The Importance and Domestication of South African Plants

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INTRODUCTION

The first records of the use, indicating the importance of South African plants in horticulture, can be traced back to the second half of the seventeenth century.

The Dutch, who arrived in the Cape in 1652, were stunned with what they were exposed to in their new country. It was not only a new world, geographically speaking, but the diversity of birds, insects, mammals, and plants in particular kept them gazing in disbelief. Many of these plants soon found their way to Europe. Simon van der Stel in particular, exported many species to the Netherlands. Descriptions and coloured prints of plants in the magnificent two volumes produced by Jan Commelijn (1697) and his nephew Casper (1701) of plants grown in the botanical garden in Amsterdam, include many of these plants from South Africa. Although many of the names have since been changed, the plants can unmistakably be identified from the descriptions and colour plates. The following serves as examples: *Aloe arborescens, A caulescens, Gloriosa superba, Polygala myrtifolia, Salvia africana-lutea*, and *Zantedeschia aethiopica*. Amongst the trees grown, were an *Encephalartos* sp., *Leucadendron argenteum,* and *Sideroxylon inerme.* The diversity was so large and the opportunities so unlimited, that for the first 50 years collectors from the northern hemisphere experimented with almost everything. That it was not always easy, was also true. The winter rainfall climate of the Cape, with mild temperatures differed in so many ways from the European climate, that the focus changed and preference was given to those plants that could be grown in glasshouses, like bulbs, herbaceous plants, and succulents.

The nineteenth century saw a new revival of interest in South African plants, especially when plants from other parts of South Africa, especially Natal, became available. The climate of the Drakensberg in particular with a summer rainfall and bitterly cold winters, often with snow, was close to the European climate. Examples of genera that can be listed are the following: *Agapanthus, Euryops, Kniphofia, Osteospermum, Phygelius, Rhodohypoxis,* etc. (Rourke, pers. comm.). *Encephalartos altensteinii,* grown at Kew and dating back to 1775, can probably be regarded as the oldest glasshouse plant.

Closer to home reference is made of the Company Garden in Cape Town, and to Simon van der Stel who appointed, amongst others, also persons with botanical knowledge. They introduced a wide variety of plants which they collected on their expeditions to the interior. Many of these plants in particular though, were of more interest to botanists, than to cooks. The names of the two botanists Oldenland and Hartog, must be mentioned, both of whom added many South African plants to the Company Garden (McCracken and McCracken, 1988). It is not the intention to dwell much on the history of South African gardens and collections, but a reference to Schonberg's Estate, "Felhausen", in Flora Herscheliana by Warner and Rourke, 1996, is very interesting and serves as an example of the early domestication of many South African plants, mainly bulbs from the western Cape. On a detailed plan of the estate, prepared by Sir John Hershell, who, with his family occupied the house between 1834-1838, a bulb garden is indicated. It is not known for sure whether Schonberg or his predecessors established the bulb garden, but Hershell definitely used the position as a nucleus for his own collection. By the autumn of April 1835 he reported: " I have at least 100 sorts of Cape bulbs in progress and all have rooted and are doing well (Warner and Rourke, 1996, p.149).

Apart from drawing the flowers with the aide of a camera lucida by Hershell himself and beautifully painted by his wife Margaret, the intention was undoubtedly to build up a vast collection of bulbs to send back to friends in England as well as to take back himself at the conclusion of his Cape sojourn.

It is not clear how many species Hershell collected, but it must have been extensive, both in numbers and in volume. He did record that he lost some thousands of plants, due to moles. It is a fact though that he succeeded in taking back to England "hardly less than 200 species" (Warner and Rourke, 1996, p.159).

THE CURRENT STATUS

It is common knowledge today that we have an exceptionally rich and diverse flora in South Africa. Though it is difficult to precisely establish what percentage of the 23,258 known taxa (species, subspecies, and varieties) are in cultivation today, it must be substantial.

A survey carried out in commercial nurseries across South Africa, indicated that there is a growing awareness of South African plants amongst the public. This must certainly be ascribed to numerous popular books on South African plants, radio and TV programmes, articles in journals, newspapers, and promotions by nurserymen. In this regard, I think it is fitting to mention the name of the late Kristo Pienaar, who has done so much to promote our flora. Undoubtedly, the tireless efforts by the horticultural staff of our national botanical gardens should also be mentioned.

The total number of species grown and displayed in the eight botanical gardens today is estimated to be in the order of 12,000 species. It must, however, be kept in mind that only plants with either horticultural, medicinal, educational, or scientific merit, specifically rare and endangered plants, are normally selected.

It is very encouraging to note that there is a new revival amongst some of our universities to develop botanical gardens and to expose their students to our unique flora. A proper survey still needs to be carried out, but it seems as if a national awareness outside the institutions already mentioned, is still lacking.

Kruger (1988) in one of a few reports available, reports that 271 different species of indigenous plants are used in amenity horticulture by 16 Cape local authorities. These plants were specifically selected for their resistance to drought, frost, and wind. Of these 271 species, more than 60% were recorded only once.

The examples mentioned this far, dealt mainly with the utilitarian value as display plants in botanical gardens, home gardens and parks, or trees planted for their shade, etc.

Without going into too much detail or trying to give a comprehensive report on the status of the industry, especially the commercial side of it, the following is just an attempt to draw the attention to other areas of importance of the South African flora.

COMMERCIAL IMPORTANCE

For most propagators, this may certainly be the most important facet in dealing with indigenous plants. The potential of each "new" plant as a source of revenue is very carefully considered and compared to other plants in cultivation, new trends in the industry, etc. The question can, however, be asked, how do you estimate the value of an indigenous species? Higgins and Cowling (1997), concluded that this indeed is very difficult: "As many fynbos species have horticultural potential, we considered that the minimum value of a species is the cost of producing a new horticultural variety. In essence this means that we are using the cost of commercial breeding and hybridisation to estimate the value of a species."

Agriculture. Looking at the way income is generated, a distinction must be made between growers and farmers harvesting from the veld. Unfortunately the sales figures are not always indicated separately, with the result that the importance of indigenous plants as a "crop" is difficult to establish.

Uncontrolled harvesting from the veld, specifically fynbos, is of great concern, especially looking at it from a conservation point of view, as the depletion of the seed resource could lead to the extinction of species.

Not trying to justify this kind of activity in any way, but in order to put it into perspective, Middleman, 1990 states: "in spite of it being true in some instances that the natural veld is over-exploited by opportunistic elements, the wild flower industry has created public awareness of the rich floral heritage, and also protected the natural veld from transformation for other pursuits, to some extent its loss to invasive alien species. The industry earns nearly R30 million per annum and provides jobs for 10,000 to 15,000 people."

As far as the intensive cultivation of indigenous plants is concerned, the Proteaceae are the most widely used wildflower from the Cape floral kingdom in the international floricultural trade. The genus *Protea*, with 15 species used commercially is the most important genus in the family.

This is illustrated in a report on the status of industry development by Malan (1977) where he provides a summary of intensive cultivation of three genera of the Proteaceae.

	Hectare	Total plants (× 1000)	Flower production (× 1000)
Type	1996	1996	1997/1998
Protea	207	1132	3000
Leucospermum	66	173	1300
Leucadendron	12	60	900

Unfortunately no monetary value was attached to this report.

This same phenomenon is also reflected in the yearly report from Miltiflora (March 1998 - February 1999) with *P. compacta* on the top of the list with 381,407 stems sold and *P. repens* with 309,936 stems sold, in a close second place.

The sales figures of indigenous flowers by Multiflora according to this report, indicates a turnover of ± R10.4 million.

Due to the new Government's initiative, more land has now become available to small farmers. Looking at the potential of indigenous plants, especially to these farmers, Leivers (1998) refers to a trial planting of six collections of indigenous bulbous plants in the church grounds of the Moravian Mission Church at Pella. Based on an average yield of 150 bulbs m^{-2}, 60% area per ha planted and an income of 5c per bulb, an income of R45,000 per ha is attainable.

Although the utilization of indigenous plants by man can be traced back for many centuries, it is only in the latter part of this century that the cultivation of plants on a commercial scale began in South Africa. Reference has already been made to the use of fynbos plants, mainly in the floricultural trade, and enough has been said about it. I would like to focus on other fynbos genera that have received a lot of attention in recent years.

Rooibos tea produced from various *Aspalathus* spp. is becoming increasingly popular. Until the 1930s it was not commercially cultivated, but today the annual production is more than 11,000 tons.

Another local tea, honeybush tea, produced from mainly 10 different *Cyclopia* spp., has suddenly become almost a household name. Many small farmers have became involved in the production. Although the annual production, in many cases still harvested from the veld, is ± 50 ton, export to England, Germany, and the far East is growing.

Medicinal. The use of indigenous plants by traditional healers is part of the history of Africa. The pharmaceutical industry is on a continual basis busy screening many of our plants for the medicinal properties. Many claims have been made and wonderful success stories are being told about the use of products made from local plants — the most recent being the various aloe products, and the African potato, *Hypoxis hemerocallidea* (*H. rooperi*), for the treatment of rheumatoid arthritis. Extracts from buchu and honeybush are also now available in other "forms".

Tourism. The important role of South Africa's flora in the tourism industry is receiving more and more attention. It can be assumed that the majority of the visitors to the Kruger National Park and the other South African parks are attracted by the animal life in the first instance. It cannot be denied though, that the vegetation, supporting the wildlife does not go unnoticed.

However, a visit to Namaqualand during the springtime, or the various wildflower shows, can only be to enjoy the beauty and diversity of our flora.

Visit numbers to the various National Botanical Gardens are increasing every year, with more than 600,000 visitors to Kirstenbosch alone this past year. Our estimate is that ± 20% of these visitors are from overseas.

"LOST OPPORTUNITIES"

That South Africa has lost many opportunities in the international trade is a well known fact. Leivers (1998, pers. comm.) states that Holland earns more foreign exchange annually from the export of plants originally discovered in South Africa than South Africa earns from the export of gold. However, he concluded that it is futile to bemoan the commercial loss to South Africa of many of the plants that are now household names through the world — pelargoniums, freezias, gerberas, and nerines, to name but a few.

Littlejohn (1998) dealing with the hybridisation of *Leucadendron* states along the same lines that Australia and New Zealand realised long before South Africa that *Leucadendron* had commercial potential as cultivated product. Not less than six well known cultivars originated from these two countries. In response to this the ARC Fynbos unit of Elsenberg has undertaken since 1986 a hybridisation programme using seven *Leucadendron* species. From these hybrids, the following cultivars were released: "Chameleon", "Rosette", "Laurel", "Flash Gordon", "Disco", "Kam-ee-lion", and "Robin Red". The tragic irony is that many of the plants which originated from South Africa and were domesticated in other countries are now being exporting back to South Africa — e.g., *Sandersonia aurantiaca, Clivia miniata, Gerbera jamesonii,* and various *Pelargonium* species.

MEASURES TO ACCELERATE THE DOMESTICATION OF SOUTH AFRICAN PLANTS

Similar to the fashion world, there is and always will be a need for new cultivars, be it better colour form, bigger flowers, longer shelf-life, better resistance to pests and diseases, drought or frost tolerant, etc.

It is not my intention to report on the excellent work done by, for example Elsenberg, Roodeplaat, Hadeco, and various other nurseries/growers to develop and introduce better selections or new cultivars, but to briefly reflect on the work done by the National Botanical Institute (NBI).

Research. The NBI lacks the facilities and other resources to conduct breeding programmes. Through the years, however, the horticulturists were always aware of and on the look out for variations that occurred. By carefully selecting and propagating material for display in the gardens, they managed, not only to introduce several forms of superior quality, but also to create an awareness amongst the public of the potential of our indigenous plants.

The discovery made by De Lange (1990) and co-workers of the long overlooked effect of smoke on the germination of seed is an important finding which promises to be of a major economic importance. Brown (1995) reports that approximately 180 species from the *Proteaceae, Ericaceae, Restionaceae, Bruniaceae, Asteraceae, Fabaceae, Geraniaceae, Rutaceae,* and *Poaceae* have been screened for a response to smoke. Of these, at least 95 species showed significantly improved seed germination. They reported that amongst the Cape reed species (*Restionaceae*), an increase in germination from 0.2% to 50.6% was obtained when the seed of *Rhodocoma capensis* was treated with smoke. Similar results were obtained with various *Erica* species. The most outstanding was *Erica glouca* var. *glouca* (14 seedlings per gram for untreated seed to 1000 seedlings per gram of smoke treated seed).

Reference has already been made to honeybush tea. In order to establish this industry, packets of tea were sold under the name of Kirstenbosch. The South African Honeybush Tea Producers Association was established on 24 Feb.1999, and the future looks very promising. (This is mainly due to the initiative of Mr. Hannes de Lange from the NBI).

An Ethnobotany Unit has been established at the Natal Herbarium, Durban, to study medicinal plants, particularly those threatened by extinction. This has lead to the compiling of a Medicinal Plants database (Medbase) as well as the establishmentt of medicinal gardens in several of our National Botanical Gardens.

The Medbase consists of four separate databases, one of them, the "Muthi-base," deals with medicinal uses, chemical analysis (where available).

Publications. The horticultural staff at the NBI have, over the years, produced a wide range of publications ranging from taxonomic treatments to popular books, horticultural notes, and pamphlets on the cultivation of plants. The latest being the Kirstenbosch gardening series on how to grow proteas, cycads, agapanthus, and succulents.

Commercialisation. Mention has been made of the role played by horticulturists in the selection of plants of exceptional horticultural merit. In an attempt to become more self sufficient, it was decided not to display these plants initially, but to make them available to interested parties through trial agreements.

Unfortunately a significant number of these plants with horticultural potential currently in the NBI's possession are already in the market due to various activities of the NBI's, e.g. plant and seed sales, or plants that have simply "disappeared" from our collections, resulting in limited success.

Since April 1995, the NBI has entered into 18 trial agreements for evaluation, with local nurserymen, totaling 59 plants.

Experience has also shown that in a few cases, some of the plants did not survive the growers standard production methods because special growth media or specialised propagation methods were required.

Plants exported to four overseas countries also died because of the methyl bromide treatment in quarantine. On request 143 plants were provided to the Pershore College of Horticulture in the U.K., to be tested under local conditions. Of all these plants, only one was released in the U.K.

A research and licence agreement with Ball is currently in its final stage of drafting and will be discussed with local stakeholders before it is signed. It is a 5-year agreement, restricted to horticultural/floriculture products, and will result in technology transfer and benefit sharing.

Agreement With Straathof Seeds. In order to promote the utilization of our South African flora and acknowledging the highly repute name of "Kirstenbosch" being synonymous with indigenous flora, Straathof will market their range of indigenous seed under this name.

Education. The NBI realised that in order to conserve and preserve our flora for future generations, it is important to educate and inform the youth — especially those that in the past, very seldom visited our gardens — of the importance of our plants. For this reason an outreach programme has been launched in Kirstenbosch. It consists of two programmes:

- Bringing children from the townships to the garden,
- Involving the township communities in greening programmes.

Today 28 schools on the Cape Flats are involved in this environmental education programme.

In our other gardens the staff has also been, to a lesser extent, involved by developing school gardens, donating trees to schools and hospitals, etc.

Acknowledgements. I would like to thank the following persons for sharing their knowledge and making information available: Mr. T. Arnold (NBI - Medbase), Dr.

N. Brown (NBI), Mr. J. Coetzee (Multiflora), Dr. H. de Lange (NBI), Mr. R. Jaques (NBI), Mrs. M. Middleman(Sappex), Mrs. F. Powrie (NBI), Dr. J. Rourke (NBI), Mrs. J. Loedolff (MNI) for taking the slide, the NBI for permission to use their slides and Mrs. G. Kriel for typing the manuscript.

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Plant Material Propagation: Catering for the Landscape Architect

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INTRODUCTION

With the purpose of highlighting the landscape architect's involvement with plants in the course of executing the planning phase of a project, and to show where and how plant material is applied during this process, it is necessary to describe the various steps of the landscape design process briefly. Once this background is set, the impact of current availability of indigenous plant material on the success of the designs will be considered. The conclusion will focus on the needs of the landscape architect in the form of a wish list and a few recommendations for the future will be made.

BACKGROUND

Historically, from an availability point of view, it has been much easier designing with exotic than with indigenous plants. The history of the use of plant materials and the influence of the northern hemisphere in this regard is quite important. Garden styles developed over many centuries and horticulture responded to these in grand style by creating a plant material palette to suit each era. The historical development of countries and their trade amongst one another is reflected in their landscapes and the use of newly encountered and acquired plants increased as the globe was conquered. All this knowledge and the relevant northern hemisphere plant materials found their way to our shores, in particular through the old parks departments of local councils and the council nurseries. Many of the horticulturists in their employ during those days had studied in the United Kingdom and brought their experience to South Africa. This has left us with a legacy of exotic plants that cannot be discarded overnight. This situation has, however, become environmentally unacceptable and also inhibits the potential of creating a large indigenous plant supply.

To set the stage it is perhaps necessary to indicate what, in terms of plant material, is currently available to the landscape architect. The basic starting point here is the general grower's catalogues, price, and availability lists that general growers make available from time to time. Certain basic standards, mainly intended to satisfy the retail market, are set for the majority of plants listed. They have to grow easily from seed or cuttings, grow reasonably fast to a size acceptable for the market, be easy to maintain in terms of feeding and pruning and be disease resistance and last by not least, be highly attractive and guaranteed sellers on the floor. These factors all contribute to keep the grower's stock moving and earning him/her a successful business. When these lists are inspected carefully, the conclusion is drawn that the main criterion according to which most indigenous plants, excluding trees, manage to appear on these lists are above all, the attractiveness of their flowers.

The second source is the catalogues of plant material supplied by specialist propagators of indigenous plants, again with the intention to mainly satisfy the demand of the retail market, created by the current wave of "planting indigenous" to save water or to attract birds into the home garden. With that as background, the next step would be to consider the process of landscape design, and how plant availability affects the end result of a landscape design.

THE PROCESS OF LANDSCAPE DESIGN

Landscape architecture is defined as being a form of art by which the earth's surface is modelled and shaped on a scientific basis into surroundings, often picturesque, that suit a variety of human activities. Landscape architecture involves the planning and design of all open space, be it interior such as atria or exterior such as parks, home gardens, golf or office park estates. Landscape architecture also involves dealing with the natural landscape by restoring it after constructions such as roads, bridges, or dams have cut into it, or by rehabilitating the natural landscape when lesser developments have caused the landscape to deteriorate somewhat. This description of landscape architecture leads to dividing the work into two distinct categories, i.e., restoration of natural landscapes and designed landscapes.

Landscape Restoration. In an extremely simplified way, supplying materials for the restoration of the natural landscape is in some ways easier. The supply of plant materials in this regard is two-fold, and entails harvesting and supplementation. The first entails harvesting from the natural environment before the project commences. This includes collecting seed over a period of time for hydroseeding, and tree and shrub rescue from the project area and growing them in containers for later planting back to the site. Supplementation implies that harvesting alone might not be sufficient and therefore the planting can be supplemented by the supply of trees and shrubs that naturally occur in the area and have been specifically procured or grown for the particular project.

Landscape Design. The designed landscape is the more important section in terms of plant material supply because it presents a greater plant use opportunity. Landscape design emphasises the concept of spatial relationships and aesthetics. This category of landscape architecture is a more direct form of art, applying hard and soft surface materials to the landscape as an artist would apply paint to a canvass. The application of plants within the field of landscape architecture is collectively called planting design and forms the basis for this part of the discussion. The following review will explain where planting design fits into the whole process, which consists of two main sections, namely site planning and detailed design.

Site Planning. Site planning involves:

- Site analysis (internal and external natural and man-made features and influences).
- Identification of the needs and requirements of the user and the resultant demand thereof upon the site.
- Zoning and circulation planning to achieve the solution to the spatial arrangement of the activities, and lastly.
- Synthesis of the aforesaid into a schematic prefiguration of the layout proposals, called a master plan.
- Once the designer has completed a master plan, the process moves on to the more detailed level of design.

Detailed Design. Detailed design involves: (1) A sketch plan presenting the execution of the concept, objectives, and design principles; (2) The supporting drawings of site engineering solutions, and, (3) Planting design.

Planting design involves the extensive use of plants and their combinations to give expression to the concepts developed for the design, and gives specific quality to the conceptual spaces created on plan. It culminates in the proposal of a list of specific plant species to be used in a particular design. In this regard the landscape architect can opt for any of the following points of departure:

- Pure design-based planting, using any plant, of any origin — indigenous or exotic — that would complete or give absolute meaning to the design;
- As above, but using only indigenous plants from any part of the country;
- Create/adapt the design to accommodate only local indigenous species; or;
- The design being such that it simulates nature as far as possible in any part of both the functional and aesthetic application of plants.

The planting design process is solution-driven plant material application. Two categories are identified:

- Functional solutions: The pure functional solutions to site and user needs, are screening, shade provision, creation of microclimate, etc.
- Aesthetic solutions: Aesthetic solutions of the design are dealt with on three levels.

1) A basic aesthetic solution: This is achieved by creating spaces with walls, floors, and ceilings, and perhaps also, if required, by manipulating those spaces to become smaller or larger, closer or further away by applying line, colour, texture, focal points, repetition, etc.
2) The contextual application of the basics: Styles such as formal, informal, tropical, seasonal, or Japanese as well as the current ordered informal indigenous style for example form the context within which the plant material application takes place.
3) Enhanced aesthetics: In conjunction with the basics, enhanced aesthetics are applied by stimulation of the senses, i.e., sight (colours, textures, shapes), touch (surface textures), smell (flowers, fruit, and leaves), taste (flowers, fruit, and leaves), and sound (rustle of leaves, stems, seed in dried fruit pods, etc.). In addition, the enchantment of wildlife is added to the aesthetic experience by addition of elements for butterflies, birds, and beasts for their breeding, feeding, resting, and nesting requirements.

Plant material selection includes the following:

- Planting spot specification: From the abovementioned processes a point is reached where each planting spot in a specific design has a very detailed specification in terms of function and aesthetics. For example: a screening plant in a public open space, 2 m tall, forming a dense wall, that should be perceived to be far away, and be colourful. It is also part of an informal design depicting movement through the various seasons. The plant should also impart a fragrance and attract birds. In addition, aspect, as well as climatic and soil conditions needs to be taken into consideration. This process is repeated for each of the planting spots within the design. From this arises lists of required plant species characteristics.

- Plant species characteristics: When plant species characteristics are considered, they can be grouped into a number of encompassing basic criteria where no subjective application evaluation is included, i.e., no subjective deduction is made as yet to categorise a plant as an ideal street tree. These basic criteria would include growth form; plant size, visual shape, growth rate and life expectancy; colour of the trunk, new growth, flowers, leaves, fruit; texture of bark, leaves, the plant as a whole; leaf type, shapes, and size; inflorescence and flower types, shapes, and sizes; flowering and fruiting times; root characteristics and preferences; metamorphic organs; fragrance; poison; edibility; ecological characteristics such as minimum and maximum temperature tolerance, water requirements, wind tolerance, humidity preference, exposure to light intensities, region of occurrence, specific habitat, soil texture, pH and drainage preferences, tolerance to pollution, attraction to birds and other wildlife for their specific needs; and lastly litter production, pest, and disease tolerance/resistance, as well as practical use such as cut flowers and medicinal aids. To each criterion a number of specific categories can be assigned, i.e.,

1) Criterion: Flower colour — would include a complete range of categories from primaries through all their combinations as well as shade and hues by adding the neutrals of black and white, as well as degrees of brightness.
2) Criterion: Minimum temperature — would include for example very hardy (below -12°C), hardy (-5°C to 12°C), semi-tender (0°C to 05°C), and tender (above 0°C).
3) Criterion: Shape/form — would include categories such as round, conical, triangular, bushy, flat crowned, candelabriformed, weeping, slender or wide, sedentary, or stemmed or grafted standard.

When the earlier planting spot specification example is considered, this leads to the following description in terms of plant species characteristics: an evergreen dense shrub; 2 m tall; pastel coloured flowers in pink, mauve, blue; dull green to grey leaves, finely textured with a sweet fragrance; no thorns or spines; and either flowers or fruit that attract birds. It should be able to grow in an open aspect, with minimum temperatures of the region falling to -7°C in winter, an average annual rainfall of approximately, 550 mm per annum, and no major dropping of leaves, flowers or fruit — a grouping of 14 specific requirements.

CONSIDERATION OF THE IMPACT OF CURRENT AVAILABILITY

Range of Available Material. The apparent combinations of the various criteria and categories as listed earlier are numerous and to each specific set a plant name needs to be attached. Quite often the conclusion is reached that the perfect match for all possible situations is unattainable given current availability of indigenous material. Certain trade-offs need to be made in terms of changing certain requirements in order to complete the planting design. Therefore, propagators should move closer to satisfying as many of the parameters as possible, and for that a much larger palette than the current list of available plants is needed. The palette also needs to move away from only supplying colour and attracting bird life, to also accommodate many of the other criteria mentioned above. A need exists to supply more than just focal elements for a design, but to also supply background elements and fillers.

The Environmental Framework. In terms of the more practical implication and current tendencies in landscape design, an added consideration to the above is that each project has to happen within the environmental framework of the region in which the development is taking place. An identity statement of place needs to be made through the planting design. Depending on where that region is, and bearing current commercial availability in mind, the solutions are either easy or more difficult. The following should be considered:

- The greater occurrence of development in South Africa, in terms of industrial and office park developments and then the related housing developments in need of designed landscapes, exists around the major cities and metros of the country, i.e., Cape Town, Port Elizabeth, East London, Durban, Johannesburg, Pretoria, Nelspruit, Rustenburg, Pietersburg, Bloemfontein, and Kimberley. When the publication edited by Low and Rebelo is consulted, the vegetation communities represented by these cities result in the following:
- Cape Town Metro: Dune thicket, west coast renosterveld, mountain fynbos, and sand plan fynbos.
- Post Elizabeth-Uitenhage Metro: Dune thicket, mesic succulent thicket, south and south-west coast renosterveld, and grassy fynbos.
- East London: Coastal forest, dune thicket, and eastern thorn bushveld.
- Durban Metro: Valley thicket, and coastal bushveld/grassland.
- Johannesburg-Midrand-Centurion: Rocky highveld grassland and moist cool highveld grassland.
- Petoria Metro: Clay thorn bushveld, mixed bushveld, and rocky highveld grassland.
- Nelspruit: Sour lowveld bushveld.
- Rustenburg: Clay thorn bushveld and mixed bushveld.
- Pietersburg: Mixed bushveld.
- Bloemfontein: Dry sandy highveld.
- Kimberley: Kimberley thorn bushveld.

This presents quite a diverse set of plant material requirements. Especially when the trend has become to plant what grows in the area in order to naturally fulfil the needs of the plant and to avoid artificial augmentation—especially when it comes to the water requirements of plants—what almost could be called sensible landscape design.

Two of the vegetation communities listed above that are perceived to have not received too much attention in terms of propagation by comparing availability lists of commercially available plants to the species listed for these vegetation communities, are those covering the Port Elizabeth-Uitenhage Metro and the Johannesburg-Midrand-Centurion areas. They are represented by the dune thicket, mesic succulent thicket, south and south-west coast renosterveld, grassy fynbos, rocky highveld grassland and moist cool highveld grassland. If the design concept is to simulate nature, certain vegetation communities need to be represented by a larger list of commercially available plant species. In addition, a start would be to identify the plants that are common to as many vegetation communities as possible and to start growing those to cover as large as possible base.

Also on the subject of vegetation communities, the next issue returns to the issue of the restoration of natural landscapes. Infrastructural developments such as roads and dams occur throughout the country and therefore could be in any number of vegetation regions. To be of service, should additional plants need to be acquired as mentioned previously, it would be necessary that a larger range of plants from a wider spectrum of vegetation communities should be propagated.

Procurement of Plant Materials. Further to the abovementioned, and including designed landscapes, another situation should be considered which deals with the procurement of plants. Two scenarios are put forward. Firstly, some projects, mainly design projects, happen extremely fast from planning to planting, requiring plants to be available immediately. To cater for this type of demand larger numbers per species should be available. Often a situation occurs that a shortage of numbers are experienced when landscape architects call for more than 50 plants of less common species. The second scenario is one where the project time span, true for most large-scale developments and rehabilitation projects, covers at least 1 year, perhaps even longer. This situation, where the timing of the planting phase of the landscape construction is known well in advance, allows for the procurement of plants ahead of time and creates the opportunity for propagating and growing specific species on a contract basis for the particular project. In this regard it is therefore necessary to know which growers are able to render contract growing for the industry, and who will be able to grow what. Close ties between the landscape architects and the growers need to be developed to enable the landscape architect to specify his plant material realistically.

Scientific Support. The current planting designs seem to become more and more indigenous orientated. Some landscape architects are starting to use plants from within the region of the development. With the shortage of variety, especially in certain regions, new "designer" combinations, as opposed to natural communities, are being made. It is therefore important that research be undertaken to establish whether the newly created species groupings could become sustainable plant communities. Are landscape architects perhaps playing a role in constructive modification of the environment, or would this perhaps over time lead to driving other species out of their niches which under no circumstances should be allowed?

South Africa's resource in terms of vegetation is one of the world's largest, a major opportunity on the propagators' and growers' doorstep. Many overseas horticultural/floricultural concerns have already taken the initiative and are continuously ready to take advantage of the horticultural significance of South Africa's indigenous flora. The amaryllis, pelargoniums, barberton daisies, and freesias immediately spring to mind in this respect. Many more recent publications have whetted the landscape architects' appetite, by people such as Joffe, Onderstall, Pienaar, Pooley, van Wyk, and Smith as well as the nine field guides under the auspices of the Botanical Society. Furthermore, exotic plants are generally speaking hardier and large cultivar variations within species are available, i.e., *Alstroemeria* - at least 11 cultivars; *Argyranthemum* - 16; *Bougainvillea* - 22; *Coprosma* - 7; *Hebe* - 15; *Hemerocallis* - 11; *Hibiscus* - 16; *Lavendula* - 10; and *Phormium* - 14. Many of the species mentioned above are used so abundantly that many lay people actually think that they are indigenous. Therefore, once the necessary groundwork has been done to cultivate a wider range of plant species, the next step would be to improve by selection and maybe also genetic engineering, hardier plants in terms of temperature, and drought tolerance, as well as wider ranges of colours and other aesthetical attributes.

Practical Considerations. The aforementioned hopefully deals with the variety of choices needed. In addition to that the format and quality in which these materials are supplied, as well as the cost, should be considered. Only a few importance aspects in this regard need to be highlighted. For large-scale developments, where large quantities of ground cover types or small shrubs (< 1 m) are required, they need to be supplied in small format, such as plugs, in order for the project to be cost effective.

To date many growers have set supply to the retail market as their goal and have set their standards accordingly. The plants look good in their bags when they leave the propagation section for the market floor. It is, however, also important that they grow well in the landscape, which implies that the quality of the material should be high, i.e., well rooted, hardened-off, established and healthy plants, whether small or large specimens.

Conclusion. When all the above issues are concerned, and we compare our wish list to what is currently available, it becomes quite apparent that the designer's indigenous palette is limited at this stage and, therefore, especially in certain areas, the resultant landscape "pictures" become somewhat boring and repetitive and stifle creativity in terms of planting design, the end result being a designed South African landscape that is universally bland. The palette of the landscape architect cannot be complete when only the basics, such as the primary colours for a painter, are supplied. Unlike the artist he/she cannot mix the basics to create a palette of unlimited colour variations. The landscape architect needs to mix lines, colours, shapes, textures, etc. in order to achieve the desired effect of his landscape "picture".

RECOMMENDATIONS TO FULFIL THE NEEDS OF LANDSCAPE ARCHITECTS

Recommendations. A summary of the above culminates in the following recommendations:

Improvement of the Variety of Available Material.

- Propagators should move closer to being able to satisfy as many of the plant characteristics as possible. The new palette also needs to supply more than just focal elements for a design, but also background elements and fillers.
- Vegetation communities need to be studied and plants for propagation should be identified to enlarge the list of commercially available plant species.

- Propagate and grow larger numbers per species.
- Set up a list of growers that are able to render contract growing for the industry as well as indicating the spectrum of plants that could be provided by the growers.
- Develop closer ties with the landscape architects to enable landscape architects to specify plant material realistically.

Offer Scientific Support.

- Initiate and coordinate research to be undertaken to establish whether the newly created species-groupings could become sustainable plant communities. Verify the scenario of landscape architects playing a role in constructive modification of the environment.
- Improve by selection, and maybe also genetic engineering, hardier plants in terms of temperature and drought tolerance, as well as wider ranges of colours and other aesthetical attributes.

Recognise and Deal With Practical Considerations.

- Start supplying groundcover types or small shrubs (< 1 m) in small format, such as plugs, in order for projects to become cost effective.
- Ensure high quality of the material, i.e., well rooted, hardened-off, established and healthy plants, be they small or large specimens.
- Revisit the current price structures in the industry to present a reasonable and affordable price structure and stimulate a large turnover.

Addressing the Recommendations. A point of departure to fulfil the needs of landscape architects would be to consider the role of introduced plant species in the South African horticultural industry and how it can assist in creating a more substantial indigenous plant material market.

A Comparative Selection Process. A useful exercise could be to take the list of available exotic material and compare them on aesthetic grounds to indigenous counterparts, i.e., we could compare *Nandina domestica* to *Halleria lucida, Gardenia augusta* (syn. *G. jasminoides*) to *Oncoba kraussiana* (syn. *Xylotheca kraussiana*), *Jasminum polyanthum* to *J. angulare*, or *Berberis thunbergii* f. *atropurpurea* to *Combretum celastroides* subsp. *orientale* in winter. This would create an immediate result of what types of indigenous plants could be added by the growers and for which there probably would also be an instant market. Also, if the counterparts of the wide range of hardy, low-growing, colourful exotic ornamental grasses such as *Acorus, Carex, Festuca, Holcus, Liriope, Ophiopogon,* and *Phormium* could be identified, they would all be guaranteed winners. In this field the restios are coming onto the market, but quite often these plants from the winter rainfall region, struggle to adapt to a summer rainfall regime, especially where the landscape is not irrigated sufficiently. The indigenous counterparts of the following few exotic species would also be welcomed: *Coprosma* and *Euonymus* —small, evergreen, medium-textured shrubs (< 1 m); as well as *Prunus laurocerasus* and *Viburnum odoratissimum* —large, evergreen, fast-growing, dense shrubs.

Development of Identified Potentially Successful Species. Certain groups of indigenous plants have been identified as potentially successful species for the market. The genus *Rhus* has already delivered quite a number of specimens and has the potential of delivering many more, especially those species in the small shrub and trailing groundcover group. The list of available indigenous climbers and very hardy, shade-loving groundcovers are often inadequate and should also be expanded.

PROPOSALS FOR THE WAY FORWARD

The challenge of responsibility towards South African indigenous plant materials, their cultivation, and selection enhanced/improved specimens should be taken up. It will take time. However, if addressed actively and in a coordinated manner by embarking on a major holistically approached plant propagation development project, with clear goals and objectives, it will be achieved. A project should be formulated where each individual in the industry can indicate the specific role he/she wishes to play to achieve the end result. To achieve this, two levels of planning need to be undertaken. Level one being the input of the Society as such and level two being the input of the individual members. The following is needed:

LEVEL 1 - THE ROLE OF I.P.P.S. (SA)

Bear the wish list in mind, translate the need in terms of a specific species list.

- Categorise the list in terms of development opportunity, i.e., immediate results possible, medium-term results — minor research required, and long-term results — major research and development required.
- Assign project to participants (propagators and growers, post-graduate students, and communities).
- Identify the gaps and problem areas.
- Propose a long term plan to overcome the problems and to fill the gaps and thereby setting the goals for the International Plant Propagators' Society (S.A.) for the new century.
- Market not only the plants, but the research findings by creating a web page to indicate what is happening in the industry, what research is being undertaken, what possibilities and problems are present.
- Participate in projects aimed at educating the public on a continuous basis regarding all aspects of indigenous planting. (Many people are under the impression that by planting indigenous, they will save water. They are also under the impression that only succulents are drought resistant).
- Set up a closer relationship with landscape architects through annual workshops.

LEVEL 2 - THE ROLE OF INDIVIDUAL MEMBERS

Identify the markets that the individual member wishes to service, i.e., propagating for retail markets, the landscape industry, wholesale farming for commercial export of proteas for example, or a combination of any or all of the above.

- Set personal objectives to reach the set goal in terms of service delivery.
- Market the service type as well as the products.
- Build a relationship with the user market through mailing, fax, email, or Internet.

- Offer the personal field of service to the Society in terms of where the individual would like to fit into the overall plant propagation development project.

It is known that many propagators, growers, and researchers are already actively involved in their own way to achieve some of these goals. Landscape architects, as part of the industry, would like to thank them for the endeavours to date.

CONCLUSION

Propagators and growers alike should stimulate a demand for their products by planting the right seeds in the minds of the designers. By creating closer links within the industry, the balance of the supply and demand for indigenous material will be found, and a profitable indigenous plant material industry will be created. By treating the above as a small contribution to the proposed plant propagation development project, the end result may lead to great achievements by the plant propagating industry in the future.

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Effect of Two Temperature Regimes and Watering Frequency on the Growth of *Lachenalia* 'Ronina'

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***Lachenalia aloides* is endemic to South Africa and has good characteristics as a flowering pot plant. For optimal outdoor bulb production, the upper temperature limits for bulb yield and quality are needed for international bulb trade. The effect of two temperature regimes and two watering frequencies on the growth of small bulbs to a flowering export quality size were studied with *L.* 'Ronina'. Plants were grown under two temperature regimes and two watering frequencies. The fresh weight of plant parts was determined monthly. Quality bulbs of commercial size were produced under moderate temperature regimes. Under high temperature regimes, the retarding effect on plant growth was counteracted when sufficient water was supplied. Under both temperature regimes, bulb growth followed a typical sigmoidal curve. Bulb growth was delayed by floral emergence but increased after senescence.**

INTRODUCTION

The genus *Lachenalia* Jacq.f. ex Murray belongs to the family Hyacinthaceae (Duncan, 1988) which was previously a part of the family Liliaceae, *sensu lato* (Dahlgren, Clifford, and Yeo, 1985). It is the largest genus in the family consisting of approximately 110 species which are all geophytes with tunicate bulbs (Duncan, 1988). *Lachenalia* is endemic to Southern Africa where it has a wide distribution in the south and south-western regions of South Africa (Duncan, 1988).

A breeding programme was initiated at Agricultural Research Council (ARC) Roodeplaat near Pretoria to develop *Lachenalia* cultivars for commercial use as pot plants. *Lachenalia* 'Ronina' is one of the registered cultivars that has excellent characteristics for use as a flowering pot plant and has the potential to be accepted on markets in different countries (Coertze, et al., 1992). It follows a growth cycle of winter rainfall plants which usually entails rapid vegetative growth in autumn (April to May), followed by flowering in winter and spring (June to September). Flowering and fruiting are followed by a long dormant period during the hot dry summer months (November to March) (Duncan, 1988).

Temperature is an important environmental factor in the in vivo (Niederwieser and Vcelar, 1991; Perrignon, 1992) and in vitro (Nel, 1983; Louw, 1991) propagation of plants. Temperature regimes also have a major role (Louw, 1992) in in vivo bulb storage for successful flower forcing. In addition, the effects of temperature and watering frequency on the growth of small bulbs of *Lachenalia* 'Ronina' to bulbs of final commercial flowering size has not yet been extensively studied (De Hertogh and Le Nard, 1993; Roodbol and Niederwieser, 1998).

Lachenalia bulbs can contribute to the international bulb trade, for which high quality bulbs are required. For optimal outdoor bulb production information on the upper temperature limits for bulb yield and quality are needed as well as the interactions between moisture levels and temperature.

The objective of this study was to determine the effect of two temperature regimes (relatively high and moderate) and two watering frequencies on the growth of small bulbs to flowering size.

MATERIALS AND METHODS

Eight hundred flowering size bulbs (10 to 15 mm diameter, ±1 g) of *Lachenalia* 'Ronina' were received from the ARC Roodeplaat in 1996 and 1997. The quality of the bulbs differed between the 2 years because of different origins. For each year the bulbs were planted in 9-cm plastic pots containing a sterilized peat moss growing medium. On 1 March 1996 and 1997 the potted bulbs were moved into two environmental growth cabinets (Model PGW-36, Conviron, Canada) with 14-h illumination at ± 200 μmol m^{-2} s^{-1} photosynthetic active radiation (PAR) supplied by WHO fluorescent and incandescent bulbs at plant height level; each cabinet ran at a different temperature regime (Table 1). In 1996 all pots were flushed with distilled water three times a week. In 1997 the watering frequency of temperature regime (TR1) (high-temperature treated) pots was done daily. From 15 Aug. the watering frequency in both cabinets was gradually decreased until 15 Oct. whereafter no water was applied. This decrease in watering frequency forced the plants into a dormant stage before storage.

Table 1. Temperature regimes during the bulb preparation phase in 1996 and 1997.

