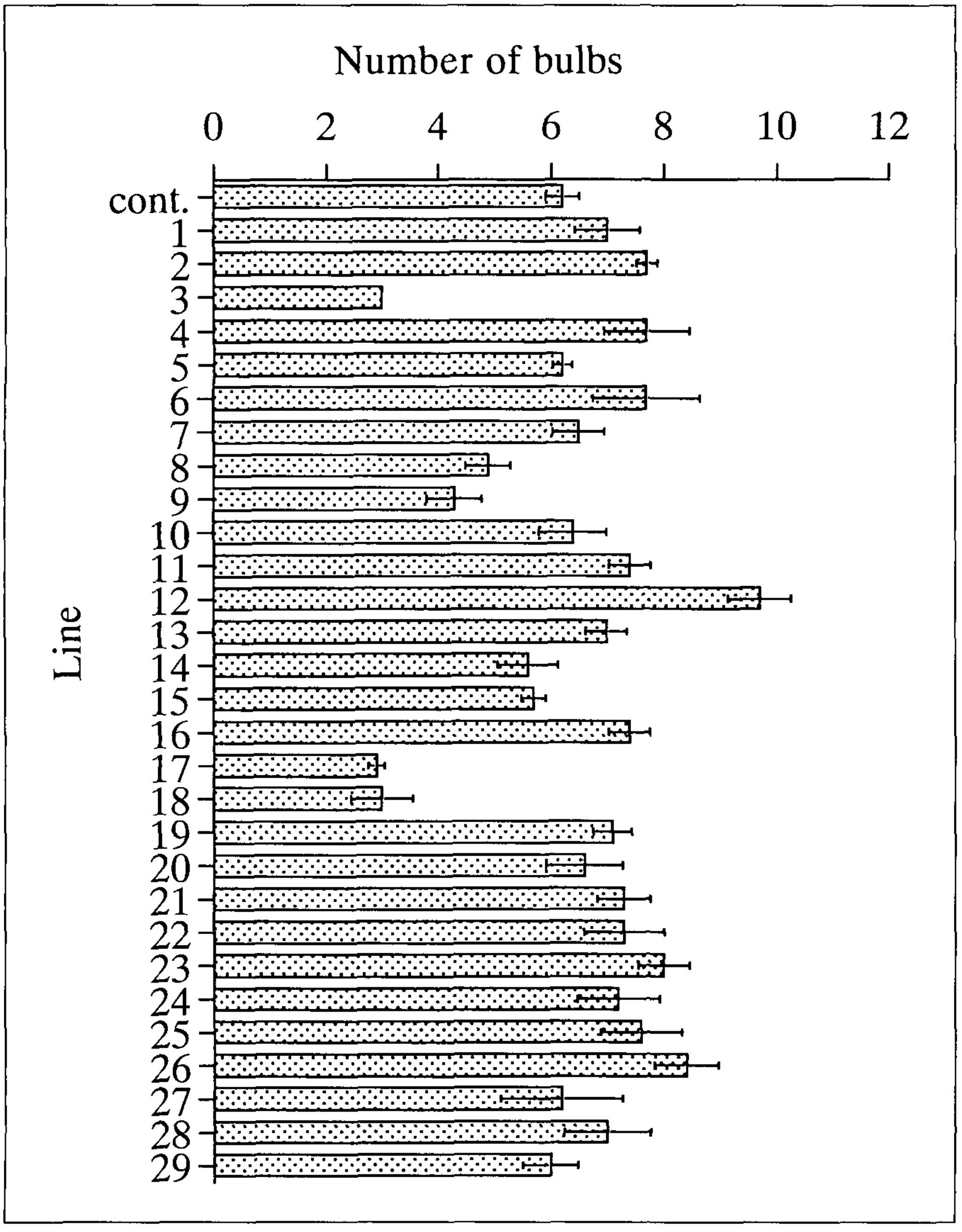

Figure 2. Comparison of the number of bulbs from leek plants regenerated in vitro. Vertical bars indicate S. E.

(Fig. 3). Group 3 had the highest fresh weight of bulbs, 25.3 g. However, the number was small compared with other groups, while group 12 had the lowest fresh weight, 3.8 g.

In leeks, leaf-bud formation occurs at the basal plates when the bulbs are subjected to low temperatures after flower-bud formation. The leaf-bud grows gradually as the temperature increases to develop the mature bulb (Yakuwa, 1963). The process of leaf-bud formation is also similar to that of garlic. However, the leaf-bud formation