	Temperature Regime 1 (TR1) (°C)		Temperature Regime 2 (TR2) (°C)	
Duration	Day 14 h	Night 10 h	Day 14 h	Night 10 h
1 March-15 June[1]	28	12	22	10
15 June 15 July[2]	28	12	22	10
15 July 15 August	28	12	27	15
15 August 15 October[3]	33	17	32	20
15 October 15 November[4]	35	35	35	35

[1]Foliage emergence
[2]Full-bloom (Anthesis)
[3]Foliage and Inflorescence senescence
[4]Bulbs were dormant

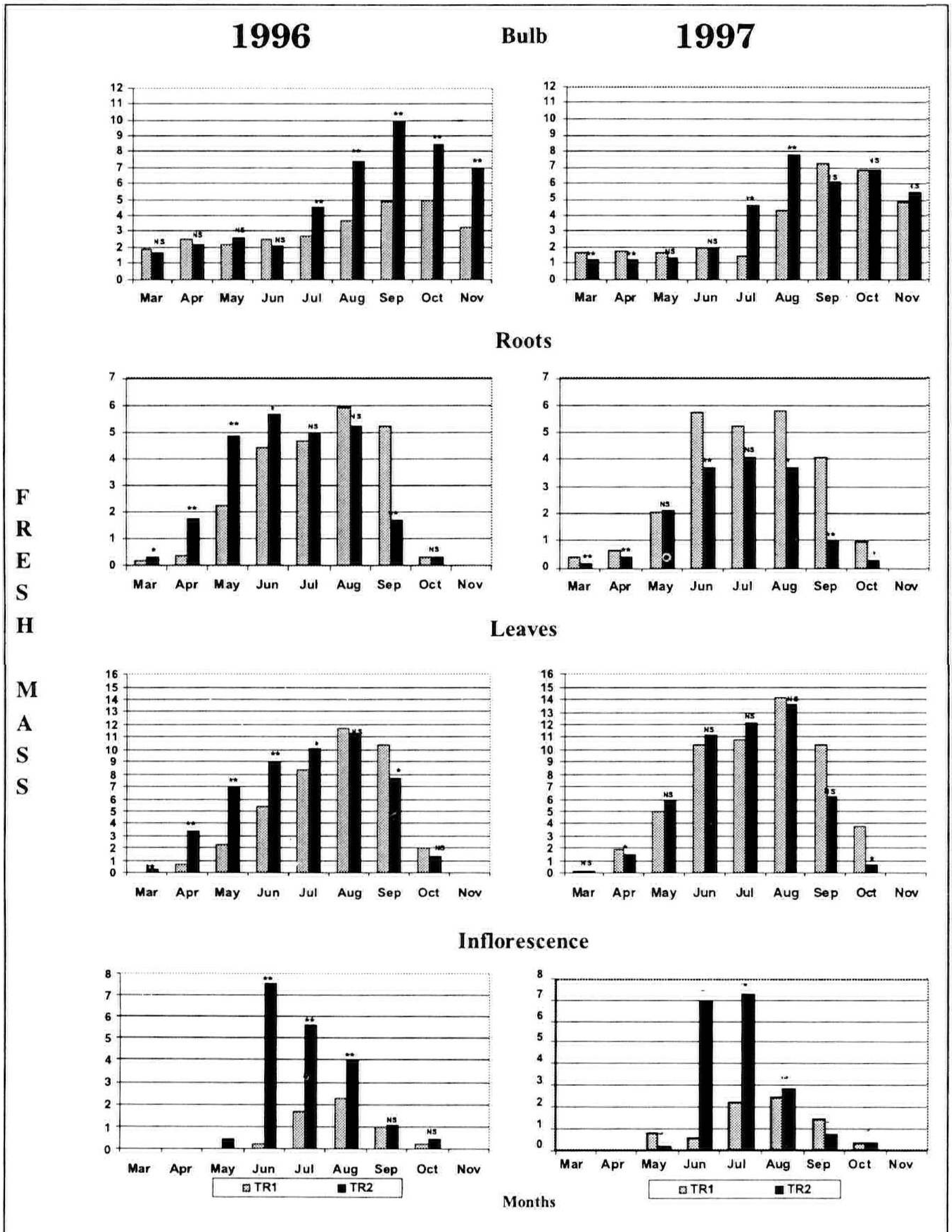

Figure 1: Effect of two temperature regimes on the growth of *Lachenalia* 'Ronina' during bulb preparation phase.

Ten replications of 40 potted bulbs each were randomly arranged in each of the two cabinets. On the 15th of every month during the growing phase, 10 plants from each cabinet (treatment) were dissected into bulbs, roots, leaves, and inflorescence and the fresh weight of each portion determined. Data were analysed using the PROC. G.L.M. (General Linear Models) procedure in the S.A.S. (Statistical Analysis

System) program. Analysis of variance was performed and the F-test (Steele and Torrie, 1980) was calculated to compare treatment means.

RESULTS AND DISCUSSION

Figure 1 illustrates the fresh weight of plant parts as effected by the two temperature regimes and the two watering frequencies during the bulb preparation phase in 1996 and 1997.

Bulb growth followed a typical sigmoidal curve up to the time of full flower (March to June) and irrespective of treatment, there was practically no increase in bulb mass (Fig. 1). Similar results were obtained by Roodbol and Niederwieser (1998) with 'Romelia'. During this period the inflorescence was the main sink for nutrients. Bulb mass increase coincided with flower senescence. In all treatments, except for the moderate temperature regime (TR2, 1997), bulb mass increase continued until September in spite of the water cut which started in August (Fig. 1). This phenomenon is probably a result of re-translocation of nutrients from the senescent leaves which started during August.

The high watering frequency treatment of the high temperature regime (TR1) bulbs in 1997 led to a significant increase in fresh weight compared to the bulbs grown in 1996 (Fig. 1). These results are in accordance with Rees (1992) on winter flowering bulbs in the northern hemisphere. It also shows that a long exposure of high temperatures and insufficient water supply adversely effects the growth rate as well as the fresh weight of *Lachenalia* bulbs.

Bulb growth was delayed by floral emergence which for TR2 plants occurred in May and for which TR1 plants started in June (Fig. 1). The inflorescence become the first major sink for photosynthates, where after bulb scales become the dominant sinks. Rees (1992) and De Hertogh and Le Nard (1993) found similar results with tulip and other winter flowering bulbs. After full-bloom, during June and July, the photosynthates were translocated into the bulbs (major sink), where a significant increase in bulb fresh weight occurred.

At the end of the 1996 season TR1-treated bulbs were smaller than those of the TR2 treatment and had an outer covering of hard, dry membranous tunics. A few of these bulbs were rotted. Due to the competitiveness between the two main sinks, it is clear that there were not sufficient amounts of photosynthates produced for simultaneous inflorescence and bulb development. These results are in accordance with those of Saniewski, et al. (1979) showing the relationship between bulb growth and aerial plant organs of *Hyacinthus*. Bulbs produced during the 1997 season under both temperature conditions were healthy and of export quality mainly because of the increase in watering frequency.

The maximum fresh weight of the roots was reached during full bloom which was 2 months before the leaves reached their maximum biomass. After the maximum fresh weight of the roots was reached, the roots maintained their fresh weight until full bloom, then decreased rapidly because of the senescence of the whole plant (Fig. 1).

The higher water application rate during 1997 increased the root fresh weight of TR1-treated plants (Fig. 1), thus stimulating root emergence and elongation. This confirms the results of Richards, et al. (1952) and Gregory (1983) that increasing root temperatures increase root meristem initiation and differentiation of higher plants.

Leaf emergence and growth in all treatments reached its peak during August after which the leaves started to age rapidly towards the end of the growing season (Fig.

1). The slower growth rate of leaves at the high temperature regime (TR1, 1996) indicated that a water deficiency under a high temperature regime may have led to low photosynthetic rates, followed by a decrease in overall carbon supplies (Chaves, 1991; Hsiao, 1973; Lauer and Boyer, 1992; Sharp and Davies, 1989). In 1997 the effect was reversed by the increase in watering frequency (Fig. 1). This evidence reflects that soil moisture, independent from the two temperature regimes, plays an important role in foliage emergence and growth. Leaves of the moderate temperature regime (TR2) were also robust, broad, lanceolate, upright, and healthy compared to long, narrow, and curved leaves of the high temperature regime (TR1).

Inflorescences of bulbs grown at the moderate temperature regime (TR2) emerged 1 month earlier and were much larger than those of plants grown at the TR1 (high temperature regime) (Fig. 1). Although flower initiation and differentiation took place at the same time and at the same temperature during storage before planting (Louw, 1992), we show evidence that different temperature regimes during the bulb preparation phase affected flowering rate. Roh and Meerow (1992) also stated that temperature plays an important role in inducing early flowering of *Eucrosia bicolor* bulbs. In 1997 the increase in watering frequency on TR1 plants (Fig. 1)minimized the high temperature effect on floral development. An increase in watering frequency thus improves inflorescence emergence, but not the inflorescence size. These results are in contrast with Roh and Meerow (1992) who claimed that watering treatments had no effect on days to flower of *Eucrosia bicolor* bulbs.

CONCLUSION

In conclusion, bulbs of a commercial flowering size can successfully be grown under a moderate temperature regime. The negative effect of a high temperature regime on bulb growth can be counteracted if sufficient water is supplied. It is also evident that temperatures to which the bulbs are subjected during their enlargement can affect their physiological state at harvest. A following report will stress about the timing, duration, and sequence by which drought-stressed plants reallocate their limited photosynthates to growth, reproductive development, and storage and the effect it will have on the commercial end product the following year.

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Integrated Plant Disease Control

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Integrated plant disease control is discussed with specific reference to nurseries and hydroponic systems. Application of the fundamental principles of disease control, based on the disease triangle, is applied in designing disease management strategies for nurseries and hydroponic systems as models.

INTRODUCTION

Integrated disease control implies the principle of integrating different disease control measures in an overall, holistic strategy. A disease control strategy can be designed for any plant production/propagation system, be it a nursery, a hydroponic system, or open production system on a farm, regardless of the size of the operation. In the absence of such a strategy disease control often takes place as an ad hoc operation based on crisis measures. The benefits of an integrated disease control program are more efficient and cost effective disease management which is often based on prevention rather than cure.

In this paper, integrated disease control will be discussed with special emphasis on nurseries and hydroponic systems.

FUNDAMENTAL PRINCIPLES OF INTEGRATED PLANT DISEASE CONTROL

Any plant disease is based on three fundamental components — namely the host plant, the pathogen, and environmental conditions — which constitutes the disease triangle. For a disease to develop the plant must be susceptible, the pathogen must be virulent, and the environmental conditions must be conducive to disease development. Disease control can be achieved by influencing or manipulating any one, or any combination of the three components.

Integrated plant disease control is based on the premise of integrating various control measures in a synergistic way. The main aims of an integrated disease control program are: (1) eliminating or reducing initial inoculum, (2) reducing the effectiveness of initial inoculum, (3) increasing resistance of the host, (4) delaying onset of disease, and (5) slowing down disease development.

INTEGRATED DISEASE CONTROL IN THE NURSERY

The three greatest dangers in a nursery are: (1) infected seed, seedlings or propagation material,(2) infested irrigation water, and (3) infested growth medium.

The main components of a disease control strategy for nurseries fall into two categories namely preventative measures and curative measures. The following is by no means a complete list, but does cover the main aspects.

Preventative Measures.

Pathogen-Free Seed, Seedlings, and Propagation Material. Depending on the types of plants propagated, great care should be taken to ensure that disease-free mother material is used. Testing of the mother material in a plant pathology laboratory to confirm the absence of pathogens is essential, even in the absence of any visible symptoms of disease. A range of detection techniques exists for the various types of pathogens including viruses, fungi, and bacteria.

Pathogen-Free Irrigation Water. Pathogen-free irrigation water is imperative for any nursery. The nature of the water source and the quality of the water will dictate the measures required for water purification and sterilization. A substantial amount of literature exists on the different methods of water sterilization with their advantages and disadvantages (Mebalds et al., 1996; Mebalds et al., 1997). The irrigation water should be tested regularly by a plant pathology laboratory for the presence of pathogens to ensure sustained efficiency of the sterilization programme.

Pathogen Free Growth Medium. Various methods of media sterilization exist, of which heat sterilization is probably the most effective (Mulder, 1979). The most applicable method of sterilization will depend on the type of medium used. The use of pathogen-suppressive media based on bark mixes (Hoitink et al., 1991) is a viable alternative to total sterilization. Again, regular testing of the medium for the presence of pathogens is imperative.

Design and Lay-out of the Nursery. Disease prevention and phytosanitation should be a key factor in the design of a nursery. High risk areas such as the medium preparation area should be identified as a highly sterile area and isolated to prevent introduction of pathogens into that area. The concept of regulation of the direction of "traffic flow" from highly sterile to less sensitive areas should be implemented.

Application of Phytosanitary Measures Throughout the Nursery. These measures should involve integrated control measures aimed at eliminating or reducing pathogen inoculum. This would include chemical control measures such as use of surface sterilants and preventative fungicides as well as certain biological control measures. Cleaning and sterilizing implements, equipment and walkways should be a routine procedure. Entrances to the nursery should be equipped with a basin (foot bath) containing a sanitizing solution such as copper sulphate.

Manipulation of Environmental Conditions. In certain instances such as production of plants in greenhouses or tunnels, manipulation of environmental conditions such as temperature and humidity can affect the incidence of diseases. Proper management of irrigation is often an important factor in disease management. Irrigation frequencies can be manipulated to reduce the incidence of soilborne diseases. Overhead irrigation which wets the foliage often aggravates foliar diseases.

Chemical Control. Preventative (nonsystemic) fungicides are powerful tools which can be implemented in an integrated disease management program. In terms of pathogens developing resistance against chemicals, preventative fungicides have a lower risk than selective systemic fungicides.

Curative Measures.

Chemical Control. Curative measures in the nursery include the use of curative fungicides. Modern selective fungicides are high-risk compounds in terms of development of pathogen resistance. Resistance-prevention measures should therefore be implemented (Delp, 1980).

Manipulation of Environmental Conditions. It is often difficult to change environmental conditions. Some aspects such as irrigation frequency can be changed to suppress root diseases. In greenhouses, temperature and humidity can also be controlled to a degree.

INTEGRATED DISEASE CONTROL IN HYDROPONIC SYSTEMS

Hydroponic systems being dependent on a continuous supply of nutrients through the irrigation water, are particularly vulnerable to water-borne pathogens, such as *Pythium*, the causal organism of wilt and root rot. The three greatest dangers in a hydroponic system are infested irrigation water, infected seed or seedlings, and infested growth substrate. As is the case with nurseries, control measures for hydroponic systems also fall into two categories namely preventative measures and curative measures.

Preventative Measures.

Pathogen-Free Seed or Seedlings. Introducing infected seedlings into the system will immediately jeopardize the whole system, especially in the case of a water-borne pathogen such as *Pythium*. This pathogen is distributed through the system by means of mobile zoospores which move in water. Re-circulating systems are particularly vulnerable to the disease.

Sterilization of Irrigation Water. This aspect is again of primary importance, especially in re-circulating systems. The type of sterilization procedure (Mebalds et al., 1996) will depend on the requirements for the specific type of system used.

Sterilization of Growth Substrate. When a substrate such as gravel or perlite is re-used in a hydroponic system, sterilization of the substrate is essential. Although heat sterilization is very effective, it is often difficult to apply in practice, depending on the type of system. Various chemical sterilization procedures are being evaluated by the author at the University of Pretoria for their ability to eradicate pathogens from infested hydroponic substrates (unpublished data).

Frequent Monitoring for the Presence of Pathogens. Regular testing of the irrigation water for the presence of pathogens such as *Pythium* is of primary importance.

Disease Prevention Measures Included in the Design of the System. Components such as an effective water sterilization unit should be included in the design of the system as one of the key components. Other disease control measures such as phytosanitation, medium sterilization, etc. should be taken into account in the design of the system.

Curative Measures.

Chemical Control. Chemical control measures are still indispensable in most crop production systems. It is, however, essential to integrate chemical control with preventative measures in a disease management strategy. As with nurseries, ways of preventing development of resistance against fungicides should be implemented (Delp, 1980).

Manipulation ofEnvironmental Conditions. Hydroponic systems in greenhouses or tunnels afford the opportunity of controlling environmental conditions such as temperature to a degree.

CONCLUSIONS

Plant disease control should never be conducted on a fragmented, ad hoc basis triggered by crisis situations, but rather on the basis of an overall (holistic) strategy of integrated control, developed according to the requirements of each individual production system.

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Recycling of Water in a Seedling Nursery

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BACKGROUND

We all know that South Africa is a dry country with limited water resources. Droughts are normal. The increasing demands made on present water resources are likely to reduce future supply. Legislation restricting the use of surface and underground water resources will expand.

The country can ill afford water consumers that have no basic plan to conserve water. No industry should be without a blueprint as to how it can conserve waste water — least of all the horticultural industry. It is inevitable that the Department of Water Affairs will begin monitoring the use of water by the horticultural industry. Therefore, the industry must become more pro-active insofar as water conservation is concerned. Future legislation could be tempered if the industry is seen to save water.

We are mostly aware that we nursery operators are wasteful users of water. None more so than the seedling industry. We often do have to over-irrigate to ensure even watering. We know that we often rely on a well drained growing medium to sort out the problems of over irrigation. However we also know that we are wasteful. Many nurserymen are not able to purchase high quality regional water. In many instances raw water needs to be treated. To irrigate, reclaim, and re-use water is problematic.

The following presentation discusses the use of poor quality water and the recycling of run-off after irrigation from an existing irrigation scheme.

A PRACTICAL EXAMPLE OF RECYCLING WATER

Nurserymen have enough problems in growing plants using clean water from a reliable source such as treated water. To apply recycled water that has a potentially high level of plant pathogens is tantamount to suicide. The other major consideration is the nutrient levels from a recycled source will change. This may affect a well-tried-and-trusted fertiliser program and the resulting consequences could be damaging.

At Top Crop Nursery we recognised that we had a major problem—however, how to solve the problem has always been the million-dollar question. At Top Crop we needed to understand the magnitude of the problem. The nursery has a capacity of about 150,000 trays. If spring is dry the nursery capacity can grow to 200,000 trays. During a similar period let's assume that it is a hot, late spring day with a strong dry wind blowing. The evaporation–transpiration rate is high—maybe extremely high. The situation may require that we need to apply 3 litres of water per tray to ensure that the seedlings are kept alive. However as we may only be 50% efficient (50% of the water drains through the medium and flows to waste.) This waste is highlighted by the following simple calculations:

Water-Use Pumping Capacity. We can pump about 20,000 litres of raw water h^{-1}. Therefore, over a 24-h period we can pump 20,000 × 24 or 480,000 litres. At the same time we have a storage capacity of 1.2 million litres.

Water Use on the Hottest Days. With 200,000 trays using 3 liters of water per day a total of 600,000 litres is consumed per day.

If this were to carry on for a few weeks (the months of January, February and March 1999 required this application rate) there would be little margin for error as our maximum use would exceed our maximum input. Our storage would soon be depleted.

Potential Recyclable Water. A 50% wastage of 600,000 litres of water translates into a 300,000 litres loss. After subtracting 20% for evaporation 240,000 litres could potentially end up in a reservoir ready for recycling. This means that we have the potential to re-use 240,000 litres of water. This water contains 24 mg $liter^{-1}$ of phosphate. Therefore, nearly 6 kg of pure phosphate is going to waste a day at this rate. This phosphorus is almost totally reclaimable.

By recycling 240,000 litres we are now only consuming 360,000 (600,000 less 240,000) litres per day. This means that we now have spare pumping capacity of 120,000 per day.

The above calculation showed that it was essential for Top Crop Nursery to look at the possibility of recycling water.

CONSIDERATIONS NEEDING TO BE ADDRESSED WHEN RECYCLING

Chemistry of the Water. There are three considerations that need to be addressed before recycled or polluted water can be used.

- Organic matter and dirt removal.
- Dissolved chemicals in the water.
- Treatment of the water to remove pathogens.

Organic Matter and Dirt Removal. The suspended organic matter must be removed prior to any treatment of the water. If a chemical such as chlorine is used it will be bound onto the organic fraction and become unavailable. The removal of pathogens is ensured only when free chlorine can be measured. If the organic fraction is high it is impossible to treat the water as the application of chemicals required, such as chlorine, to saturate organic sites will be extremely high. If treatment of the water with ultra violet light is chosen water clarity must be high to allow penetration of the UV light.

To remove the organic matter we have chosen a process known as flocculation. It is relatively inexpensive and other savings offset the added running costs. Our choice of chemical to effect flocculation is a PAC (polyvinyl aluminium chloride). Other products are available and the most efficient is alum (aluminium sulphate). We have been wary of alum as the high levels of aluminium could retard root development. However, trials are currently being done to assess the aluminium levels after flocculation using this chemical. The addition of any of the above products reduces the pH substantially and one would need to readjust the pH if too low. In our case the lowering of the pH is an advantage as our source of water has a high pH especially during the drier months. The addition of the PAC or alum helps bring the pH down.

Dissolved Chemicals. If the water quality is poor in the first instance (high in dissolved salts) it may be very costly to treat the water for irrigation. One may need to look at desalinization systems that I will not cover here. However, if the quality of the water is good enough to use for irrigation the re-use of the water after fertilisation should be no problem. The only consideration is the nutrients that were added. The stored run-off water tested at Top Crop proved to have very little nitrates or nitrites and the only chemical in large quantities is phosphorus at 24 mg liter^{-1}. This has proven to be an advantage as the re-use of this wastewater means that massive saving in expensive phosphorus purchases will be reduced. We fertigate with lower levels of phosphate.

Pathogens in the Water. There are many ways to sterilise water. However, one needs to find a simple economical way to ensure that all pathogens are killed. At Top Crop we chose chlorine in the form of calcium hypochlorite. The product is simple to use and even at high rates, around 3 ppm, little or no detriment to plant growth is noticed. However, taking regular measurements to assess free chlorine easily monitors the chlorine levels. A simple unit is available to measure infinitesimal levels of free chlorine. As we are treating water at a pH of about 4 the efficiency of the chlorine is enhanced.

Equipment.

Reservoir. We had to ensure that all run-off water was drained into a central reservoir. This reservoir must have sufficient capacity to store a minimum of double the maximum daily run off. The larger this reservoir the better as this will allow for collection of rainfall. A system of canals lead the water to this reservoir.

Pump. A submersible pump is floated in the reservoir. A sludge pump that can handle substantial solids was chosen. The capacity of the pump was matched to deliver 10,000 litres h^{-1}.

Injector. An injector capable of overcoming the pressure of 5 bars was installed. It needed to be able to inject about 5 litres of liquid h^{-1}. At the current rate we pump about 1.2 litres h^{-1}. This allows for about an application rate of 70 ppm of the flocculent. The pH of the floc is about 2.0 and is therefore very corrosive. The injector pump must be able to handle this.

Separator. A separator designed to handle 10,000 liters h^{-1} is necessary. This is used to remove the organic material and other solids.

A Chlorine Dispenser. This is needed to add the chlorine to the system. The type used is simple and as we buy the tablets in bulk the costs are reduced.

Tanks. Two 5000-liter tanks in line to enable sufficient contact time with the chlorine to ensure a complete kill of all pathogens.

Intermediate Reservoir. An intermediate reservoir of 250,000 liters to allow any residual chlorine to volatilise and be broken down by sunlight prior to the water being used is advisable.

SUMMARY

We have run the system since mid-February 99 during some of the hottest driest weather ever experienced. The results have been most encouraging.

Tests of the water were conducted before and after to assess pathological problems. Extremely high levels of *Escherichia coli* and *E. coliforms* were found in samples in the reservoir prior to the treatment. After the water was treated the levels were zero.

We no longer need to add acid to the system to reduce our abnormally high pH which we find can reach 9.5 in winter.

There has been no build up of chemicals. The phosphate is being managed by reducing this portion of the fertiliser. As all nutrition being applied is being controlled by the use of conductivity the same procedure reduces the phosphate applications. We have estimated that we are saving in excess of 20% of our phosphate purchases.

No water is being returned to the river and all water is being re-used.

Pumping costs to move water 600 m at a head of 80 m has been reduced. We still need to evaluate this but we know that this saving is significant.

At certain times we run for days on end from the recycling plant only. What is extremely rewarding is to see that in general the seedlings look healthier.

If anyone would like to correspond with the author on this subject please feel free to do so on topcrop@intekom.co.za or topcrop@lantic.co.za

A Germination Strategy for Seed of Verbena ×*hybrida*

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The influence of temperature on *Verbena*×*hybrida* Voss seed germination was evaluated in terms of current germination recommendations to overcome erratic and low germination.

During three experiments, nondormant seeds were exposed to continuous constant temperatures and alternating diurnal temperatures. Seeds were germinated on germination paper inside clear petri dishes, using dark temperature-controlled incubators.

Cumulative germination was modelled by the Weibull distribution function, correlating closely (R2 ≥ 0.99) to the observed germination data. No germination occurred at constant 10°C. Significantly (P ≥ 0.05) reduced germination occurred at constant 15°C and at irregular fluctuating temperatures, while 25°C was assumed as a cardinal constant temperature. Controlled fluctuations did not significantly reduce germination.

It is recommended that only hermetically sealed verbena seeds are germinated according to current germination recommendations, at any temperature regime between 28°C day and 14°C night temperatures, ensuring constant amplitudes during temperature fluctuations.

INTRODUCTION

The cultivation and utilization of bedding plants are dependent on seed germination, and the potential to germinate is economically important (Armitage, 1994; Bewley and Black, 1985 and Hartmann et al., 1997).

Verbena ×*hybrida* is a tender perennial grown commercially by all major bedding plant producers in Gauteng, indicating its economical value. Germination is erratic with total germination between 40% and 60% (Carpenter and Maekawa, 1991; Duif, We no longer need to add acid to the system to reduce our abnormally high pH which we find can reach 9.5 in winter.

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Production seasons in Gauteng province in South Africa are characterised by relatively high and fluctuating temperatures. To maintain a greenhouse near the recommended 20°C is difficult and costly, if not near impossible, during these seasons. According to Armitage (1994) temperature is the most important environmental factor governing seed germination rate and germination percentage.

Previous results indicated that verbena seeds should be germinated under dark and dry conditions, while temperature recommendations per sé varied between 15 to 30°C (Armitage, 1994; Atwater, 1980; Ball, 1991; Hartmann et al., 1990; Heit, 1965; Maekawa and Carpenter, 1991; Nau, 1993 and Styer and Laffe, 1989). The most recently consulted literature recommends verbena seeds to be germinated at 24°C (days) and 15°C (nights) (Hartmann et al., 1997). Despite the practical application of the abovementioned germination recommendations, unfavourable crop yields persistently render uneconomical crop values.

This research therefore proposed to evaluate verbena seed quality in terms of seed viability. Seed germination value was tested in terms of the influence of temperature on germination percentage and germination rate in order to overcome erratic germination patterns and low germination percentages.

MATERIALS AND METHODS

Three separate experiments were conducted during March to June 1997. Each experiment lasted for 14 days. In each experiment, seeds were germinated in clear plastic petri dishes, placed inside dark temperature-controlled incubators. One control test was subjected to greenhouse conditions. All experiments were conducted in the facilities at Technikon, Pretoria, South Africa.

Hermetically sealed seeds of verbena were collected during March 1997. All seeds were from a standard commercial seed lot representing the cultivar 'Romance'. On receipt, all seeds (24 g) were stored at room temperature of ± 23°C. Each working sample consisted of 400 seeds, representing the individual treatments of each experiment. Each treatment consisted of four replications of 100 seeds. Visual inspection for pathogens was performed during incubation for the duration of each experiment.

To ensure optimum oxygen exchange, all substrates and petri dishes were treated similarly in terms of relatively low moisture levels and temperature regimes (Hartmann et al., 1997). In each case constant moisture levels were maintained by supplying 2-ml distilled water every 4 h for each replication, for the duration of each experiment. Germination counts of seeds with 1-mm radicle protrusion through the testa were made every 4 h for the duration of each experiment. All germinated seeds were discarded.

Temperature Treatments for Experiment 1. There were five treatments and one control. Seeds were exposed to constant temperatures: 10, 15, 20, 25, or 30°C. The control was subjected to normal fluctuating greenhouse conditions. Ambient greenhouse temperatures were measured every 4 h and daily minimum and maximum observations were noted.

Temperature Treatments for Experiment 2. Five treatments were subjected to alternating temperatures of 27/20°C, 29/20°C, 31/20°C, 33/20°C and 35/20°C, respectively, at 16/8-h cycles in each case. The control was subjected to constant 20°C.

Temperature Treatments for Experiment 3. There were five treatments and one control. The treatments were subjected to alternating temperatures of 28/10°C, 28/12°C, 28/14°C, 28/16°C and 28/18°C, respectively, at 16/8-h cycles in each case. The control was subjected to constant 28°C. All treatments were physically transferred from the relatively low temperature regimes to the control temperature regime and vice versa, according to the 16/8-h cycle.

Duncan's Multiple Range Test for variables was used to indicate significant differences. For each of the experiments, the cumulative Weibull distribution function was fitted to the cumulative germination data in order to analyse and model the germination responses of all the temperatures (Brown, 1987; Dumur et al., 1990). The Statistical Analysis System software program was used:

$$\mathbf{y = M\,[1\text{-}exp\{\text{-}k(t\text{-}\mathit{l})^{c}\}]}$$

where y is the cumulative germination at time t, M is the maximum cumulative germination, k is the rate of germination (hours), l is the interval (lag) between the start of incubation and the start of germination and c is a shape parameter which describes the shape of the cumulative germination curve, especially in terms of its degree of skewness. Values lower than 3.6 indicate positively skewed distribution, while greater values indicate negative skewness. Values of ± 3.6 indicate symmetrical distribution (Dumur et al., 1990).

RESULTS

Precautions in terms of hygiene were successful, as no pathogenic infections were found. The seeds were relatively easy to handle and radicle protrusion through the testas were easily observed.

Experiment 1. During Experiment 1, at fluctuating greenhouse temperatures, as well as at relatively lower constant temperatures, significantly less seeds germinated over a longer period than at the relatively higher constant temperatures. The highest percentage germination was observed at constant 20 and 25°C, while no germination occurred at constant 10°C. A germination percentage as high as 91% was observed in one of the treatments (Fig. 1).

Duncan's Multiple Range Test for variables indicated a significant difference (P=0.0135) between the 10, 15, and 20°C treatments, as well as the greenhouse control treatment and the constant temperature treatments on a 5% level of significance. No significant differences were indicated between the 20, 25, and 30°C treatments.

In general, the Weibull distributions for the constant 20, 25 and 30°C temperatures correlated very closely with the actual data and two of the three coefficients of correlation exceeded 0.99.

Experiment 2. During the second experiment, seeds were subjected to constant 20°C night temperatures and different alternating day temperatures. Seeds germinated significantly more in less time at temperature regimes with relatively small fluctuations (7 to 11°C), than during relatively higher fluctuations (13 to 15°C). Germination percentages ranging from 63% to 89% were observed (Fig. 2).

An analysis of the Weibull constants (k) and (c) shows that the rate of germination decreased at the extreme temperature regimes, while more positively skewed

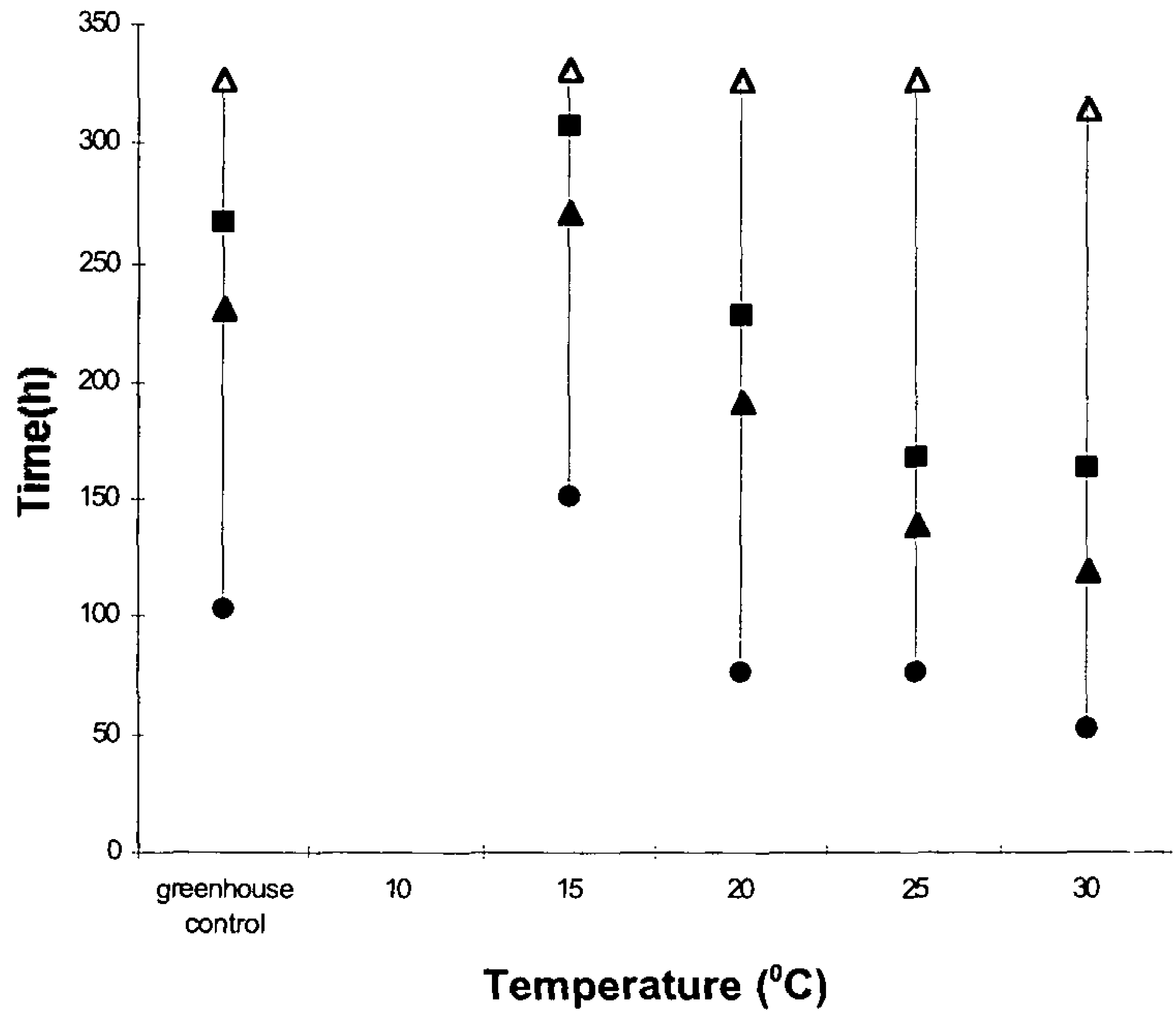


Figure 1. Time to onset (h) and spread of germination in *Verbena* ×*hybrida* seed, in response todifferent constant temperatures (°C). Symbols: (●)represents start of germination, (▲)represents 50% germination, (■)represents 80% germination, (△)represents total germination.

germination curves are estimated for the lower temperature regimes. This is similar to the actual germination observations. The delay in the start of germination (*l*) correlates well with the actual data for all the temperature regimes. The shape parameters (*c*) indicate positive skewness at all the temperature regimes, except at the extreme temperatures of 33/20 and 35/20°C. In general, the Weibull distributions for all the temperature regimes correlated very closely with the actual data and all the coefficients of determination (R^2) exceeded 0.99.

Experiment 3. In Experiment 3, seeds were germinated at constant 28°C day temperatures and at different alternating night temperature regimes ranging from 10 to 18°C. Duncan's Multiple Range Test for variables indicated no significant differences between any of the temperature regimes (P = 0.976) on a 5% level of significance. Germination percentages ranging from 82% to 91% were observed (Fig. 3).

The Weibull parameters demonstrates that generally the distributions correlated very closely with the actual observed data. All the coefficients of determination exceeded 0.99.

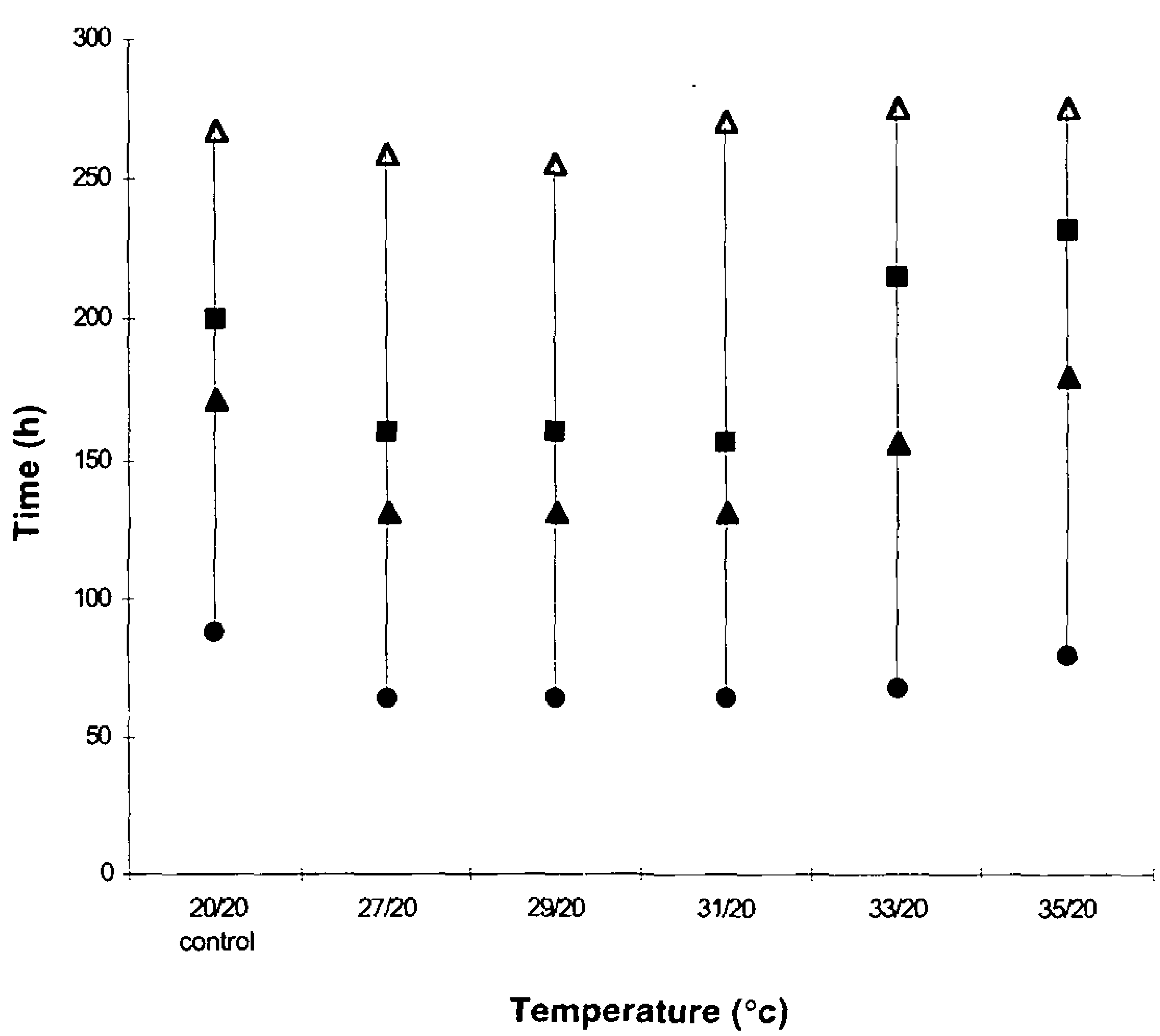


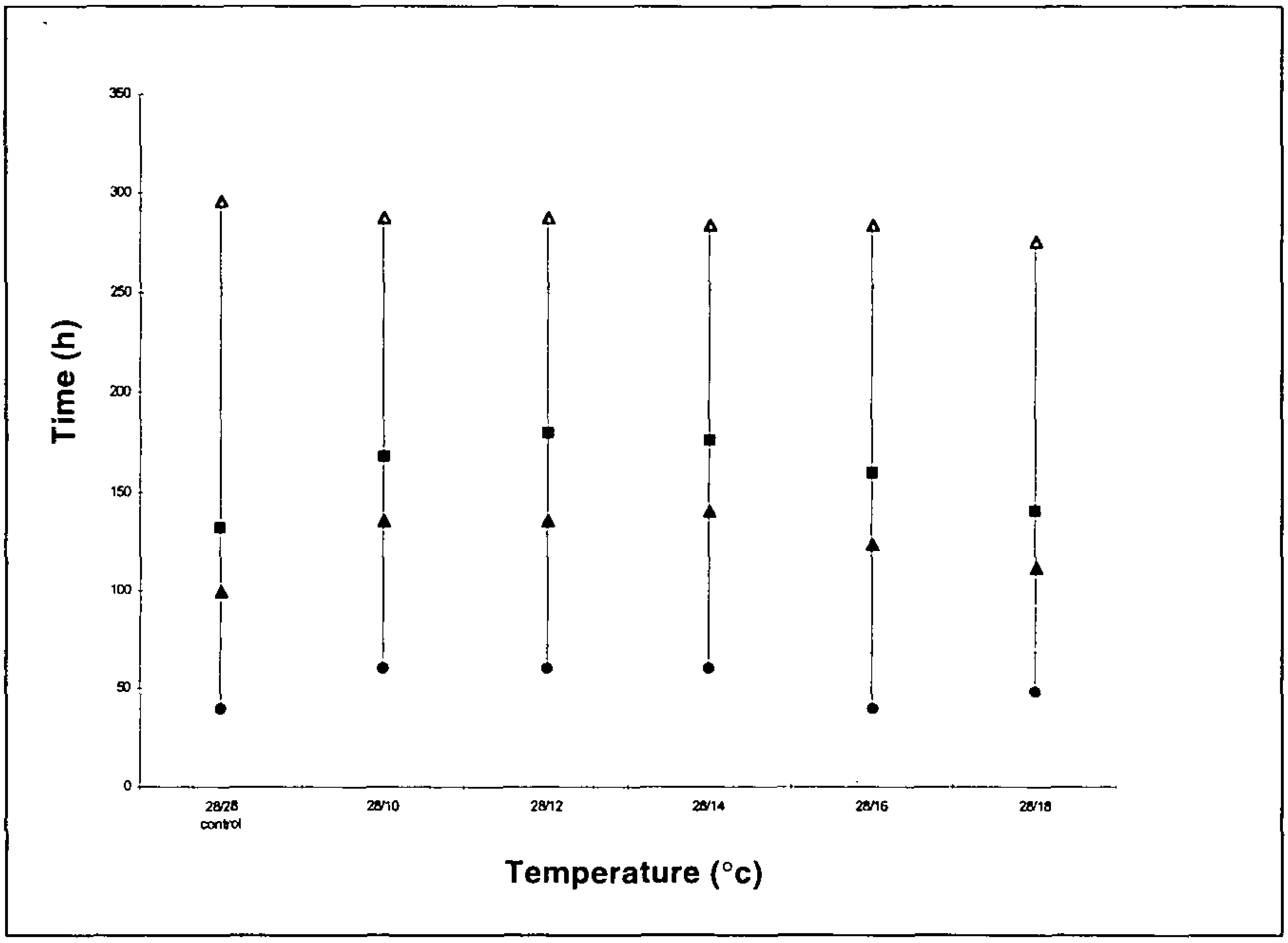
Figure 2. Time to onset (h) and spread of germination (h) in *Verbena ×hybrida* seed, in response to different alternating temperatures, with constant 20°C night temperature. Symbols: (●) represents start of germination, (▲)represents 50% germination, (■)represents 80% germination, (△)represents total germination. Duncan's Multiple Range Test for variables indicated a significant difference (P = 0.0068) between the 33/20°C, and the 35/20°C alternating regimes and the other three treatments including the control treatment on a 5% level of significance.