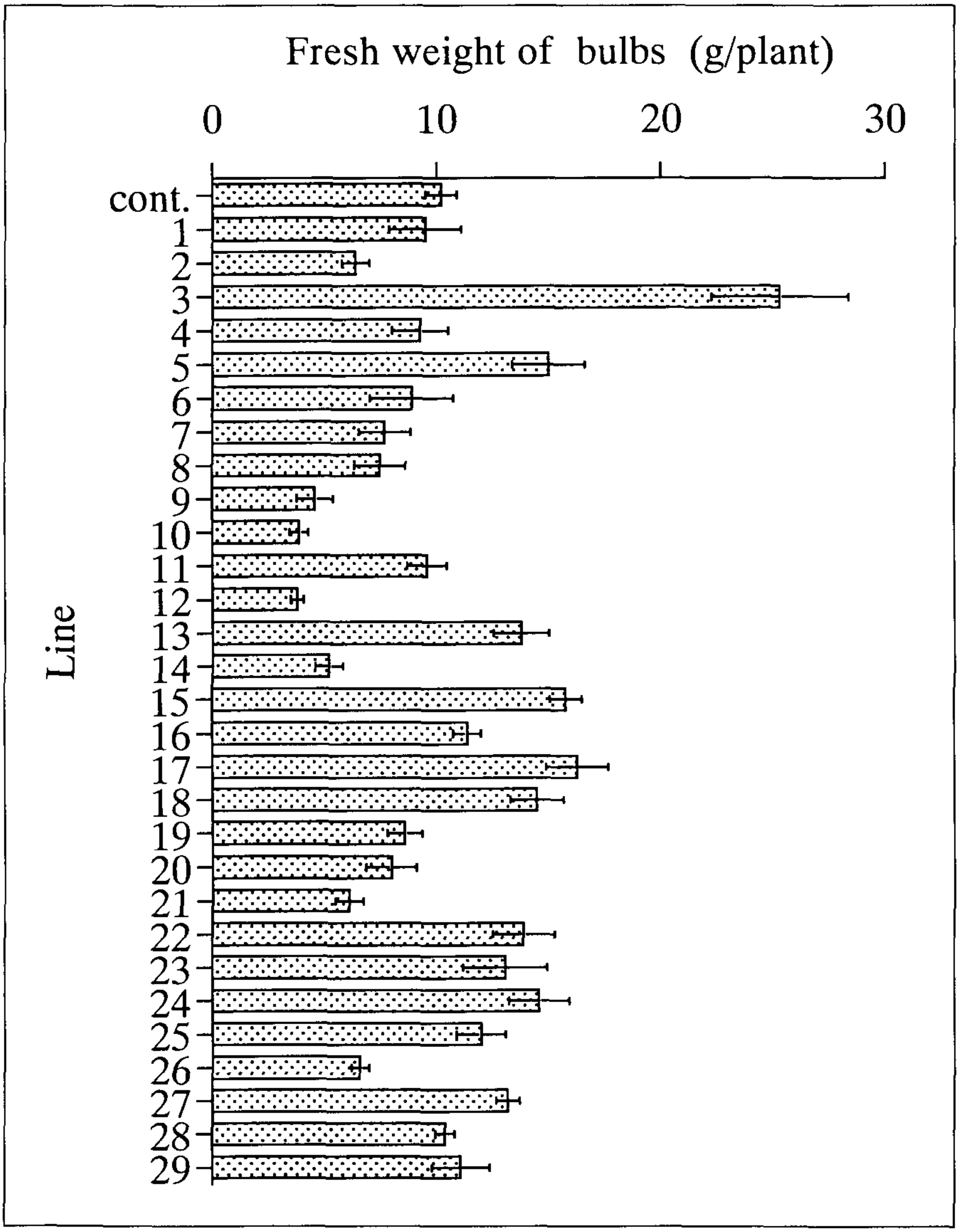

Figure 3. Comparison of the fresh weight of bulbs among leek plants regenerated in vitro. Vertical bars indicate S. E.

and the numbers of buds are different from those of garlic. Results indicate that the differences in the number and fresh weight of the bulbs are useful criteria for selection.

The relationship of the fresh weight of the bulbs between planting in 1995 and harvesting in 1996 was significantly positive (r = 0.86) (Fig. 4). This characteristic was recognized to be constantly stable in both 1995 and 1996. The plants regenerated in vitro proved to have significant differences in some growth characteristics.