DISCUSSION

Germination problems during bedding plant production are a reality. A sound knowledge of the basic germination process per sé and also of the influences of environmental variables and diseases on seed germination, must be understood and managed accordingly. Germination recommendations for *V. ×hybrida* seed appeared to be inconsistent, particularly in terms of recommended temperatures. Germination responses in terms of moisture, gaseous exchange, light, and disease control corresponded with previous research.

Seed germination performance during controlled laboratory conditions suggests that verbena seeds are capable of rapid germination at ≥ 80% with no pathogenic infection, probably due to the absence of freewater on the germination substrate. Thus, verbena seed quality appears not to be only inherently dependent on the seed, but rather on the germination practices. These observations provide practical support to previous hygiene guidelines (Nau, 1993).

It was assumed that *V. ×hybrida* would react as a high-temperature-requiring crop, in terms of current germination recommendations. This assumption was



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based on the fact that *V. ×hybrida* originated in tropical southern Brazil (Jones and Luchsinger, 1987). This is of practical significance, because relatively constant high temperatures associated with humid, dark forest conditions characterize such tropical areas. The assumption appeared to be true for *V. ×hybrida*. Contrary to conditions in its original habitat, greenhouse temperature fluctuations were erratic with varying amplitudes. These uneven temperature fluctuations might have inhibited initial embryo development, possibly due to abnormal respiration and enzyme activities (Atwater, 1980). Thus, set greenhouse temperatures must be carefully monitored to prevent uneven temperature fluctuations, particularly at the start of germination.

Observations were made every 4 h rather than daily. This provided more data and consequently greater accuracy, particularly because of using the Weibull distribution function. This is of practical significance because not only total germination percentage would be measured, but practical information of the start, spread, and the cumulative extent of seed germination at each temperature treatment, would be provided. This is possible because of the multi-parametered nature of the Weibull function and its ability to model cumulative germination. Constant 25°C indicated significant practical value in terms of both germination percentage and germination rate and is recommended as an optimum constant temperature for verbena seed germination. *Alternating temperatures often present better gemination results* than at constant temperatures (Hartmann etal., 1997). This possibly happens because the temperature fluctuation effect decreases with sowing depth (Thompson and Grime, 1983). In the case of verbena this is of practical significance because of the small seed size and its sensitivity to moisture, as well as its requirement for darkness.

CONCLUSION

It is recommended that nondormant *V. xhybrida* seeds are germinated in darkness, with no free-water on the substrate and at any manageable constant temperature regime between 28°C day and 14°C night temperatures. Temperature fluctuations must remain even for the duration of germination.

Acknowledgement. The author would like to express his appreciation to Straathof's Group for financial assistance.

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Effect of Mycorrhiza on Plant Growth

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Various ornamental, micropropagated plants, and fruit tree seedlings were inoculated with mixed indigenous arbuscular mycorrhizal (AM) fungal cultures in a marginal wasteland, nutrient-deficient soil. Inoculated *Petunia ×hybrida* showed three-fold increase in the reproductive growth over uninoculated plants while that of *Callistephus chinensis* was two fold in comparison to the uninoculated controls. Micropropagated *Syngonium podophyllum* and *Dracaena* sp. showed maximum response when inoculated at weaning stage. Both the AM fungal inoculum and stage of inoculation influenced shoot P uptake and plant growth. At present, inoculation of some indigenous fruit trees with various AM cultures is being attempted and their growth and development monitored.

INTRODUCTION

Arbuscular mycorrhiza (AM) fungi are obligate biotrophs, forming a symbiotic relationship with roots of higher plants. The major effects of AM fungal inoculation include enhanced growth, saving on phosphate requirement, increased survival rate, increased resistance to water stress, increased flower production and vase life of cut flowers, higher enzymatic activities, and greater resistance to root disease (Chang, 1994). Applications of AM fungal technology include a wide variety of plants ranging from field crops, including pasture forage legumes, wheat, vegetable and ornamental plants, fruit trees, and micropropagated plants. The major objectives of this study were to produce highly infective and effective AM fungal inocula for field application, and to test this inoculum with various micropropagated, ornamental, and fruit tree plants.

MATERIAL AND METHODS

Arbuscular Mycorrhiza Fungal Inoculum. A mixed indigenous culture (Mi) containing native populations of *Glomus, Gigaspora,* and *Scutellospora* spp. was used as the inoculum.

Preparation of Growth Substrate. The substrate was prepared by mixing soil (pH, 8.2; EC, 0.2; organic C, 0.22%; Olsens P, 0.53 ppm) and compost (pH, 7.2; EC, 0.91; organic C, 4.72%; Olsens P, 25 ppm) in the ratio of 1 : 1 or 2 : 1.

Experiment 1. The treatments consisted of three host species (*Allium cepa, A. sativum,* and *Solanum tuberosum*) cultivated in the 1 : 1 and 2 : 1 mixture substrates, respectively, each inoculated or uninoculated with AM fungi (3 × 2 × 2 factorial structure). The compost amended soil mixtures were used to form raised beds (30 cm wide × 224 cm long × 16 cm high). Seedlings of onion (*A. cepa*), raised from surface-sterilized seedlings were transplanted to respective treatment beds. Ten seedlings were transplanted 10 cm apart in each bed. Inoculum was applied at the rate of 2000 infective propagules per plant. Sprouted cloves of garlic (*A. sativum*) and single potato (*S. tuberosum*) tubers were planted directly in furrows in the experimental beds 10 cm apart.

The crops were harvested at Week 16. The bulbs and tubers were removed from each bed and weighed separately. The P content in the shoot was determined using methods described by Jackson (1973). A subsample of root segments was taken for analysis of mycorrhizal colonization (Biermann and Linderman, 1981).

Experiment II. Micropropagated plantlets of *Syngonium podophyllum* and *Dracaena* sp. were obtained either in the weaning stage on agar rooting media or as 7-day-old hardened plants. The experiment was a completely randomized factorial design with a 2 × 2 × 2 × 2 structure consisting of each species taken from two growth stages (weaning stage or hardened plants), inoculated or uninoculated at two fertility levels. The plants were transplanted into polybags (1.25 kg of substrate), kept in a mist chamber (RH 75%; 24°C) for 4 weeks, and observed for survival percentage. After 4 weeks the plants were taken out and transplanted into large earthen pots (3.5 kg substrate per pot) and kept in a greenhouse (30 ± 2°C, RH 60%). The measurements included shoot dry biomass, shoot P, AM fungal colonization, and soil infectivity at harvest.

Experiment III. Surface sterilized seeds of *P. ×hybrida* 'Blue Bird', *Callistephus chinensis* 'Dwarf Chrysanthemum', and *Impatiens balsamina* were germinated in moist sand in sterile petri dishes at 30°C in darkness for 48 h. Five kilograms soil containing inoculum mixture was transferred to earthen pots (17 cm diameter). Inoculation of substrate with AM fungi was achieved by thoroughly mixing 2000 infective propagules per pot. Control plants were given 5 kg of pot mixture without inoculum. The experiment was a completely randomized design with 3 × 2 structure containing three ornamental plants, inoculated or uninoculated. Counts of number of flowers were taken at an interval of 10 days for all six replicates in each treatment up to 120 days. Shoot P, AM fungal colonization and soil infectivity was measured as described earlier.

Table 1: Influence of arbuscular mycorrhiza (AM) fungal inoculation on three ornamental species.

Hosts	AM inoculation	AM colonization (%)	Shoot P (g kg^{-1})	Shoot dry weight (g)	Flower initiation (DAT)
Petunia ×hybrida	+	68	4.5 a	0.84 a	29
	-	4	3.1 b	0.64 b	41
Impatiens balsamina	+	54	2.8 a	0.72 a	50
	-	-	2.5 b	0.62 b	53
Callistephus chinensis	+	51	2.7 a	0.34 a	27
	-		2.0 b	0.27 b	49

Table 2: Influence of AM fungal inoculation at nonrooted (Nr) or hardened (Hs) stage of two micropropagated plants.

			Syngonium			*Dracaena*		
Inoculation stage	Fertility levels	AM inoculation	Shoot P (µg)	% AM colonization	Shoot D.W. (g)	Shoot P (µg)	% AM colonization	Shoot D.W. (g)
Nr	Hf	+	2.3 a	20	21.6 a	2.1 a	14	22.8 a
		-	1.9 b	4	18.2 b	1.9 ab	1.5	22.0 a
	Lf	+	1.9 bc	32	18.6 b	1.9 ab	35	19.8 a
		-	1.4 de	2	16.3 c	1.4 cde	2	19.1 bc
Hd	Hf	+	1.6 bcd	17	15.3 d	1.7 abc	20	22.9 a
		-	1.5 cde	2	15.0 d	1.3 de	-	23.0 a
	Lf	+	1.7 bcd	30	15.4 d	1.3 de	20	19.0 a
		-	1.2 e	4	14.1 d	1.3 e	-	18.0 a
LSD			0.3		0.72	0.37		1.4

Abbreviations: Hf, high fertility; Lf, low fertility.

Experiment IV. Three species of indigenous fruit trees (*Vangueria infausta, Strychnos cocculoides,* and *Thespesia garckeana* [syn. *Azanza garckeana*]) have been inoculated with various mixed and pure inocula and are being monitored for their response in terms of the root colonization and growth parameters.

Statistical Analysis. The recorded data on all the parameters observed for each treatment were analyzed using analysis of variance (ANOVA) with Duncan's multiple range test at 5% significant level. The data were also analyzed for standard deviation within the treatments using Costat software (Cohort, Berkeley, California, USA).

RESULTS AND DISCUSSION

The result of the present study clearly demonstrates the effectiveness of AM fungus in increasing productivity and plant establishment. Inoculation with AM fungi resulted in a significant ($P \leq 0.05$) increase in yield over uninoculated plants, particularly at low fertility (Experiment I). At low fertility, inoculation with AM fungi produced 71%, 31%, and 48% increase in yield over uninoculated plants in onion, garlic, and potato, respectively, as compared to 12%, 19%, and 10% increase in yields of the respective plants at high fertility (Table 1). The extent of positive growth response in our experiment is in agreement with the results reported by others. Furlan and Bernier-Cardou (1989) reported a 41% increase in yield by AM fungus inoculation in onion.

Arbuscular mycorrhiza fungal inoculations at either the nonrooted (Nr) or hardened (Hs) stages resulted in an increase in survival rate (Experiment II). The survival was 74% in *S. podophyllum* inoculated at Nr stage as compared to 60% in uninoculated plants. In contrast, the hardened plants showed 78% and 75% survival in the inoculated and uninoculated plants, respectively. Arbuscular mycorrhiza inoculation in *Dracaena* sp. did not result in increased survival rate. The effect of AM fungal inoculation was more evident at weaning stage than at hardened stage. Arbuscular mycorrhiza fungi promote renewed shoot apical growth of micropropagated plants, and inoculation at the weaning stage produces plants with a more effective root system for uptake of P and other nutrients (Berta et al. 1990).

Flower initiation time (days after transplantation, DAT) in AM-fungal-inoculated plants was significantly shorter as compared to uninoculated plants (Experiment III). The three host plant species showed significantly higher number of flowers in the inoculated plants. At harvest, AM-inoculated plants resulted in an increase of 190% and 75% in *P. ×hybrida* and *C. chinensis*, respectively, in flower number as compared to the non-inoculated plants (Table 1). The P concentration of shoots was significantly (P 0.05) higher in all the inoculated plants though the effect of inoculation on P uptake varied with fertility and host species. The various hosts tested responded differently in terms of the percent root colonization (Table 2). Thus AM fungus enhanced the growth, nutrient uptake, and flower production in the respective ornamental hosts tested.

CONCLUSION

The study demonstrated that the AM fungi could establish a symbiotic association with the host plants tested, which could ensure maximum survival, growth, and productivity of plants. However, the involvement of other physiological process in mycorrhizal and P treated plants and effect of potting mixes used in horticultural systems cannot be excluded.

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The Propagation of Native Plants

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INTRODUCTION

In giving this paper I feel that I may provide more questions than answers. In spite of its all-embracing title I intend to deal with just one or two aspects of the propagation of native plants. I must say that, the more I travel around the country and talk with various people, the more I discover that there is a wealth of knowledge out there. The main problem with it is that so much of it is only in a particular person's head and is not recorded for others to use.

Some of this is because of professional jealousy and that phrase which is becoming so common these days — "the information is commercially sensitive". Quite often I believe it is because the person concerned has just not thought about recording it, or does not feel that anybody would be interested. I well remember the very generous help I was given when I was in the process of gathering information for my book *The Propagation of New Zealand Native Plants*. Four people, in particular, provided me with a great deal of information. Had they not done so, much of their information might never have been recorded and we would have all been the poorer for it.

PROPAGATION HISTORY

Before continuing I am going to give a brief historical overview of the propagation of native plants in New Zealand. As might be expected, the first people to attempt to propagate some of the native plants of this country were the early Polynesian immigrants, the Maori. From their tropical homeland they brought with them some of their staple plants such as the kumara (sweet potato), yam, taro (*Colocasia esculenta*), aute (*Broussonetia papyrifera*), *Cordyline terminalis*, and no doubt the coconut and banana, as well as possibly one or two other species. They must have been quite disheartened to discover that most of these plants could only be grown successfully in the warmest and most favourable areas of New Zealand and that some, such as the coconut and banana, could not be grown at all.

Naturally, the Maoris then turned their attention to suitable native plants, but their new homeland was not as well endowed with economic plants as the other Pacific islands. One plant that they found almost indispensable was the flax, *Phormium tenax*. Over a period of several hundred years they had recognised and named over 50 different kinds of flax according to their uses, strength of fibre, and so on. They also propagated these different kinds of flax so that they had ready access to ample supplies of them.

Another plant, which was of considerable importance, being prized for its nuts or kernals, was *Corynocarpus laevigatus* or karaka, which was second only to the kumara (sweet potato) in economic importance. The Maoris discovered that it was easily propagated by seed and they used to plant groves of it adjacent to their villages or at seasonal camping places, where it would be useful to them. They also cultivated the para or king fern (*Marattia fraxinea* [syn. *M. salicina*]) for its starchy rootstocks. Apart from perhaps one or two kinds of variegated flax, about the only plant they are known to have cultivated for ornament was the kaka beak, *Clianthus puniceus*.

The establishment of towns, following the arrival of the first European colonists, saw the beginning of the nursery industry in New Zealand. The first ones appear to have been established in the early 1850s and 1860s. It is interesting to note that as early as 1865, overseas-produced cultivars of *Hebe* were being imported into New Zealand, from England. *Hebe* ×*andersonii* 'Andersonii' appears to have been the first, but *H.* ×*franciscana* 'Lobelioides' and some others followed from the 1870s onwards.

Apart from the odd specialist nursery, few different species and varieties appear to have been propagated. The 1899-90 catalogue of the well known Nairn's Nursery in Christchurch revealed that no more than 12 different kinds of native plants were being propagated. No doubt some other nurseries may have grown more but the number appears not to have significantly increased until late in the 1900s. Back in those days some nurseries adopted the practice of obtaining seedlings from bush areas and then growing them on for sale — hardly plant propagation. This practice continued until quite recent times. Even as late as 1948, Duncan and Davies, and no doubt other nurseries, had an arrangement with people, living in bush areas, to supply them with seedlings of trees such as rimu (*Dacrydium cupressinum*) and totara (*Podocarpus totara*) which they then grew on.

Nowadays, large quantities of native plants are propagated either vegetatively or sexually, depending on the kind of nursery, and few would resort to growing seedlings collected from the wild. Obviously there are exceptions to this where seedlings and sporeling ferns are gathered from pine plantations prior to clear felling taking place. With nurseries that specialise in growing re-vegetation lines most plants are propagated from seed, whereas those which produce mainly ornamentals would produce most of their plants by vegetative means.

From here on, I wish to discuss one or two aspects of native plant propagation which interest me.

ASTELIAS

In 1994 I became interested in the propagation of *Astelia*. They are plants for which I have a great deal of regard, because of their horticultural and landscape possibilities, and I also consider that they have for too long been overshadowed by the plethora of variegated flaxes with which we have been bombarded for the last 20 odd years. Anyway, a chance remark by a nurseryman friend about the effect of frost on his plants of *A. chathamica* set me thinking. He commented that when their young plants of *Astelia* were frosted in the winter they stooled from the base and they were then able to easily divide-off young plants.

Having had my own plants of *A. chathamica* killed or almost completely killed by frost I decided that this was a very chancy way of propagation and just too risky. Therefore, I mulled over the problem for a while and eventually came to the conclusion that it should be possible to solve the problem by artificial means. If the apical bud could be mechanically destroyed so as to induce the plant to branch from the basal plate then there would be a more certain method of propagation, particularly for cultivars, which cannot be propagated from seed.

At the same time I was also aware of Kevin Gdanitz, of Camside Nursery, who had been struggling for some years to build up stocks of his *A. nervosa* 'Alpine Ruby'. I really think that he had a cultural problem with his container growing, because I had grown it in the open ground for a number of years and had had absolutely no problem with propagating it.

Accordingly, I then began to experiment with some seedling plants of *A. fragrans*, which I happened to have. The first thing was to slice down through the apical part of one of the seedlings in order to examine its structure and find out exactly where the apical bud was situated. Having determined that I then commenced to decapitate one or two plants so as to find out whether my idea would work.

In common with some similar plants, *Astelia* has a rather slow rate of branching so that propagation by division may be equally slow. This is caused by apical dominance, which is responsible for its relatively slow rate of branching. Mechanically induced branching, if successful, would obviously have a great deal to commend it. I discovered that the leaves all arise from a well defined basal plate at the crown of the rootstock, from which both the leaves and roots are produced. In order to gain easy access to the apical bud it is necessary to cut off all leaves quite close to it. This basal plate has a relatively flat, dome-shaped profile so that when cutting off the outer leaves care must be taken not to actually cut into the basal plate, or to cut off its top portion. Cutting off too much of the basal plate limits the number of new shoots which will be able to appear from it.

Once the apical bud has been located it is then carefully excised so as not to damage any more of the surrounding tissue than is necessary. This operation is best carried out during late winter or early spring, just as growth is about to commence. After about 4 to 6 weeks the first new shoots should appear, and then later in the season, as soon as they are large enough, it is possible to divide off the new plants. From then on, the plant should keep on producing a multitude of new growths, from which it is possible to repeatedly divide off new plants.

Some of you will probably be saying what is the point of all this when it should be possible to send material to a plant propagation laboratory and have new plants produced by tissue culture. Well, the simple answer is that this method of propagation can be done by anybody because special facilities are not required. You are not bound by the minimum quantities required by plant propagation laboratories, you can produce to your own requirements, be they 50 or 500 plants, and it is far less costly. The only possible disadvantage that I feel this method of propagation may have is that the new plants so propagated appear to have a tendency for the continuing proliferation of their growth buds.

A plant of a seedling-raised *Astelia* initially produces a plant with apical dominance so that the central bud makes strong growth before any branching occurs. With plants propagated by the mechanical branching method they very quickly commence branching and do not appear to have the one central bud that would normally assume apical dominance. The next step is to see what happens when these plants are planted out in garden conditions. Do they begin to behave in a more normal manner or will they forever continue to produce a proliferation of leaf buds?

COPROSMAS

The other aspect of native plant propagation that I am going to mention is that of root cuttings. For some time I have noticed that certain coprosma produce adventitious growths or suckers from their roots. These growths arise at varying distances from the plant and to me indicate that there is the possibility of propagating some species and cultivars by means of root cuttings. Most coprosma are quite easily propagated from stem cuttings so that propagating them from root cuttings may not have any practical application; however, purely out of interest, I intend to follow up on this in order to see where it takes me. Very few native plants appear to have this capability and I feel that it will be interesting to explore it.

The main species, which sucker from their roots, are *C. acerosa* [syn. *C. brunnea*] and *C. rugosa*, plus any cultivars which have either of these species in their parentage. In particular, 'Hawera' and 'Lawrie Metcalf' produce suckers from their roots, the latter having *C. rugosa* as one parent.'Hawera' is possibly just a cultivar of *C. acerosa* and not a hybrid. Interestingly, hybrids from *C. brunnea* which have *C. repens* or some other broad-leaved species as the other parent do not appear to exhibit this tendency to sucker. *Coprosma* ×*kirkii* 'Kirkii' is a good example. Never in all of the years that I have known it have I ever seen any indication that it would produce suckers from its roots, however, that is not to say that it will not reproduce from root cuttings and so it will be necessary to experiment with it.

SEED DORMANCY

Seed dormancy is another aspect of native plants about which we know so little. What are the factors, which cause dormancy in many species, and what treatment is necessary for that dormancy to be overcome? One grower may find that miro seeds (*Prumnopitys ferruginea* [syn. *Podocarpus ferrugineus*]) will germinate within a relatively short time (say 12 to 18 months) and another finds that germination is very erratic and may extend over a period of up to 5 years.

Some growers do not bother to give their native plant seed any kind of treatment before sowing. They just clean the seed and do whatever else is necessary to facilitate sowing and sow it, and then wait for it to germinate, regardless of how long it might take. Others religiously stratify the seeds or give them some other treatment. However, it appears that in either case the results can be variable. This is where we need more experimentation and research so as to find answers for these questions.

THE BEST CLONAL CULTIVAR

And finally, just a word about never being satisfied that the particular clone of a native plant being grown is the best one. It may be that it is a very old one which was brought into cultivation many years ago, and nobody has thought to see whether there might be a better one. In this respect I am referring to hardiness, pest or disease resistance, horticultural qualities, and anything else that will make it a good garden plant. It does not matter whether it is *Pittosporum tenuifolium* or *Hebe salicifolia*; there are always better clones out there and we should always be seeking to grow the best. I know that some propagators are doing this, but there are probably just as many who do not and just propagate whatever they have or happen to get.

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Taxus: Renewed Interest in this Genus and Implications for New Zealand

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BACKGROUND

A tree crop, which may be of interest to the New Zealand nursery industry, is the yew (*Taxus baccata*). A member of the family Taxaceae it is a slow-growing and long-living, dioecious evergreen tree which can grow to a height of around 20 m. It is extremely tolerant of variations in temperature, light, soil moisture, and pH. The yew, which is a native of Europe and West Asia, is widely cultivated and is often found near churches and other meeting places, as it was considered a sacred tree before Christianity, and is still associated with places of worship. In the Middle Ages it was valued as a wood for long bows and is now often used in gardens as an ornamental species and for topiary.

The yew is poisonous and was blamed for untimely deaths as early as 51 B.C. In North America; native Americans are known to have used the bark from Pacific yew (*T. brevifolia*) as a disinfectant and as a treatment for skin cancer (Nicolaou et al., 1996).

MODERN DEVELOPMENTS

Interest in the medicinal properties of the yew tree was reawakened in the early 1960s when the U.S. National Cancer Institute (NCI) started screening natural sources for possible medicinal properties (Abell, 1997). Extracts collected from the bark of the Pacific yew (*T. brevifolia*) were found to kill artificially preserved leukemia cells. In 1967 the active ingredient was identified, isolated, and named taxol or paclitaxel. In 1978 researchers were able to demonstrate taxol's mode of action against cancerous cells. It was found that taxol binds to microtubules, which act as part of the cells' internal skeleton, causing them to become rigid. This disrupts cell division especially in rapidly dividing cells such as those found in tumours (Schiff et al., 1979; Horwitz et al., 1992). Today taxol is used to treat breast and ovarian cancer (Nicolaou et al., 1996).

Unfortunately the bark from a mature Pacific yew provides only 500 mg taxol, enough for only one ovarian cancer treatment programme (Abell, 1997) when ovarian cancer afflicts 20,000 women annually in the U.S.A. alone. Producing taxol from yew bark from natural populations has led to the decimation of wild yew populations in North America, and subsequently to shortages of taxol (Webb, 1997) resulting in a search for other sources. Research has identified taxol in other *Taxus* species and in other plant components including the foliage. This means that, in the long term, sustainable yields of taxol and taxol precursors could be produced from large yew orchards that were regularly trimmed to harvest the foliage.

RESEARCH IN NEW ZEALAND

Any industry based on harvesting *Taxus* foliage in New Zealand would require suitable planting stock. In 1993 Crop & Food Research began an initial survey of the concentrations of taxol and taxol-related chemicals (taxanes) in existing populations of Irish yew (*T. baccata*), Japanese yew (*T. cuspidata*), and the Japanese plum yew (*Cephalotaxus harringtonia*). No taxanes were found in the Japanese plum yew, only low concentrations in the single tree of the Japanese yew, but significant amounts were found in the Irish yew. This initial survey was followed by a comprehensive survey of Irish yew tree foliage from Northland to Southland. Trees were sampled and the foliage analysed using an HPLC to identify the concentrations of the taxanes (10-deacetylbaccatin III, baccatin III, cephalomannine, and taxol) (Lauren et al., 1995). This survey of 72 trees found individual trees varied in taxol concentration from 7 to 510 mg kg^{-1} (Lauren et al., 1995). On the basis of these analyses five trees, including one golden-leafed cultivar (*T. baccata* Aurea Group), with high concentrations of taxanes were propagated. The trees are being grown at two sites to determine whether the high taxane concentrations within the plant are stable.

Propagation. The propagation of *Taxus* species is well documented with most Northern Hemisphere nurseries using cuttings collected from September to December (March to June in New Zealand) (Thomsen, 1978; Bauer, 1978; van Hof, 1978). Rooting hormones are often used (van Hof, 1978; Scheer, 1976; Verkade, 1976; von Kornya, 1976) along with a variety of rooting mixes based on either sand (van Hof, 1978) or peat (Thomsen, 1978) or combinations which often include perlite (Scheer, 1976; von Kornya, 1976). Most nurseries report good survival and plant growth using these methods with Verkade (1976) quoting rooting percentages of 90% to 95%.

Cuttings (15 cm long) from trees with high taxane concentrations were collected in late August 1994. These cuttings were then dipped in plant rooting hormone powder containing 0.8% ß-indolebutyric acid before being lined out in three different rooting media — straight sand, standard potting mix, and a vermiculite and perlite mix (1:1, v/v). The cuttings were kept in a glasshouse under mist. There was no significant difference in the number of rooted cuttings produced by different treatments or trees. Approximately 50% of all cuttings produced roots after 6 months. The relatively low rooting percentage, compared with figures for overseas nurseries, is probably the result of collecting cuttings in late winter rather than in the more traditional autumn-early winter period.

Production. A large number of production trials are currently in progress overseas to determine the growing conditions required for optimum taxol production in the field (Wheeler and Piesch, 1993). To date no trials have been established in New Zealand to determine the growing conditions required to optimise taxol production.

DISCUSSION

The survey has demonstrated that there are a number of high-taxane-yielding trees amongst the existing *T. baccata* population in New Zealand. Provided the taxane concentrations remain stable, these selected trees could provide the basis for establishing orchards to provide the raw material for extracting and manufacturing taxol for the treatment of ovarian cancer. At least one North American company has taken this approach with large scale biomass production for the long term economical supply of taxanes for the pharmaceutical industry (Wheeler and Piesch, 1993). Taxol is a complex molecule and while research is being undertaken to develop biotechnology fermentation methods of producing it, the lower cost method of extracting it from managed plantations is likely to remain in place.

If New Zealand is to develop a successful industry growing *Taxus* species for the production of taxol, the nursery industry will need to be able to rapidly supply large numbers of selected trees capable of producing high taxol or taxol-related compounds in the foliage.

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Root Pruning Can Influence First Order Lateral Root Development of Containerised Plants

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There is a strong positive correlation between the number of first order lateral roots (FOLR) of a tree seedling and its rate of growth after planting. This number is under genetic control, but can also be optimised or reduced by characteristics of the seedling tray. The choice of container to be used for seedling propagation is, therefore, one means of enhancing the chances of plantation success, in this instance by choosing a container likely to result in seedlings with a higher number of FOLR. Two seedling trays currently used for plantation seedling propagation in Australia were tested and the number of first order lateral roots (FOLR) counted. The number of FOLR was significantly different. The tray with a greater lateral root pruning effect produced the higher number of FOLR. A second trial comparing copper root pruning and no pruning confirmed that lateral root-pruning increases the number of FOLR of containerised seedlings. These trials confirm that FOLR initiation can be influenced by nursery practices and that lateral root pruning, by air or chemical means, is one way of increasing the number of FOLR.

INTRODUCTION

A greater number of first order lateral roots (FOLR) at planting out is positively correlated with improved survival and growth in a wide range of woody perennials (Fig. 1) (Whitcomb, 1988; Schultz and Thompson, 1990; Kormanik et al., 1994; Kormanik et al., 1995). These lateral roots form the basic framework of the developing root system (Nambiar et al., 1979) which is responsible for the plant's mechanical stability (Burdett, 1978).

Control over the number of FOLR developing in a seedling is under strong, but not exclusive, genetic control (Kormanik, 1986, 1988; Kormanik et al., 1989, 1990). Nursery practices, for example reducing seedling density and pruning the tap root at a young stage, can increase the number of FOLR (Barrett, 1981; Whitcomb, 1988; Schultz and Thompson, 1990; Donald, 1992). Auxin treatments can massively increase FOLR numbers (Seaby and Selby, 1990; Simpson, 1990), although these chemically induced lateral roots do not appear to have a similar effect on subsequent plant vigour.

Two trials were conducted to determine the differences in FOLR development of *Pinus radiata* seedlings. Firstly, seedlings were grown in two trays already in use for seedling propagation. The trays differ in side slot exposure and therefore air root-pruning ability. Secondly, the differences between lateral root pruning and nonpruning effects, using copper as the pruning agent, were tested in a smooth-walled tray.

MATERIALS AND METHODS

Two types of trays being used for large-scale plantation tree seedling propagation in Australia were used. These are the Lannen Plantek side slot 121F and the Col-Max model 64. In spite of the substantial differences in cell specifications, these two trays are frequently considered equivalents in the biological plant results obtained from them although no comparison trials have been conducted (Table 1 and Fig. 2).

Pinus radiata seed (Pro Seed, GF10) was direct sown in August 1995 into the cell trays filled with Palm Peat (Horticom, Auckland, New Zealand). After germination, the plants grew in outside conditions in Christchurch, New Zealand. The seedling trays were placed on raised benches to ensure airflow beneath them for good air root pruning. The seedlings were fertilised with Peters Excel 13:5:20 (Grace Sierra, The Netherlands) at 1 g $litre^{-1}$ applied as required until harvesting and assessment in Nov. 1996.

Trial 1. Twenty-four seedlings were harvested from each tray type, chosen at random but excluding the outer rows of each tray. The roots were washed clean of growing medium and then cut back to expose only the taproot and FOLR. These laterals were counted, separated into the group of laterals growing nearest the root collar and tending to grow in a clearly demarcated whorl, and total number of laterals along 20 mm of tap root measured from the topmost lateral (Selby and Seaby, 1982; Seaby and Selby, 1990). Root systems below this 20-mm level tended to become very difficult to separate and distinguish as in many cases this was only just above the air-pruning point at the base of the cells. Data were subjected to analysis of variance and F-test of significance as an exact test (unpaired data).

Trial 2. Seed from the same batch as Trial 1 was sown into a Landmark 512-plug tray. Every alternate row of the tray had been treated with Spin Out™ (Griffin Corporation, Valdosta, USA), a copper-containing paint intended to prune roots as they come in contact with the copper-treated cell walls. Seed was sown in July 1997, then in Jan. 1998 10 seedlings from each treatment were selected at random, excluding the seedlings on the edge rows. Because of the shallow depth of these cells (25 mm), only the first whorl of lateral roots was counted. As before, the data were subjected to analysis of variance and the F-test for significance was applied.

RESULTS AND DISCUSSION

Trial 1. Results from other container systems (Table 2 and Fig. 3) indicate an increased number of FOLR develop at lower plant density, greater container volume, and reduced container depth (Barrett, 1981; Whitcomb, 1988; Donald, 1992). There was clearly a difference between FOLR development in the two trays under study (Fig. 4). These results indicate that some of these factors play a larger role in inducing FOLR development than others. The model 64 tray, in spite of a lower plant density and shallower depth, resulted in fewer FOLR.

Early pruning of the tap root is considered important for increased FOLR initiation (Whitcomb, 1988), while diverting of existing lateral roots downwards by container walls inhibits initiation of further laterals (Halter et al., 1993). It would appear that the degree of lateral root pruning is of greater significance for determining the number of FOLR than earlier tap-root pruning by shallower containers. The amount of flashing covering the slots in the Col-Max container was so great that this trial could almost be regarded as comparing lateral root pruning and no pruning.

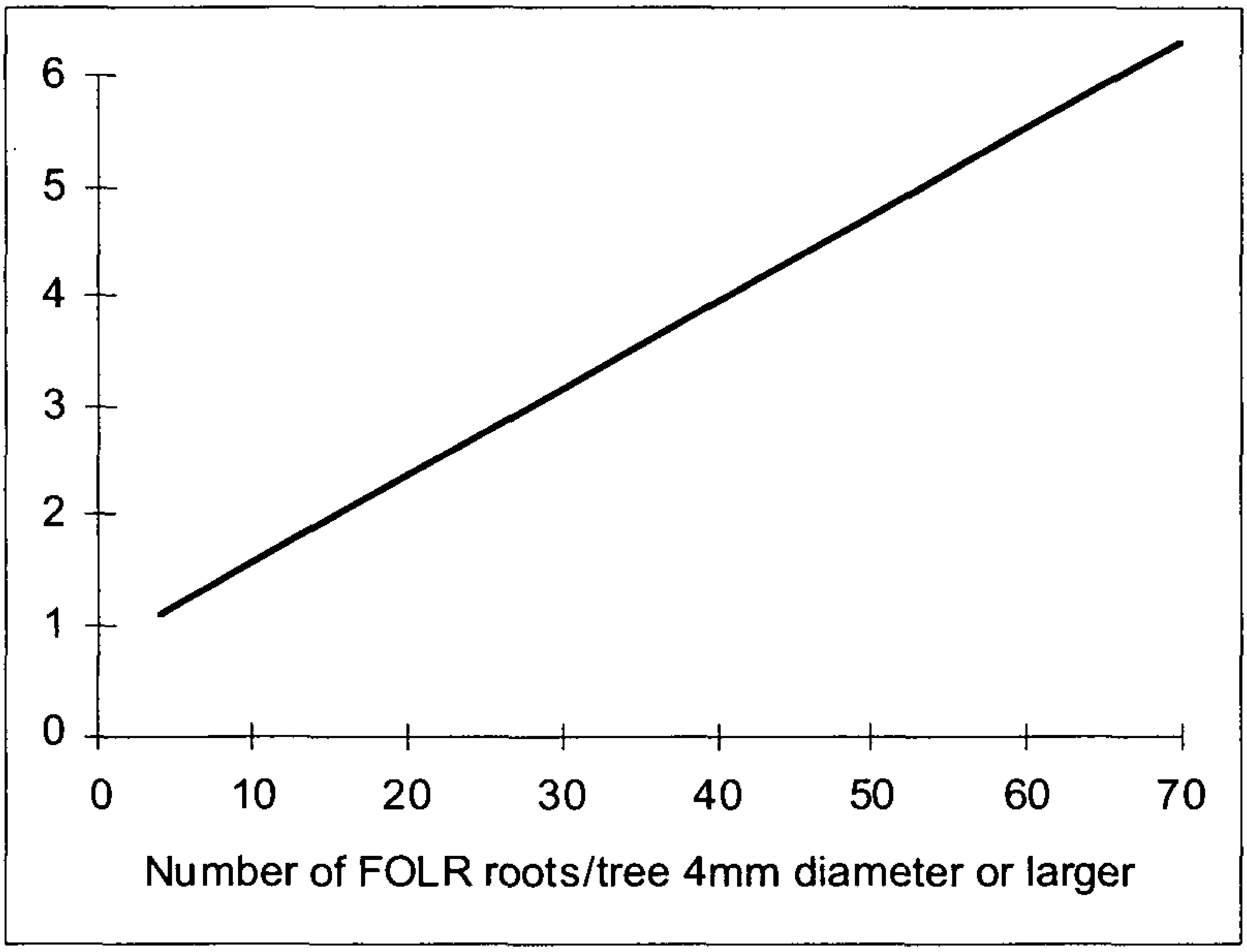

Figure 1. *Stem diameter related to number of FOLRs at time of planting. After* Whitcomb, 1988.

Table 1. Physical dimensions of the seedling trays.

	Lannen 121F	Col-Max 64
Tray dimensions (mm)	385 × 385 × 72	293 × 345 × 55
Cell dimensions (mm)	34 × 34 × 72	34 × 34 × 55
Cells m^{-2}	820	633
Cell volume (ml)	50	63
SA:D (cm^2 cm^{-1})	1.61	2.10
% of side wall as slot	6.8	1.3 to 5.2*

* Cells varied enormously as to how many and to what degree any of the slots were open. The outer edge of the outer row of each cell has no slots, but many of the internal cells showed no slots either.

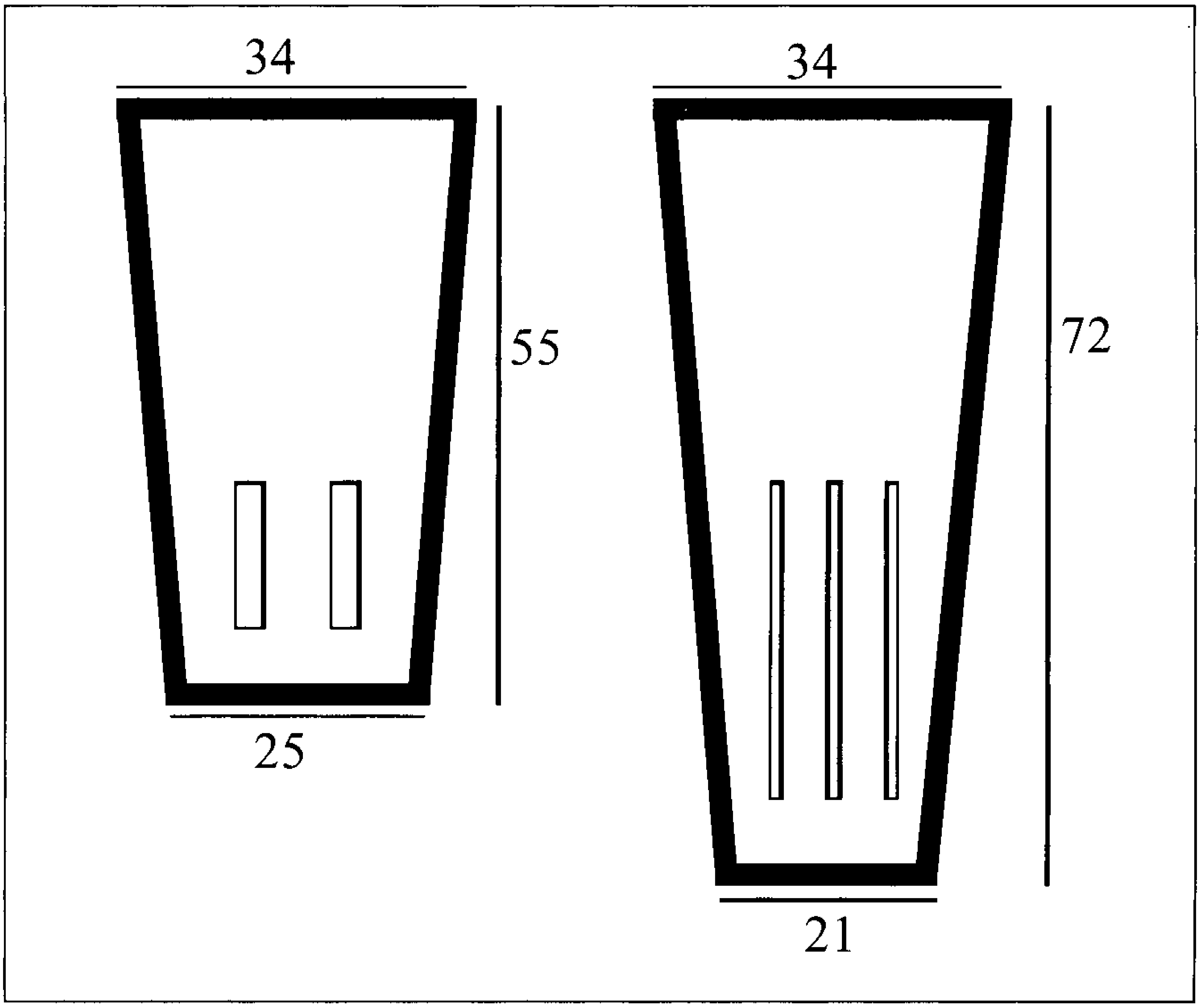

Figure 2. Detail of the sides of the cells showing size and position of the side slots. Measurements in millimetres. Col-Max 64 on the left, Lannen 121f on the right.

Table 2. Summarised results of FOLR numbers reported elsewhere.

Author, species	Cell volume (ml)	Cells/m^2	FOLR
Barrett, 1981 (*Acacia mearnsii*)	36	550	6.35
	22	860	5.50
	35	1280	4.40
Donald, 1992 (*Pinus radiata*)	36	550	5.70
	66	421	6.87
	80	310	6.80

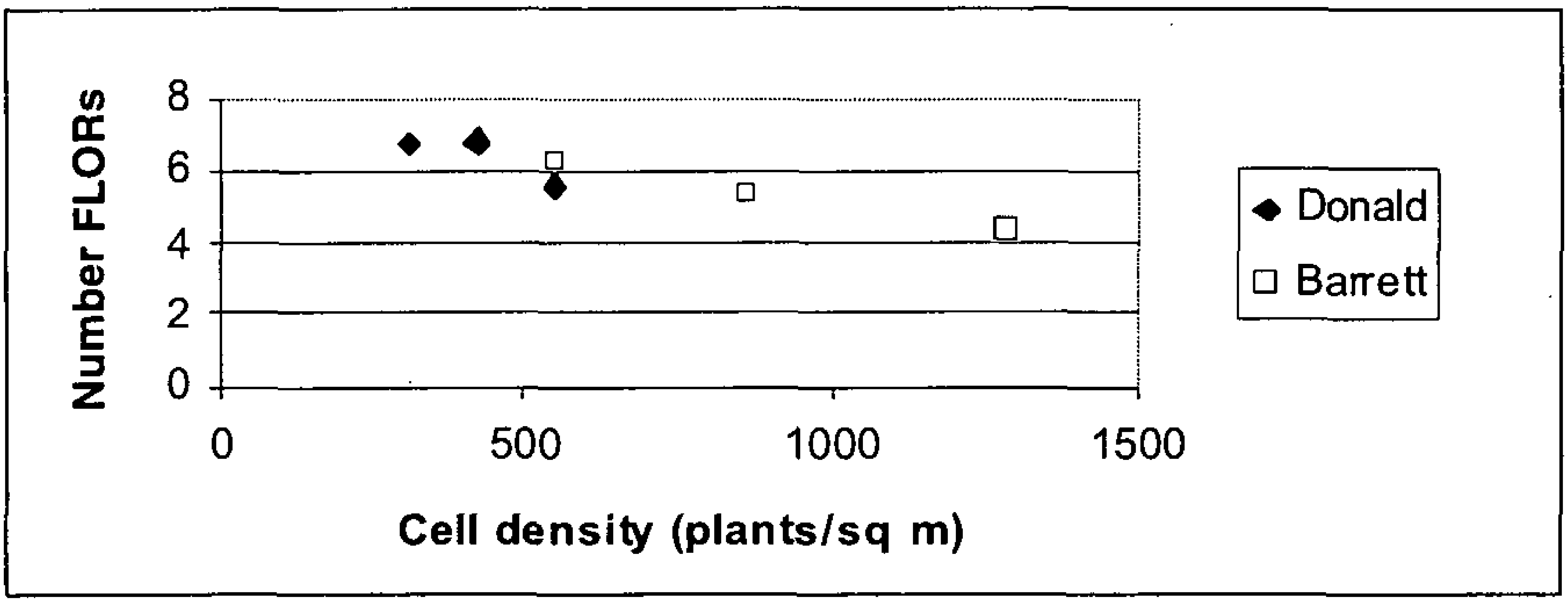

Figure 3. Relationship between cell density and FOLR numbers of containerised seedlings. Figures of Barrett, 1981 and Donald, 1992

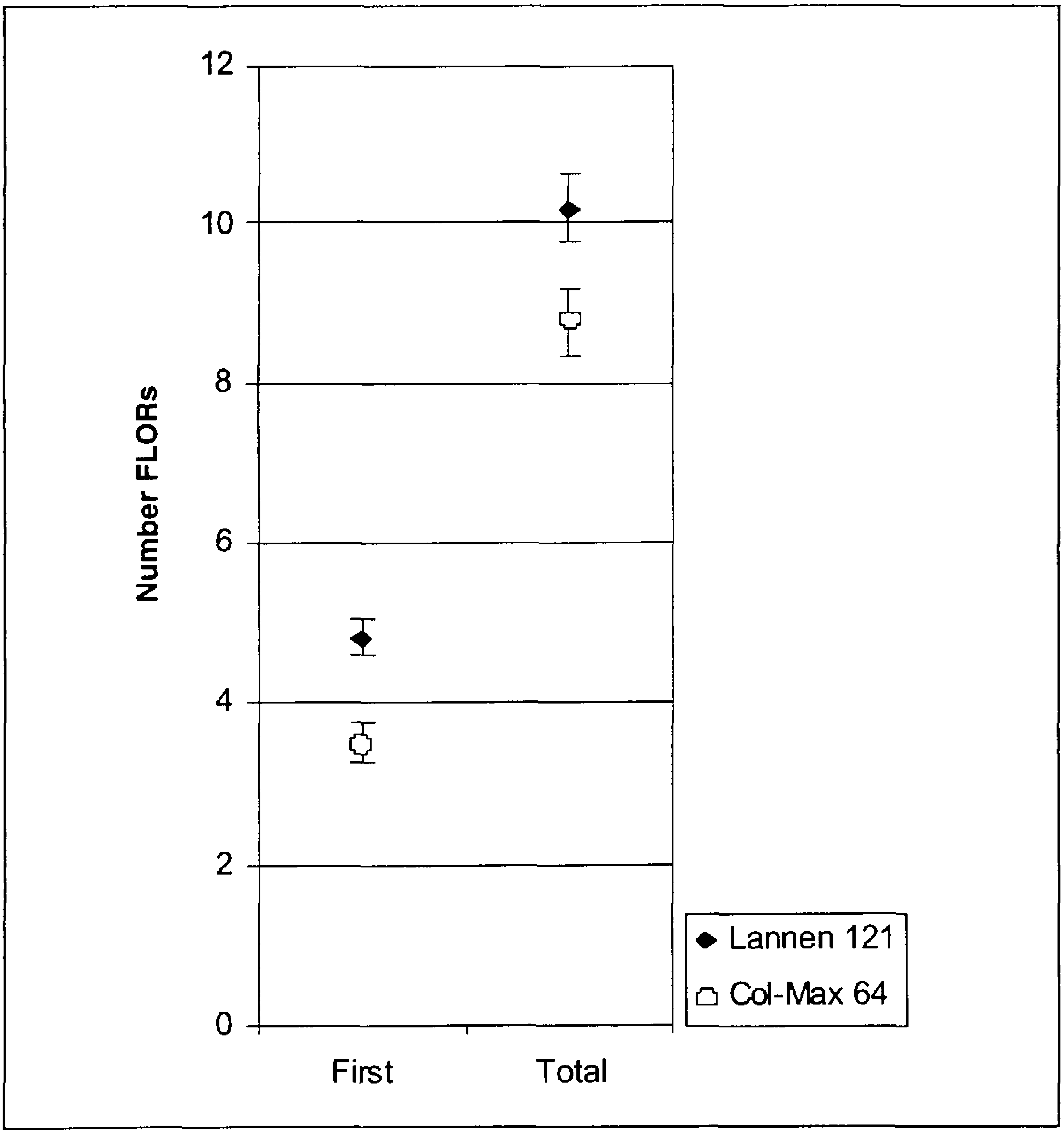

Figure 4. *Pinus radiata* seedlings grown in two tray models (Trial One). The bars indicate L.S.D. (p=0.05).

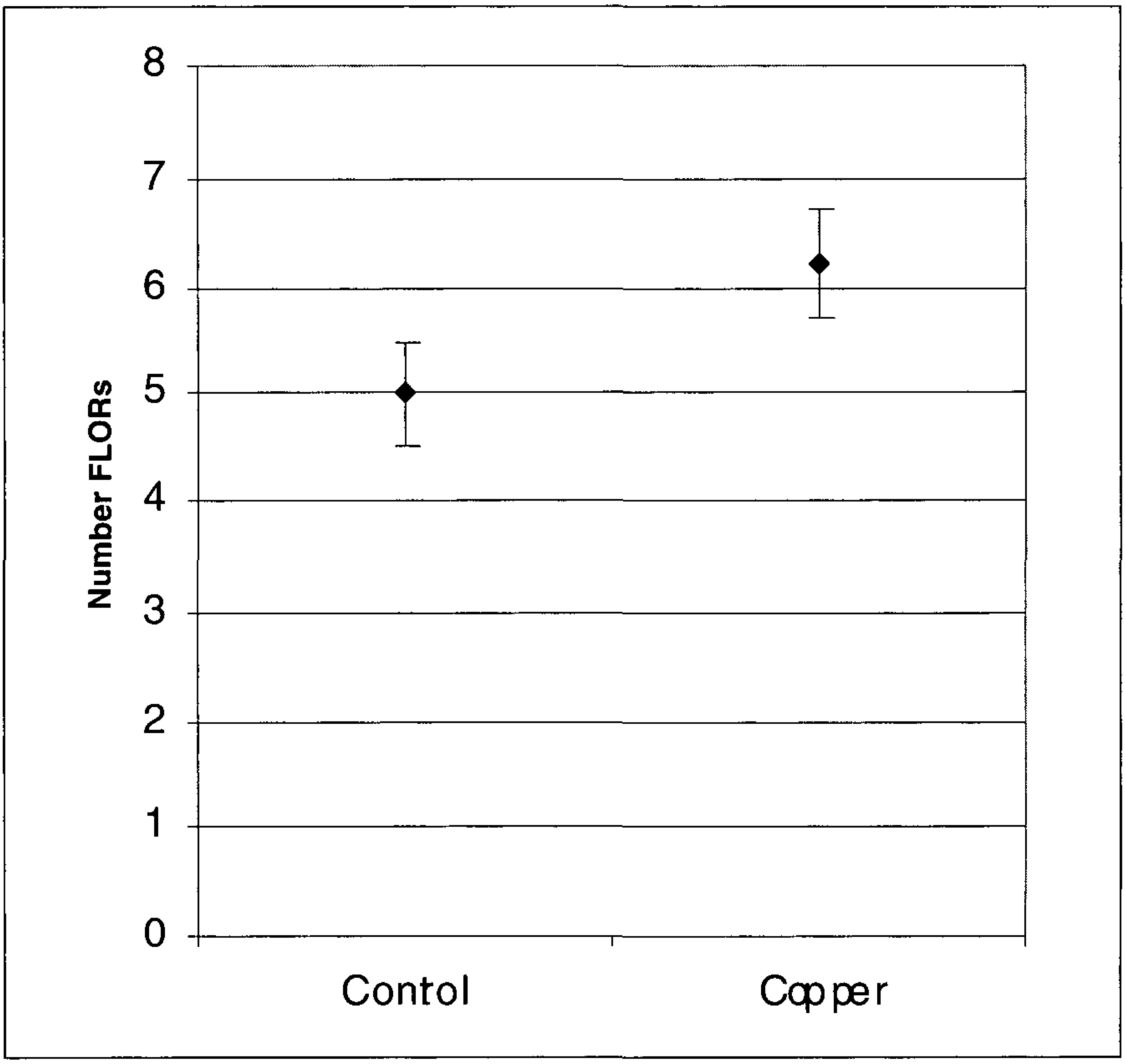

Figure 5. *Pinus radiata* seedlings grown in a 512 plug tray treated with copper for lateral root-pruning (Trial Two). The bars indicate L.S.D. (p=0.05).

The slight differences in overall height growth of seedlings in the two trays was not measured, but is consistent with expectations of growth from cells varying in volume and plant density. Seedling height and collar diameter have not been linked to FOLR development in the nursery stage as the irrigation and fertilisation practices allow even poor seedlings to grow to a normal size, thus masking the effect of increased numbers of FOLR (Kormanik et al., 1994).

Trial 2. The copper-pruning trial confirms that simply having a difference between lateral root-pruning and no pruning can have a significant effect on FOLR numbers (Fig. 5). The only difference between treatments in this trial was the presence or absence of lateral root pruning. Copper-pruning has been demonstrated to increase the number of FOLR previously, for example in cork oak (*Quercus suber*), Jeffrey pine (*Pinus jeffreyi*), roundleaf eucalyptus (*Eucalyptus polyanthemos*) and mesquite (*Prosopis tamarugo*) (Nussbaum, 1969), ponderosa pine (*P. ponderosa*) (McDonald, et al., 1981), and rose gum (*Eucalyptus grandis*) (Smith and McCubbin, 1992).

CONCLUSIONS

These results agree with other observations that seedling tray design features influence the number of FOLR. This is therefore a practical means of at least partially overcoming the genetically controlled component determining the number of FOLR. Choice of containers likely to improve the number of FOLR, and therefore also positive plantation outcomes, is one factor available to plantation managers in their quest to reduce risk factors to the plantation investment.

Key factors in container design apparently affecting the expression of genetic control of FOLR initiation are:

- Preventing lateral roots from being diverted downwards by the container walls (root pruning by air or chemical means).
- Early pruning of the tap root (shallow container).
- Sufficiently low plant density in the nursery.

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A Review of the Propagation of *Pinus radiata* by Cuttings, with Emphasis on Juvenility

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INTRODUCTION

Ritchie (1991) surveyed the production of forest trees from cuttings and reported that the annual world production at that time was more than 65 million rooted cuttings. He also noted that half of this production was in Japan where *Cryptomeria japonica* had been grown by this method for more than five centuries. Another 10 million or more cuttings of radiata pine (*Pinus radiata*) were reported to be grown in Australia and New Zealand at that time. Canada, Scandinavia, and the U.K. together were annually producing about 21 million cuttings of various spruce species (*Picea* spp.). New Zealand sales of *P. radiata* cuttings in 1992 were 6.1 million and this rose to a peak of 24 million in 1996 and have steadied to 19.8 million sold in 1998 (Anon., 1999).

The propagation of *P. radiata* in New Zealand was for many years based solely on raising open-ground seedlings. Seed was initially collected from existing forest trees to provide bulk seed. Then in the early 1950s breeding programmes were commenced based on the selection of superior types, which were then collected together in separate open-pollinated seed orchards. Grafts were taken from trees that showed high quality due to such desirable characteristics as high growth rate, good tree form, few stem cones, etc. Control pollinated (CP) seed orchards were introduced in 1986. In this system bags are placed over the female cones and only specific previously collected pollen is used on individual trees. Good pollination is ensured by several applications of pollen resulting in seed which can have a large proportion of potential high-grade individuals. Although plants had been successfully raised from cuttings in New Zealand by the early 1930s (Field, 1934), it was not an economic proposition until the cost of CP seed rose to high levels in the late 1980s. It was found that cutting production became economically viable when seed costs were greater than or equal to $1800 per kg (Arnold, 1990).

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A UNIQUE PLANT

Pinus radiata is quite a unique conifer in its ability to be grown from open-ground set cuttings with no added hormone and with high success rates. One attribute is its strong apical dominance. A wide range of shoots can be selected and yet the plant still forms an upright single-leader tree. Other conifers like Douglas fir (*Pseudotsuga menziesii*) or Norfolk Island pine (*Araucaria heterophylla*) require careful selection of material to avoid unacceptable variations in growth habit due topophytic effects.

Pinus radiata timber crops can be grown in relatively short cycles of 25 to 30 years in New Zealand. This is a reflection of the special genotype of this conifer, which comes from a small geographic area of coastal California and offshore islands. The northern most strain of a group of five principal types is thought to be the one most closely resembling that found in typical New Zealand plantations (Bannister, 1973).

JUVENILITY

Pinus radiata is also unique in that it requires a quite precise level of juvenility for high-grade forest planting stock. The usual advantages of juvenility are present such as highest vigour and ease of cutting propagation when selected from the most juvenile material. However, there are certain advantages to be gained from using material that has a specific physiological age. Physiological age is the popular term used in forestry, which relates to the ontogenetic aging of an individual as it matures through the phases of its life cycle. It can differ from the chronological age, which merely states the elapsed time from germination of a seedling.

Success rates for cuttings at the Forest Research Institute, Rotorua, New Zealand, in 1984 were evaluated as 75% plantable cuttings, 18% dead, and 7% unacceptable grade cuttings (Menzies et al., 1985). Commercial nurseries may not always achieve these rates and figures can be expected to range from 50% to 70% plantable stock. Juvenility is a key variable in success rates and Thulin and Faulds (1968) stated that a strike rate of 90% from 1-year-old seedling stock could be expected to drop to about 80% by age 5 and to only 15% at age 15, i.e., full maturity. It was also found that there is greater variation in rootability of cuttings between mature clones rather than more juvenile material. A further propagation advantage of juvenility is that those plantable cuttings, derived from young stock, produce a stronger and more fibrous root system than those from more mature material. Cuttings from older stock tend to have fewer roots and poorer survival rates than those from juvenile material.

Work by Menzies et al. (1988, 1991) at the Forest Research Institute, Rotorua, has shown that, unlike many conifers where cuttings are selected from the most juvenile material, some increase in physiological age will improve the quality of the planting stock. There is an aging gradient whereby increasing physiological age gives improved tree form, including a range of desirable characteristics such as straighter stems, reduced tapering, less malformations and lighter branching, over seedling stock. Menzies et al. (1991) found that there was no consistent effect on height but cuttings from 4- and particularly 5-year-old stock plants usually had smaller stem diameters for about the first 6 years after planting, compared to seedling material. Holden et al. (1995) found that on fertile farm sites cuttings produced trees with substantially higher recoverable volumes than seedlings due to improved form, especially straightness. These advantages have helped to maintain the use of cuttings.

STOCK BEDS

Seedlings from control pollinated plants are usually used to produce stool beds for the production of cutting material. The mother plants can then be retained as a source of propagating material for up to about 8 years (Menzies and Aimers-Halliday, 1997), although in practice this may be for 4 to 5 years. The aging process is minimised by continual severe pruning. In fact physiological age is strongly related to height growth, which in turn links with genotype and growing environment. Physiological age increases most rapidly on fertile, warm coastal sites where growth is most rapid (Menzies and Aimers-Halliday, 1997).

Physiological age can be assessed by the morphology of the plants. Juvenile growth appears as tufted rosettes of short primary needles. In contrast a greater physiological age of say 5 years, is indicated by the growth of secondary needles that are much longer (7 to 10 cm). These long needles each have a fascicle, which is subtended by a short brown bract, and associated with a sealed bud at the growing tip (Menzies and Aimers-Halliday, 1997). Stock plants are trimmed in late spring with a hedge trimmer to 10 to 30 cm. Secateurs may also be used to trim off maturing shoots.

PREPARATION AND SETTING OF CUTTINGS

Conifers benefit from being taken as large cuttings and *P. radiata* is no exception. The greater the stem diameter the more roots are produced (Faulds and Dibley, 1989). An ideal size for rapid subsequent growth is a cutting 25 to 35 cm in length and a diameter at the root collar of 8 to 10 mm but this provides a plant that is too big for planting operations. Shorter cuttings are usually used to keep the lifting size to a minimum. This again illustrates the quite unique potential of this conifer to adapt and grow.

Cuttings are pushed into the nursery bed to the point where the tips of the bottom needles are still left exposed. The bottom needles are best retained, as they remain a source of promoters for adventitious root formation to the adjoining sites (Faulds and Dibley, 1989).

CONCLUSIONS

Cuttings are an important method for the propagation of *P.radiata* and juvenility is a key consideration with this method. This is a factor of unusual significance because it governs not only the success rate in various ways, but also the quality of the developing trees. Therefore the level of juvenility in the cutting material has to be carefully selected.

Field set cuttings provide an economic way of multiplying superior clonal material from control pollinated stock of *P. radiata*, which has been the corner stone of the New Zealand forestry industry for many years.

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Labelling and Branding of Plant Material

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When labelling or advertising plant material for sale, it is recommended that the varietal name, plant variety rights number, and trade mark be represented so that your trade mark and plant variety rights are less likely to be infringed. If you have a trade mark or trade name, it is essential that this be used in a manner distinct from the varietal name. Use the initials "TM" after the trade mark, always represent it in capital letters or a distinctive form, use the trade mark as an adjective, not a noun, and do not abbreviate it.

INTRODUCTION

Three main issues will be addressed. Firstly the labelling requirements under the Plant Variety Rights Act 1987. Secondly branding, and specifically what is a trade mark, and how can it be protected. Thirdly some guidelines for correct trade mark usage are presented below.

LABELLING REQUIREMENTS UNDER THE PLANT VARIETY RIGHTS ACT 1987

What Exactly is a Denomination or Varietal Name? When you seek a plant variety right (PVR) for a new variety, you must include a varietal name in the application. This name is called the "denomination". It can be a breeder's reference or any name you care to select for the new variety. But there are some rules. For instance, the name must conform with international usage relating to the names of cultivated plants. Further, it cannot be a name already registered or applied for as a trade mark in New Zealand, and the name must not be misleading or deceptive about the characteristics or value of the variety.

Every proposed denomination is advertised in the *Plant Variety Rights Journal* along with other details about the application. Anyone may then object to the name chosen by writing to the Commissioner of Plant Variety Rights within 3 months of the date of the *Plant Variety Rights Journal* and setting out their reasons for the objection.

How Must the Denomination be Used? The Plant Variety Rights Act 1987 (the PVR Act) also has rules as to how a variety name of a protected variety is to be used. By "protected variety" I mean any variety, which is under application for or has been granted plant variety rights. If you sell reproductive material of a protected variety, it is necessary to use the varietal name in association with that material. Also you may not use a trade mark on the reproductive material of a protected variety, unless the varietal name is also clearly labelled.

These rules apply even after a variety is no longer protected under the PVR Act. In this way, the varietal name remains in place forever.

Use of the Varietal Name by the PVR Owner. If you own plant variety rights you should make sure that any reproductive material of the variety you are selling is labelled correctly. The label should include the Plant Variety Rights application

[1] solicitor

or grant number, as well as the varietal name. The advantage of correct labelling which includes the PVR application or grant number is that if someone allegedly infringes your plant variety rights, they can not argue that they were not aware of the existence of your rights. This means that you will be entitled to claim damages if the infringement is proven.

Recommendation. It is my recommendation that you make sure that reproductive material of your variety that you sell is labelled:

- "Varietal Name" PVR Application No. "123456", or
- "Varietal Name" PVR Grant No. "XYZ".

Although action for infringement can not be taken until the plant variety rights have been granted, once this occurs the PVR owner can sue for any infringement that has occurred since the filing date of the application. It is thus worthwhile labelling your variety with its denomination and plant variety rights application number as set out above, even if plant variety rights have not yet been granted for the variety.

Incorrect Use of a Denomination — What Not to Do. You must be careful not to label plant material stating that you have applied for plant variety rights, if you have in fact not done so. It is also not allowable to label plant material using another plant's varietal name.

Another thing to avoid is using the varietal name as a trade mark. It is best to choose a separate trade mark for your variety, or for a range of your varieties. The trade mark should be distinguishable from the varietal name and should itself be distinctive. Preferably this trade mark should then be registered at the Intellectual Property Office of New Zealand (IPONZ).

To clarify — a trade mark is distinct from a varietal name for the following reason: the varietal name is specific to the variety itself, while the trade mark indicates the person or organisation that produces or sells the variety.

BRANDING — WHAT IS A TRADE MARK AND HOW CAN IT BE PROTECTED?

A trade mark is a sign (or combination of signs) capable of being represented graphically and capable of distinguishing the goods and services of one person from those of another. A trade mark can be registered in New Zealand at the Intellectual Property Office of New Zealand ("IPONZ") in relation to goods and/or services subject to satisfying a number of conditions. I will refer to these shortly.

The trade marks register is divided into 42 classes of goods and services. The classes most relevant to your industry are class 31 (fresh fruits and vegetables; seeds, natural plants, and flowers) and class 35 (retail and wholesale services). If your goods and services fall into more than one of these 42 classes, it may be necessary to file a trade mark application in each relevant class.

CONDITIONS OF REGISTRATION:

Availability. A trade mark will be considered available for registration provided such mark (or a mark confusingly similar to such a mark) is not already registered in New Zealand in relation to the same or similar goods or services. In order to determine this we can conduct a search of the New Zealand trade marks register.

In addition a more common law search can be conducted that considers registered company names, telephone directories, domain names, and the Business "Who's Who." This would help determine if another party is using the same or a similar trade mark or name in relation to the same or similar services.

Is it Registrable? The register of Trade Marks is divided into two parts, Part A and Part B. Part A registration provides a stronger form of protection than a part B registration. There are a number of additional differences between Part A and Part B registration which I will not comment on in this forum.

To achieve registration of your trade mark in Part A of the Register, it is necessary to convince IPONZ that your mark is **distinctive**, or **adapted to distinguish**, your goods or services from those of another trader. For Part B of the Register there is a slightly lower standard, namely that the mark is **capable of distinguishing** the goods or services for which it is to be used. If your trade mark is descriptive (either directly or indirectly) of the goods or services which you intend to use it on, or have used it on, or if it is a geographical name or surname, it may be difficult to obtain the registration for it. It is for this reason that a trade mark should preferably be distinctive of the goods and services for which it is to be used.

In some cases, however even where a mark is descriptive, or contains a geographical name or surname, it may be eligible for trade mark registration if evidence of substantial use of the mark in New Zealand can be filed at IPONZ. In this way it can be shown that the mark has become well known to persons in the industry as being associated with the applicant and their goods or services.

Once a trade mark application has been filed at IPONZ, an Examiner will consider whether its registrability, availability, and other formality matters during the examination. If it is then accepted for registration it will be advertised in the Patent Office Journal. From such date of advertisement there is then a 3-month period of time during which third parties can object to registration of the trade mark. Assuming no opposition is lodged, the registration fee will then be paid and the trade mark will proceed to registration. A registered trade mark will remain in force for an initial period of 7 years from the filing date. This can be extended by further periods of 14 years by payment of renewal fees. The period of protection can thus be extended indefinitely.

GUIDELINES FOR CORRECT TRADE MARK USAGE

If you have a trade mark registered at IPONZ it is important that the trade mark be represented on labels, promotional, and other advertising material in the same manner as it appears in the trade mark registration because this is what you have obtained protection for. If you have obtained registration for your trade mark at IPONZ in ordinary block letters (the broadest form of protection), then any use of that word, however represented, will be considered to be use of the registered trade mark. One danger of incorrect trade mark usage is that the mark can become generic; for example, the public becomes used to referring to the product or service by its trade marked name. If this occurs it may not be possible to stop other traders from using the name in association with their own brand. This is because the trade mark will be considered to have lost its distinctiveness associated with the product or service. Examples of trade marks that have become generic are SELLOTAPE, JANDAL, and XEROX.

To prevent this happening, the common commercial name for the product should follow the trade mark. For example: PACIFIC ROSE apples or ZESPRI GOLD kiwifruit. Also the trade mark should be used as an adjective, not a noun and should not be used in plural form. For example:

The taste of ZESPRI GOLD kiwifruit is exquisite. — Right

The taste of ZESPRI GOLD'S is exquisite. — Wrong

The trade mark should be displayed in capital letters, or in a distinctive form, and should never be abbreviated.

Trade marks on Labels. It is not compulsory under the Trade Marks Act 1953 for a trade mark to be represented with an indication that trade mark protection has been applied for or obtained. However, it is important to represent a trade mark with the initials "TM" after it, to indicate it is being used as a trade mark rather than a varietal name, and thus to indicate to purchasers the origin of the plant material. If registration of the trade mark is obtained from IPONZ, the symbol "®" can and should be used directly after the registered trade mark. However, it is an offence to indicate that a trade mark is registered when this is not so, even if one has applied for trade mark registration.

REFERENCES

Intellectual Property Office of New Zealand (IPONZ). Lower Hutt, Wellington, New Zealand.

New Zealand Business Who's Who. 1999. New Zealand Financial Press Ltd, Wellington, New Zealand.

SEED GERMINATION FORUM

PANEL MEMBERS: Lindsay Hatch, Eric Appleton, and Graham Milligan

Each member of the panel gave a presentation followed by discussion.

Preparing, Patience, and Persistence in Seed

Lindsay Hatch
Joy Plants, Runciman Rd, RD2, Pukekohe East

PREPARATION FOR SUCCESSFUL SEED COLLECTION IS IMPORTANT

This is the beginning of useful or useless seed propagation. There are several methods of collecting your seed. Some devised are simple and effective, others slow and cumbersome. Collection by hand is the most common practice, but not necessarily the best. It is very time consuming, and the seed is not always ripe, therefore time is wasted. This is also a common occurrence from kind old ladies who come into our nursery. We find that two of the most effective ways of collecting seed is the use of net bags, which are placed over seed heads and the laying down of shade cloth catch sheets. Net bags are most effective in collecting seed from plants which have spring-loaded seed capsules, such as *Geranium*, or plants that have fruits that are desirable to birds and animals. By using net bags, seed can be left to ripen completely and are easy to pick with no waste. Catch sheets are best when collecting off large trees, such as *Podocarpus*, *Dacrydium*, and *Dysoxylum* (kokehoke). The use of shade cloth means that moisture does not collect on top of the cloth and plants are not killed off underneath while the cloth is in place.

PREPARATION FOR SEED STORAGE OR SOWING

Once seed has been collected it is essential that seed is clean for good storage and germination. There are several cleaning methods, which can be used for the many seed types. Some of the various methods we have used are listed below.

Fuel and Pounder. For seed such as *Pittosporum*, when seed capsules can be quite hard to remove due to their sticky covering.

Decomposing in Water. For seed in pulp such as *Coprosma*, and other such seed, is left for several days or weeks in water. The washing is also very effective for cleaning and removal of nonviable seed.

Winnowing. For seed that has been dehusked, or has high dust, or light nonviable seed. It can be used for many seeds such as most bulb seeds. A vibrating conveyor and fan system can be a very effective winnowing system.

Sieves. Are most useful for cleaning many seeds. Either sieving out rubbish bracts or capsules, and other undesirables from your seed can do this.

An Old Washing Board. This has proven a most effective way to clean grass seed. By rubbing seed heads on the board, the small seeds are removed from their sheath.

Birds. This has been most effective when you can find roost sites.

Once seed is clean, it should be either ready for storage or sowing.

If storing, place in the appropriate storage package, with the name and date when collected. Most seed can be stored in paper bags in a cool dry room, but certain seed may need to be stored in a moist container of sand or moss in the fridge.

If sowing your seed is the next intended step, it may need other treatments before sowing to aid in germination. To break a seed's inhibitors, various methods of scarification or stratification are used in this process. Some of the more usual and uncommon methods are listed below.

Scarification. The abrasion or chemical treatment of a seed's coat in order to help speed up water intake and induce germination.

Stratification. The storage of seed, either in warm or cold conditions, to overcome dormancy and assist germination.

Filtration. Is a method very rarely used but can assist in germination of a number of seeds. *Sandersonia* seem to respond to the simple method of being placed in a net bag in a toilet cistern were water is continually flushing the seed, and then replaced, removing the seeds inhibitors. Another method of this is placing bagged seed in a stream.

Smoking. This can be done in various ways. The purchase of various smoke products on the market and application as directed. A less expensive method is creating your own smoke using a smoker or sieve. When selecting material for your fire to produce smoke try and find materials similar to that of the area from which the seed has come. For Australian seed, use material like *Banksia*, *Hakea*, *Leptospermum*, and *Eucalyptus*. For African seed, use Proteaceae, *Acacia*, *Senna* [syn. *Cassia*], and various rushes. When using a sieve to smoke seed, light your material and smother so that it smoulders and produces smoke, but not heat, and smoke seed for several minutes. When using a smoker, seed is sown in its growing container and placed in the smoker. Make sure the smoker dose not get too hot burning or melting your growing container. Once finished, water and wait.

PATIENCE FOR SEED SOWING AND GERMINATION

Most seed may be relatively fast growing but some may have long time lapses before germination that can not be broken. The sign of a good propagator is one with patience, which we must have. Since, as in one or more cases, we have had seed for 3 or more years after sowing before germination. Miro (*Prumnopitys ferruginea* [syn. *Podocarpus ferrugineus*] is a perfect example of this. When sowing seed think how it grows in the wild situation and try to simulate this situation. Do not go by the textbook situation every time, it is not always right. Too often you see seed sown in trays that looks like a roller has been over it then seed sown and covered. When germination takes place, the roots can not penetrate the soil. When we fill containers the mix is placed in the container and given a light tamp to firm the soil. The seed is then sown and covered, if needed, with pumice sand, and watered. In many cases trays are then placed under trees and left to germinate naturally. Some is germinated on a hot bed or under frost cloth. Ninety percent of our seed is grown this way with high success.

PERSISTENCE

If at first you don't succeed, try try again. There is much to learn about growing plants from seed. Trial and error is common practice; so if you don't try you will not learn; and if you don't learn you can't teach and if you don't teach you're not carrying out the I.P.P.S. motto.

Seed Treatment of New Zealand *Sophora* Species With Concentrated Sulphuric Acid To Hasten Germination

Eric J. Appleton
Appletons Tree Nursery Ltd, 1748 Main Road South, Wakefield, Nelson

INTRODUCTION

Sophora microphylla and *Sophora tetraptera* are small trees with attractive yellow flowers in spring. Their mature seeds have hard yellow seed coats, which must be scarified to allow the entrance of moisture before germination can begin. Unscrarified seed can lie in the soil for many years without germinating. If only a few seedlings are needed the hard coat can be cut with secateurs or a sharp knife at the end farthest from the micropyle. Soaking in water for 24 h will swell the seed to twice its size and it can be sown.

SULPHERIC ACID TREATMENT

If larger quantities of plants are required, consistently good results have been achieved by soaking dry seed in 96% commercial grade sulphuric acid initially for 1 h. Full protective clothing is advisable to protect skin, eyes, and clothing from accidental acid spillage. Use glass jars to hold the seed and pour the acid carefully over the seed, which will rise in the jar. Stir regularly with a glass or wooden rod to avoid the seed setting in a solid lump. Time the treatment carefully. If red blotches appear on the seed coat remove from the acid. When 60 min has passed pour the seed and acid into a stainless steel kitchen sieve held by a plastic funnel over a heavy-duty plastic container clearly labelled "Used Acid". The acid can be re-used several times even though it is now black. Thoroughly rinse the seed in the sieve with running water, collecting the diluted acid-rinse in a plastic container for disposal. The seed is now soaked in clean water for 48 h. Some or most of the seed will swell and must be separated from the nonswollen seed.

The South African technique of using a sugar solution to separate germinating from non-germinating *Eucalyptus* seed may have application here. Non swollen seed must be redried before re-treating with acid. Seedlots vary considerably in the total time needed in acid to achieve close to 100% germination. Usually a 30-min acid treatment is used as a second treatment if the majority swelled after the first 60-min treatment.

Trials with boiling water or near boiling water poured on to *Sophora* seed have given variable results, whereas acid treatment has given consistently good results.

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Trials with boiling water or near boiling water poured on to *Sophora* seed have given variable results, whereas acid treatment has given consistently good results.

The third New Zealand species *Sophora* 'Little Baby' [syn. *S. prostrata*] has a brown or black seedcoat that appears softer. A warm water soak may be sufficient to swell the seed; only if this fails should acid be tried for a short period. Trials continue.

TAKE CARE

- Never add water to acid; it will react violently and splash acid out of the container.
- Never add acid to damp seed; the seed will get very hot and cook.
- Never put acid in metal containers; it is highly corrosive.
- Always wash acid off clothes or skin immediately.

Seed Collection, Treatment, and Storage

Graham Milligan
Milligan Seeds, P O Box 23, Dipton, Southland

INTRODUCTION

When a packet of seed arrives on your desk, it is to all intents and purposes dead. It doesn't appear to move, grow or breathe. Unfortunately it sometimes is dead on arrival (DOA). Most species of plants flower and once pollinated, develop into seed. Once seed is shed it goes through a period of conditioning that allows it to germinate when conditions are near optimum so as to ensure maximum survival. In most cases this conditioning involves removal of chemical inhibitors surrounding or within the seed coat. These inhibitors are removed by; washing (rain), acid drench (bird and animal digestive system), temperature (stratifying), light, fungal, or a combination of the above.

We are fortunate that by collecting and storing seed we are able to hold seed in a relatively dormant state until we germinate. To do this we need to understand and apply the methodology needed to break down the chemical inhibitors. Substitutions for natural conditionings can be used to facilitate ease of germination. These include:

1) Washing in clean water — often several times over a period of days. (This is why I recommend overhead watering of the seed trays rather than capillary watering).
2) Adding a few drops of household detergent or a few drops of lemon juice to enhance cleaning.
3) Washing in a "cola"-based soft drink.
4) Stratifying by utilising a refrigerator.
5) Exposing the seed to light whilst in the seed tray.

My job as a seed collector/supplier is to ensure seed isn't DOA. To do this one must have a basic understanding of the seed. This differs between species and often within species (provenance).

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COLLECTION AND STORAGE

From a practical perspective, I find observation and understanding of what happens after seed shed can greatly assist germination techniques, for example:

1) Birds eat the drupes from miro (*Prumnopitys ferruginea* [syn. *Podocarpus ferrugineus*]) and matai (*P. taxifolia* [syn. *Podocarpus spicatus*]) and the seed is excreted often in a mound of corrosive dung.
2) Seed from high altitude and/or cold winter areas lie in the ground over the cold winter period and germinate in the spring, often after a few false starts, i.e., warm days then freezing nights.

Be aware that poor collection, extraction, and storage practices can create more intensive dormancy and death to the seed. Avoid high temperatures, and store in airtight containers under dark, cool, dry conditions. Animals, insects, and fungi readily consume seed exposed to outside pathogens. It is interesting to consider how many seedlings are needed to replace one giant tree in nature. If the seed isn't stored correctly, it may already be exposed to conditioning events that leads to an abortive attempt to germinate without your knowledge. When you attempt to germinate, the seed is already dead.

TREATMENT

To produce quantities of seed we find a domestic food processor with a variable speed useful, for example:

1) *Pittosporum* species - mix capsules with fine sand and mix with cutting blade. Free running seed can be obtained by sieving or windrowing.
2) Beating *Sophora* or *Acacia* pods soon removes the seed from the pods.
3) Pulping of drupes enhances ease of flesh removal and seed cleaning.

A recent trend in our business is cleaning and sizing of seed for precision automated sowing. Specialist seed cleaning techniques and absolute precision sieves are necessary tools here. Germination rates are critical, as is consistency in time of germination and subsequent growth rates if good robust seedlings are to be produced in large numbers.

GENERAL PRESENTATION DISCUSSION

Cleaning of Sticky, Resinous, or Fluffy Seed. The cleaning of some seed can be very difficult such as the fluffy seed of *Celmisia*. A method of cleaning fluffy seed is winnowing, sieving, or perhaps burning off if the seed is hard. Some suggestions for cleaning sticky or fleshy seed include fuels and detergents. Another possibility is the domestic food processor with the seed alone or placed in liquid or sand.

Selection and Collection of Source Trees. The seed from one tree of the same species or genera may not have the same seed properties as another tree of the same species or genera. This may be related to effects of provenance. When collecting seed it is worthwhile to be aware of this. It may occur that seed from a particular tree may clean or store better than seed from other trees in the same area. An example is in *Sophora*. The amount of stratification required seems to vary between trees from different localities. A useful method of collecting tree seed is to use a drop cloth underneath the tree and then shake the tree to encourage the seed to fall.

PROPAGATION MIXES AND TRAYS FORUM

PANEL MEMBERS: Warrick Nelson, Nicola Rochester, Geoff Stent, and Dave Lloyd

The panel members each gave a short presentation based on their own experience of the trays and mixes used by or known to them. A general discussion followed which covered the following:

MIX TYPE

The peat and pumice mix in varying proportions is still widely used and favoured by many, however bark pumice mixes, rock wool, vermiculite, perlite, river sand, palm peat, Oasis' foam, and ponga fibre are all in use or have been tried as propagating mixes. The use of standard commercial propagation mixes was raised with some favouring these over putting together you own mix from scratch. Additives to mixes such as fertiliser and fungicides are widely used. In selecting the type of mix for your crop it is important to consider availability, reliability, handling considerations, efficiency, and economics. In many nursery situations a low number of types of mixes are desirable, e.g., one for seed and one for cuttings. A simple approach has benefits. The type of mix must also match the management of the propagation environment and the crop. If a mist system is used then the mix's draining qualities could be of particular significance where as in a fog system less water is put on so the mix may need to have better water holding capacity. If a mix has very high water holding capacity, such as ponga fibre, then the management system must be suited to this.

MIX QUALITY AND TESTING

The propagator should be aware of the quality of the mix. It is a mistake to assume that the mix quality is correct even in commercial standard mixes or mixes prepared by the propagator. Mixes should be tested regularly to ensure the desired air-filled porosity and water-holding capacities are actually present. There are a number of simple tests that can be done. One suggestion was to fill a pot with mix, add water until full and time how long until all the free water has gone and running out the bottom. The propagator should know if the time is too long or too short. Species that are hard to root may need precise levels of mix porosity. Too much air in a mix could lead to a lot of callusing but poor root formation. With some mixes, porosity or water holding may be too good. In preparing and blending mixes, care should be taken as to how long the media is mixed. Overblending can create a number of problems including the breakdown of components, resulting in a reduction in the overall quality of the mix. A maximum 3 minutes of blending was suggested.

PROPAGATION TRAYS

The large range of propagation trays available can make the selection of the most suitable type for your propagation situation somewhat difficult. In the discussion the term tray included cell and plug trays. Some important considerations are hygiene, air porosity, availability, handling, and price. One approach is the use of a single type of standardised tray that fits most situations. A more specialised approach would be the matching of particular crop requirements to a specific tray type. The use of plugs or cells is becoming more common however reports of propagator experience are not all reporting success. Plugs certainly have a place but not for every crop. It was emphasised by several that the use of plugs needs a management system that meets the requirements of their use. It is not entirely straightforward to simply switch from cutting production in conventional trays to direct sticking in cell trays. Each tray type has particular features and usually takes some experimenting to test if the tray and the propagation system as a whole are meeting the crop's requirements. This often leads to flexibility within the propagation system, which allows a range of tray types to be used. This emphasises the important principle of the tray matching the management of the propagation environment. This is similar to the earlier discussion in this forum regarding the matching of the mix to the management system. The propagation environment, the tray, and the mix are all connected and each component should not be separated out. Changing one will have an affect on all.

PROPAGATION ENVIRONMENTS FORUM

PANEL MEMBERS: Don Currey, Jeff Elliot, Lee Gilbert, Richard Whisker, and Jan Velvin

The panel members each gave a brief presentation based on their own experience of the propagation environments used by or known to them. A general discussion followed which covered the following:

BENCH CONSTRUCTION AND DESIGN

A problem with some bench designs is their thermal properties. This is the bench's ability to hold and distribute heat. A bench construction which appears effective in tackling this problem is a solid concrete bench containing hot water piping. This method creates a very effective thermal mass and also encourages improved hygiene allowing easy cleaning of the bench surface. Another bench material that has good thermal properties is ferrous sand. Constant, even heat and good hygiene are significant components of any propagation bench environment. A problem with concrete benches is their high weight, especially if the bench is raised off the ground. Some thought is needed as to the framing required to achieve this. Benches containing peat, sand, or pumice in varying mixes have advantages of enabling good contact between the tray or pot and the bench surface for water and heat uptake but often have various hygiene problems. Benches raised above the ground provide easier working conditions, however if your environment is aiming for as much cool air above the tray surface as possible then raised benches may not help due to heat rising. With this in mind it was suggested that instead of monitoring the environment air temperature it was more important to monitor the plant level or bench erations are hygiene, air porosity, availability, handling, and price. One approach is the use of a single type of standardised tray that fits most situations. A more specialised approach would be the matching of particular crop requirements to a specific tray type. The use of plugs or cells is becoming more common however reports of propagator experience are not all reporting success. Plugs certainly have a place but not for every crop. It was emphasised by several that the use of plugs needs a management system that meets the requirements of their use. It is not entirely straightforward to simply switch from cutting production in conventional trays to direct sticking in cell trays. Each tray type has particular features and usually takes some experimenting to test if the tray and the propagation system as a whole are meeting the crop's requirements. This often leads to flexibility within the propagation system, which allows a range of tray types to be used. This emphasises the important principle of the tray matching the management of the propagation environment. This is similar to the earlier discussion in this forum regarding the matching of the mix to the management system. The propagation environment, the tray, and the mix are all connected and each component should not be separated out. Changing one will have an affect on all.