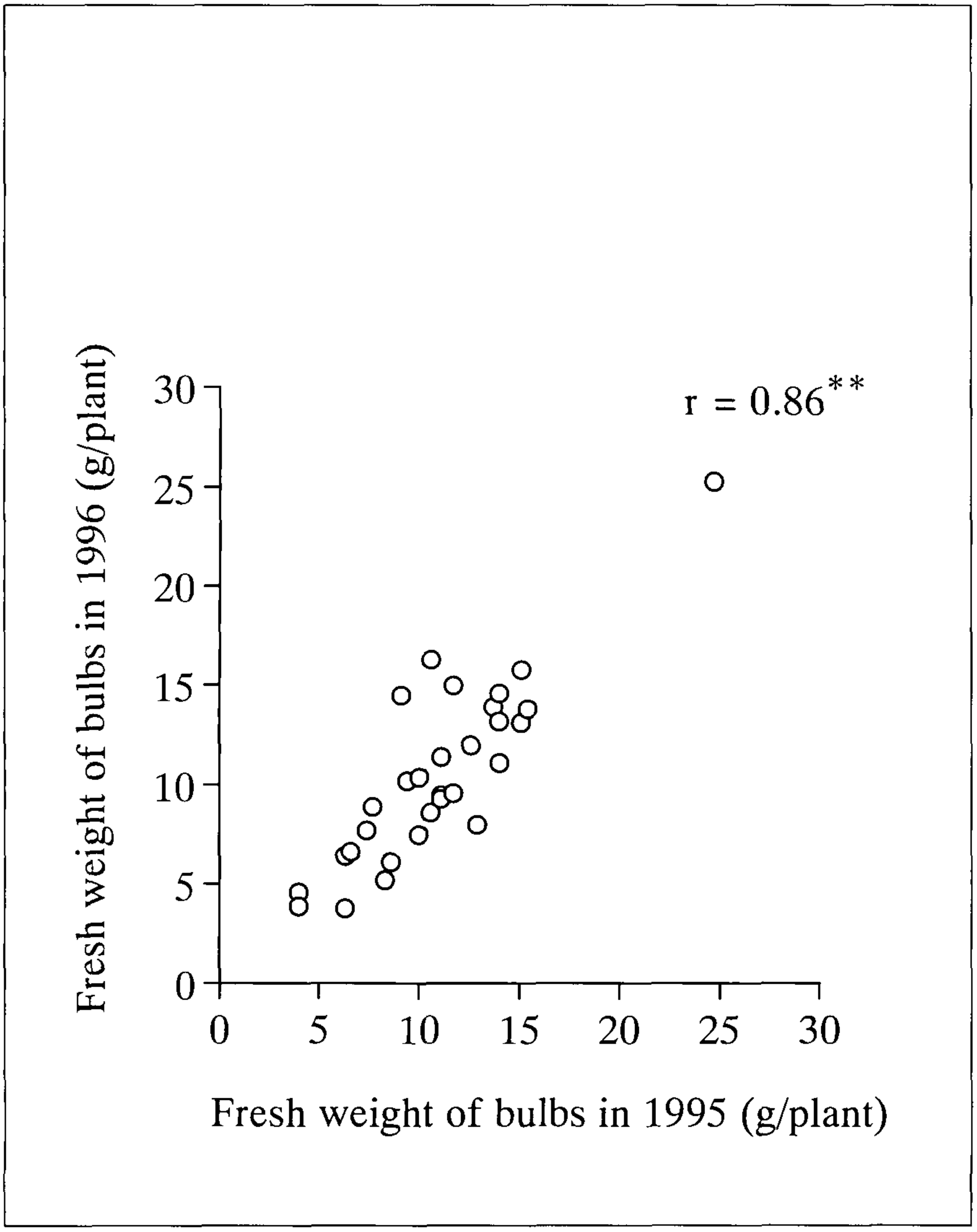

Figure 4. Relationship of the fresh weight of bulbs in 1995 and 1996 among leek plants regenerated in vitro. ** Significant at 1% level.

These results provide significant information on the growth characteristics of leek plants regenerated in vitro. It is shown that individual selection by numbers of bulbs and fresh weight of bulbs as an index, increases the efficiency of cultivation.

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In vitro Inoculation Test for Resistance to Crown Gall Disease on Roses

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***Rosa* 'Fashion Parade', *R. canina*, *R. canina* 'Superbe', *R.* 'Pekcougel', Anna® hybrid tea rose, and *R.* 'Meihartfo', Kalinca® floribunda rose (*syn. R.* 'Pink Wonder') were cultured by shoot tip culture and were micropropagated every 6 weeks in vitro. *Agrobacterium tumefaciens* was isolated from crown gall collected from a rose plant. The shoots inoculated with *A. tumefaciens* formed white or white-green crown galls. Four methods were used for inoculation: (1) needle prick inoculation (needle), (2) spread inoculation at upper end of shoot (upper), (3) spread inoculation at lower end of shoot (lower), (4) slice off bark and inoculate (slice). Shoot growth was not affected by inoculation of *A. tumefaciens* except for slice. Four weeks after needle inoculation, the rate of shoots which formed crown gall rose to 70% and remained stable. Therefore, the needle prick inoculation was the most successful and easiest to administer.**

Five roses: *R.* 'Fashion Parade', *R. canina*, *R. canina* 'Superbe', *R.* 'Pekcougel', Anna® hybrid tea rose, and *R.* 'Meihartfo', Kalinca® floribunda rose were inoculated by the needle method. *Rosa canina* and 'Fashion Parade' had no resistance to infection and disease. *Rosa canina* 'Superbe' was resistant to infection but lacked resistance to disease. *Rosa* 'Pekcougel', Anna® hybrid tea rose, and *R.* 'Meihartfo', Kalinca® floribunda rose (syn. *R.* 'Pink Wonder') were not infected and resisted disease infection.