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MISTING AND FOGGING CONTROL

Light meters could be an effective method to regulate misting and fogging. This method provides water when it is actually needed. When sunlight is strong misting or fogging will be frequent to counter evapotranspiration and alternatively on cloudy days watering would be less frequent. The light meter does provide a precise method to control air humidity and mix moisture in your environment. As with any tool, the light meter will only be effective if it is used together with sound environment management and observation. Observation skills are very important in managing water requirements. Technology can assist in the creation and management of a propagation environment but it should be monitored regularly and supplemented with human intervention. One approach to the control of misting or fogging and to the whole environment, is the interception of light or heat before it reaches the plant. This can be done by the use of shade or thermal screens. This could in turn reduce water requirements. It should be remembered that where water is used to cool the air temperature, maintain humidity, and water the plants, concentrating on one of these may cause a problem in another area. An example shared was the use of fog, which effectively maintained humidity and cooled the air, but did not water the plants adequately.

MIST LINE BLOCKAGES

A common problem is the blocking of mist lines with moss and algae when white plastic pipe is used due to sufficient light entering the inside of the pipe. A possible solution was to paint the pipes black to keep out the light but this resulted in the pipes becoming over heated with drastic results. Another, more successful solution is to paint pipes with aluminium paint. This reduces the light but does not overheat the pipe. Other solutions to overcome this problem include treating the water with ozone or dilute chlorine; or flushing the pipes for several minutes each day.

GREENHOUSE DESIGN

The propagation environment is made up of a number of components including light, temperature, humidity and air movement. All are related to each other and altering one will change another. This principle has been emphasised throughout this forum. Greenhouse design is the physical putting together of all these components to achieve an optimum environment for propagation. The use of shade screens can control light and temperature where thermal screens have a stronger influence on temperature. The use of tents or tunnels within the greenhouse can be used to control humidity and temperature. Wet walls can be used to control air temperature and humidity. They are most effective in drier climate areas. A basic principle of cutting propagation is the aim for cooler temperatures around the leaf and warmer temperatures around the root; the "hot bottoms and cool tops" idea. The design of the greenhouse has particularsignificance on the air temperature component of this principle.

Measuring Copper Root-Pruning Effect

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Copper root-pruning treatments are now quite commonly accepted as a means of achieving root pruning during plant propagation. Many different formulations of copper treatment can be used. They are commonly manufactured from at least a copper salt and a water-based paint emulsion sticker. Determining whether a product is effective or not is dependent on visual assessment of the root system. There is currently no objective means of ranking the pruning effect. This paper shows that air-filled porosity (AFP) of the growing medium during plant growth can be used to obtain a measure of copper root-pruning effect.

INTRODUCTION

Subjective measures of copper root-pruning effect are normally based on a visual assessment (Figs. 1 and 2). Seedlings are typically easier to extract from the cells if there has been effective root-pruning. These are not easy to measure nor offer an objective means of ranking effect.

Improved seedling growth is sometimes reported (Smith, 1984; Arnold et al., 1993). This could be related to a number of different factors. Copper is an essential nutrient for plant growth, although in excess it can inhibit plant growth by inducing iron deficiency symptoms (Struve and Rhodus, 1990). There is limited, but strong, evidence indicating that copper-containing coatings are severely inhibitory to damping-off pathogens (Brophy et al, 1990). The occasional observation of very large growth differences can possibly be attributed to the copper inhibiting a sub-lethal pathogenic organism. It has been suggested that the increased number of fine root tips occurring with copper pruning allow the root system to explore the substrate volume more completely (Arnold and Struve, 1993). Improved plant growth is not sufficiently constant to consider as a means of measuring copper root-pruning effectiveness.

The use of copper in a container coating is known to produce a structurally different root form of containerised plants (Ruehle, 1985; Hunt, 1990; Smith and McCubbin, 1992; Arnold and Struve, 1993; Stafford et al, 1996). A fine, fibrous root system is commonly reported, as well as a reduction in root weight (Burdett, 1978; Burdett and Martin, 1982; Wenny and Woollen, 1989; Hunt, 1990; Beeson and Newton, 1992). These reports rely on laborious manual means of separating and counting or weighing root components, or on computerised imaging and analysis methods. Some tests require lengthy growing periods after the copper-pruning treatment to assess new root growth. So far, no standardised means of assessing root-pruning effect has been suggested arising from these test procedures.

The marked change in root structure, reduced root weight, and easier extraction of seedlings from treated containers all suggest a smaller root volume. Since the roots must take up a proportion of the total pore space originally present in the growing medium, a simple measure of air-filled porosity should indicate even subtle differences in root volume.

Table 1. Air-filled porosity (AFP) measures (as percent of cell volume) of copper treated containers after tomato seedling growth. The letters represent significant differences (p=0.05) between treatments.

	Trial one		Trial two	
Treatment	AFP	Increase over control (%)	AFP	Increase over control (%)
Control (C)	32.6a	-	18.0a	-
Styhropdip (S)	38.3b	17.5		
Plazdip (P)	45.8c	40.5	23.9b	32.8
Spin Out (S)			24.9b	38.3

A number of trials were conducted over a 6-year period, some including various other heavy metals and variations on type and concentration of emulsion used. Only three trials are reported on here as these indicate best the potential of this air-filled porosity (AFP) method for assessing and comparing copper root-pruning treatments.

MATERIALS AND METHODS

Over the years, I have had occasion to observe root systems of many plant species with and without copper root-pruning treatments. For the purposes of trials, the species chosen must be responsive to copper, readily available, and grow quickly and easily. Tomato seedlings meet these requirements.

In the first trial, seed of tomato FMX785 was sown into Palm Peat (Lignocell, Colombo, Sri Lanka) in injection-molded plastic tubes of an inverted pyramid design, 90 mm deep and 38-ml volume. These tubes were untreated (C), or treated with Styrodip (S) or Plazdip (P) (Starke Ayres, Cape Town, South Africa). Seedlings were watered on demand, and supplied nutrients as Chemicult (Starke Ayres, Cape Town, South Africa).

In the second trial, tomato Scoresby Dwarf seed was sown into New Zealand peat (Watkins, Auckland, New Zealand) into vacuum-formed 84-cell hexagonal seedling trays (Landmark Plastic Corporation, Akron, Ohio, USA) with a cell volume of 22 ml. Cells were untreated (C), or treated with Plazdip (P) or Spin Out (SO) (Griffin Corporation, Valdosta, USA). Seedlings were watered on demand, and supplied nutrients as Peters Excel (Grace Sierra, The Netherlands).

In the third trial, growing conditions similar to the second trial were used, but using Palm Peat (Horticom, Auckland, New Zealand) again. Different levels of copper (as a suspension of tetramino copper sulfate) were included in the Plazdip-type emulsion.

In all cases, AFP measurements were done when the seedlings were judged to be ready for field transplanting. Submerging in water, followed by free drainage until they had stopped dripping saturated the root plugs. The free air space was measured by blocking the base and measuring the volume of water required to saturate the substrate again. This test is a modified version of the method described in AS3743 (Anon., 1989).

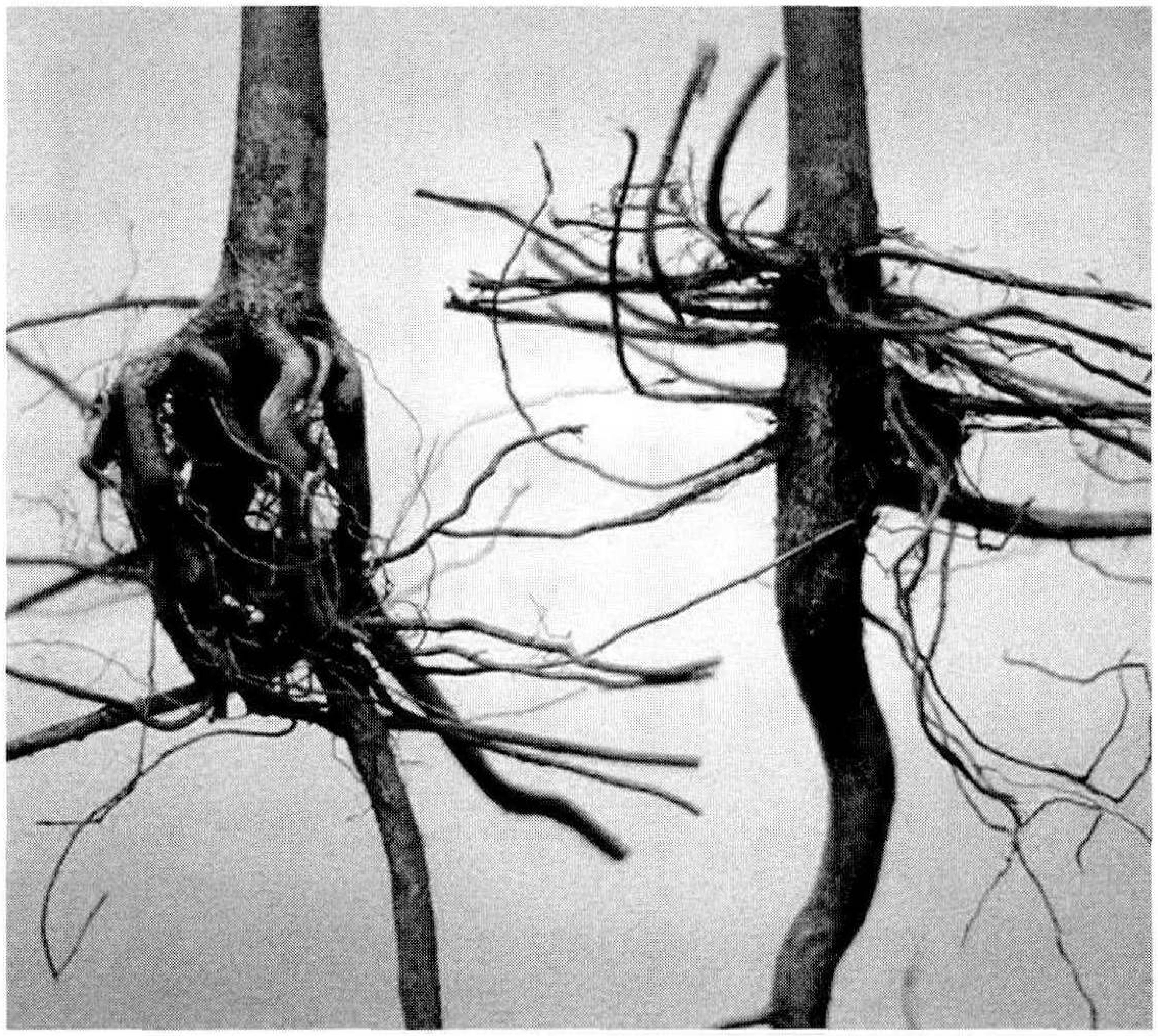

Figure 1.

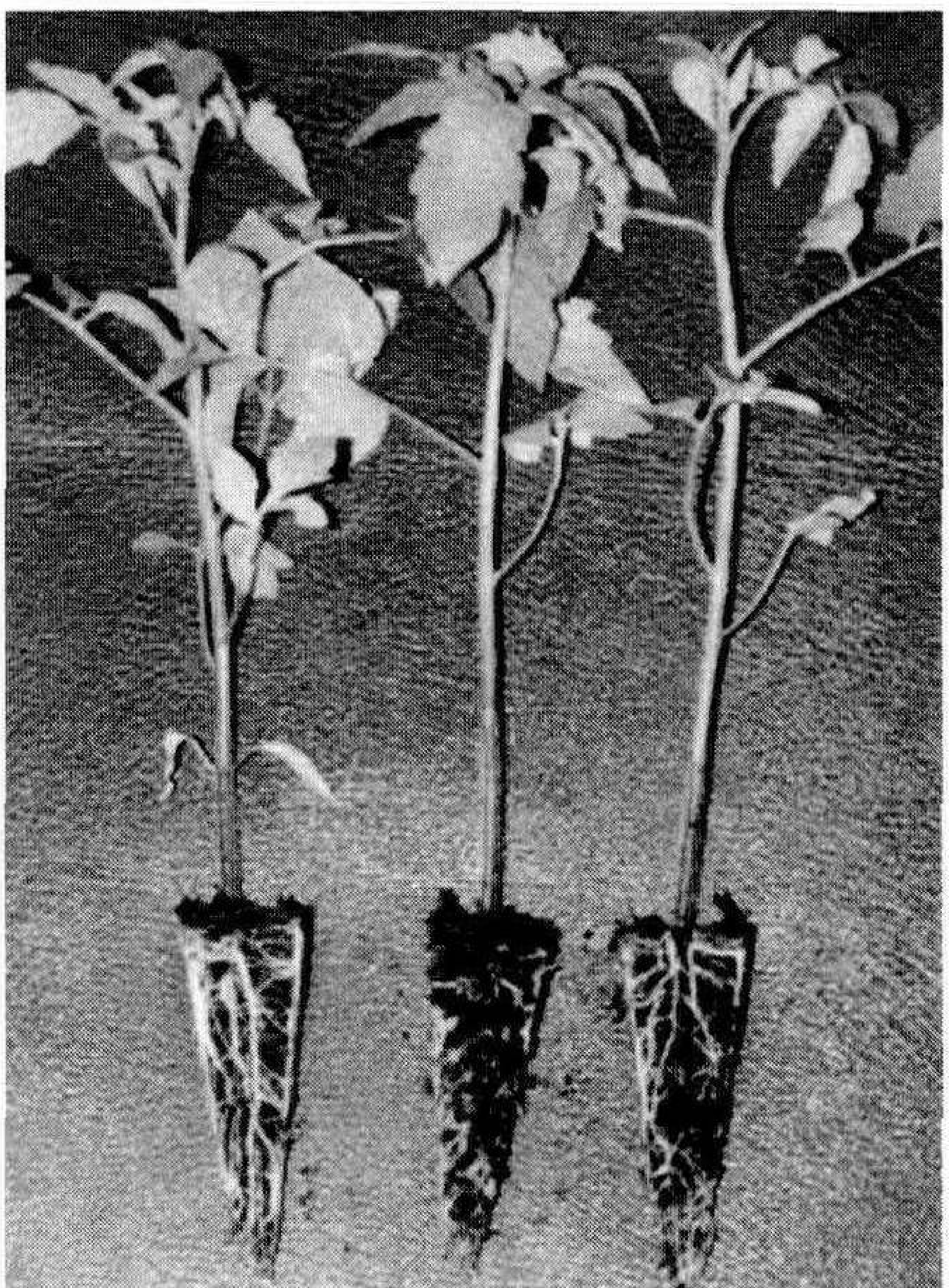

Figure 2.

Figure 3.

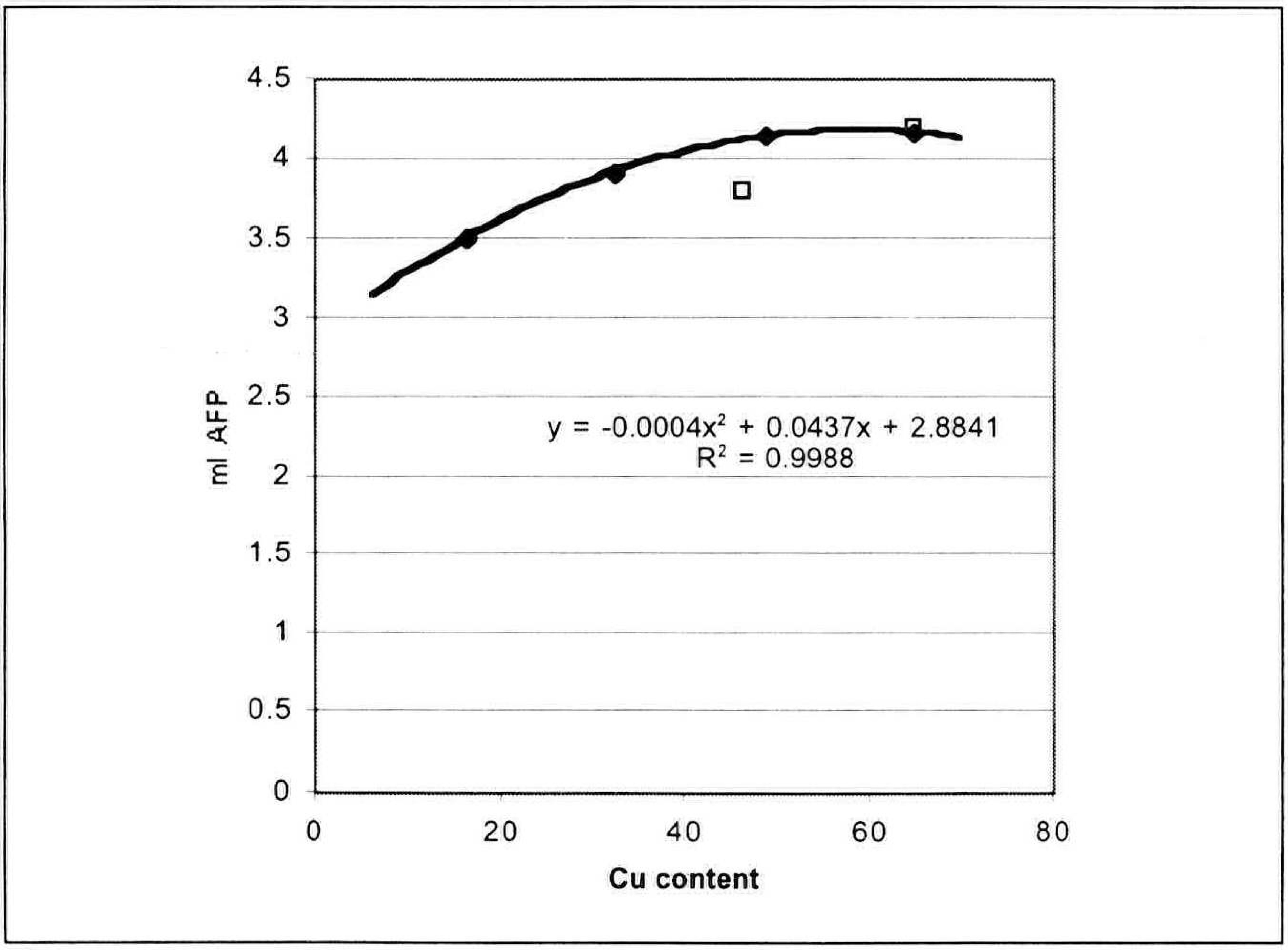

Figure 4.

In all trials, treatments were randomised during the growing period and a visual assessment of the roots was done after AFP measurement. Statistical analysis is by Analysis of Variance.

RESULTS AND DISCUSSION

Significant differences between treatments were noted for both the visual assessments of root pruning (Fig. 2) and the AFP measures (Table 1). The very large differences in measured AFP between the two trials is an indication of the differences between the two forms of peat as well as the deeper cells used in trial one. No direct seedling measures were done, as there was no visual difference in growth of seedlings between treatments at the time of measuring.

Different copper concentrations in the copper treatment illustrate the difficulty of ranking treatments clearly (Fig. 3). In graphical form (Fig. 4), the relative ranking of effectiveness is easy. In addition, it is possible to establish a concentration of copper giving a maximum root-pruning response, in this case about 50 g Cu litre^{-1}. The obvious visual differences in root form of tomato seedlings with and without copper pruning are matched by a measurable parameter, air-filled porosity of the substrate. Exactly why the AFP should be higher in the pruned roots is unclear, but could be related to an overall smaller volume of root growth.

In spite of the very large differences in AFP measurements between trials, the AFP of pruned cells is similar when expressed as a percentage of the unpruned cells. This suggests that AFP could be used as a means of assessing effectively any comparison between different formulations of copper-containing products, without having to rely purely on visual assessments of root pruning.

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Japanese Traditional Techniques of Plant Cultural Propagation

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GRAFTING TECHNIQUES FOR PROPAGATION PECULIAR TO JAPAN

These grafting techniques were developed in Japan a long time ago. A German, Philipp Franz von Siebold (1796-1866), introduced the techniques to the world in 1828. Prior to this introduction, the Japanese disliked publicising the advanced techniques and traditional propagators worked hard to find new and better ways of grafting that differed from other propagators. This led to the development of many new and useful techniques. A new technique was kept as a secret technique by the master propagator and was only taught to very few pupils. This is why, with the death of master propagators and the few pupils who had received their knowledge, over time numerous techniques were lost. It is unfortunate that the philosophy of "Seek and Share" did not exist in the past in Japan. Due to the past secrecy surrounding these techniques, it is sad that few Japanese today have expertise in practising these advanced plant propagation techniques. The techniques that remain are mainly used in Bonsai. I would like to introduce some of these Japanese plant propagation techniques to the world. Today I will demonstrate a few of these techniques.

UNDERSTANDING BONSAI

In the past, the Japanese took pleasure in making miniature plants. A plant size that would comfortably fit a table top. Then the influence of artistic expression, similar to that of monochrome ink painting, caused change resulting in the present expression of Bonsai. In Bonsai, we express the environment in which plants are growing in by the form and tone of the flowerpot. However, it is the expression of Bonsai's unique tree style that I wish to demonstrate to you today. Bonsai is the expression of Japanese nature. There are four seasons, graceful but sometimes very severe in Japan. Many Japanese rural people have the "belief in nature". An example is "the old tree growing in this season and climate, there will be god".

Spring is a welcoming and cheerful time when many flowers are in bloom and trees sprout into new life. Between spring and summer there is the rainy season. In this period there is high rainfall and it becomes humid. Pest and disease can harm new shoots. In summer, it is very hot and humid with temperatures up to 38°C. Later in the summer it becomes hot and dry, and often causes plant stress and damage. Between summer and autumn high winds can occur with wind gusts up to 50 m sec^{-1}. Trees can be damaged and on wetter soils could be blown down. Also in autumn, there is pleasure in watching the leaves turn red and many trees bear fruit. In winter, branches are bare and brace against cold temperatures down to about -10°C. Branches are sometimes broken by snow. These four seasons and the climatic conditions in each, create the unique tree style of Bonsai. Bonsai is a living art form, which is a copy of nature.

THE FOLLOWING TECHNIQUES WERE DEMONSTRATED:

The shoot pointed out, the shoot for propping up, the pulled shoot and the standing style.

The basic technique for carefully pulling branches out and creating the tree style by winding copper wire around the stem and bending to shape.

The technique for making a sapling graft; top graft; cleft graft (split graft); spliced side graft (veneer side graft), root graft; up tree graft; down tree graft (peg graft) and a root base graft. Traditional specialist Japanese grafting tools were used for all grafts.

PLANT BREEDING AND SELECTION FORUM

PANEL MEMBERS: Jack Hobbs, Jeff Elliot, Dennis Hughes, Keith Hammett, and Terry Dowdeswell

The panel members each gave a short presentation based on their own experience of plant breeding. A general discussion followed which covered the following:

GERMPLASM FOR BREEDING AND SELECTION

The "building blocks" of any breeding or selection, whether it is a chance find or a managed programme, is germplasm. Access is important to a wide range of germplasm. This germplasm may come from a range of sources including home gardens, hobby collectors, a breeder's own resources, or directly from the centre of origin. A recent threat to the availability of germplasm from overseas are the new border restrictions on the importation of genera and species. The new legislation makes importation of some genera or species costly, complicated, and in some cases impossible. "Plant people" should be aware of these problems. It is unknown what the full impact will be of stricter border control legislation on plant breeding. However, if breeder's and selector's do not have reasonable access to imported germplasm, then this may result in a decrease in new plant introduction and a decline in these activities in the long term.

BREEDING OF *HEBE, HELIOHEBE,* AND ×*HEOHEBE*

There is potential in the breeding of New Zealand native plants, particularly in the above genera. These genera offer the possibility of new cultivars with new flower and leaf colours and longer stems. With these genera as with all native plant breeding the surface has only been scratched as to the new cultivars that could be bred or selected. A view was expressed that Claim Wai 262 to the Waitangi Tribunal concerning Maori rights over native flora is a real or potential barrier to using native genera and species for breeding. This claim has yet to be determined and what the outcome will be is unknown.

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APPROACHES TO BREEDING

There is no exact method to breed or select new plants. The most important thing is to have a goal and identify what you are trying to achieve. How you get there depends very much on the breeder and the crop. The method can be structured and planned as in the breeding of deciduous azalea, a mix of chance and some planning as in the breeding of *Delphinium*, or chance and skilled observation in the selection of mutations and chance seedlings. All have special skills that should be recognised and value should be added to new plants to reward the breeder's efforts. In a planned breeding programme research is often critical. The barriers to what the breeder is trying to achieve need to be recognised and solved. An example is pollen incompatibility or pollen tube growth abortion. It is useful for plant breeders and selectors to have a list of criteria for making selections. This ties in with having a clear goal.

BREEDERS AND SELECTORS NEED THE ASSISTANCE OF OTHERS

A plant industry needs new plants but breeders also need the industry. Breeders may not recognise value in a plant that another person will and breeders often need help to know the worth of their creations. Always be on the look out for surprises. The plants that a breeder discards may be of value to someone else. The criteria of novelty should not necessarily be the only breeding or selecting aim. It is good practice to involve other industry people in your breeding or selecting activities. These people may not be other breeders but could contribute skills such as commercial knowledge and market information to your breeding and selecting efforts.

The Plants of Macquarie Island: The Development of a Subantarctic Plant House

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This paper reviews some of the information available on the ecological and physical influences on Macquarie Island's complex range of plant communities. The plants that have managed to reach the island and successfully colonise it exhibit a range of strategies for dissemination, reproduction, and colonisation. The conjunction of climatic factors and inherent soil instability creates a shifting mosaic of colonisation and succession. We believe an understanding of these processes will contribute to the successful cultivation and management of the plants in the new Subantarctic Plant House at the Royal Tasmanian Botanical Gardens. Germination trials and field observations of these plants by researchers from the University of Queensland and Royal Tasmanian Botanical Gardens staff has and will continue to provide additional information.

BACKGROUND

Subantarctic Macquarie Island lies at latitude 54°30' S in the Southern Ocean, approximately 1000 km south-southeast of Tasmania. It is a relatively young landmass, emerging from great depth as oceanic crust between 300,000 and 80,000 years ago (Selkirk et al., 1990). The island now lies in isolation on the eastern edge of the Australian tectonic plate and is shaped like a narrow rectangle, measuring 34 km in length with a maximum width of 5.5 km. The highest point is 433 m above sea level (asl) with the mean elevation of the plateau above 200 m asl, although a number of areas exceed 300 m asl.

CLIMATE

The island lies on the outer edge of an important oceanic boundary, the Antarctic Convergence, where cold waters from the south meet warm waters from the north. The circumpolar currents and a belt of low atmospheric pressure surrounding Antarctica at between 35° and 60°S have a major effect on the island's weather, resulting in only a moderate variation in the diurnal temperature. Overall, the mean maximum temperature is 6.3°C and the minimum 2.9°C, giving an annual mean temperature of 4.8°C.

Precipitation falls as rain, mist, sleet and snow but snow cover is erratic over the year and is neither regular nor persistent over winter (Bergstrom et al., 1997). Mean annual precipitation is not high at 895 mm but because of its constant nature and the low degree of evaporation, the soil remains continually moist. The "Furious Fifties" exert a commanding influence on the climate of Macquarie Island which lies directly in the path of these winds, and mean wind flow over the island is in a northwest to westerly direction (Streten, 1988). The severity of the winds is greater on the exposed plateaus where soil and air temperatures are also lower, and precipitation higher than for the rest of the island.

Cloud cover averages seven-eighths in all months making the island one of the cloudiest places on earth (Streten, 1988). Despite prolonged summer daylength, overall light intensity is low but the island's plants are able to use light efficiently at prevailing temperatures. These temperatures are not low enough to limit metabolic activity and plant productivity is high (Selkirk et al., 1990). These climatic factors have a strong influence on the geomorphic processes and vegetation distribution on Macquarie Island (Selkirk et al., 1990).

SOIL DYNAMICS

The interaction of several of the physical and, to a lesser extent, the chemical forces which prevail in this climate result in bare soil becoming available for colonisation by plants. Frost, wind, and water combine with the force of gravity to produce a varied and shifting pattern of erosion, complicated at a more local level by the activity of marine birds and mammals. The common factor underlying the soil structure on much of Macquarie Island is that of instability. This leads to mass movement of soil, root damage, loss of plant communities and their replacement by others, often in a recognizable cycle. This sequence is well illustrated in the freeze-thaw cycles which disrupt the feldmark communities of the higher regions (Heilbronn and Walton, 1984).

VEGETATION

Macquarie Island has never been connected to an adjacent land mass (Selkirk et al., 1990) so all flora and fauna must have reached it by long-distance oceanic dispersal. The flora shows taxonomic linkage to other subantarctic islands, the continents to the west and the islands to the south of New Zealand. Current established plant species could thus be considered as obligate colonisers, and 45 vascular plants, 80 mosses, 50 liverworts, and 100 lichens have been successful (Selkirk et al., 1990). Three plants, *Azorella macquariensis, Puccinellia macquariensis* [syn. *Triodia macquariensis*] (George et al., 1993), and *Corybas dienemus* (Jones, 1998) are considered endemic to Macquarie Island, with naturalised aliens including *Poa annua, Stellaria media*, and *Cerastium fontanum.*

Zoning of plant communities on Macquarie Island is basically a function of their proximity to the sea and their altitude. The structure of the near-shore plant communities and those of the coastal terraces are strongly influenced by the sea itself, the substrate, and faunal impact. The almost exclusive communities of *Poa foliosa* and *Stilbocarpa polaris* on the coastal slopes give way to the short tussock grasslands and herb fields of the upland plateaux. The latter are recovering from the heavy grazing inflicted by the rabbit population, which is now in decline. At the highest level, on the exposed plateau the communities are moss-dominated, with the combination of wind and frost proving too hostile for most vascular plants (Selkirk et al., 1990).

Within the broader topographical context of floral communities there exist further subgroups based on the dominant species. Several of these groups may coexist side by side in the same geographic area. These groupings can be broadly categorised into: tall tussock grassland, short tussock grassland, fern brake, mire, herb field, and feldmark. Within these broad groupings, there exists a range of alliances, associations, and sub-associations that make up a complex matrix of plant mosaics (Selkirk et al., 1990).

Bergstrom et al. (1997) have identified four basic growth patterns displayed by Macquarie Island plants and related them to their colonising ability. Firstly, small herbs and grasses with vegetative growth potential, rapid flowering, and seed set with high germinability, all of which enable them to colonise bare ground. Secondly, medium herbs and medium to large grasses, the major contributors to biomass on the island, with the capacity for juvenile vegetative expansion and high seed germinability. The third group, typified by large herbs have extensive storage tissue and vegetative growth, attributes which enable them to function as perennial stayers. Lastly there is a group of plants which have no vegetative reproduction, very slow flowering and seed production levels but which can tolerate and colonise difficult sites. Species which demonstrate some of the preceding growth patterns will form a significant part of the display in the Subantarctic Plant House.

ROYAL TASMANIAN BOTANICAL GARDENS (RTBG) SUBANTARCTIC PLANT HOUSE

The Subantarctic Plant House is a teardrop-shaped, solid-walled, clear-roofed display facility which measures 14 m on its long axis, is 6 m wide, and stands 4 m high; it has high curving walls to maximise the opportunities for visual display combined with a separate steel framed external structure. This building is a unique response to the problems of creating a cool climate house. Internally the structure will be cooled by piped cold water at ground level; air conditioning and misting systems will cool the atmosphere. The steel frame will support a shading system and external watering.

CLIMATE AND CULTIVATION

Given the practical and financial constraints it has been impossible to replicate the extremes of the Macquarie Island climate. The temperature variation within the house will be several degrees above the equivalent on the island. The island's constant high winds and minimum temperature are difficult to duplicate. Air movement in the building will be provided by fan-driven chiller units, and though this will supply ample air flow it will not provide the extremes experienced on the island. Trial cultivation has indicated that a high level of air flow is an important requirement for the successful growth of these plants.

The island's constant high humidity will be maintained in the new structure by chiller units and a fogging system. Macquarie Island House will have solid sides and a clear double-skinned polycarbonate roof, protected by a 75% shade cloth. Given the plants ability to thrive in low light conditions this will provide adequate light levels for cultivation. Some variation occurs within the house, with areas closest to the north wall in constant shade while the base of the southern wall receives direct sunlight in summer. The feldmark cushion plant, *Azorella macquariensis*, requires higher light levels and will be grown at the base of this wall. An unknown factor is how plants from the exposed plateau will adapt to the new conditions, *A. macquariensis* tends to produce larger leaves and has a more open habit in cultivation. Experience to date, growing the plants in refrigerated containers under artificial light, indicates that environmental conditions in the house will be suitable for successful growth.

PLANT COMMUNITIES IN CULTIVATION

Scale and dimensions within the house do not permit enough variation in the environmental conditions, therefore our approach will be a horticultural one. The composition of community plantings will be defined from the outset and maintained by weeding out unwanted species. Communities dominated by single species will be planted as such, but others, for example short tussock grasslands, mire, and coastal vegetation will be composed of representative species. Small-scale replication of some of the more complex plant combinations will be trialled but several plants will not be considered due to their weed potential. Mosses and hepatics will be added as named provenanced collections become available.

SOIL STRUCTURE

The complex and unstable nature of the island's substrate cannot be reproduced although this has significant influence in the make-up of the community structure on the island. Over the past 3 years of trial cultivation the Gardens have developed a generic soil mix for all Macquarie Island plants. This replicates many of the characteristics of the island's soil in that it has good structure and high water-holding capacity. The base mix contains composted pine bark, sand, and Tasmanian peat (2 : 1 : 1, by volume). Low nutrient levels will be supplemented by regular application of liquid fertiliser. Initial plantings will use the one standard mix rather than attempting to vary them to suit individual plants.

PROPAGATION

The material at the Gardens has been mainly collected by staff members and researchers from the University of Queensland over the past six years. Most material was collected from the north of Macquarie Island. Grasses, rushes, and sedges have been successfully propagated by division using tillers. Smaller herbs like *Callitriche, Montia, Colobanthus, Acaena,* and *Leptinella* have been easily divided into rooted sections although the feldmark cushion *Azorella* has been difficult to propagate by division. The important large herbs *Pleurophyllum* and *Stilbocarpa* have been cultivated only from direct transplants from the wild. Successful long-term cultivation of *Pleurophyllum* has only been achieved by transplanting wild collected seedlings at the second to third true leaf stage and a process of regular repotting. *Stilbocarpa* can be successfully transplanted using large sections of rhizome provided a reasonable root system has developed. Small cuttings of adventitious growth excised from the rhizome will be trialled as another potential method of propagation. Germination experiments using seed from the island and cultivated plants will continue.

SUMMARY

There is a wealth of information about the plants of Macquarie Island and their ecophysiological requirements which we have used to define the environmental conditions within the Subantarctic House. With limited physical and financial resources, we have had to develop a more moderate set of environmental parameters than those which prevail on the island. An assessment of the cultural requirements for each species has been based on a knowledge of their habitats and associations in the wild, coupled with a practical approach to their horticultural needs. The result will be representative selection of plant communities which should grow successfully in the environment of the plant house to give a realistic representation of Macquarie Island's vegetation.

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Armillaria Control at the Royal Tasmanian Botanical Gardens

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Fungal root rot disease caused by members of the genus *Armillaria* is a phenomenon that has a global distribution (Shaw and Kile, 1991). *Armillaria luteobubalina,* a species endemic to Australia, has been a major problem in the Royal Tasmanian Botanical Gardens (RTBG). Some background to the situation and the methods to treat the disease are covered below.

The fungus can be either saprophytic or pathogenic. It commonly exists in dead wood but in appropriate conditions can also infect living plants. The saprophytic phase, typically in a buried tree stump, can last several decades (Kile, 1981; Summerell, pers.comm.), or even centuries (Anderson et al., 1979) which makes its control problematic. The species does not produce rhizomorphs. Spread of infection can take place in one of two ways: either by windblown spore dispersal or by subterranean contact, usually across root systems. Local spread by root contact is believed to be the most common.

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Armillaria Control at the Royal Tasmanian Botanical Gardens

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Not all plant species have equal susceptibility to the disease, but at present it is not possible to identify with any certainty species that are wholly resistant. The prognosis for plants that do become infected is bleak: younger trees tend to die quickly but older individuals may reach an apparent equilibrium for some years before eventually succumbing.

The pathogenicity of *Armillaria* seems to be a result of the hyphal invasion of the hosts' cambial layer, eventually spreading into, and obstructing the vascular system, though damage from fungal exotoxins has also been suggested (Kile et al., 1982). Visible signs of infection tend to reflect the extent of underlying vascular damage: sudden death in young trees and gradual foliage loss in the earlier stages in mature plants. Larger trees exhibit bole necrosis, reduction of height and diameter growth, with death occurring as vascular occlusion produces a ring-barking effect.

The picture that emerges is of an aggressive disease whose dominant features are rapid underground spread and a long list of potential hosts.

ARMILLARIA IN THE RTBG

Although the first confirmed diagnosis of *Armillaria luteobubalina* was made in early 1994 it is highly probable that the organism has been active for much longer than that, and may indeed have been present in the original native forest that occupied the site until nearly 200 years ago (Mohammed and Wardlaw, 1995). Until quite recently it was normal practice that if a tree was removed for any reason, the stump was cut close to the ground and either left or grassed over: except for small trees it was unusual for the root mass to be removed. One result of this has been to provide a large food resource for potential *Armillaria* inocula in sites which are mostly unrecorded.

The site of the first confirmed diagnosis was a mature cape chestnut almost in the centre of the rectangular main lawn. One year later a *Betula papyrifera* was affected, from a bed below the cork oak, and infected roots of the cork oak itself were subsequently identified.

Prior to about 1995 there is little accurately resourced data. However, it seems likely that the fungus has been active *in situ* for many years. Why there was a sudden apparent explosive extension of the disease from 1994 onward is explicable if it is postulated that the disease had been present but largely unrecognised. Proper recognition of the problem was quickly followed by the initiation of a program of systematic investigation and treatment which is continuing today. When the disease had been accurately identified and definitive action decided upon, the affected area occupied an elongated polygon, roughly 250 × 60 m, some 15,000 m^2.

Long before any comprehensive plan had been evolved it was clear that the size and complexity of any solution was going to be expensive. There were at that time no provisions in the budget for an outlay as large as this was likely to be, and so external fund-raising options were canvassed. Applications to government for funding provided some immediate assistance, but it was clear that it would not be sufficient. Therefore, a major public appeal was organised. Aided by *The Mercury* newspaper and other sponsors, *The Mercury* Save the Gardens Appeal 1996 raised over $220,000 to fund the work required.

OPTIONS

There were two steps in dealing with the disease. First, it was realised that we needed to contain the spread of the fungus and eradicate it wherever possible, and second that we needed to implement a long-term strategy to prevent infection in new sites. Containment and eradication involved trialling mapping, chemical containment, and inoculum reduction. Prevention has involved attempts to limit spread by quarantining areas, by the use of competitive or antagonistic fungi, and by an ongoing program of stump removals.

CONTAINMENT AND ERADICATION

Mapping. Before you can contain or eradicate the disease you must know where it is. It rapidly became apparent that although sites of known infection had been identified satisfactorily, nothing was known about the extent of subterranean spread towards plants not yet affected. The difficulty here is that the fungus grows only inside wood, and it is not possible to make a diagnosis until plants are showing signs of infection, by which stage the disease is well established.

A trial using wooden stakes as bait to determine subterranean spread was therefore organised. It was hypothesised that, if brushwood stakes of a species susceptible to infection by *Armillaria* were inserted into the ground close enough to an inoculum, left in place for several months and then withdrawn, evidence of infection on them should be detectable. Using a large number of stakes in a pattern around the infective foci it was hoped that the true limits of the disease could be defined and then mapped.

Stakes were implanted to a depth of about half a metre in parallel rows with each stake half a metre apart. Stakes were withdrawn after they had been in the ground for more than 6 months. Those showing visible mycelia were retained for further examination, the remainder being discarded. The outcome revealed a disappointing result and a disparity in patterns between the two sites.

In the main lawn, *Armillaria* was grown from only 10 stakes, and from the bank above the gazebo only four, even though the disease was known to be present in both sites.

The low percentage of infected stakes placed in highly contaminated areas is probably due mainly to the absence of rhizomorphs formed by this species. Though *A. luteobubalina* is extremely infectious, to colonise a new host it must be in close contact with it and it is this lack of proximity which is the most likely factor in the low success rate. There are other possibilities such as the length of time spent in the soil, the wood used and even local environmental conditions, but a better strike rate could probably have been achieved simply by placing the stakes much closer together.

As a predictive tool, in its current form this technique is of little value: a negative culture does not reliably mean that the fungus is absent from the area being tested. Some improvement could be obtained by not only reducing the inter-stake distance but by using a concentric or spiral pattern of placement around the suspected focus.

Chemical Containment. Neither of the two known chemical treatment techniques of *Armillaria* infection has received universal approval for its effectiveness (Shaw and Roth, 1980) but there have been reported successes for some species of *Armillaria* in some specific situations.

We decided to use a few selected stumps for a limited trial with the fungicide sodium *N-methyldithiocarbamate* (Vapam), using stump injection as the delivery medium. Ten stumps of various ages, species, and diameters were chosen. Holes were drilled at appropriate intervals in the stump and around the root collar, a measured dose of fungicide was poured in, the holes were stoppered, and the stump and immediate environs were covered by plastic sheeting.

As with the stake-baiting trial, this was not set up as a controlled experiment: the pre-treatment criteria of infection was the presence of basidiomes or mycelia on the roots, but laboratory diagnosis was not always available. The post-treatment criterion became the reappearance of fruiting bodies, though some culture of stump material was carried out later.

About 9 months after treatment, in the autumn fruiting body season, most of the stumps produced vigorous clumps of basidiomes indicating the disease was flourishing; in those few that did not, there existed a possibility that the infection had been absent in the first place. Again, because of the design of the trial it would be misleading to draw firm conclusions, as the apparently universal failure may have more than one cause. What was clear was that chemical treatment had not worked for us.

Inoculum Reduction. Countries of the northern hemisphere in which *Armillaria* root disease is a long-standing and continuing problem have used removal of stumps and roots as a primary control measure for decades (Barss, 1913; Roth et al., 1980). The persistence of infectivity in buried stumps (vide supra) makes their removal an attractive curative treatment, but as with most aspects of the treatment of this problem there are limitations. Most obviously, unless there is an accurate horticultural history, or the stumps themselves are identifiable, removal is likely to be incomplete. The difficulty of tracking underground spread and the seasonal unreliability of the basidiomes has already been alluded to, which means that accurate excavation may not be possible and large additional volumes of soil have to be removed to ensure a reasonable safety margin.

Cost is possibly a more significant factor in this treatment than in the others, as is feasibility: in a small area with few infective foci the outlay may be reconcilable with the probability of a cure. In the situation in the RTBG however, where a large area was affected but the stump locations inaccurately known, excavation and refill is an expensive exercise.

The decision to use stump removal in the RTBG was taken when it was realised that there were few other viable options. The disease was extending its area and the loss of any more large trees in a setting as small as this would have had a disproportionally large effect.

There were four main excavation sites: adjacent to the cork oak (300 m^3); on the main lawn (1000 m^3); above the gazebo (1200 m^3); and north of the gazebo (400 m^3). Essentially, the areas to be excavated were determined empirically, using the infected trees and stumps as starting points, then digging outward to a point beyond the limit of that trees' rhizosphere. Where roots from adjoining trees were encountered and also found to be infected, then that tree too was sacrificed with its root system.

Excavation stopped when we ceased to find infected wood material or live roots in the ground. At that stage all roots at the edge of the excavation were sampled for *Armillaria*.

The results of this work have been in a dramatic improvement in the health of the RTBG. From a high of 1.5 ha infected with 98 identified sites in 1997, the incidence of the disease fell to zero positive identifications in 1998, and so far, one positive in 1999.

PREVENTION

We have tried three approaches to prevent the spread of *Armillaria*:

1) Quarantining areas of the RTBG that are believed not to have the disease;
2) The use of competitive and antagonistic fungi;
3) Removal of all stumps and roots of trees that die in the future.

Quarantine. With quarantining the technique is to cut trenches through the RTBG to below the level of root penetration to separate off areas. Root barriers are then installed in the trenches which are then filled with gravel, covered with soil and re-grassed. The first such trench was dug across the main lawn between the infection site and the large conifers on the upper side of the Arthur Wall. This technique is however, of limited application because of the need to minimise damage to drainage lines, natural aquifers and to tree roots.

Trials of Competitive Fungi. Following the work by Pearce and Malajzcuk (1990) the RTBG began trials inoculating stumps with a friendly nonpathogenic wood rotting fungus, *Phanerochaete filamentosa,* to test if this would out compete *Armillaria* and thus prevent its spread. Subsequent examination and culturing from treated stumps have failed to find any evidence that this process has been successful.

Antagonistic Fungi. Although excavation and the removal of infected trees and wood material has been found to be effective in eliminating the disease, it means that infected trees are sacrificed. There is no known cure for the disease in living trees. Considerable research is clearly needed into this subject. One option worthy of investigation is the proposal to inject another fungus, *Trichoderma*, into the trees. It is claimed that this procedure cures Kiwi fruit vines of *Armillaria* infection in New Zealand. Researchers Hank Cutler and Robert Hill (pers. comm.) have also proposed the injection of an extract of *Trichoderma* could be an effective fungicide that would translocate better than the fungus itself. However, although universally acknowledging the technique would be nonharmful, local plant pathologists were strongly opposed to the trialing of this technique and without their assistance research had to be abandoned.

SUMMARY

The RTBG has suffered from a significant and debilitating infection of *Armillaria.* Although many techniques have been trialled, and some are worthy of further investigation, to date excavation of infected wood material and removal of infected trees have proven the only effective way to deal with the disease. The latter have been spectacularly successful, with a massive reduction in the number of confirmed infected sites. The dramatic improvement is attributable to positive action in informing the public about the disease, proactive fundraising, and direct action to address the problem.

The future health of the RTBG, and other similar sites will depend on vigilance, adequate funding, and the courage to act.

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The Role of Vegetative Propagation in CSIRO Forestry and Forest Products

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Vegetative propagation by means of cuttings, grafting, and micropropagation is playing an increasingly important role in research projects in CSIRO Forestry and Forest Products. It is being used as part of an integrated tree improvement program that includes selection of superior clones as parents in seed orchards and for the production of interspecific hybrids. Techniques have been developed to manipulate flowering to allow rapid turnover of generations, reliable selection from field trials, and to change selection criteria over time. Particular attention is being paid to the development of forest trees adapted to planting on farms in the lower rainfall areas of southern Australia. CSIRO Forestry and Forest Products is also a partner in a number of overseas aid projects and joint ventures that involve vegetative propagation of superior clones for plantations.

INTRODUCTION

CSIRO Forestry and Forest Products played a major role in the early development of *Pinus radiata* cuttings for planting of selected clones (Eldridge and Spencer, 1986; Eldridge and Owen, 1986; O'Regan and Sar, 1989). Cuttings of superior clones and families of *P. radiata* now represent a large proportion of current plantings. More recently our work has concentrated on eucalypts and other species.

Vegetative propagation MUST form part of a genetic improvement program. It is not an alternative to breeding and selection but a valuable tool, as it enables trees with unique genes and gene combinations to be included in the program. One-off gains can be achieved by selection of superior clones but conventional breeding may soon overtake these gains or leave the plantation exposed to unacceptable risks as too few clones are planted.

Two of several projects in the Division demonstrate how vegetative propagation plays an important part in the future domestication and breeding of forest trees. The two projects are:

1) Tree improvement for the lower rainfall areas of southern Australia. The aim is to breed trees adapted to planting on farms in the drier regions of southern Australia.
2) South Pacific Regional Initiative on Forest Genetic Resources (SPRIG) where tree improvement for several South Pacific countries is underway.

Vegetative propagation plays an important role in both of these projects. Some of the techniques used are:

- Grafting to bring selected trees into a breeding arboretum for manipulation of flowering and cross pollination. Grafting is also used to bring superior parents into seed orchards, e.g., *Eucalyptus maculata* [syn. *Corymbia maculata*].

- Cuttings to produce trees for field trials.
- Micropropagation as an alternative to cuttings.
- Microcuttings as a means of high-density propagation.

This research is part of the larger research program of Tree Improvement and Genetic Resources Program of the CSIRO Forestry and Forest Products and involves participation from many CSIRO staff and collaborators. The Tree Improvement and Genetic Resources Program is 70% externally funded and its projects are closely linked to the demands of our clients.

DOMESTICATION OF TREE SPECIES

In all but a few commercial species (*P. radiata, Eucalyptus globulus, Araucaria cunninghamii*) our forest trees have had no selection for adaptation to site or to produce particular products. In many cases we are still at the stage of determining the best species to plant in a particular area.

In order to determine the best trees for particular sites in the shortest possible time, well conducted field trials are essential. CSIRO has simplified trial design and statistical analysis by developing two, user-friendly computer packages. The packages CycDesigN (Whitaker et al., 1997) and DataPlus (Williams et al., 1999) cover the complete range of procedures from trial design, allocation of treatments to trial plots, data entry into spread sheets, preliminary analysis of data, and then links into the Genstat statistical package for data analysis. Feedback from many training programs in several countries was used to modify the packages.

CSIRO is not a plantation agency, it does not own any forests so we need to work with forest growers and plantation agencies to get our results tested in the field. Our collaborators include state forest services, farm forestry networks, private companies in Australia, and overseas joint venture partners.

TREE IMPROVEMENT FOR THE LOWER RAINFALL AREAS OF SOUTHERN AUSTRALIA

This is a new initiative for the genetic improvement of trees adapted to the lower rainfall regions of southern Australia (Harwood and Arnold, 1999). This project involves CSIRO and State agencies with support from the Rural Industries Research and Development Corporation - Joint Venture Agroforestry Project.

Superior species and provenances adapted to the lower rainfall areas of southern Australia will be selected and incorporated into genetic improvement programs (Harwood and Arnold, 1999). Several seed orchards have been established, some from field trials of provenances of particular species. All of these field trials were established with collaborators in both Government and private organisations. Table 1 lists the seedling seed orchards that have been established.

Table 1. Eucalypt seedling seed orchards established in the lower rainfall areas of southern Australia.

Eucalyptus species	Orchards (no.)	Date planted
badjensis	1	1996
benthamii	4	1994, 1995
camaldulensis	4	1996, 1998
dunnii	3	1995
grandis	2	1996, 1997
maculata [syn. *variegata*], *henryi*	4	1995
cladocalyx	1	1998
occidentalis	2	1998

The above seed orchards represent only a part of an extensive network of seed orchards that the Division has established throughout Australia. All of these seed orchards have been established with collaborators.

These seed orchards will provide superior seed of particular species to growers in the next few years. In addition, CSIRO is also developing hybrids between species for testing alongside the pure species in field trials. Hybrid eucalypts being tested are: *E. saligna* × *E. grandis, E. saligna* × *E. tereticornis*, and *E. grandis* × *E. camaldulensis* (from CSIR in South Africa).

Additional hybrid combinations are being developed using selected *E. grandis* and *E. camaldulensis* parents. Both interspecific and intraspecific hybrids will be created. Vegetative propagation plays an essential part in all of these research projects. Grafting is used to maintain the parents for cross pollination. The most successful grafts have been tip-cleft grafts using scions about 4 to 5 mm in diameter and containing 2 to 4 nodes. Other grafting techniques tried include splice-grafts done with the aid of a graft guide (Brennan and Mudge, 1998), side-cleft, patch-budding, and micrografting. Micrografting skills are important, as they allow rapid multiplication of selected scions from scarce material. Not all of our grafts have been successful. In a few cases overgrowth or poor growth of both the scion and the rootstock has occurred, implying graft rejection or a poor union.

Once successful grafts are established it is necessary to encourage the trees to flower as soon as possible. Placing the plants in a breeding arboretum where treatments such as water stress, cold, and Paclobutrazol, can be applied to grafted trees to encourage flowering. In the breeding arboretum the plants are in large movable pots so that they can be transferred to different environments. Once selected parents flower they are cross pollinated using standard techniques.

The production of large amounts of hybrid eucalypt seed is costly in terms of both time and labour. Even after hybrids are produced they need to be tested in the field to ensure that only the best trees are propagated for commercial planting. It is common for many seedlings from a cross to be abnormal.

Hybrid seedlings are grown on under greenhouse conditions and screened for abnormalities, for rooting ability, and other parameters important in selecting trees suitable for planting as clones. Selection parameters include:

- Production rate of ramets from mother plants.
- Rooting ability and survival to field planting.
- Performance of cuttings in field relative to seedlings.

The importance of selecting clones that are easy to propagate cannot be overemphasised. All of the successful clonal eucalypt plantation programs overseas such as in Brazil, South Africa, and Morocco always select clones that are easy to vegetatively propagate. Only a small proportion of trees initially selected in the field get through this final barrier of being suitable for large-scale, commercial vegetative propagation (Zobel, 1993).

The main technique used for propagation of clones is stem cuttings from hedges maintained under greenhouse conditions. Cuttings are rooted in Aircell containers (BCC, Sweden) that allow aeration of the medium, root pruning, and sorting of the cuttings after rooting.

Other techniques that are being tested are microcuttings produced from mother plants grown under greenhouse conditions and under hydroponics. Microcuttings offer high rates of production of cuttings per unit area. The method is being extensively used in Brazil with eucalypt hybrids. Rates of production of over 1000 rooted cuttings per month, per square metre of mother plants have been reported.

Micropropagation will also be used to propagate some clones. Simple techniques of micropropagation developed at CSIRO involve growing the mother plants in vitro as rooted plants rather than as multiple shoots in shoot cultures. The advantages of this system are:

- High rates of production of shoot explants suitable for transfer to a rooting medium.
- Shoot explants with normal leaf development and greater vigour.
- Plants that are easier to acclimatise.
- Easier maintenance of production stock and scheduling of production.

Simpler and therefore cheaper methods of micropropagation offer the advantages of high-density propagation under sterile conditions and under conditions where many factors can be controlled compared to cuttings. A recent example is the work of Dr. Tatsuya Shiraishi (pers. comm.) where he promoted rooting of recalcitrant clones using specific strains of mycorrhizal fungi in vitro.

Once results from field trials are analysed, the next step is to transfer this technology to the field. This may involve joint ventures or licensing nurseries to propagate superior seedlings and clones. Royalty payments will form part of these arrangements.

SOUTH PACIFIC REGIONAL INITIATIVE ON FOREST GENETIC RESOURCES (SPRIG).

This is a collaborative regional project between countries the South Pacific (Fiji, Vanuatu, Samoa, the Solomon Islands, and Tonga) with three Australian consortium partners (CSIRO Australian Tree Seed Centre, Queensland Forest Research Institute, and Fortech). AusAid provides funding for the project as part of the Australian Government's overseas aid program.

The aim of SPRIG is to improve the sustainable development of forest tree resources in the South Pacific. It has three main components:

1) **Conservation.** Develop strategies for conserving genetic resources of priority indigenous species. Both Forest Department and community views (via rapid rural appraisal) are evaluated and priority species and varieties are selected.
2) **Tree improvement.** Collection, distribution, and exchange of germplasm, field trials to select superior genotypes and propagation.
3) **Strengthen institutions.** Improve capability of institutions to continue this work in the future. This involves supply of computers, database programs to manage germplasm, seed collection gear, and staff training.

Species to study were selected by a regional meeting of Pacific experts. They suggested a number of indigenous species and one exotic species (mahogany, *Swietenia macrophylla*). About 10 priority species have been selected for collection in each country.

Extensive collections of *Toona australis* (Australian red cedar) have been made in Australia and of *Endospermum medullosum* (whitewood) in Vanuatu. *Toona australis* is in the same plant family (Meliaceae) as mahogany and has performed well in Tonga where it is highly regarded.

Vegetative propagation has an important part to play in the Pacific because many of the species present difficulties in propagation from seed but are easy to vegetatively propagate. Some are already planted as stump-cuttings and used as living fences. Species such as *Pometia pinnata* have recalcitrant seed that is difficult to store for long periods.

Using cuttings from seedlings, success has been achieved with sandalwood, *Toona australis*, mahogany, and *Endospermum* (Walker, Collins and Haines, 1999).

The Queensland Forest Research Institute developed a versatile portable mist propagator to assist the vegetative propagation program. These units provide battery-operated mist propagation units, for use in areas where power supply is either unavailable or unreliable. The units are also used as part of the training programs.

An important advantage to Australia is that the trees from the extensive collection of *Toona australis* (Larmour, 1999) will be grown in field trials in Australia to screen for resistance to the cedar tip moth (*Hypsipyla robusta*), which has devastated previous attempts to grow plantations.

FUTURE ISSUES

These two projects illustrate the importance of vegetative propagation as a valuable component to tree improvement programs. Vegetative propagation is also important with many other projects in which CSIRO is involved.

The ability to graft mature selected scions will always have a role in a genetic improvement program. Similarly, the ability to propagate cuttings of selected trees assists in evaluating genotypes in field trials.

However, if vegetative propagation is to play a role in providing planting stock for large-scale commercial planting then major challenges still remain in reducing the cost of each ramet. All vegetative propagation techniques require much more labour compared to the production of seedlings. Microcuttings or a combination of simple forms of micropropagation and microcuttings may provide a solution.

Attempts at reducing the labour costs of vegetative propagation of forest trees by using robotics and automation have so far failed. This is particularly so where robots have tried to emulate the human propagator. Propagators rapidly make decisions on selection of suitable shoots, where to cut the shoots in relation to the node, and plant the shoot at a set position and depth in the propagation medium. Such decisions are very complex for a machine to handle as they include vision, handling, and many decisions need to be made rapidly. Such systems are neither easy nor cheap to emulate by robotics.

Alternative approaches to automation such as the RITA system (INRA, France), simple bioreactors (Osmotek - Rehovot, Israel), and meristematic nodules (Ziv et al., 1994) do not involve such complex decision making procedures. These systems may be more suitable for large-scale propagation in the future. However, each system needs to be evaluated under commercial conditions.

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The use of Beneficial *Trichoderma* in Grapevine Propagation

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INTRODUCTION

For some time, the beneficial effect of *Trichoderma* on plants has been known. Laboratory and field experiments have shown it to have antifungal properties as well as growth-promoting effects in field cropping situations (McPherson & Hunt, 1995). More recently, its use has been promoted in growing media (Brooke, 1998) and seed treatments (Bjorkmann et al., 1998).

Previous attempts to use *Trichoderma*-based products by Sunraysia Nurseries in vine propagation failed to provide any improvement in vine quality. However, as researchers have discovered more about how to better handle and utilise the organism, more reliable preparations have become available. On learning of these improved formulas at the 1998 I.P.P.S. conference in Perth, it was decided to revisit the trial. Two products were tested. The first was a nutritive pellet impregnated with *Trichoderma* spores called Trichopel®. The second, a wettable powder formulation called Trichoflow™. Both these products contain strains of *Trichoderma harzianum* and *T. viride*. At the time, experience with the product had been in vermiculite filled callusing boxes, not in organic striking media such as our own. For this reason we trialed both vermiculite and peat-based striking media.

METHOD

Grafts were packed in layers of the appropriate media in sealed styrofoam boxes. They were arranged in layers of 20 grafts, with 8 layers to a box (i.e., 160 grafts to a box).

The Trichopel was sprinkled over the tops and bottoms of the cuttings as they were layered in the box. The amount of Trichopel used was 5 g per layer in vermiculite media (recommended rate), and 2.5 g in peat-based media. This reduction was due to the organic nature of the peat media, and its ability to better support microorganisms.

The Trichoflow was used as a soaking solution. Usually, while scions await grafting, they are soaked in water to prevent desiccation. This water was simply substituted with a Trichoflow solution. Two strengths were trialed: a full strength (2 g $litre^{-1}$), a half strength [1] (1 g $litre^{-1}$), as well as a water control.

RESULTS

Effectiveness of Trichoderma Inoculant on Various Striking Media.

Peat-Based Striking Medium (Peat, Redgum Sawdust, and Isolite, 1 : 2 : 3 by Volume). This medium was the optimum media for *Trichoderma* growth, but the callusing of the cuttings was poor. The *Trichoderma* grew as a thick carpet of white mycelium. Not only was it feeding off the nutritive pellet, but also off the organic matter in the medium, and eventually off the cutting as well. The rapid growth of *Trichoderma* appeared to have used up all the oxygen in our sealed callusing boxes.

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Table 1. Effect of callusing media on callus growth and disease development with and without a *Trichoderma* inoculant.

Media used	Treatment	Callus growth	Trichoderma development	Disease level present on covered part of canes
Peat : sawdust : isolite	Control	Moderate	None	High
Peat : sawdust : isolite	Trichopel	Poor	Excessive	None
Sawdust : isolite	Control	Poor	None	Moderate
Sawdust : isolite	Trichopel	Poor	Excessive	None
Vermiculite	Control	Moderate	None	Moderate
Vermiculite	Trichopel	Excellent	Ideal	None
Vermiculite : isolite	Trichopel	Excellent	Ideal	None

This resulted in extremely slow callus growth. The average time to reach pot-up condition was 28 days. Some vines were still not ready after 36 days. The rate of *Trichoderma* was reduced to 1g per layer, but still the *Trichoderma* swamped the cuttings. The controls of regular medium averaged 21 days to pot-up. There was better callus growth in these boxes, but still some rotting of shoots due to a range of different fungi, including *Botrytis*. These fungi were not present in the *Trichoderma*-treated boxes.

Sawdust-Based Medium (Sawdust and Isolite, 2 : 3 v/v). In order to slow the development of the *Trichoderma*, we trialed a mix with less readily degradable organic matter, i.e., we removed the peat component. In the *Trichoderma*-treated boxes, there was still an abundance of mycelium, and there was no callus at all after 25 days. The vines had to be transferred to vermiculite to get them to move. In the control, there was no white mycelium, but the callus growth was still poor and *Botrytis* was present on many of the cuttings.

Vermiculite (Grade 4 – Coarse). From the beginning of the season to the end, vines packed in coarse vermiculite were of more consistent development and quality. Those packed without *Trichoderma* averaged 21 days to pot-up, the same as for vines in peat media with no *Trichoderma*. Again, there was a range of fungi growing on these canes. Those that were packed with 5 g per layer of Trichopel had a fine white mycelium over the wood, and no sign of *Botrytis,* though there was some benign yellow growth on the vermiculite, and some black fungal growth on the exposed parts of the scion. These cuttings were ready for pot up sooner, on average in 18 days. The callus growth was faster, especially at the graft union. The shorter time in callusing boxes meant that less buds had the opportunity to burst while in a sealed environment and, therefore, didn't rot off. This led to more even growth of the grafts in the greenhouse after potting on.

Vermiculite and Isolite Medium (Vermiculite : Isolite, 1 : 1 v/v). On observing the improvement to graftling development in vermiculite in the first half of the season, we attempted to make a medium which was free of organic matter, but with less of the expensive vermiculite. We mixed vermiculite with isolite 50 : 50, and packed vines with 5 g per layer of Trichopel. These were ready in 18 days. The callus growth was as good as vines packed in straight vermiculite, and there was no sign of *Botrytis* on the canes. There was some fungal growth other than the *Trichoderma* on untreated scions. All these boxes were packed with *Trichoderma*, as we had seen the improvement it made to callusing time, and we were approaching the end of the season.

Effectiveness Of Soaking in a Trichoderma Solution.

Table 2. Effect of soaking buds in a *Trichoderma* solution.

Scion soak	*Trichoderma* growth	Disease presence
Full strength	Good	None
Half strength	Good	None
Water	None	Moderate

All treatments in this trial were packed in vermiculite, with 5 g of Trichopel per layer.

Full-Strength Trichoflow (2 g litre^{-1}). These vines had a covering of white mycelium over the scions, even though the scions were exposed. There was no other fungal growth on the canes. Remember, the vines without the scion soak weren't covered all the way to the top, and had some black fungal growth.

Half-Strength Trichoflow (1 g litre^{-1}). These vines were almost identical in development to those soaked in full-strength solution.

Water Control. These vines had a covering of *Trichoderma* over the covered parts of the canes, but not over the exposed scions. The scions had growths of black fungi on them, particularly on the buds.

DISCUSSION

The use of *Trichoderma* in vermiculite callusing medium and vermiculite : isolite callusing medium improved the amount of callus produced at the graft union. It also improved the callus and number of roots at the bases, and shortened the callusing time. In organic media, *Trichoderma* growth was at detrimentally high levels, even with the inoculum doses substantially reduced. In all cases where *Trichoderma* was included in the callusing media, disease growth on the covered portions of the canes was nil or substantially lower than in control boxes. The uncovered scions were protected from disease by soaking in a *Trichoderma* solution at half label rates.

CONCLUSION

From the results of these experiments, the advantages of using *Trichoderma* in callusing grapevine grafts are:

- Less time in callusing boxes resulting in faster production time.
- Stronger graft union and root system
- No use of toxic fungicides.

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Influence of IBA Concentration, Bottom Heat, and Medium on Propagation of Camellias

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The influence of IBA concentrations in the range 0 to 3000 ppm on the rooting of either japonica or sasanqua camellias was examined. The response depended on genotype; the two sasanquas showing a response to rooting hormone, but not the japonica. *Camellia sasanqua* 'Shishigashira' gave optimum rooting with 750 ppm IBA and *C. sasanqua* 'Jennifer Susan' gave optimum rooting with 3000 ppm IBA. In a trial comparing the use of bottom heat and various media on three sasanquas, there was a good response to bottom heat in all three camellias ('Jennifer Susan', 'Gulf Glory', and the ground cover 'Marge Miller'), and all rooted best on a mixture of sand and peat (10 : 1, v/v) or sand and pinebark (10 : 1, v/v).

INTRODUCTION

Propagation of camellias is normally by rooting cuttings. Successful propagation depends on the source of the cuttings, the type of cutting, and the propagation conditions (for a review see Scott, 1986). The results tend to vary with the cultivar, for example *Camellia reticulata* 'Captain Rawes' and *C. japonica* '66' gave no rooting without the application of rooting hormones (Gonzalez et al., 1989; Iglesias et al., 1989) whereas *C. japonica* 'Orando-Ko' gave 92% rooting without hormones. In a study comparing *C. hiemalis* 'Hongchamei' and *C. japonica* 'Xiaodaohong', Huang and Li (1986) found good rooting in *C. japonica* without rooting hormones, but improved rooting with hormones in *C. hiemalis*. Another issue is the propagation medium. Of particular interest is the report by Gleeson (1992) of the faster rooting of *C. sasanqua* in coal ash compared to a more conventional mixture of sand, peatmoss, and perlite. This paper reports the effect of rooting hormone concentration and rooting medium on the propagation of a number of camellia lines.

MATERIALS AND METHODS

The trials on auxin concentration used two sasanquas and one japonica, all known to be sunhardy and to prefer warm conditions, namely *C. sasanqua* 'Shishigashira' and 'Jennifer Susan' and *C. japonica* 'Dona Herzilia de Freitas Magalhaes'. The hormone was IBA, supplied in a liquid dip from the product Initiator at concentrations up to 0.9% (9000 ppm), depending on the cultivar. The propagation mix was Kangaloo sand and peat moss (10 : 1, v/v). Kangaloo sand is a white mined sand with most particles larger than 2 mm.

The trial comparing various mixes, with and without bottom heat used three sasanquas, 'Jennifer Susan', 'Gulf Glory', and the ground cover 'Marge Miller'. All were given a standard liquid dip of 3000 ppm IBA from Initiator. In addition to testing bottom heat (18 to 21°C) the following media were compared:

- Ash
- Ash and peat (10 : 1, v/v)
- River sand
- Sand and peat (10 : 1, v/v)
- Sand and pinebark (10 : 1, v/v)

Both the auxin concentration and propagation mix trials were set up with 25 cuttings per community pot (170 mm wide, 100 mm deep, volume 1.8 litre), with four blocks (auxin trial) or two replicates (rooting mix trial), each with one community pot per treatment. Humidity control was by a fog system, with the plants watered by hand. The trials were set up early in March, and assessed in early September.

The rooting of each cutting was assessed using a scoring system: 1 = dead, 2 = callus or otherwise healthy with no roots, 3 = one root or 2 to 3 small roots, 4 = good rooting, 5 = abundant rooting on a vigorous healthy cutting.

The mean score was calculated for each treatment/cultivar combination, and the mean scores were subjected to an analysis of variance. The bars in all figures are standard error bars.

RESULTS

In the study of hormone response the japonica, 'Dona Herzilia' de Freitas Magalhaes, showed no response to rooting hormone. However, both sasanquas showed better rooting with hormone (Figs. 1 and 2). 'Shishigashira' showing best rooting with 750 ppm IBA and 'Jennifer Susan' with 3000 ppm IBA. Statistically the response to hormone by 'Shishigashina' was significant at a 17% level, but not at the 5% level. In 'Jennifer Susan' the response was significant at the 5% level.

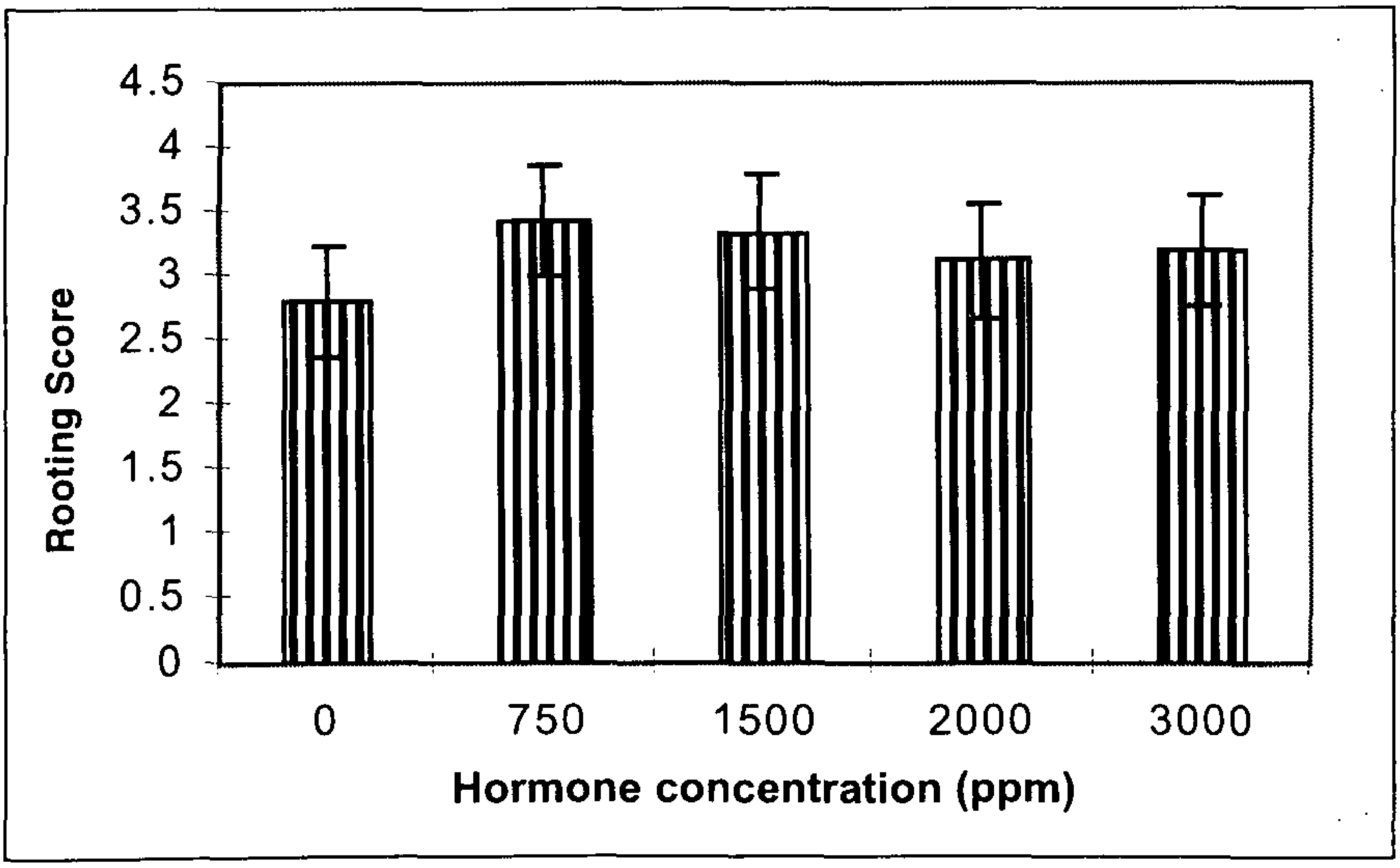

Figure 1. Effect of IBA concentration on rooting in *Camellia sasanqua* 'Shishigashina'.

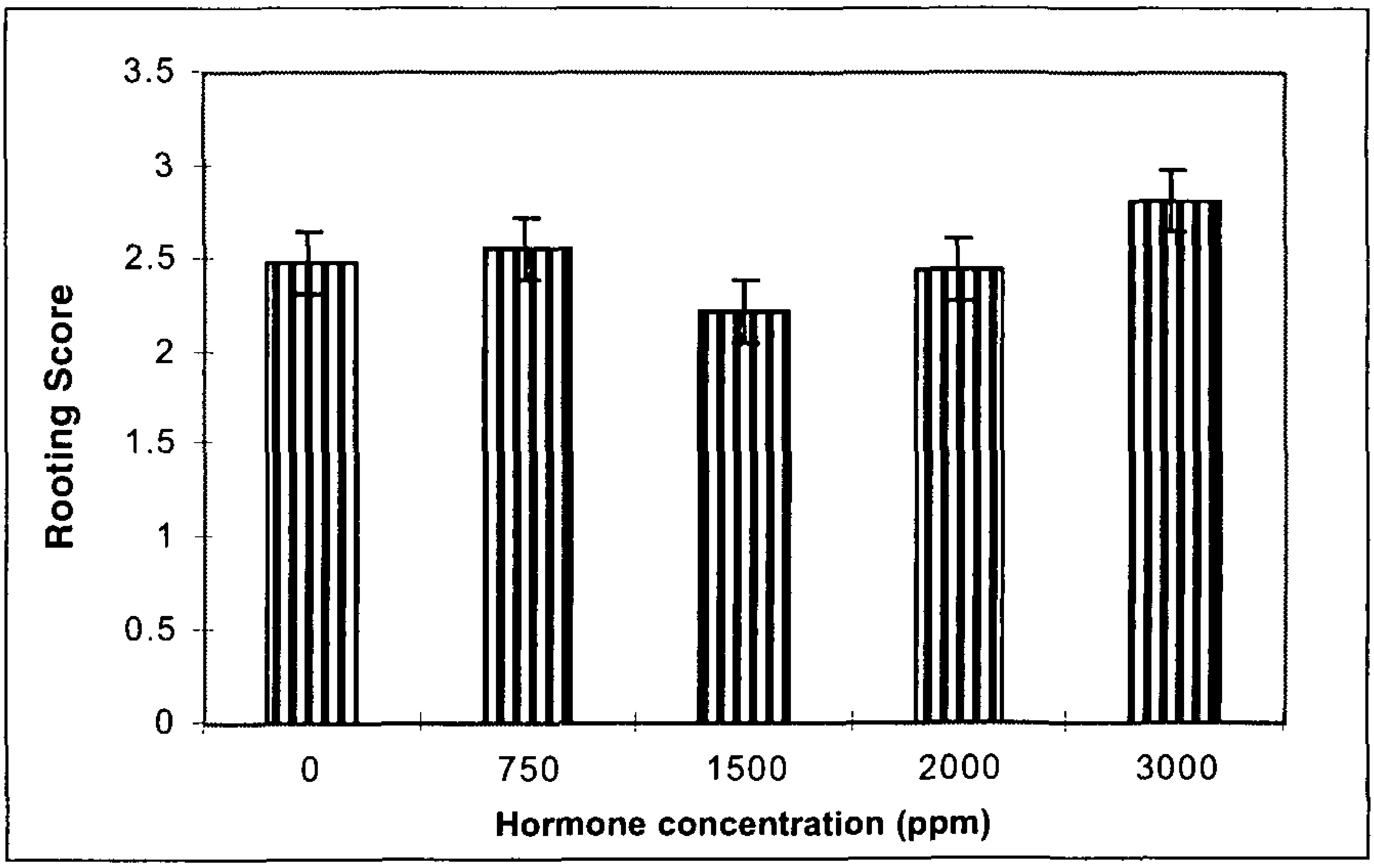

Figure 2. Effect of IBA concentration on rooting of *Camellia sasanqua* 'Jennifer Susan'.

In the tests of media and bottom heat, all three cultivars gave a significant response to bottom heat, as illustrated by the results for 'Jennifer Susan' in Fig. 3. The sand and peat medium was the best for 'Jennifer Susan'. With 'Gulf Glory', except for poor rooting with pure ash in the absence of bottom heat, all media gave similar results.

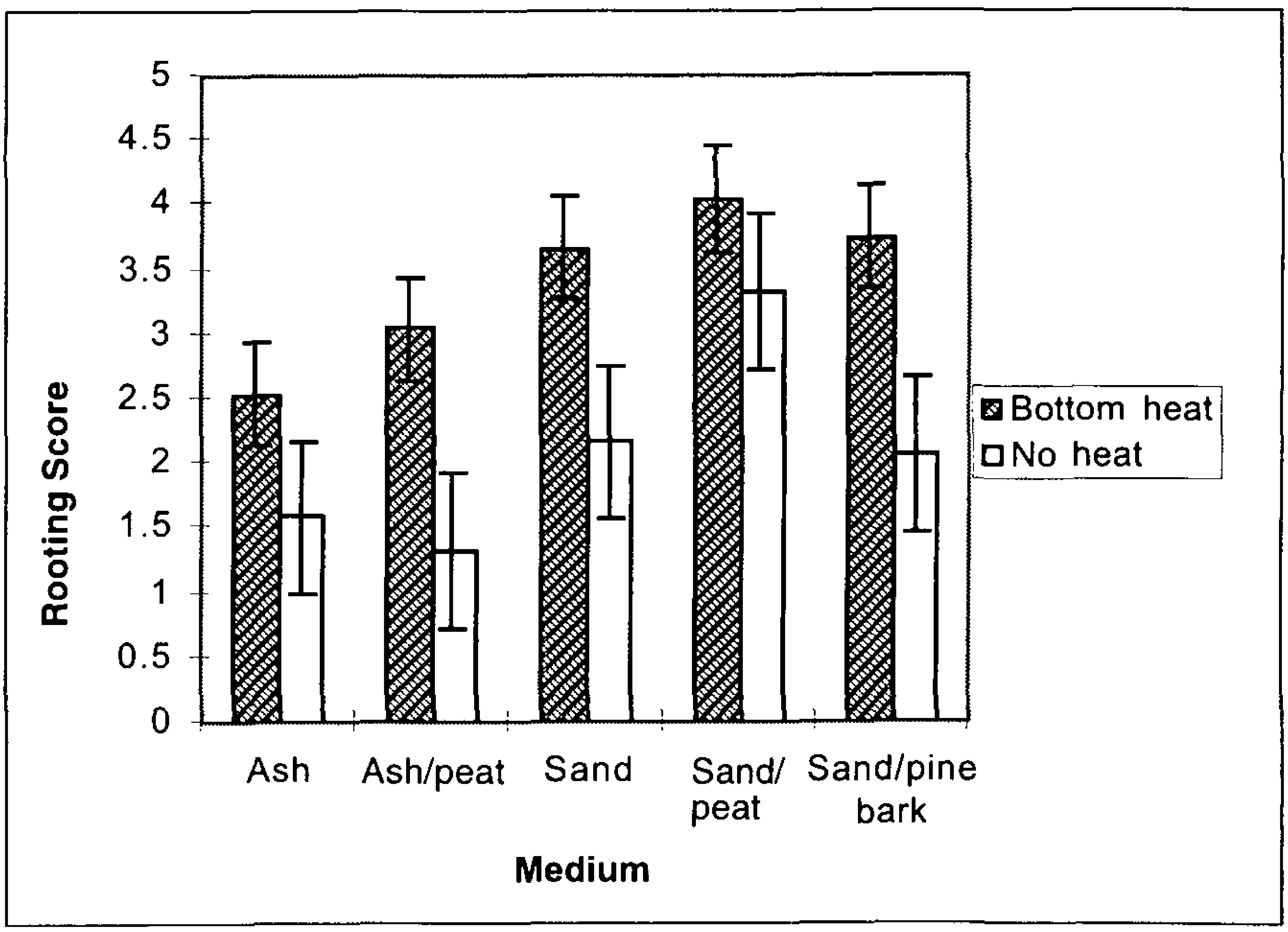

Figure 3. Rooting scores in various media, with or without bottom heat, for *Camellia sasanqua* 'Jennifer Susan'.

With Marge Miller the best two media were sand and peat, and sand and pinebark (Fig. 4).

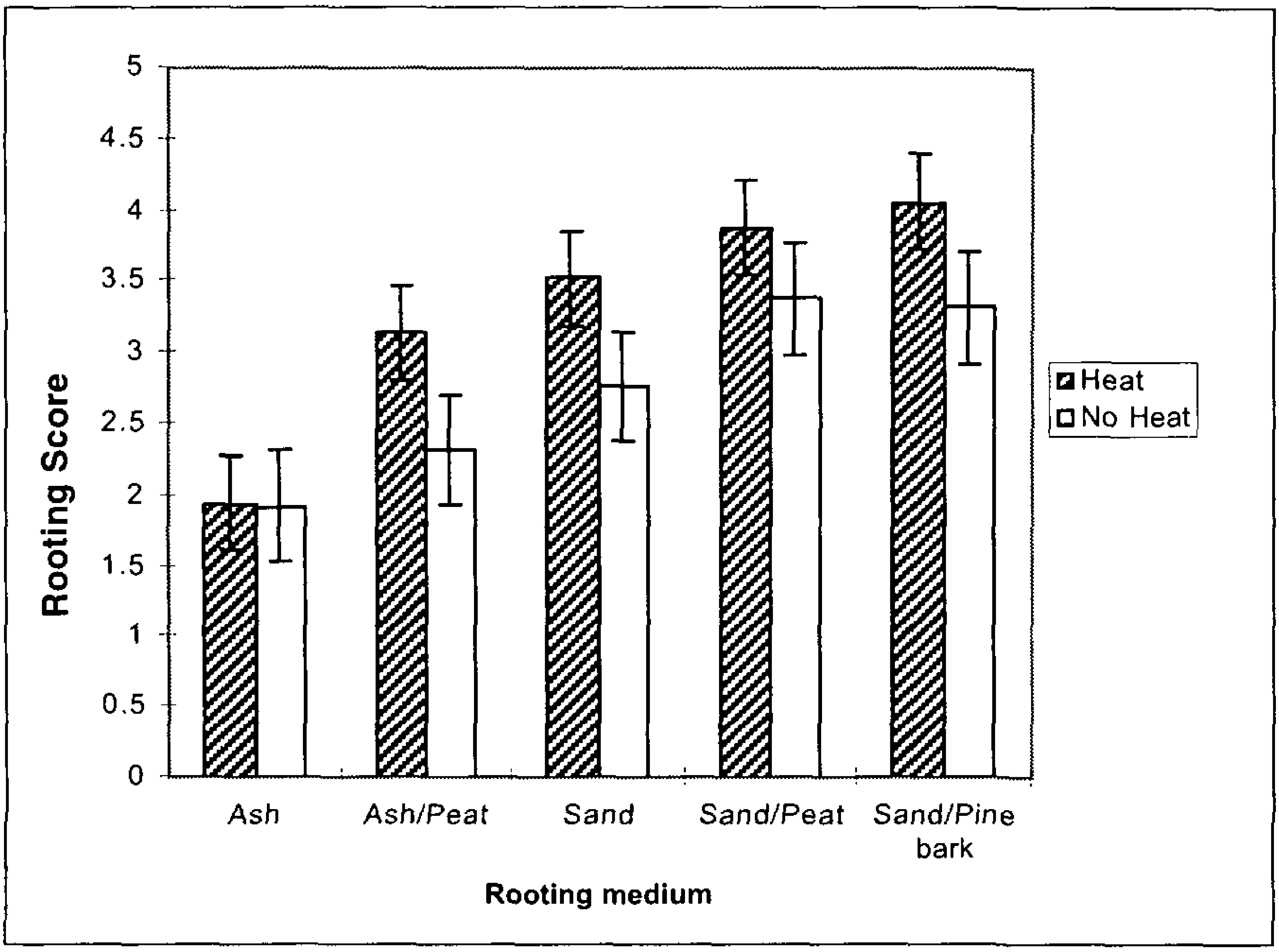

Figure 4. Effect of bottom heat and medium on rooting scores for *Camellia sasanqua* 'Marge Miller'.