INTRODUCTION

Crown gall disease is a soil-borne disease caused by *A. tumefaciens* and damages dicotyledonous plants, especially fruit trees and ornamentals. This disease is difficult to control with chemicals. Using resistant rootstocks is a good method for the control of crown gall disease, and some resistance rootstocks have been selected for roses (Boelema, 1969). However, the in vivo inoculation test for selection of resistant rootstocks to crown gall disease is affected by climate, soil conditions, and plant growth. Recently, there has been increased research on shoot-tip culture and micropropagation of *Rosa*. Therefore, we tried, in this study, to test the in vitro inoculation of micropropagated shoots and resistance to crown gall in five rose taxa.

MATERIALS AND METHODS

Plant Materials. The following rose species and cultivars were used: *R.* 'Fashion Parade', *R. canina*, *R. canina* 'Superbe', *R.* 'Pekcougel', Anna® hybrid tea rose, and

R. 'Meihartfo', Kalinca® floribunda rose (syn. *R.* 'Pink Wonder'). These cultivars were cultured by shoot-tip culture and were micropropagated every 6 weeks in vitro. The medium for shoot-tip culture and micropropagation of these roses was Murashige and Skoog's medium containing 3% sucrose and 0.2% Gelrite and adjusted to a pH of 5.7. The concentrations of 6-benzylaminopurine (BAP) and gibberellin A_3 (GA_3) were selected at the most suitable concentration for growth of each cultivar from previous experiments (Table 1). Cultures were kept at 25C with a 16-h light period for 6 weeks under 3000 lux.

Table 1. Culture condition for micropropagation of rose species and cultivars.

Rose species and culitvar	BAP concentration	GA_3 concentration
Rosa 'Fashion Parade'	1.0×10^{-5} M	1.0×10^{-6} M
R. canina	1.0×10^{-6} M	-
R. canina 'Superbe'	1.0×10^{-5} M	1.0×10^{-7} M
R. 'Pekcougel', Anna® hybrid tea rose	1.0×10^{-5} M	-
R. 'Meihartfo', Kalinca® floribunda rose	1.0×10^{-5} M	-

Pathogenic Bacteria. Crown gall was isolated from a rose plant growing in a glasshouse. *Agrobacterium tumefaciens* was isolated by culturing on Brisbane and Kerr's medium (Brisbane and Kerr, 1983) and was cultured on YEB medium containing 5 g litre^{-1} Bacto beef extract, 1 g litre^{-1} Bacto yeast extract, 5 g litre^{-1} peptone, 5 g litre^{-1} sucrose, 0.493 g litre^{-1} magnesium sulphate heptahydrate and 15 g litre^{-1} agar, and adjusted to pH 7.2.

Experiment 1. Comparison of Inoculation Methods for In VitroInoculation Test. In this experiment, the miniature rose 'Fashion Parade' was subcultured for 6 weeks and inoculated with *A. tumefaciens* cultured for 24 h on YEB medium. Four methods were used for inoculation: (1) needle prick inoculation (needle), (2) spread inoculation at upper end of shoot (upper), (3) spread inoculation at lower end of shoot (lower), (4) slice off bark and inoculate (slice).

Experiment 2. Resistance to Crown Gall Disease. Five roses: *R.* 'Fashion Parade', *R. canina*, *R. canina* 'Superbe', *R.* 'Pekcougel', Anna® hybrid tea rose, and *R.* 'Meihartfo', Kalinca® floribunda rose, were inoculated by the needle method.

RESULTS AND DISCUSSION

Experiment 1. Comparison of Inoculation Methods for the In Vitro Inoculation Test. The shoots inoculated with *A. tumefaciens* formed white or white-green crown galls (Fig. 1). Fig. 2 shows the rate of shoots forming crown gall by the four inoculation methods. The rates of infection by the needle and lower methods reached 45% after 2 weeks and were higher than those using upper and slice. Inoculation by needle and lower, therefore, stimulated infection of *A. tumefaciens*.

Four weeks after inoculation, the rate using the needle method, rose to 70% and remained stable. That by slice increased rapidly and continued to rise until the 6th week. The rates by the lower and upper methods leveled out at about 50%.

For the in vitro inoculation test, a stable rate of infection has to be established earlier. Although slice indicated a high rate after 6 weeks inoculation, the rate continued to increase. Therefore, the rate will not be constant. With the needle method, infection reached 70% after 4 weeks and then remained stable and we consider this the best method.

Figure 1. Shoots inoculated with *Agrobacterium tumefaciens* formed white or white-green crown galls.

Shoot growth was not affected by inoculation with *A. tumefaciens* except under the slice method. Growth of shoots inoculated by slice, declined as the crown gall increased, and the shoots turned brown.

The resistance to crown gall disease on roses has been measured by in vivo testing (Boelema, 1969; Brown, 1923). The results of this in vivo test method are affected by the stage of growth and the environment, i.e. temperature, humidity, solar radiation, soil condition and watering, and are not constant.

Recently, the resistance to some diseases has been tested in vitro, in tomato (Toyoda et al., 1988), potato (Nakahara et al., 1990), and tobacco (Chatani et al., 1994). These results are constant, because the growth of the plants in vitro is not affected by environmental conditions, also we are able to use plants in the same growth stage for the test.