DISCUSSION

Probably the most clear-cut response in this study was the response to bottom heat. Bottom heat is commonly used, but before these trials had not been in use in this nursery. Scott (1986) recommends a minimum bottom heat temperature of 15°C, but also reported that, in some seasons, 18°C improved the speed of rooting. It is possible that bottom heat would aid the strike rate of any autumn-propagated camellias.

The response of *Camellia* species to rooting hormones is known to be variable (Gonzalez et al., 1989; Huang and Li, 1986; Iglesias et al., 1989). Similarly in this study, there was a clear difference between the two sasanquas, showing some response to rooting hormone, and the japonica, showing no response. At this point there can be no clear recommendation.

A number of potting media have been used for camellias, with several reports of good results with rockwool (Gonzalez et al., 1989; Inglesias et al., 1989; Scott, 1986). The poor rooting in ash, in contrast to the results of Gleeson (1992), indicates that the properties of the ash need careful evaluation before a particular source is used as a propagation medium.

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Steps in the Development of a New Nursery

Ian Ravenwood
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INTRODUCTION

North Forest Products (NFP) has recently commissioned a new 10 million per year capacity container nursery in N.W. Tasmania to produce *Eucalyptus nitens* and *E. globulus* seedlings, mainly for its own tree farm program in Tasmania.

BACKGROUND

The Company. NFP is Tasmania's largest private forestry company with tree farm programs (including Australia's largest tree farm south of Burnie), a leading tree breeding and research centre, and export woodchip operations. North Forest Products is the leading supplier of hardwood to the Japanese pulp and paper industry and operates four export pulpwood mills in Tasmania. It is part of North Limited, a diversified resources company.

Previous Nursery Operations. For about 40 years NFP has operated forest nurseries to produce seedlings for its own tree farm programs. The new nursery replaced two older nurseries:

Container Nursery. This nursery had been built up incrementally over the years as the company's operation increased. Maximum production of about 4.5 million plants in paper pots per annum was the limit for the site we were on. All this was achieved using a very simple but labour-intensive pricking out system. The main component of the potting substrate was the typical NW Tasmanian red basaltic soil, which was difficult to keep free of weeds. Its high organic matter content, coupled with the necessary use of controlled-release fertilisers, made it difficult to manage seedling growth and quality. Our internal customers had no option but to take what they were given.

Field Nursery. About half the annual container nursery crop was transplanted into a field nursery to produce a "half : half". The term half : half is used in forest nurseries to describe a seedling that has started life in a container nursery (i.e., spent half its life there) and finished off in a field nursery (i.e., the other half of its nursery life) within the same year. The main difference between half : half and regular container seedlings (i.e., those that went directly to the field from the container nursery) is one

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In the earlier nineties, NFP's seedling requirements reached about 6 million per year. This exceeded the production capacity of the two nurseries. The balance of our requirement was farmed out to contract growers. Given that these growers obviously need to include a profit margin in their rate, contract-grown seedlings were expensive compared with those produced "at cost" in-house.

Four years ago NFP entered into a joint venture with Mitsubishi to establish tree farms in N.E. Tasmania. This venture lead to a quantum increase in the seedling requirement to 7 million, all of which would have to come from contract growers. A review was called for of the seedling supply system.

A NEW NURSERY PROJECT

Review of Nursery Operations. In the modern corporate world, "core business" is a phrase often heard. The core business of NFP is to grow and supply wood fibre. Many processes ancillary to the core business had been contracted out by the company over the last decade, e.g., clearing, cultivation, planting, and fertilising, to name a few. The first question we asked, therefore, was "should NFP be in the nursery business at all". Why not leave it to someone for whom it is "core business".

The decision was quickly made to keep the nursery operation in-house, the supply of seedlings was seen to be a critical step in the value chain. In tree farm establishment a significant cost is incurred prior to planting the seedling. This investment, e.g., cultivation, weed management, and vertebrate pest management, can only be realised if a seedling is planted that season. If the nursery had a major failure and was unable to supply seedlings for that season, these "on farm" activities needed to establish the plantation would have to be repeated the following year. It provided us with greater control, and more confidence, to carry out the nursery operations internally.

Given that we had made the decision to stay in the nursery business, a number of important questions needed answering:

- Should we modify the existing nurseries or start afresh?
- What sort of nursery did we want?
- Did we want to change from seedling to clonal production?
- What was the best way to deliver the project?

The answer to the first question was simple, neither the field nor the container nursery lent themselves to expansion. It was decided to rebuild on a green-field site. We would start afresh.

A New Nursery. The second question required more study before an answer could be found. It could also be answered at two levels, the general and the specific. At the general level we quickly determined that we wanted a nursery which:

- Produced the most cost-effective seedling with the quality attributes our customers wanted; and

- Was safe to work in (best practice in terms of occupational health and standards) and environmentally sound (e.g., water use and run-off management).

To determine some of the specifics, we looked closely at forest nurseries and nursery technologies worldwide.

We also asked ourselves what might appear to some to be a silly question, "what is a nursery?". We developed a paradigm shift in answer to that question, and what I'm about to say will be anathema to some of you, a nursery is not a "green thumbs" operation. The growing side of a nursery operation is merely the application of scientific principles, there is no magic in it. This represents only 10% at most of what a large wholesale nursery is about. The rest of the time is spent on management tasks and paperwork, housekeeping, training and developing staff, processing orders, despatching, shipping, customer relations, etc. A large slice of time is, in fact, spent moving stock from one place to another, e.g., into germination rooms and out again; putting it under shade and then out again; and finally into the despatch area.

When we thought about it, we saw a nursery as just another factory, nothing special about it. You take a series of inputs, in our case potting media, seed, water, sun light — and transform them into an output, a seedling, which is warehoused for a length of time. Admittedly it is an unusual warehouse in that the inventory changes shape while it's on the shelf. But when you look at factories and warehouses you often find that their success is usually underpinned by efficient material handling systems. These often provide their competitive edge.

Over the years we had visited forest nurseries in South Africa, South America, Spain, Portugal, Scandinavia, Morocco, France, and New Zealand and seen many good ideas. However we focused a lot of our research on the Celbi nursery built in Portugal in 1992, which incorporated mostly Dutch nursery technology and automation that addressed the material handling issue and consolidated the best of what we had seen in our travels. We liked the concepts we saw. Known as "Dutch frames" in America, "containers" in Holland, or maybe "rolling benches" here and running on rails, we immediately recognised the efficiencies this system would bring to our new nursery. Closer to home we also had the opportunity to visit a celery transplant grower in Victoria who had installed a similar system.

The green-field site allowed us a clean slate, a once in a lifetime opportunity to try and get it right. We also knew from history that we would need to be able to increase seedling production in the future. A clear expansion path needed to be identified so that we didn't make decisions now that closed out future options.

We also knew that we did not want to keep on pricking out seedlings. In our 40 years of nursery ownership we had allowed technology to pass us by. We now had superior genetic material coming on line and direct seeding technology would make the optimum use of this expensive seed.

We also wanted to apply all nutrients through the irrigation water (fertigation). This we knew would give us unprecedented control over the seedlings we produced. You can't stop a controlled-release fertiliser releasing when a seedling gets to its size specification, but you can very easily turn off an injection pump.

Clonal or Seedling? The Celbi nursery in Portugal had initially been built to produce Tasmanian Blue Gums (about 1 million hectares of *E. globulus* are grown in Spain and Portugal). There were close similarities between Celbi in Portugal and

NFP in Tasmania. A common species of course, but it went deeper than that. We both had sophisticated tree improvement programs including extensive research programs to try and realise the potential of clonal production. When we compared research, we often found we had similar results.

Celbi were confident that they could produce operational quantities of clonal plants and they built their nursery accordingly. After about a year of operation it was converted to seedling production. We were confronted with the same decision as them — clonal or seedling? Fortunately, in 1994 we were able to spend a fortnight working in their nursery and repeatedly asked "if you could do it all again, what would you do differently". The knowledge gained from this was applied to the now developing specification for the new NFP nursery.

Taking into account Celbi's experience with large-scale clonal production, as well as carrying out a review of the value of the genetic gain to be expected from a number of seedling and clonal scenarios, we opted to build a seedling nursery.

PROJECT DELIVERY

We were planning to spend a lot of shareholders money. As a commodity-based company, we were beginning to see price falls in most of our products. A factory needs engineering to ensure it all fits together. A well engineered project that could be built to a price and, more importantly, with minimal likelihood of a cost overrun, was essential.

There are various ways to package projects like this. They can be ranked according to where the degree of risk is located — with the engineer or with the principal. At one extreme is the fully reimbursable, where the principal pays the engineering firm for every item and for every hour clocked up on the project. All the risk lies with the principal and consequently the engineer operates with his lowest margins. If some unanticipated problem crops up, however, you pay for the remedy.

At the other end of the scale is design and construct built to a fixed contract price (lump sum). If a problem occurs, the contractor incurs the cost. Of course, this risk is factored into a larger margin in their tender price — if things go well the engineer makes a tidy profit on that project.

We opted to go down the path of design and construct to a fixed contract price. We wanted the satisfaction of knowing exactly how much it was going to cost. To tender the project we produced a specification that was performance based rather than prescriptive. In the ideal world our contract would have contained one sentence "build a nursery to produce 7 million eucalypt container seedlings per year". We eventually ran to a hundred pages or so to make sure we got what we wanted!

SUMMARY

We would do very few things differently. We now have a very efficient nursery that produces a quality seedling. Our internal customers (always the hardest to please), who have no alternative but to get their seedlings from us, are more than satisfied with the service and product.

We have vowed not to rest on our laurels and let nursery advances pass us by. We are currently attempting to identify the thresholds in production quantity which justify the next level of technology and automation.

Trends in Horticulture in the United Kingdom

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This paper is based upon observations of the horticultural industry in the United Kingdom (UK) whilst on a teaching exchange from Australia during 1997/1998.

1) EXTERNAL FACTORS INFLUENCING TRENDS

Perhaps the most significant external factors influencing trends are developments within Europe. The UK is a member of the European Union (EU) and is involved in common policies towards, amongst other things, legislation and trade. There remains substantial competition between EU members, however, and in the case of nursery plants and products this is intense. Recently there has been a campaign to "Buy British", initiated by UK growers of advanced trees, where there is substantial competition between producers in Britain and those of Germany and Holland (Medhurst, 1998a).

European legislation covering environmental and consumer issues is slowly leading to changes within the nursery industry in the UK, not without some difficulties, however. At present the registration of agricultural chemicals is different between EU countries, leading to considerable grower frustration, although common legislation is on the horizon (Adlam, 1998). New standards are also being developed across Europe for the testing and assessment of growing media, which should lead to greater consistency of products (Rosenberg, 1998a). The BSE or Mad Cow Disease crisis in Britain has had a profound effect on the public perception of "safe" foods and has influenced changes in consumer attitudes in the acceptance of genetically modified products. Some supermarket chains are refusing to stock these items. Recently these same companies rejected stocking a new genetically modified carnation, developed by the Australian company Florigene (Rosenberg, 1998c).

2) INTERNAL FACTORS INFLUENCING TRENDS

The economy in the UK is generally seen to be fairly robust at present with solid growth, comparatively low levels of unemployment, and a strong currency. Related to this are demographic changes in the UK. More people are now moving into urban and suburban/commuter localities, with government estimates of 4.4 million new homes needed by 2016, most in the already congested southern parts of the country (Ardle, 1998a).

The political landscape changed substantially with a new Labour government in 1997. Associated with this change has been the phrase (and image) of "Cool Britannia", used to promote growth and development in the arts, technology, and design. Many landscape companies are seeing a shift in their clients, with younger, wealthier customers being far more prevalent than in the past and seeking more innovative design solutions for domestic gardens (Scaresbrook, 1998).

Gardening seems more popular than ever in the UK; indeed one prominent broadcaster has stated that it is the new rock and roll! (James, 1999a). The extent of this popularity was demonstrated recently when the gardening writer Dr. David Hessayon, author of the "Garden Expert" series, was named the best-selling living author in the UK.

Apart from gardening as a "culture", it is the growth in the horticultural media, particularly television, which has a significant influence on trends. There are a number of regular television gardening programs each week catering for different interests, including design, construction, garden maintenance, and plant groups. At least one program, the BBC's Ground Force, has been credited with increasing garden centre custom and making people experiment more with their gardens (James, 1998c). There are also many horticultural magazines and journals, even a consumer magazine, *Gardening Which*, which, amongst other activities, trials and evaluates new plants and products. In a similar vein, the many large garden shows held throughout the UK are increasing in popularity and profile and have influence in the fashions and directions in horticulture.

3) TRENDS IN GARDEN DESIGN AND PLANT USE

Perhaps the major showcase for garden design and plants each year is the Chelsea Flower Show. In 1998 the main themes mirrored the main trends in design:

Naturalistic Themes. The uses of naturalistic elements through foliage, form, texture, contrast, water, and softer colours were strongly represented at Chelsea. This included gardens using popular foliage materials, but also newer "indigenous" plant materials, such as pollarded willows, woodland perennials, and flowering meadow species. Many gardens used water and aquatic plantings as elements or display themes.

This style of design is gaining more interest in the UK, partly as a result of trends elsewhere, such as Europe and the U.S.A. At one level this trend is best demonstrated by Penelope Hobhouse's recent book advocating greater use of naturalistic materials in a garden context (Hobhouse, 1997). The results of which can be seen in the nursery industry where increasing sales of plants such as grasses, sedges, hosta, and bamboo have been reported (Gress, 1998a; James, 1998b). At another level, in public landscapes, there is now demand for provenance forms of many British plants and greater use of flowering meadows and grasslands is slowly being appreciated, chiefly through studies undertaken at Sheffield University (Dunnett, 1999).

Heritage Themes. The UK has a long gardening history and it's hardly surprising that heritage themes are popular in design. One garden that attracted considerable attention was the "Imaginary Garden of Coco Chanel". Consisting of pleached hornbeams, an intricate parterre, carefully positioned sculpture, and simple colours (green and white), it provided a showcase of heritage materials in a new design context. A number of other gardens displayed similar, more formal design features such as symmetrical and terraced plantings, topiary, standards, and tightly clipped *Buxus* and *Taxus* hedges. This type of plant material has become more widely used, particularly in smaller domestic landscapes (Ardle, 1998a).

Historic gardens in general in the UK are riding a wave of popularity at present, especially those under the auspices of the National Trust (James, 1999c). There has also been considerable press regarding the "discovery" and redevelopment of historic gardens in the UK. Perhaps the best example is the "Lost Gardens of Heligan"; a

Cornish hillside garden rediscovered after almost 100 years of neglect and recently extensively renovated over a period of several years. Here, and at other redeveloped historic gardens such as West Dean Gardens in West Sussex, there has been huge public interest in the kitchen garden. This is another area in which trends have developed, particularly in the cultivation of vegetables where a surge in sales has been linked to the popularity of new cooking styles (James, 1998b).

Outdoor Living Themes. One of the main movements in garden design has been greater utilisation of outdoor living spaces — the patio is making a comeback!. Many gardens at Chelsea in 1998 displayed features associated with this trend; including hard surfacing, smaller, compact, and often unusual plants, different forms of garden sculpture, and containers. Some garden centres in the UK now regularly use completed displays of garden designs to increase sales. These designs can even be priced for supply, with one centre selling a Japanese garden kit, which includes an installation manual, all plants, and accessories and retails for £2000 (James, 1998b).

It seems that new plants are gaining most as changes in outdoor living continue. There is now great demand for more interesting forms of plants, particularly those suitable for smaller spaces and container growing and plants grown for "instant effect" (Ardle, 1998a). This includes fastigiate, weeping, and standard trees, but also more compact forms of bedding plants, herbaceous perennials, and small flowering shrubs, such as new cultivars of dwarf *Hydrangea* (Ardle, 1998a; James, 1998a). Increases in sales have also been reported with scented plants, such as new sweet peas (James, 1998c; Rosenberg, 1998b), unusual groups of plants, such as Australasian and carnivorous plants (Ardle, 1999), exotic plants, such as palms and tree ferns (James, 1998a), and interior and tropical plants (Pawinska, 1998). The variety of potted colour materials is also increasing. Given that 40% to 60% of purchases from garden centres are said to be impulse-buying lines (Webb, 1998) this is hardly surprising, although the plants associated with promotional activities appear to be those doing best (Gress, 1998a). Consumers are also said to be demanding a greater range and type of flowering materials, even if this provides some difficulties to nurseries producing this material throughout the year (Medhurst, 1998b).

4) TRENDS IN THE NURSERY INDUSTRY

Quality assurance in nurseries is a common issue between Australia and the UK. A program of nursery accreditation is currently being led by the Horticultural Trades Association and in the 18 months since its introduction, 43 major production nurseries have become fully accredited, while others are in the process of doing so (Rosenberg, 1999). Another recent trend is the formation of marketing cooperatives of production nurseries joining together to increase sales and product export, particularly to Europe. This has been aided by substantial government funding to form such cooperatives (Gress, 1998b).

New marketing approaches are also being used to improve retail sales. Market trials of new plants from growers to selected garden centres are now being used to gauge the likely consumer success of their product (James, 1999b). Better plant labelling and product presentation are also becoming more common in retailing (Ardle, 1998b); particularly as studies in English garden centres have shown that consumers are far more responsive to good labelling than any other presentation factor (James, 1999b).

One of the main area of trends within horticulture in the UK is through environmental issues, indeed this has been heralded as a major area of development for the future (Cox, 1998). One example is the growing demand for fibre-based containers, such as those made from recycled paper and peat. Whilst this is partly due to new EU requirements for waste management, it is also due to greater product availability, lower costs, and improved quality (Shaddick, 1998). As in Australia, new regulations aimed at minimising water pollution are now leading to more efficient irrigation systems and increased water recycling in nurseries (Briercliffe, 1998). Other areas within the industry which have been affected by this trend include integrated pest management and chemical alternatives, such as biological, organic, and biodynamic pest controls (Bennison, 1998); and the increased availability of eco-friendly nursery products in retail outlets, such as "green" product labelling schemes (Stebbings, 1999).

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Round Plants In Square Holes

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Round tubes have been a defacto standard in the nursery industry for many years. It is timely that we learn from the mass of evidence available worldwide, that pot shapes other than round have so many more advantages in growing better root systems. It has been accepted for too long, that while manufacturers originally found it easier to make round tubes, new moulding and injection techniques no longer make it necessary for them to continue to produce that shape. The business of container manufacturing is very competitive, so as users we have an opportunity and an obligation.
Our OPPORTUNITY is to be able to shop around to get the best value for money.
Our OBLIGATION is to analyse our potting operations, look to future trends and directions, and tell the manufacturers what industry standards and shapes we need, to be better propagators.

WHY CHANGE?

Watch a propagator try to place 99 tubes in a 12 inch × 10 inch [310 mm × 255 mm] sloping sided "standard" propagation tray, and see the difficulties encountered by the user. It is the "round peg in the square hole" syndrome all over again, every time we pot:

- Those sloping tray sides never could support the tubes upright. [Strike 1]
- What chance have the individual plants got to equal watering? [Strike 2]
- Try moving or placing the trays on a table, bench or trailer, without tilting or tipping the outside tubes. [Strike 3]
- Do you enjoy counting in multiples of 99 or has the metric era got to you. [Strike 4]
- Have you calculated how much water is wasted between the gaps? The unused area is more than 20%. [Strike 5]
- Add fertiliser and potting media losses to this, and the losses get serious. [Strike 6]

How many strikes do we have to suffer before we take action? And we have not yet looked at the **root** of the problem. How about the plant? Before we assess that curly one, what are the alternatives?

There are pot and tube makers who have responded to producing better shaped designs, and the business is competitive, so why is there a problem? As propagators, we are failing to control our own agenda by settling on a range of sizes and containers that will meet ever-increasing standards towards growing better plants. We do need a standardised approach to durable tube frames. The essential advantages for square tubes in square frames are:

- The combination is stable for movement between potting and placement.
- We can develop aeration under the tube bottom to produce automatic root pruning.
- Pathogen build-up is avoided by creating an antagonistic environment under the tube.
- Square tubes will produce a better structured root development.
- Square tubes with ridges inside protruding down each side will prevent root circling, particularly if you develop advanced plants.
- Square tubes stay firm together in a tray because they touch on flat sides.
- Square tubes lend themselves to improved automatic tray filling, seeding, and fertigation techniques.

AIR FILLED POROSITY AND WATERING CONSIDERATIONS

One essential assessment of whether you have an acceptable potting media environment, for the right container, is to know your air filled porosity. As a general guideline, a range between 20% to 25% is satisfactory for fast growing plants, but if you need more information, get a copy of Kevin Handreck's *Growing Media for Ornamental Plants and Turf.*

Understanding the basic facts in best watering practices as your most important task can not be overemphasised. Start with the right containers, fill them with the right media, place them in the right environment, and concentrate on the most important job in the plant production process.

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ISO 9002 Revisited

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It seems more than 4 years since the Hahndorf conference where David Cliff and Michael Cole spoke on Quality Assurance (QA). After hearing them speak, we decided that QA was for our business. Before I can go into what ISO 9002 has done for Larkman Nurseries I must go over some basic issues.

Over the centuries many great minds have written on the subject of "quality". Robert Pirsig in his book, *Zen and the Art of Motorcycle Maintenance*, devotes many a page trying to define the intrinsic characteristics of quality, without real success. It is amazing that with the amount of usage the word receives, very few people can give a good definition of what it is. Yet we use it when describing food, accommodation, entertainment, clothing, art, and just about anything else we are likely to spend money on. The advertisers would have us believe that everything their client sells is "top quality" and everyone else's is poor quality.

When you add this conundrum to the fact that what is quality for one person is not quality for the next, you have a real commercial problem. Our customers all want quality products but are unable to define what that means. Indeed quality is so subjective that it is the perception that really matters and not the reality.

The essence of a successful business is one that can provide the quality that each of its customer's desires. A business that has managed to determine what it is that each customer wants prior to production and is then able to ensure that what is delivered is slightly ahead of what is expected will not only succeed but will stand out from its competitors.

It is imperative that we determine what we are talking about when we discuss quality. We would all agree that a *Buxus sempervirens* that is 45 cm tall and 20 cm wide with dark green foliage in a 15-cm pot is a quality plant. We may also say that a *Buxus* that is 20 cm tall and 10 cm wide also in a 15-cm pot is poor quality. What would we say if the customer had ordered plants for a hedge and one supplier delivered 50 that were all 20 cm tall and 10 cm wide whilst the other delivered 50 that varied between 25 cm and 55 cm tall and varied between 15 cm and 30 cm wide? The latter plants may as individual plants be better quality but as a group are lesser quality (in the customer's opinion).

This is the crux of quality assurance. Delivering what is appropriate to the customer's needs. ISO9002 does not affect the quality of the product. It does not mean that our plants are better than our competitors (although this is usually the case). It means, first of all, that the system we use to produce and despatch our plants works the same each and every time. In other words, whomever is doing a task knows what has to be done and to what level. Secondly, it also means that our customers can feel confident that we understand what it is that they want/need, and that we are capable of delivering it.

To deliver exactly what is specified requires a set procedure for each step in the production line. Each procedure also has a set of prescriptive work instructions with a corresponding set of records to enable management to monitor the production. These records are important in two ways. By filling out the record the employee is making a greater level of personal commitment to the task. As they complete the record they are committing to writing their statement that they have done what they are supposed to have done. The record also allows the management team to satisfy themselves that the procedures are being completed properly.

I have heard many people refer to ISO as a paper burden. Although being ISO certified does require that you have a comprehensive paper trail, I feel that this description devalues the benefits of an ISO-certified system. Sure there is a lot of paper generated in operating the system, but the trail is more than just paper. For each piece of paper there is a series of procedures and work instructions that have to be followed to generate it. This paper trail allows the manager, or owner, to follow an order right through from tender to payment of invoice.

In most businesses there are numerous steps between order acceptance and payment. Some of these are critical and some are not. They are all necessary (if not they should be removed) and usually the completion of each step is a prerequisite for the next step.

Once this concept is accepted then it is not hard to understand the concept of internal customers. This is often a serious "phase change" for many companies as it engenders an acceptance of the requirement for every member of staff to produce to the same level of quality and perfection. For too many years it has only been the sales or despatch departments that have been concerned with what the end product looks like. Once internal customers are recognised, the performance of the whole company will improve as each person will have to face up to the responsibility of what they do.

In a properly running ISO system people understand the interdependence of what they do and what their workmates are doing. They will pass criticism on what the person prior to them has done. This criticism will be both positive and negative and will be generated with the aim of improving the productivity of the whole. It will not be used for personal grandstanding nor exacting retribution for past wrongs.

An ISO system generates forms called non-conformances which some companies call Opportunities for Improvement. These are produced when a member of the team does not follow the required procedures and the aim of them is to improve the end product. Sometimes a non-conformance is just a matter of reminding a member of the team that there is a procedure and that it should be followed. Other times a non-conformance will highlight a shortcoming in the system. Either way they can be generated by any member of the team on the actions of any other member, including management.

It would be a rare operating system that does not generate non-conformances as it is through these forms that a good quality assurance system is able to grow and improve. They enable the staff to demonstrate whether they need improvement or whether the system needs adjustment. A good ISO system also empowers the staff to develop their own work places by allowing them to set their own parameters within the defined requirements of the production system. It also means that new staff have prescribed guidelines which are known to work. Guidelines that are simple and easy to read yet comprehensive enough to ensure correct training.

With all ISO systems there should be a Quality Assurance (QA) manual. This manual will vary in size depending on the level of prescription that each company has. For example, if the company is basically a creative or design-based business there will be few prescriptive procedures and work instructions, and the manual will be quite small. Whereas, if the company is production based and has a high number of detailed procedures and work instructions, then the manual will be quite large.

As we are a "production line" with a large number of regimented production methods we have a large and comprehensive QA manual. Through the development of this manual we have defined and refined our work practices and production methodologies. Inside the manual is our quality policy which defines our approach to the ongoing quality assurance system. We detail all the positions within the company and how they relate to the others thereby clearly outlining the lines of responsibility. Also within the manual is enough information and procedures/work instructions to enable the duties and tasks of all the positions to be clearly and comprehensively understood. By extracting the relevant policies, procedures, and work instructions a work manual can be compiled for each member of staff.

Over the past 4 years much of the extensive marketing and development work that we have done has started to pay off. We have gone through a rapid and prolonged growth phase which could have put great strain on the company if it wasn't for our ISO system

If a small company is to reap maximum benefit from a growth phase it must have, and utilise, efficient operating systems. A good QA management system will allow for rapid expansion. This is due to the fact that it must undergo regular review by all members of the staff. Also, by its very nature, ISO9002 brings about improvements as the inadequacies occur. As a shortfall comes about, non-conformances will be issued. These non-conformances will show that the staff have followed procedures but problems have still occurred which indicates that the system is failing and that improvements need to be undertaken.

A company with a culture of QA, with an understanding of the importance of procedures and systems, is best placed to develop a safe and efficient workplace. One of the issues facing modern business operators is that of legal "backside protection". In areas such as occupational health and safety, industrial relations, and insurance, the ability to ensure that all staff perform to a set standard and to then be able to prove it many years later will be a must in the next century.

Using our QA system we have developed a set of procedures for the use and application of chemicals. These procedures cover storage, mixing, and use of the pesticides. It also covers what records need to be completed and filed to satisfy all legal, occupational health and safety, and industrial requirements. Granted the procedures do not guarantee full compliance but the culture of a QA enterprise makes it more likely. The records generated can be kept for as long as required to demonstrate staff compliance.

The main purpose of a QA system is to satisfy the needs of the customer. To enable them to buy with confidence. This is not so critical when they are able to personally select their products, but are of major importance when they are purchasing over the phone, fax, or (heaven forbid) the internet. When ordering in these ways the customer must feel confident that they will get want they want. A money-back guarantee is not sufficient as there are out-of-pocket freight expenses, loss of income from preplanned sales, and staff costs that still have to be accounted for. In other words getting their money back, is just not enough.

Being ISO 9002 certified enables a producer to advertise confidence in purchase. It enables the company to advertise to a remote client base, thereby allowing them to compete in new markets. At the same time giving them a marketing advantage over their competitors in the local markets. A company undertaking a marketing campaign of professionalism and reliability would reap great rewards from ISO 9002 certification.

As discussed above, ISO doesn't guarantee what level of quality a company produces. Quality assurance is about the procedures; industry-based accreditation or endorsement systems are about business infrastructure. In the nursery industry this is called the Nursery Industry Accreditation Scheme of Australia (NIASA). With NIASA a nursery has plant, equipment, and facilities that are equal to or above professional best practice; therefore, it is most likely to produce healthy, hygienic well grown plants.

When a company has both ISO and industry endorsement it could be said that they have a Total Quality Management System. A customer would expect to receive product that meets industry benchmarks and is delivered to meet their expectations. These two marks of professionalism should be the aim of every business.

In summary, ISO 9002 is not an end but a means to an end, a tool that enables a company to achieve its full potential. Our ISO system has allowed us to grow without losing touch with our customers and staff. It has helped us develop a culture of quality and professionalism. The benefits we have gained from our certification are far greater than what it has cost us.

I would commend both the process and the certification to any company, large or small, for whom high profits through full customer satisfaction are their ultimate aim.

Managing Perennial Stock Plants

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INTRODUCTION

At the New Town Station production nursery we had a history of spasmodic over and under production. I was your classic hit and miss plant propagator. Firstly, I took too many cuttings from some plants because I knew they would strike easily and, therefore, I would have the numbers to sell; or I sowed too many perennial seeds just because they were cheap and they germinated quite easily. Unplanned I was hoping the market would somehow absorb the surplus. However, in most cases it would not, so my surplus heap got larger and larger.

The plants that the market did want I often could not supply because I did not take enough cuttings at the right time and/or I did not have access to enough propagation material. Basically I seemed to be operating without much of a plan. I also had the plants ready for sale either too early or too late for the market place. My timing was off! Therefore, my stock management had to improve so that I had enough cutting material and at the right time. We achieved this by selecting healthy mother-stock plants and planting them either in the ground or in a specific size pot best suited to generating the maximum amount of cutting material.

FINDING THE BALANCE TO MAKE A PROFIT

Propagating costs money. Untimely plant propagation wastes money, so good preparation is essential. This preparation starts at the stock plant stage. What we need to know first is:

1) The peak selling time of the plant to be grown.
2) The growing time needed for the plant to be ready for sale.
3) The propagation time of the plant being grown.
4) What mother stock will be required.
5) How long it takes to build up the mother stock.

I call these stages the mother-stock cycle.

I have to know when vegetative growth will occur and how many cuttings I am going to get per plant. This will determine how many mother-stock plants I will need next season to achieve production demand. Building up the mother stock is the primary consideration when planning what you are going to grow for the next seasons market.

METHODS USED FOR MOTHER STOCK HOLDING

200-ml Pots. These pots are squat pots and are all a specific colour, either purple or light blue, so all staff know that these plants are for propagation only. Plants that produce a large number of tip cuttings and/or a large number of small divisions are put into these pots, e.g., *Thymus*, *Diascia*, small leaf *Campanula* sp., and *Saxifraga*. Mother stock in these pots is renewed annually.

350-ml Pots. These pots are black in colour and are multi-planted with three or more stock plants. These stock plants are hand watered because overhead watering can be detrimental to some species. The potting, trimming, and propagation dates are recorded. With correct timing, hygiene, and optimum conditions we have bingo, 100% strike rate. After striking and hardening off, the plants are potted, and in 8 to 10 weeks are ready for sale. Types of plants planted into these pots are: *Verbena*, *Scaevola*, *Antirrhinum*, and *Nemesia*.

In-Ground Stock Beds. These are made out of treated pine 40 × 1800 × 15 cm deep. The boxes sit on the ground. This provides free drainage and easy removal if the plant is trialed and does not meet our growing criteria. Mushroom compost is added to the soil and dolomite lime is added to adjust the pH according to the specific needs of the species to be planted.

These are generally planted out with 12 or more evenly spaced plants per box. At planting 12 month slow-release fertiliser (15N-3.9P-9.1K) and water-storing granules are incorporated. Regular watering is given until we can see that the plants have taken and started actively growing. The beds are then top dressed with Dynamic Lifter™ at the rate of 70 g per plant. The beds are also mulched with a fine pinebark mulch to help retain moisture in the soil and also suppress weeds.

At first we experimented with overhead watering which proved a complete disaster. It made the paths very boggy and was causing run-off problems. Now we hand water and have better control over the individual plants specific water requirements.

The beds are always hand weeded and the paths are sprayed with a glyphosate herbicide to control the weeds. By looking after these beds we are assured of healthy cuttings and very good plant divisions. Examples of species successfully propagated by this method are: *Arctotis*, *Scabiosa*, *Leucanthemum ×superbum* [syn. *Chrysanthemum maximum*], *alpine strawberry* (*Potentilla × Fragaria*), and perennial *Viola*.

Tube Stock or Plug Sheets. Once you have your initial stock production under way, these are the best source of cutting material. We achieve one to two cuttings off each plug and also get to trim the plug sheets at the same time.

HOW MANY STOCK PLANTS DO I NEED?

1) The actual number of plants required for sale must be known and the number of cuttings achievable per stock plant. From here work back to calculate the number of stock plants that will be needed to give you the number of cuttings required.
2) Approximate propagation success rate must be known and an allowance made for poor strike rate.
3) What size pot will the end product be sold in? In some cases the plants can make-up faster in a pot by multi-planting, say three to a pot, e.g., *Verbena*. This would mean triple the amount of cuttings and therefore stock plants required.
4) What time of the year will you get the optimum number of cuttings? For example, for dwarf *Polygala* a higher number of suitable cuttings can be made from the spring growth as compared to autumn growth.
5) It is also important to know which method of mother-stock production best suits each plant species.

MANIPULATING PERENNIAL STOCK PLANTS

This is done by placing potted stock plants either under shade or under plastic to make the plant elongate and produce lots of very soft tip cuttings. We use this method on *Dianthus* hybrids. We can also manipulate our stock plants by adding additional nitrogen to ensure more soft tip growth and, sometimes, nonflowering growth. Regular cutting back will also stimulate new growth, and hence potential cutting material. Controlling the soil moisture content, either in the ground or in a pot, is vitally important. Irregular watering creates stress on the plants and as a result the quality of the stock plant deteriorates. The number of cuttings from the stock plant also decreases with water stress and the strike rate of the plant decreases. So not only does the plant suffer from stress but also the propagator! Monitoring insect pests and diseases is important and must be done regularly as these can dramatically and adversely affect strike rates.

HOW OFTEN SHOULD STOCK PLANTS BE RENEWED?

This is probably a plant propagators most neglected job. Stock plants should be renewed regularly. Always keep your old stock plant until your cuttings have struck. Remember:

1) It was cloned and originally selected by you for a reason.
2) It can act as a back up if the strike rate is poor.
3) It might make a good display tub for some hungry retailer.
4) It is important to replace some of the field-grown stock plants with fresh plants.

WHICH PLANT BECOMES A PERENNIAL STOCK PLANT?

1) The first plant to flower, or the last for an extended season.
2) The plant that shows hybrid vigour above other plants in a crop.
3) The plant that may be showing a different biological characteristic such as a larger flower or a smaller leaf.

METHODS OF PROPAGATION USED FOR PERENNIAL PLANTS

Soft Tips and Stem Cuttings. At our production nursery most perennials are propagated by soft tip cuttings. These are inserted into soft plastic, 128-cell trays filled with a mix of Copra peat and perlite (2 : 8, v/v) and Osmocote mini™ (16N-03.5P-9.1K) fertiliser added. If the cuttings are taken from clean healthy vigorous stock plants no rooting hormone is used. If this is not the case, a Soft Wood No.1 powder is used.

Division. Our perennials are divided when the plants are not in active growth. By dividing plants we can achieve a larger plant much faster. Our spring-flowering plants are usually divided after flowering or in mid autumn. Our autumn-flowering plants are usually divided in spring. Summer-flowering plants such as *Geranium* and *Aster* can be divided in spring or autumn. The divisions are inserted into rigid 48-cell plug trays with a mixture of Copra peat and perlite (2 : 8, v/v), or they can be tubed up directly into 75-ml tubes.

Use of Tissue Culture in Stock Plant Renewal. This technique is absolutely essential for some perennial species to ensure virus free plants, e.g., regularly used for *Scabiosa* and *Arctotis.* Tissue culture ensures a good strike rate and healthy plant growth.

Seed. Most seed used in our perennial plant production is brought from reputable seed houses. Our remaining seed requirements are met by our in-ground stock beds and sown fresh, e.g., *Dicentra* and we are experimenting with *Agapanthus.*

Root Cutting. This technique is still very experimental at our nursery, however, root cuttings of *Rehmannia* have been 100% successful.

CONCLUSION

In conclusion, the four essential ingredients to maintain healthy perennial mother-stock plants are:

Good Record Keeping. This is very important, especially the growing cycle of the plants you are propagating and the number of cuttings you are achieving from your stock plants.

Educated Observation. An old plant propagator once told me, "walk around with your eyes open and you will never stop learning".

Willingness to Experiment. Without experimentation we will never discover new methods.

Training Staff. It is important that staff are encouraged to keep records, be trained to observe, and strongly encouraged to experiment. Most importantly the boss must set the right example.

Dianella tasmanica: Some Success

Rose van der Staay
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Dianella or flax lilies, so called because of the fibrous nature of their handsome long strap like leaves which were used by Aborigines for basket weaving. Formally in the Liliaceae, a review of this family now has the genus placed in Phormiaceae.

Members of the *Dianella* genus are perennial monocots forming tough rhizomatous clumps with tufts of long leaves that are flat and clasping at the base. Leaf length, width, and colour varies with the species and particular habitat. All have blue flowers and wonderful blue to purple berries. The genus extends from south east Africa through south east Asia to Hawaii and Australasia. Australia has 15 species, 11 of which are endemic (The Flora of Australia, 1987).

Tasmania has four species represented, all extending to south east mainland Australia. *Dianella tasmanica* has leaves 1.5 to 3.0 cm wide and 20 to 90 cm in length. Young leaves emerge upright arching gracefully downwards as they mature. This species is easily distinguished by a rough saw edge on the leaf margin and mid-rib. The flowers are violet to lavender with pale yellow anthers and orange filaments. The berries mature to a deep purple colour. It grows mainly at high altitude and extends to the Australian Alps and the New England Plateau.

Two other species are similar in leaf and size to *Dianella tasmanica*:

Dianella longifolia is distinguished by the purplish colour of the leaf bases and smooth margins and pale blue flowers.

Dianella caerulea is green leaved with smooth margins and bright blue flowers. It spreads vigorously by long rhizomes and can form extensive colonies. This species extends north to Queensland.

These three species grow in open forest particularly on moist rocky hillside in full sun or part shade from sea level to mountain foothills. They are very decorative in large containers indoors or inground as vertical tufting landscape plants with gracefully arching glossy leaves. Although not strictly water plants they look great around water features. All tolerate a wide range of soil types and are frost hardy to between -5 and -10C.

Dianella revoluta is readily identified by its smooth narrow leaves 4 to 10 mm and 15 to 80 cm long with revolute margins. It offsets freely but does not produce extensive rhizomes. Flowers are dark blue to violet the berries are smaller than other species and dark blue. Two forms are recognised in Tasmania; the type *D. revoluta* var. *revoluta* has its flower panicle above the foliage, and; *D. revoluta* var. *brevicaulis* has short wiry flower stems among the leaves and grows in coastal and lakeside habitats.

All four species are long lived and able to withstand considerable dry periods when they cease growth until rains return. *Dianella* can be propagated by seed, division, or tissue culture.

PROPAGATION FROM SEED

We grow *D. tasmanica* from seed as this produces a more even batch of plants which are earlier clumping than those grown by division of offsets. Seed is collected in March-April by picking the ripe berries which contain 3 to 10 seeds (160 seeds per gram). Mention is made that birds eat the berries but I have seen no evidence of this. The blue berries will drop at the slightest touch of the stem, I would think the berry falls into and around the plant clump where it becomes alternately wet then dry and slowly decomposes releasing the seed for dispersal by heavy rain or ants.

I have had excellent germination results by simulating this slow decomposition and release of the seed. The berries are gently squashed then steeped in water and allowed to soak 7 days then flushed with fresh water drained and dried for 7 days. This process is repeated 3 times. After this time you have a soggy brown mess flecked with shiny black seeds. The seed can be separated from the debris by flushing and gently squashing the wet material then draining and placing onto newspaper in a warm place to dry. Once dry the seed separates easily from the berry residue.

If not sown immediately the dry seed should be refrigerated. We sow in September and place the trays outside under shade and daily overhead irrigation. Temperature would vary between 3 to 18°C. When the first leaves appear in 6 to 8 weeks the trays are moved into an unheated plastic house to be grown on. These are ready for pricking out in late December, 3 months after sowing. The results are excellent, we have achieved 700 seedlings from one seed tray in 3 months.

Seedlings are then ready for potting in March, 6 months after sowing; by this time leaves will be 12 cm high and offshoots will be evident. A 14-cm pot plant takes 12 months to grow and will have three or more offshoots. A 20-cm pot plant takes 18 months to grow and will have 12 to 20 offshoots.

PROPAGATION BY DIVISION

Dianella revoluta var. *brevicaulis* can also be grown from seed, but the flower stems are in amongst the leaves and the small berries are easily lost while trying to collect them. Fortunately the coastal form we grow offsets very freely, 12 to 15 offsets in a 10-cm pot 12 months after dividing is common. Pots are divided autumn to late winter, a clump of 3 to 4 offsets potted into a 10-cm pot — the smaller plants are easier to handle than the more mature clumps from 20-cm pots or inground stock.

PROPAGATION BY TISSUE CULTURE

Tissue culture allows selection of better plant forms and types that set berries more frequently. Flower and berry colour can also be selected for. Long-term commercial viability would be dependant on volume demanded by the market.

Students from the Plant Science - Cell Biology Group at the University of Tasmania have been working on various Tasmanian species from Liliaceae and Iridaceae including *Dianella*. Diane Sward has presented papers on her work. She has successfully cultured and multiplied plants and has the first batch of transplants out of culture (Sward, pers. comm.).