There have already been many practical reports on in vitro propagation of roses, and the needle prick inoculation method in this paper was good for manipulation and sensitivity. Therefore, this in vitro inoculation method will become an important method for the selection of resistant rootstocks to crown gall disease.

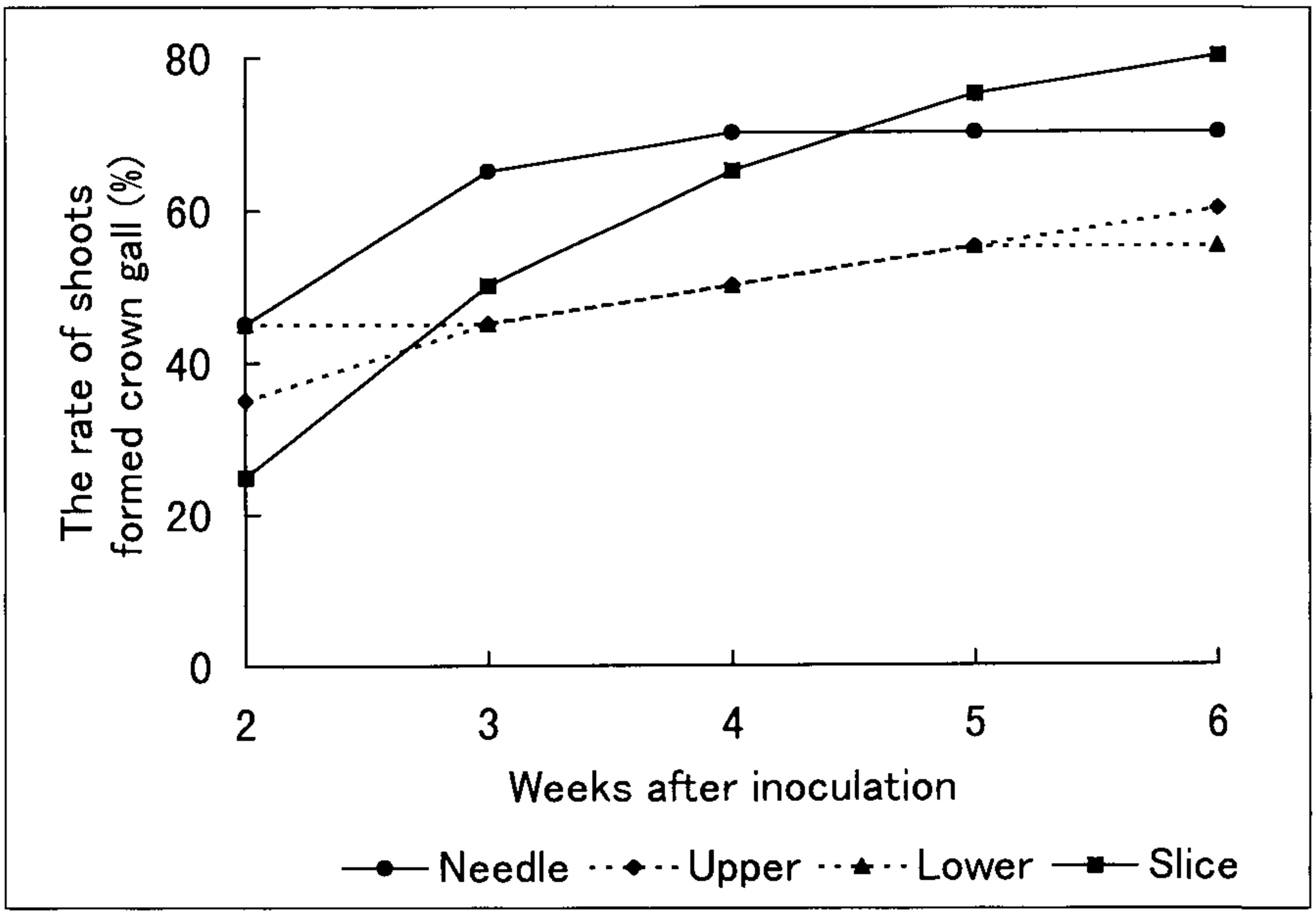

Figure 2. The rate at which shoots formed crown gall, comparing four inoculation methods.

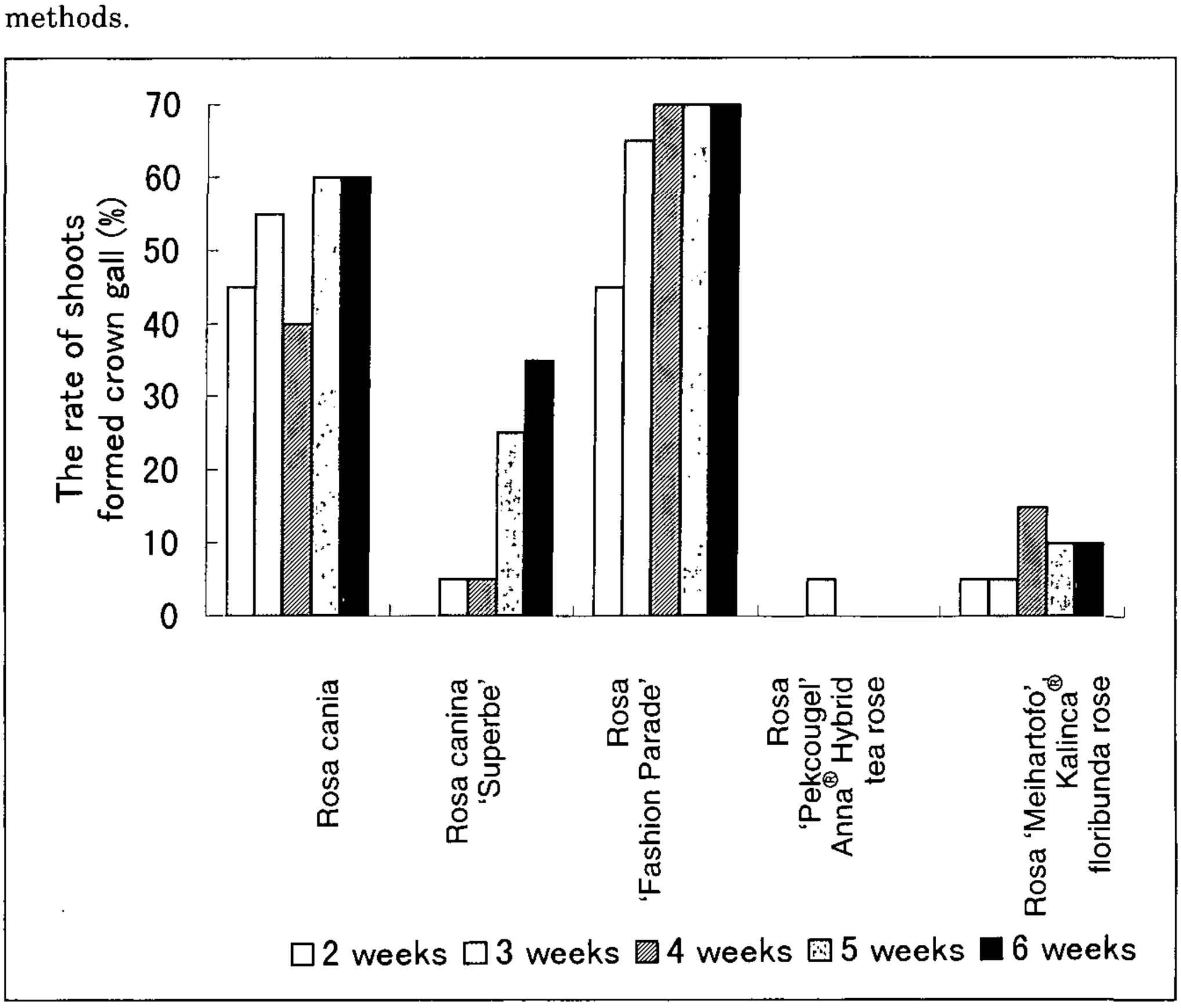

Figure 3. The rate at which shoots formed crown gall in the five roses.

Experiment 2. Resistance of Rose Species and Cultivars to Crown Gall Disease. Two weeks after inoculation 45% of *R. canina* and 'Fashion Parade' were already infected (Fig.3). Thereafter the rate of plants forming crown gall increased slightly and reached between 60% and 70%. *Rosa canina* 'Superbe', a cultivar selected from *R. canina* for rose rootstocks, showed no infection 2 weeks after inoculation. The infection rate was low until the 4th week, but thereafter shoots forming crown gall increased to 40% after 6 weeks. *Rosa* 'Pekcougel', Anna® hybrid tea rose, and *R.*'Meihartfo', Kalinca® floribunda rose showed little sign of infection.

From the high rate of infection in *R. canina* and 'Fashion Parade', we decided that these two roses had no resistance to infection and disease development. The low rate 4 weeks after inoculation in *R. canina* 'Superbe' indicated that this rootstock cultivar had resistance to infection. But, the increase after 5 weeks and over, indicated a lack of resistance to disease development in this cultivar. *Rosa* 'Pekcougel', Anna® hybrid tea rose, and *R.*'Meihartfo', Kalinca® floribunda rose had resistance to infection.

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The Effect of CCC and BA on the Formation of Potato (*Solanum tuberosum* L.) Microtubers

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Microtubers formed in vitro—which are usually in the range of 7 to 10 mm in diameter—should be a useful size for the convenient storage, long distance transport and circulation of elite clones. To date, many studies have reported on the promotive effects of cytokinins and growth retardants on the formation of microtubers. In the present experiment, using the micropropagated shoots of potatoes originated from meristem culture, we investigated the mode of formation of microtubers on solid medium and the effects of CCC (chlorocholine chloride) and BA (benzyladenine) on the formation of microtubers. Two types of in vitro tuberization were observed in dark conditions. One was a sessile microtuber, formed from axillary buds on the shoot, which occurred in an early stage of culture, and the other was a microtuber formed on a stolon arising from the shoot. The external morphology of a small organ transforming into a tuber from an axillary bud after two days of culture was observed by scanning with an electron microscope. The number of microtubers formed after 28 days of culture was the largest in the Murashige and Skoog medium solidified with 0.2% Gelrite and supplemented with CCC (500 mg liter^{-1}) and BA (5 mg liter^{-1}) in the dark at 20C. Increasing the concentration of CCC resulted in an increase in the number of microtubers, while that of BA was more effective for the increase of the fresh weight than of the number of microtubers.

Acclimatization of Bulbous Plants Between Northern and Southern Hemispheres

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During the last decade international transportation of goods has become fast, frequent, and reliable thanks to growth in the airline industry. This has created a worldwide trade in perishable floral products. These products include cutflowers, live plants, and flower bulbs. The term "flower bulb" includes bulbs, tubers, rhizomes, corms, and offsets. These plant modifications which provide food storage for survival during a resting period, create an ideal item for exporting to overseas countries. Millions of bulbs are transported between countries such as Holland and Japan with little difficulty in acclimatisation. Shipping bulbs from the Southern Hemisphere to the Northern Hemisphere creates some problems but also some opportunities.

When considering importing bulbs from the Southern Hemisphere, the environmental conditions that bring on dormancy and break dormancy must be studied. An understanding of flower induction is also necessary to get a controlled result. Bulbs can be put in the following categories:

1) Evergreens. No dormancy is required to resume growth, however plants can have leaves and roots trimmed or dried for short periods to enable transportation.

Examples: *Agapanthus, Cyrtanthus, Tulbaghia, Haemanthus, Scadoxus,* and *Crinum.*

Import: Small "rootstocks" are received in April/May and grown on for a season before being ready for sale.

2) Spring Flowering. Dormant in the summer with sprouting and vegetative growth occurring in autumn and winter.

Examples: *Babiana, Cyanella, Geissorhiza, Gladiolus, Ixia, Lachenalia, Lapeirousia, Oxalis, Sparaxis,* and *Watsonia.*

Import: Small rootstock is received in March and stored warm until planting in August to grow over autumn,winter, and spring then harvested in summer. Some genera do not produce large enough rootstocks to withstand warm storage or plant quarantine does not allow free importation. In these cases seed must be imported and grown for two seasons.

3) Summer Flowering. Dormant in the winter with sprouting and vegetative growth in the Spring.

Examples: *Eucomis, Littonia, Sandersonia,* and *Zantedeschia* (coloured hybrids).

Import: Flowering size "rootstock" from specialist propagators who can supply from April to October for forcing out of the normal season in greenhouses. For dry

bulb sales in February small rootstock must be received in May/June and grown on one season over summer.

4) Autumn Flowering. Dormant in the summer with vegetative growth after flowering in winter and spring.

Examples: *Hippeastrum* (syn. *Amaryllis*) and *Nerine*.

Import: Flowering size "rootstock" in February to flower in April which is opposite to the natural flowering season of October. Many bulbs will reflower again in October after putting on a growth phase over summer. For flowering in the natural season specially treated bulbs are imported in late July.

Ornamental Climbing Plants at the University of British Columbia Botanical Garden

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INTRODUCTION

The University of British Columbia Botanical Garden is the oldest university botanical garden in Canada. It was established in 1916 under the Department of Biology and was essentially a teaching garden, but at the same time served an important role in the beautification of the new campus. In 1968 the university's board of governors designated a new 70-acre site for the construction of a new botanical garden. The challenge to design and develop this project was taken up by the Garden's former director, Dr. Roy L. Taylor.

Today the Garden has over 14,000 accessions, some 10,000 different plants and plays a major role in education and research, as well as in developing close ties with the community and the professional horticultural industry.

CLIMBING PLANTS

The Vancouver climate provides an excellent growing environment for a diverse collection of climbing plants. The collection of vines is considered to be one of the best in North America for a northern temperate climate. The Garden has many locations where these plants can be tested, including perimeter fences, a large wooden arbor and summer hanging baskets and containers. However it is the coastal forest area of the David C. Lam Asian Garden, one of the Botanical Garden's components, where vines are seen at their best. They are able to grow up and into large specimens of native coniferous trees, e.g., *Abies grandis, Tsuga heterophylla, Pseudotsuga menzieii* and *Thuja plicata*. The David C. Lam Asian Garden contains a number of rare species, including *Actinidia hemsleyana, Aristolochia heterophylla,* and *Holboellia fargesii*.

Actinidia hemsleyana. *Actinidia hemsleyana* is native to Eastern China and grows up to 10.0 m. high. Besides its narrow leaves, its main ornamental feature is the very conspicuous fine red hairs it bears on its new growth. Greenish-coloured flowers are produced in June. Propagation is by single nodal softwood cuttings in June, using 0.5 to 0.8% IBA in talc. The cuttings take four to five weeks to root under mist. It is important that the rooting mix not become overwet, as rotting of the stem and auxiliary bud will result.

Aristolochia heterophylla. *Aristolochia heterophylla*, from Western China, is a shrubby climber growing up to 3.0 m. in height. The leaves are soft and pubescent. The small typical "Dutchman's Pipe" flowers are pale yellow and tinged purple, developing to bright yellow at the flower's center. This vine has great potential for growing up a trellis in small gardens, as well as in patio containers. It is propagated by softwood cutting in late May to early July, using 0.3 to 0.5% IBA in talc.

Holboellia fargesii. *Holboellia fargesii* has to be one of the best of all evergreen climbers, but is unfortunately virtually unobtainable in the nursery trade. The new yellow-green growth turns to a dark green, making the deeply lobed leaves particularly attractive. The pendant pale-lavender flowers in the late spring and early summer are outstanding. This vine grows well in both shade and nearly full sun in Vancouver. Unfortunately the selection of this species we wish to introduce into nurseries is extremely difficult to propagate. No success has been achieved with softwood, semi-ripewood or even micropropagation. Plans are underway to see if it will graft successfully onto *Holboellia coriacea, Akebia quinata,* and *Stauntonia hexaphylla* — all members of the family Lardizabalaceae.

PLANT INTRODUCTIONS

In British Columbia there has been a surge of interest in climbing plants from home gardeners, landscape designers and nursery growers. Recently the development of new and improved selections has been a priority for the Garden's Plant Introduction Scheme. The first plant releases were made through this program in 1983 and to date 17 introductions have resulted in over 10.0 million plants being produced in North America. Besides climbers, these introductions include shrubs, trees, perennials and groundcovers. In British Columbia alone there are now 43 nurseries participating in the program.

***Clematis* Introduction Program.** *Clematis* 'Blue Ravine' was the first vine released through the Plant Introduction Scheme. It was bred by Mr. Conrad Erlandson of Abbotsford, British Columbia, by hybridising *C.* 'Nelly Moser' with *C.* 'Hybrida Sieboldii' (syn. *C.* 'Ramona'). He subsequently gave it to the UBC Botanical Garden. It retains the best qualities of both parents. *Clematis* 'Blue Ravine' grows to 2.0 to 3.0 m. in height. An abundance of large flowers are produced in May and June, with a few later in the season. The flowers are 15 to 20 cm. across, with seven or eight soft violet-blue wavy petals with a darker pinkish-blue midrib. It is ideal for containers and for trellises for small gardens, as it flowers low down on the previous season's wood. In nursery production this also means that flower buds are quickly set on small liner plants and may need to be removed to obtain good extension growth. *Clematis* 'Blue Ravine' is now one of the best selling cultivars in Canada. A seedling from it, with silver-blue flowers, is currently under trial. Soon to be released through the program is a very attractive selection of *C. chiisanensis* from wild collected seed in Korea. Its clear-yellow solitary pendant flowers are considerably larger than the type species and turn orange-red near the pedicel. It is one the earliest yellow-flowered species in Vancouver, thus making it a useful addition for retail sales. Later the stems turn purple-black and small silver-white seed clusters appear. It is a tidier plant than *C. tangutica* or *C. tibetana* ssp. *vernayi* (syn. *C. orientalis*). Also being evaluated are some interesting selections of wild collected seed of *C. koreana* var. *fragrans*. The flower colours range from mid-purple through to yellow and the shapes of the flowers vary considerably.

A *Clematis* breeding program has been initiated for this popular genus. The goals of the program include hybridisation of different species and/or cultivars in order to develop:

- Scented large-flowered cultivars
- Muli-flowered racemose cultivars with medium to large flowers
- Yellow cultivars that do not fade in the sun

- Compact selections for small patios and pot plant production

Other Breeding Programs. Breeding new climbing plants has been a major focus for Dr. K.W. Nicholls, the Garden's research scientist. He has successfully bred a new *Lonicera* by hybridising the Chinese species, *L. tragophylla*, with the Canadian-bred cultivar, *L. ×brownii* 'Dropmore Scarlet'. *Lonicera tragophylla* is noted for its large inflorescences of yellow flowers and attractive new foliage. *Lonicera ×brownii* 'Dropmore Scarlet' has much smaller red flowers and its hardiness withstands the harsh Canadian winters. Selected from the seedling progeny was an outstanding plant which subsequently produced large inflorescences of orange-red flowers but retained the foliage of *L. tragophylla* and the hardiness of *L. ×brownii* 'Dropmore Scarlet'. This plant was subsequently named *L.* 'Mandarin' and has been released to the program's participating nurseries for sales commencing in March 1998.

There is a definite demand for more evergreen vines suitable for the Pacific Northwest and for this work the Lardizabalaceae show considerable potential.

Plans are underway for interspecific and intergeneric hybridisation of *H. fargesii* with *H. coriacea, A. quinata* and *S. hexaphylla*. Climbing plants will continue to be an important part of the Garden's collections. The UBC Botanical Garden provides an ideal environment for exploring new ways they can be used in the landscape. In the nursery production of these plants it is essential that particular attention is paid to correct naming, good hygiene and other cultural techniques to ensure quality plants are produced for the vibrant market demand.