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Tasmanian Native Orchids: Their Propagation and Culture

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INTRODUCTION

An orchid is a big spectacular delicate flower that grows in steaming jungles, it is rare and difficult to grow, and takes 7 years to flower and is surpassingly feminine. Not true.

An orchid is a tough, exceedingly common flower that will grow almost anywhere. It may be small and drab and can hardly be seen without a magnifying glass. It is one of the easiest plants to grow and produces flowers every year. Far from being feminine it is, in name at least, superlatively masculine. The ancient Greeks were the first to take botanical notice of these curious plants. Theophrastus, the father of botany, writing on the European ground orchids, gave the name Orchis to the plants from the resemblance of the paired underground tubers to masculine anatomy. This suggested to the Greeks and medieval herbalists that orchid roots may "provoke Venus" and eating them might influence the sex of unborn children (Marden, 1971).

The species of orchids found in Tasmania comprise one epiphyte, one lithophyte, and approximately 180 terrestrials. The majority of Tasmanian orchids can be grown in bush houses or cold glasshouses with a suitable environment.

EPIPHYTE

Orchids that grow on trees (epiphytes) take nothing from their host, it is somewhere to grow. Nourishment is gained from rain, dust, leaf litter, and bird/animal droppings. *Sarcochilus* is a genus of about 11 species found in Australia and *S. australis* is the southern most member of this genus extending from Tasmania through the Furneaux Group and Victoria as far north as Glen Innes in NSW (Curtis, 1979). Distribution in Tasmania ranges from the rainforests of the west and north west coasts to deep gullies on the east coast.

Sarcochilus australis grows on the branches and trunks of trees, often on small twigs in sheltered gullies near water, in tall open forests with dense understory, and in rainforests in heavy shade with only filtered sunlight. This species occurs at altitudes from sea level to 900 m (Upton, 1992). Numerous plants can be found on smooth-barked trees such as native olive (*Notelaea ligustrina*), thorny box (*Bursaria spinosa*), musk (*Olearia argophylla*), stinkwood (*Zieria arborescens*), and native laurel (*Anopterus glandulosus*).

Flowers are borne on pendulous racemes in colours of brown or green during October to January. Their location can often be found by the sweetly fragrant perfume they emit. Difficulties are often experienced with culture. Plants can be firmly mounted on a piece of wood and hung in a shade house with good ventilation (which is essential). Attachment to a living tree would probably provide the best chance of success as roots can extend for metres along branches and up and down the trunk. Plants grown in enclosed areas only seem to last 2 or 3 years due to the difficulty of providing a suitable microclimate and their susceptibility to scale.

Collecting plants from the wild is the only means of obtaining *S. australis* as orchid nurseries do not stock plants. Approximately 20 hybrids have been produced with *S. australis* in their parentage. Plant growth is midway between the parents with the pendulous raceme habit and flower shape of *S. australis* being dominant even in second generation hybrids. These hybrids can be grown in pots in a mix of radiata pine bark and gravel very successfully.

LITHOPHYTE

Dockrillia striolata [syn. *Dendrobium striolatum*] is found on the east coast of Tasmania, Furneaux Group, Victoria, and NSW (Curtis, 1979). In Tasmania it grows on granite outcrops from Orford to Bicheno. Roots attach themselves to the granite and the plant spreads by rhizomes with branched stems to form extensive mats. The flowers are pale or yellowish green with brown veins and appear in the spring.

Propagation is very easy using a branched stem with roots. Place a small pad of bush moss over the roots and tie the plant to a piece of granite using nylon fishing line. Place the rock on a shaded bench and ensure the plant receives adequate moisture to ensure maximum growth. Application of a high-nitrogen fertiliser regularly during spring and summer is beneficial. Any fertiliser used should be at less than half the recommended strength.

TERRESTRIALS

A terrestrial orchid grows in the ground. All Tasmanian terrestrials are deciduous. They grow from an underground organ called a tuberoid, which is a rounded or ovoid swollen root, resembling a tuber. Nutrients for terrestrial orchids is obtained from the soil or leaf litter via a symbiotic relationship with mycorrhizal fungi (Australasian Native Orchid Society, 1988).

Deciduous terrestrial orchids have a distinct annual growth cycle. At the beginning of the growing season a stem emerges from the tuberoid and grows to the surface where it produces leaves and/or flowers. Most terrestrial orchids form a new tuberoid to replace the old one by flowering time. Extra tuberoids may be produced at the end of stolon-like roots. Many of the *Pterostylis* produce extra tuberoids, these are colony-forming orchids. *Caladenia* produce only one tuberoid annually to replace the one that has withered away, these are solitary type orchids.

After flowering and seed production all above ground parts wither and dry out. The tuberoid becomes dormant and survives the summer buried underground before shooting again in the autumn. Solitary-type orchids can only be propagated naturally from seed, whereas colony-forming species can be propagated both vegetatively and from seed.

Some orchid species are leafless and rely totally on their association with mycorrhizae for nourishment, these are known as saprophytes. They are fleshy and can be pale coloured or darkly pigmented. Because of their total dependence on symbiotic fungi they are impossible to cultivate. Two examples are *Dipodium punctatum* (hyacinth orchid) and *Gastrodia sesamoides* (potato orchid).

Terrestrial orchids grow in a wide range of habitats from the sea shore to high in the mountains. Successful cultivation is more readily achieved by growing plants in pots rather than the garden. Conditions can be controlled and varied to suit different species.

In the wild terrestrial orchids grow in soils, the structure of which has been formed over thousands of years. If this soil is disturbed and placed in a pot the crumb structure is changed and water no longer drains away to the subsoil. This generally results in the soil retaining too much water and the orchid failing to grow successfully (Australasian Native Orchid Society, 1988). The potting mix needs to imitate the soil structure so that it supplies the plants requirements, i.e., support, nutrients, water, and oxygen in the correct proportions.

A basic potting mix developed by growers (Australasian Native Orchid Society, 1988) over the years comprises:

Coarse sand: 2 parts
Rich loam: 1 part
Buzzer chips: 1 part
Leaf mould: 1 part
Blood and bone: 1 dessertspoon per 9 litre bucket of mix
Garden lime or dolomite: 1 dessertspoon per 9 litre bucket of mix

- **Coarse Sand** is 2 to 4 mm in diameter. Fine material should be sieved out. Beach sand is not suitable.
- **Rich Loam** is a friable nutrient-rich soil.
- **Buzzer Chips** vary from paper thin to 1 mm thick and up to 10 mm square. Sawdust must be sieved out. Hardwood or softwood is suitable. Softwood decomposes more quickly. Western red cedar, treated pine, or chipboard cannot be used because they contain toxic materials. Chips should be aged in moist conditions for 4 to 6 weeks to reduce phytotoxins which may effect plants. Composting of the chips further reduces the phytotoxins and prevents nitrogen draw down.
- **Leaf Mould** is the partially rotted down leaves found under trees raked up from the soil surface. Leaf litter from the forest is very suitable because of the fibrous structure.

Black plastic pots of a minimum 100 mm in diameter are recommended for growing of terrestrial orchids. Good drainage of the pot is essential with holes across the base and around the bottom edge. The potting mix must be damp when used, there should be no dust evident. The mix should feel barely damp and gritty but combined. If it is too dry it might not wet in the pot and if too wet will pack densely resulting in insufficient air space.

POTTING DORMANT TUBEROIDS

Prepare potting mix, consider any special requirements of the species being potted.

- Use a clean pot with sufficient holes.
- Place a circle of shadecloth in the bottom of the pot ensuring all holes are covered. This prevents slugs and slaters, etc. from entering the drainage holes and the dry mix running out in the dormant season.
- Fill two-thirds of the pot with mix and arrange tuberoids in the top of the mix with the growing eyes up. Cover the tuberoids with mix and lightly firm down. The tuberoids should be 30 mm below the level of the mix.
- Label pot, include name of species, locality collected if known, number of tuberoids, and date.
- Add chopped *Casuarina* sp. needles to top of pot. This stops water splashing over the leaves when watered and provides an airy

environment around the base of the plant at surface level, reducing the likelihood of rotting at that point, prevents the mix from drying out completely and aids in the germination of seeds.

POTTING PLANTS ALREADY GROWING

- Follow first four steps above.
- Position plant in pot so that the roots and portion of stem previously below ground are below the final level of the mix. Firm the mix down around the plant and water thoroughly. Check the level of the mix and adjust if necessary.
- Add a layer of *Casuarina* sp. needles to the top of the mix ensuring the plant leaves are on top of the needles.

Annual repotting is necessary to replace nutrients, improve drainage (which lessens with decomposition over time), and to remove excess tuberoids. Repotting is best done when tuberoids are dormant, i.e., at the end of the growing season. In Tasmania this is usually December. If repotting after January, when tuberoids have commenced shooting, care must be taken so as not to break the brittle new shoot.

Allow pots to dry out prior to repotting. Tip the contents of the pot out over a 6 mm sieve, most of the mix will fall through leaving coarse material and tuberoids. Remove tuberoids and return coarse material to old mix. Replace half of the old mix with fresh mix and thoroughly mix together. Follow procedure for potting dormant tuberoids. Excess tuberoids should be potted separately.

Dormant tuberoids may be successfully stored for several months provided they are kept dry and prevented from dehydrating. Tuberoids should be stored in either dry sand, dry potting mix, or dry tissue in a sealed plastic bag and placed in a cool dry place.

When a terrestrial orchid is growing it needs a constant supply of water. The mix must be moist throughout the growing season. Fill the pot to the top with water and allow to drain. Watering frequency will be dictated by the species of orchid, growing environment (e.g., whether the roof is solid or shadecloth, air movement, and temperature), and the structure of the potting mix. Watering should commence on a regular basis around March and cease when the leaves die and the tuberoids become dormant. A light spray once a week during dormancy is sufficient to prevent dehydration.

Lack of light results in poor growth and elongated and weak plant which are prone to fungal attack. Excessive light causes stunted growth, burning, and yellowing of leaves. Most orchids grow in areas of low humidity and good air movement. They should be grown in a well ventilated area. Moss on the top of pots, damping off, and rotting leaves are indications of poor ventilation. These are also indications of over watering or poor draining mixes.

To achieve the best results growing terrestrial orchids in a specially constructed structure. The walls should be open and covered in shadecloth to provide good ventilation with a roof of solid translucent material to protect the plants from excessive rain. Benches should be wire mesh and about waist high. Benches must be well built to carry the weight of wet mix when pots are watered. A specialised growing area allows for control of the factors determining the degree of success in cultivating these orchids.

PROPAGATION FROM SEED

Those orchids which only produce a replacement tuberoid each year can be propagated from seed. Seed is harvested as the seed pod turns brown and before it splits. The ripe seed pod is placed in a paper envelope and allowed to dry for another 2 days before storing. The paper envelope containing the seed should be placed in an air-tight container in the refrigerator, with a desiccant if possible, until sowing time (Australasian Native Orchid Society, 1988).

Seed is best sown at the beginning of the growing season around a parent plant of the same species as it is assumed that the parent plant is growing with the appropriate mycorrhizal fungus necessary to infect the seed. The *Casuarina* needles provide a protected area for the seedlings to develop and should emerge in about 2 months. Care must be taken when watering not to allow water to overflow the top of the pot and wash seed away. The first leaves will appear by spring and tuberoids at the end of the growing season. They should be left for another year to develop before repotting (Australasian Native Orchid Society, 1988).

Collection of orchids from the wild should not be encouraged unless an area is being cleared or developed. Specialised production may be necessary in the future so that plants can be returned to the wild.

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Propagation of *Dicksonia antarctica*

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Dicksonia is a commonly cultivated but relatively small genus of about 25 species distributed widely throughout the world (Jones, 1987). They are strange plants, considered rather primitive, and can be traced back to the prehistoric flora of the great super continent Gondwanaland. The most graceful and hardy of the plants that are rather loosely called "tree ferns", are not trees in any sense of the word. Other tree ferns at least have trunks; these ferns are really epiphytes sitting on the top of a "trunk" composed of an entwined, elongated mass of their own dead matter. The young roots must make their way down through this dead matter to find nourishment. In the wild the trunk is usually covered with epiphytic plants which trap humus and moisture, from which the fern roots travelling down the trunk benefit. The plants struggle to survive unless the so-called trunk or root system is protected and kept moist, this is often an unsuspected cause of failure in cultivation.

Dicksonia antarctica (soft tree fern) is a hardy native of the eastern states of Australia, including Tasmania. It is widespread and abundant in Tasmania, from dry sclerophyll forest to rainforest, and ranging from sea level to subalpine forest. It is mostly absent from extremes of altitude (above 900m) as on the Central Plateau, and from low rainfall areas such as the Midlands. It may grow to 15 m tall with a frond span of 9 m, with up to 40 fronds unfurling at a time. It is an ideal potted plant, requiring little space for its roots, and thrives on regular feedings with leaf mould and bone meal. It thrives in cool, moist conditions and, if given plenty of water, will tolerate a fair degree of exposure to sun.

Dicksonia antarctica is such a hardy species and produces spores in such copious amounts (over 800 million spores per plant annually) that scattered but dwarfed individuals are commonly encountered in micro-environments of otherwise unsuitably harsh alpine, coastal, or arid regions. This is one of a few fern species that is the first to recolonise from spore in soils disturbed by activities such as logging or road construction.

HISTORY

The trade in *D. antarctica* trunks dates back well into the last century when bush harvesting of the fern was a major business. There is evidence of several businesses in the port of Hobart relying totally on the export of tree ferns back to England. This practice has now all but ceased due to increasing concern over conservation.

SPORE

Spore is collected on a dry day by taking a fertile frond with mature sori and placing it in an appropriately labelled paper bag. The bag is stored in a warm, dry place for at least 3 days to enable the spore to drop. Ripe spore will drop almost immediately, others will take longer. When all spore has dropped it is separated from debris (the indusium, sporangia, hairs, and scales) by sieving with a fine mesh sieve. It is then placed for long-term storage (up to 6 months) in a paper envelope, which is sealed in a plastic container and kept at approximately 4 to 5°C. *Dicksonia antarctica* spore has been found to retain viability for 10 to 15 years. However, fresh spore gives superior results.

SOWING

At this stage hygiene is extremely important. All trays, glass, and labels used are soaked in a bleach solution (sodium hypochlorite) for at least 30 min, and are subsequently washed down with hot water (60°C) to remove any bleach residue. Benches and any other work surfaces are also washed down with a bleach solution. The spore is sown into trays containing a potting mix which is topped with a layer of sterile peat (we use crushed jiffy pots). The mix is wet through with water at 60°C to kill any pathogens, and tamped down twice. Once the mix is just warm, the paper envelope is torn at the corner, and the spore is sown by gently tapping the edge of the envelope. *Dicksonia antarctica* is easier to sow than some others fern spores because of its bright yellow colour. Once a tray has been sown it is protected from the entry of pathogens by covering with a glass sheet.

Once all trays are sown, individual trays are placed immediately in a plastic bag, labelled, both inside the tray and on the plastic bag, and sealed. The trays are then placed on shelves under fluorescent lights in a room where the maximum temperature is controlled to under 27°C. The lights are on for 15 h per day, and this is the only source of light for the spore until the trays are removed to the growing house.

PROTHALLI

Prothalli become visible between 2 and 4 weeks after sowing. After about 10 to 12 weeks the prothalli will cover the tray, and if left, will start to bubble and grow over each other. The tray is then removed from the growing room. The prothalli are separated onto trays of moist sphagnum (which has been hot watered through to kill pathogens) in round pieces approximately 30 mm in diameter. These trays are then placed on hot-water heated bed which is covered with a plastic tent. The bed temperature is maintained at 18 to 20°C, giving an effective air temperature of around 16 to 18°C overnight.

The trays are watered two to three times a week, and the plastic tent is lifted for approximately 3 h a day. The prothalli will grow together, and after about 4 weeks the young ferns become visible. The ferns should cover the tray and be well rooted into the sphagnum in 10 to 12 weeks. At this stage the trays are removed from the plastic covered bed and place on a heated low bed in the same house in order to harden off.

PRICKING OUT

After 1 week of hardening off the young ferns are ready to be transplanted into small pots or trays filled with a potting mix. After removing as much of the sphagnum mix as possible, a small clump of ferns is placed into each tube. The trays are then labelled and placed back onto the heated beds. After 4 to 6 weeks the roots should be halfway down each tube. The trays are then raised to a higher bed where they will receive more light, and after 4 to 6 weeks the roots should reach the bottom of each tube

POTENTIAL PROBLEMS

- Infertile spore is a major cause of failure. This may occur because the spore was either immature or over mature, or because of incorrect storage.

- Attacks by pathogenic fungi or bacteria. These attacks may occur in spite of all precautions taken, and the infection site should be removed and the tray drenched with a fungicide.
- Attacks by fungus gnats (to the prothalli roots). Once the maggots of these gnats are in a tray of prothalli they are very difficult to control. It is best to ensure prevention by effective sterilisation and sealing.
- Algae and mosses may smother the newly grown ferns. This may be an indication of incomplete sterilisation of the media before sowing or later contamination.
- If spores are sown too thickly the prothalli will become crowded, misshapen, and weakened. They are therefore more susceptible to damage and the entry of disease.

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Propagation of Apple Rootstocks by Tissue Culture

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Tasmania has historically been recognised as a prime apple growing region of the world. Traditionally, commercial apple orchards have grown fruit on large seedling trees. In recent years, the trends have been for trees grown on dwarfing rootstocks to cater for new planting techniques and return higher yields per hectare. There is considerable demand in the marketplace for the supply of elite dwarfing rootstocks which are difficult to conventionally propagate quickly in large numbers.

INTRODUCTION

Forest Home Nursery's business operations began in 1985. Since its inception the nursery has delivered quality apple and stonefruit trees annually, primarily to Tasmania and several mainland states.

The nursery has conventional field stoolbeds of several *Malus* cultivar rootstocks. The quantity and quality of these stocks over recent years has varied. A decision was made in 1991 to establish a tissue culture facility. The purpose of Forest Home Laboratory is to meet the first class rootstock requirements of cultivars to meet market needs, i.e., disease free, robust, and high production levels. A fully qualified biotechnologist was employed to establish the laboratory and get production under way. Training of a second staff member commenced immediately and in 1992 two more staff were employed. The laboratory now has three skilled staff trained in basic micropropagation techniques and an additional two people managing the hardening-off stage. The operation is housed in a basic structure modified to a clean laboratory environment.

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Forest Home Nursery's business operations began in 1985. Since its inception the nursery has delivered quality apple and stonefruit trees annually, primarily to Tasmania and several mainland states.

The nursery has conventional field stoolbeds of several *Malus* cultivar rootstocks. The quantity and quality of these stocks over recent years has varied. A decision was made in 1991 to establish a tissue culture facility. The purpose of Forest Home Laboratory is to meet the first class rootstock requirements of cultivars to meet market needs, i.e., disease free, robust, and high production levels. A fully qualified biotechnologist was employed to establish the laboratory and get production under way. Training of a second staff member commenced immediately and in 1992 two more staff were employed. The laboratory now has three skilled staff trained in basic micropropagation techniques and an additional two people managing the hardening-off stage. The operation is housed in a basic structure modified to a clean laboratory environment.

Forest Home Laboratory produces quality *Malus* rootstocks using tissue culture techniques, primarily on dwarfing *M.* Malling 26 (M26) stock. Research is currently being undertaken in the commercial development of the cultivar Malling 9 (M9) and a new introduced dwarfing stock, Budagovsky 9.

During the past 15 years major advances have been made in micropropagation. Conventional rootstock beds take approximately 5 years to reach commercial production yields. The nursery management decided to adopt tissue culture because of the potential to achieve high yields in a shorter timeframe. Additionally, because the cultivar explants are multiplied vegetatively whether by traditional cutting practices or by micropropagation, high quality and clean material can be selected. Using tissue culture all explants from a single parent plant are clones, because their genetic make-up is identical to that of the parent. This allows the nursery to select superior cultivar material for mass clonal production.

MATERIALS AND METHODS

At Forest Home Laboratory, apical and axillary buds are harvested from clean *Malus* mother stock grown in an optimal environment to promote growth. This material is disinfested in the laboratory prior to placement in vitro (in glass). This method is superior to past trials which used dormant buds from a normal orchard environment. These buds were put through a harsh cleaning process and large losses were incurred. Those that did survive were difficult to stimulate into shoot proliferation.

More importantly the microcutting method allows the laboratory to initiate stocks from a guaranteed clean source of material. The final product, a 2-year-old apple tree, is a high-quality, sought-after product. The current method of harvesting explants allows the laboratory to keep *Malus* stocks dormant under refrigeration and introduce new material into the system when required.

Since the laboratory's inception, many hours have been dedicated to finding the best possible mix of ingredients for the culture medium. The laboratory currently has four basic mixes in use. Two formulations are used for shoot proliferation and two for root initiation. Each medium has its own individual identification code and each batch made has an identification number to ensure traceability. This identification is labelled on each container made.

In the initial stages of research in-vitro explants were placed in polycarbonate test tubes with 10 ml of medium. Once rapid shoot proliferation has occurred, microcuttings are taken and transferred under sterile conditions. It was quickly realised that in vitro the *Malus* stocks were prone to vitrification.

Vitrification is mainly evident in the leaves produced in vitro. Traditionally vitrification has been defined by visual symptoms such as a glassy, water-soaked appearance and irregular growth. Plantlets with these characteristics cannot survive stress after transplanting, they require a very gradual transition period to regain normal morphology and ultimately survival (Yang, 1999). The laboratory established that the vitrified shoots transferred through without change which resulted in greater losses. Several experiments were undertaken to reduce the vitrification phenomenon including using liquid media, Vita film™, membrane rafts, and imported gamma-irradiated trays. As is sometimes the case in research, by accident it was discovered that simply loosening the lids of the culture vessels enabled sufficient gas exchange to prevent vitrification.

Excellent sterile technique and selection protocols (e.g., removal of nonviable explants such as vitrified material and old growth) ensure that contamination rates are negligible and success rates high.

The labour costs of micropropagation are extremely high. Continual review of methods occurs with a view to increasing efficiency. An example of this is the conversion from polycarbonate tubes to 250-ml polycarbonate jars. A more recent introduction into the process have been polycarbonate "takeaway food" type containers, which have improved both efficiency in labour and use of space. It is anticipated that a large financial saving will be made because of this innovation in the cost of the container alone.

All polycarbonate products are sterilised and reused wherever possible. Explants are placed in jars or tubs in vitro for a minimum of 4 weeks to enable rapid shoot proliferation. A set protocol for transfer and multiplication is followed. After 4 weeks larger shoots (plantlets) are selected for rooting and placed onto media designed to initiate root development, whilst the smaller plantlets are placed back onto shooting media for further transfers.

Simmonds (1983) studied how the length of time spent on rooting media affects root production and ultimately plant establishment. The results showed that although only 34% of M26 shoots had rooted after 3 weeks on rooting media, compared to 69% rooting after 6 weeks, the post-culture establishment and growth of plantlets in the 3-week group was significantly greater than that of the 6-week group. Forest Home Laboratory explants are on rooting media for at least 3 weeks before they are removed to the humidifier to commence hardening off.

The hardening-off process has proved to be the most challenging. Over 50% losses have occurred due to unfavourable environmental conditions. This results in increased susceptibility to disease infection or desiccation of plantlets, which causes irreversible tissue damage and death. During 1997 Forest Home Laboratory approached the University of Tasmania to conduct research into the hardening-off stage. The Laboratory supplied the infrastructure and the University of Tasmania the research skills. In 1998, as partial fulfilment of the requirements for the degree of Graduate Diploma in Agricultural Science (Honours), Simon Yang completed his research towards the thesis titled *Growth and Survival of Tissue Cultured Apple Plantlets after Transplanting*.

A review of relevant literature found that exposing plantlets to an environment of reduced relative humidity without disturbing or injuring the delicate root system increased wax development in the cuticle and therefore survival rate (Fuchima et al., 1981; Ziv, 1986). Changes to the environment in vitro may produce better quality plantlets. Environmental factors which can be manipulated include: light (intensity and day-length), temperature, relative humidity, and media (mainly rooting media). It is possible to harden off plantlets while they are still in vitro or at least gradually adapt plantlets to the outside environment after transplanting.

Yang (1999) found that minimising water loss via transpiration is crucial to the survival of plantlets. The first 1 to 5 days spent in the humidifier at Forest Home are essential, firmly establishing that a consistent environment in the earliest stages of the hardening off process is vital. This, together with a proactive program to prevent infestation by fungal or insect pests, ensures a viable survival rate is achieved.

In October 1998 the laboratory won the Inaugural Tasmanian Farm Business Development Award. This funded the purchase of a cement mixer to improve the incorporation of nutrients through our potting medium and supported a study tour to a major tissue culture facility in New South Wales.

All of these factors combined resulted in the modification of the hardening-off process, converting a greater than 50% loss rate to a 90% survival rate.

CONCLUSION

The main advantages to producing apple rootstocks by tissue culture are; high yields, ability to source superior explants, and effective timeframes for production. This has to be balanced against the cost of research and development.

Small private enterprises will find the going tough unless they have adequate start-up capital. Obviously corporate and government-run facilities will have a better chance of success, as they can set up the infrastructure to allow production en masse from the outset. The challenges faced by Forest Home Laboratory have been great, however from a modest beginning the rewards are now being realised and expansion is planned. Those private enterprises that also have the courage and fortitude to persevere will see the rewards of their endeavours.

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Experience with Western Flower thrips in Tasmanian Glasshouses

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I am going to tell you about my experience assisting several Tasmanian growers deal with western flower thrips (WFT). I will stress the importance of hygiene both for avoiding the pest in the first place and for dealing with it when it arrives. After discussing WFT I will describe the widespread glasshouse white fly and the new pest, Bemesia white fly. I think similar lessons apply to them.

WESTERN FLOWER THRIPS

Western flower thrips looks similar to other thrips. It is larger than onion thrip and paler. Its colour changes seasonally but it is often two tone. With a small amount of practice you can probably identify the female WFT on sticky traps. In some environments there are other thrips that can be confused with it. Every glasshouse has its own range of thrips deriving from the plants inside and outside.

The most reliable means of identification is the presence of bristles on certain parts of the body. You need X20 or more magnification to see them confidently. They are black and contrast well with the pale body.

Western flower thrips are worse than other thrips because they:

- Can rapidly develop resistance to many insecticides;
- Are the most efficient vector of tomato spotted wilt virus (TSWV) and
- Live on a wide range of plants.

Western flower thrip feeds by lacerating the surface cells with chisel-like mouthparts and sucking up the cell contents. Whilst doing so it will transmit the TSWV if it became infected when a juvenile. Adult thrips can give the virus but do not acquire it. Systemic insecticides are effective against aphids but not necessarily thrips. Systemic insecticides do travel around the plant in the main sap flow. This can compensate for poor initial spray coverage if the pest feeds directly on the deep sap flow and consumes a large volume of sap as aphids do. Thrips suck plant tissues but not at a depth and in enough volume to fully encounter systemic insecticides.

Western flower thrip is associated with many plants and weeds. It prefers to live in flowers but does lay eggs and feed elsewhere, such as on leaves and buds. A huge benefit in WFT control can be gained by:

- Removing weeds;
- Removing unnecessary blooms.

In my experience you will never get ahead of the WFT population while you leave breeding sites like reject blooms, spent blooms, and weeds near your plants. You will find yourself spraying every second day and still having dozens of thrips on your sticky traps instead of one or two.

When buying in plants consider receiving them without blooms if possible. If the supplier removes blooms before they come to you then you have removed 90% of WFT risk on those plants. That is one big step ahead.

Like other thrips, WFT is tiny and slender. It can and likes to hide away among petals. High pressure sprays and high volumes will help to find them but this is not possible with all plants. If you want your sticky traps to show no WFT from week to week you need to consider first-class spray equipment (high pressure and volume where possible) after establishing good hygiene — removing weeds and spent blooms.

Like other thrips, WFT lays its eggs into plant tissue. The female has twin saw-like blades for cutting slots in petals, leaves, and fruit into which eggs are placed. Here the egg is safe from predators and insecticides.

Another stage in the thrips life cycle that is sheltered from insecticides is the pupal stage. It occurs between the juveniles which can walk but don't fly and the adult which can walk and fly. Young juveniles can probably be carried on the wind. Juveniles and adults feed. Juveniles usually leave the plant to change into the adult stage via the nonfeeding pupa. These pupae are sheltered in the potting mix and leaf and bloom debris.

When you spray some of the WFT population will be at egg stage and some at pupal stage. These will survive. You need to repeat the spray when these have progressed to the next stage which is the feeding juvenile or adult.

To conclude on WFT:

- Once you get it, it is very difficult to eradicate.
- We have had success in a couple of cases where one thrip was detected on a sticky trap and immediate action was taken by destroying and spraying stock. Such action can be very expensive at the time but it is better than being encumbered with this pest.
- The physical layout of a nursery can facilitate eradication.
- If sticky traps are present and frequently monitored, and new stock is segregated from main production areas while it is assessed, there is a chance of nipping imported WFT in the bud.
- Once a few get established in your main production area you have to move on to long-term control though we are still attempting complete eradication at one site where hygiene and spray standards are very high.
- WFT likes white clover. It likes other weeds. If you are growing in-ground in poly tunnels you will have major problems controlling thrips while there are weeds present in your beds. They and all unnecessary blooms need to be destroyed frequently. Effort spent here will save you from the unpleasant task of donning a spray suit every second day. If you have white clover under growing benches then get rid of it. It is a reservoir for WFT.
- If you are using insecticides do it properly. A gentle mist may be necessary on expensive sensitive blooms but is very easy on the thrips. Unless you excite them with a synthetic pyrethroid spray they will stay secure in their hideaways where mist won't reach them. The best of chemicals will not beat poor hygiene and poor application.

ANOTHER NEW PEST — BEMESIA WHITE FLY

Bemesia white fly is also known as poinsettia white fly, silver leaf white fly, and tobacco white fly. In the southern states it is more likely to be a glasshouse pest. Like

WFT it infests a wide range of plants, transmits viruses, and can resist many insecticides after repeated exposure to them.

Glasshouse whitefly looks very like Bemesia white fly. Glasshouse white fly is widespread in Tasmanian glasshouses and in the field on the mainland, while the other white fly is absent in Tasmania but widespread in warmer mainland areas.

Control of breeding sites and restricting access to glasshouse is important in white fly control. There are very few insecticides registered for whitefly control so they need to be given the best chance by preliminary hygiene measures.

Fog in Propagation: My Personal Experiences

Ian Newman
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Use of fogging in propagation was "state of the art" 10 years ago when we first installed our system. The system we installed, called Microcool™, was manufactured in the U.S.A. It was purchased via a Melbourne company. This paper presents some of the strengths and weaknesses I have observed in this fogging system over time. My propagation experience prior to the installation was zero, so I am limited in my ability to compare fogging to misting.

Our set up involves six separately insulated, thermostatically heated benches. The fog is very fine, about 5-micron droplets, and is activated by a relative humidity (RH) control box. A wet/dry bulb acts as the sensor. The whole glasshouse is covered with a retractable shadecloth cover which we use in the hotter months. Normally RH is set at 80%.

Generally, I am happy with the system. It does allow for use of very soft tip cutting material, even in summer. The cutting medium doesn't stay excessively wet and we operate virtually organically, without use of fungicides. Little maintenance of the system has been required and it operates fairly automatically. Because of the fine nature of the fog, staff can work inside the house without having to turn the unit off.

The main problem that we had initially was hardware, specifically getting parts from the U.S. and noncompatibility of electricity supply. Although the local (Melbourne-based) agent was very supportive in their post sales service, I would recommend buying Australian made equipment if possible. Of an ongoing nature, drying out of the propagation medium from the base is a problem, we have to be very vigilant to prevent drying out of propagation media from the base. To overcome this some daily overhead watering is required. Uneven fog distribution means that cutting placement is something of an art, i.e., very soft cuttings go in the foggiest places! Regular checking of the wet bulb wick and filling up the wet bulb with rainwater is needed. Greater ventilation would also assist the operation of our house.

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So, You Want to Be a Proper Gator?

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Well, I have been asked to give you some handy hints about plant life, the universe and all that. Not being one to shy away from such a task here are ten hints that may, just, get you a little further along the path of your propagating career.

HINT 1. THE BOSS PAYS THE WAGES, SO THE BOSS IS ALWAYS RIGHT.

Well that's what they would like you to think anyway. I have found that in very small nurseries, the real boss is the partner who speaks less, works hardest, and gets little of the glory. Aim to please this person and you should be OK. In a big nursery forget the pay person, aim to get along with the head propagator. Now experienced propagators are not always friendly loving little creatures, you see they have a job to do and you can easily get under their feet. Accept this and take time to look, listen, and do WHATEVER they say. After all they have a history of success, and you don't.

HINT 2. DON'T TELL DIRTY JOKES AT I.P.P.S. MEETINGS.

Not to a full conference session at least. I have it on authority that it is a good idea to put a funny story in every presentation you give. I have found this prerequisite hard to achieve, as I have been endowed with a rather warped sense of humour. That means no one laughs at my jokes but me and I know very few clean jokes anyway.

HINT 3. IF YOU ARE GOING TO USE OVERHEADS WITH A TALK PLEASE CHICK YAW SPILLING AND DOUGHNUT REALLY ON COMPUTER SPIEL CHEQUES.

Technology is great, so long as your life doesn't depend on it. Check any overheads you may have for a talk and learn the lesson about microchips, **they are stupid**.

Hey! Forget working out which day it is, they can't even tell which millennium it is. Mix this with human frailty and you really do have a recipe for disaster. Remember this fact when you rely on the sprinklers working when you are out or the inventory being up to date when you need it.

I would not go away from the prop shed on 1 Jan. 2000, especially to go flying.

HINT 4. ANYONE WHO GETS 100% SUCCESS RATE DOESN'T (KEEP RECORDS THAT IS).

You can try, you can get things really moving, but a consistent 100% forget it. That doesn't mean you stop trying. There is nothing better than to get close, and brag about it. Get a book and keep your own records, put in the book everything you do in the minutest of detail. This is important particularly if you fluke a high take. Especially keep records of anything that has gone wrong, you may need the excuses later when your take really drops. It is surprising how many things you can forget without accurate records.

HINT 5. IBA AND OTHER HORMONES ONLY WORK ON PLANTS.

I guess some of you were waiting for this, so I decided not to disappoint.

My conclusion follows some discrete studies (made scientifically at the bar last night) that were somewhat inconclusive, depending how much the respondent drank and the company they were keeping.

There was a suggestion it helps a few studs, but maybe they were mixing it with other things... now there is a bit of research, I wonder if plants would take longer to wilt if you watered them with Viagra?

Seriously though, these chemicals are not play things and can cause serious health problems, far worse than pregnancy. Be safe and keep them away from your hands, mouths, or other body parts.

HINT 6. YOU WILL BE IN GREAT DEMAND IF YOU KNOW HOW TO PROPAGATE *IPOMEA HORSFALLIAE.*

This is the most requested propagation question at I.P.P.S. meetings. After you have cracked it, people will beat a path to your door. You will be feted, paid large sums of money, and generally seen as a great in propagation. For the first few weeks anyway until some one else claims that they told you how to do it months ago.

HINT 7. ASK NOT, LEARN LITTLE.

Keeping quiet has its benefits, but not at I.P.P.S. meetings. If you have a burning question no matter how basic, ask. If you have a suggestion, suggest. I have NEVER seen anybody ridiculed for asking a question or making a comment.

I have however seen plenty of people walk away without getting the answers they wanted because they were shy or nervous. The basis of I.P.P.S. is to share, so get yours.

HINT 8. PROPAGATING PLANTS BY CUTTINGS IS EASY.

If you start with good parent plants, take the cuttings at the right time, look after their every need, keep their bottoms warm at night, and have the right attitude you will have success. Sounds like it could apply to kids as well.

If you were to look up the Proceedings and see what is familiar about propagating all hard to do lines, and you will see that this is true.

Also remember to keep all your equipment clean. To do so use alcohol in liberal amounts.

You know maybe that is the way to propagate *I. horsfalliae;* try it out when you get back to work, and if it is a goer send me a card, attached to a pressie. If you are successful then I'll claim that I told you how months ago!!

HINT 9. YOU WILL NEVER KNOW IT ALL, BUT THAT SHOULDN'T STOP YOU FROM TRYING.

We all need a challenge, something to keep the mind in operation as well as the hands. So try to propagate the unpropagatable, you never know it just may be possible. Check out new techniques that may at first seem unbelievable. Sometimes the most offbeat idea works, so keep an open mind about any idea until you have proven it doesn't work.

Who would have though that smoke would have such a profound effect on seed germination? I wonder what the next breakthrough will be?

We have witnessed a real advance in propagation in recent years and yet we really know so little. The reality of living in the 90s is that things are changing faster than they ever have. It is quite possible that all that we have learned so far probably won't relate to tomorrows nurseries.

I can foresee that in the near future nurseries will be very different from what we now see. I bet that most will not even have sprinklers in 10 years time and be able to operate with nil runoff and sod all ground or mains water, as it won't be available.

HINT 10. IN THE END WHAT YOU GIVE IS EQUAL TO WHAT YOU TAKE.

Well the real lines are "and in the end the love you make is equal to the love you take" (Beatles) but that didn't neatly fit into our sort of propagation.

It is amazing that so many people still want to take and never give, they only look at what they can get without ever giving some back in return.

I have been around long enough to see that those who are open about what they do and share really do get ahead. This is why I.P.P.S. is so successful.

Being a good propagator is like taking a journey of discovery. Remember it is the journey that is important in life not the destination.

SO what of the proper gator of the future?

The propagator of the future will be highly skilled, a professional, sought after, and well paid. You don't get to the last point without the others.

I thought I would end with a graduated scale of measure for the successful propagator.

YOU KNOW YOU HAVE MADE IT AS A PROPER GATOR WHEN:

- You can choose the radio station at the work bench.
- Another nursery tries to poach you.
- Your propagation rate for grevilleas tops 80%.
- Des Boorman asks you for a propagation tip.
- Frances suggests you would make a good board member.
- Flash Gordon tells a story about you at a dinner.

What Makes a Weed a Weed?

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The quest to define the term "weed" is almost as interesting as the search to find successful methods of controlling weeds. The web site, http://www.geocities.com/researchtriangle/thinktank/8204 , records many attempts to define the term weed, including the following:

- "A weed is a plant in a place where it is not wanted"
- "Environmental weeds are plants that invade native vegetation, usually adversely affecting regeneration and survival of the indigenous flora and fauna"
- "Weed is a concept created by bipeds to justify the control and extermination of unwanted plants"
- "A weed is a plant whose virtues are yet to be discovered"

Weeds can inspire many emotions in people from anger and frustration through to admiration and passion. The botanist who named Shepherd's purse, *Capsella bursa-pastoris*, was deeply moved, not by the heart-shaped seed case, but by its resemblance to the scrotum of sheep.

What makes many plants so successful as weeds? Listed below are some of the features that would be possessed by the ideal weed:

High Seed Production. Shepherd's purse can produce around 30,000 seeds per plant while gorse, *Ulex europaeus*, can build up seed banks in the soil of over 100 million seeds per hectare (Parsons and Cuthbertson, 1992). In astrology, gorse appropriately typifies "cheerfulness in adversity"

Easily Dispersed Seed. For example:

- Wind: pampas grass, *Cortaderia* spp. and dandelion, *Taraxacum officinale*.
- Water: dock, *Rumex* spp.
- Birds: *Cotoneaster* spp. and blackberry, *Rubus fruticosus*.
- Ants: gorse.
- Cats: cleavers, *Galium aparine*.
- Grazing animals: storksbills, *Erodium* spp.
- Pod explosion: flickweed, *Cardamine hirsuta*.

Long Seed Dormancy. Gorse can retain up to 85% seed viability after 25 years in the ground (Parsons and Cuthbertson, 1992).

Rapid Growth Rates. For example: chickweed, *Stellaria media*.

Climbing Habit. For example: banana passionfruit, *Passiflora mollissima*.

Difficult to Remove by Hand. For example: sow thistle, *Sonchus oleraceus*.

Vegetative Methods of Reproduction or Spread. The "weeds of cultivation":

- Rhizomes: bracken, *Pteridium esculentum*.
- Bulbs: soursob, *Oxalis pes-caprae*.

Repel Predators or Grazing Animals.

- Toxic: ragwort, *Senecio jacobaea*.
- Spines: boxthorn, *Lycium ferocissimum*.

Tolerance to Chemicals. For example: to glyphosate — willow herb, *Epilobium* sp.

High Ornamental Value. For example: *Cotoneaster* spp.

Resemble Native Species. For example: Spanish heath, *Erica lusitanica*.

Be a Native Species. For example: *Acacia pycnantha* has now become a weed in parts of Tasmania following patriotic efforts to plant Australia's floral emblem.

Many of the plants given as examples in the above lists also may be regarded as virtuous weeds. Fennel, *Foeniculum vulgare*, frequently regarded as a roadside weed, is now widely grown as an essential oil crop in Tasmania. Variegated thistle, *Silybum marianum*, has long been recognised as a weed. However, attempts in Tasmania to cultivate it as a commercial crop for alkaloid production failed when the monoculture stands of thistles were ravaged by fungal disease. More recently I have heard of variegated thistle being used as a window box display plant, prized for its showy foliage and resistance to vandalism.

However, discovering a virtue or economic value for a "weed" usually raises a whole new set of problems.

Perhaps the most spectacular case of "virtuous weed syndrome" has occurred recently with St. John's wort, *Hypericum perforatum*. Despite being on the noxious weed list in several states, vast amounts were being imported by herbal companies as St. John's wort outsold echinacea to become the most popular herbal remedy in the world. With reputed claims of curing bed-wetting, insomnia, nervous problems, gout, witches, and the added bonus of being able to dream of future lovers the spectacular sales are not surprising.

Farmers who once battled St. John's wort are now being paid up to $1500 per tonne wet weight to grow and harvest the weed. This makes it more valuable than some pastures and now growers are trying to develop management techniques to suppress the weedy pasture and maintain purity in their stands of St. John's wort.

After all it is mainly a matter of how us bipeds view the situation. An article by Kate de Selincourt (1992) describes how Australian weeds such as *Hakea lissosperma* [syn. *H. sericea*], *Acacia longifolia*, and *Acacia mearnsii* are wreaking havoc on the South African native bush. Presumably they are replacing such delicate local plants as cape ivy (*Delairea odorata*), bridal creeper (*Myrsiphyllum asparagoides*), boxthorn (*Lycium ferocissimum*), and boneseed (*Chrysanthemoides monilifera*).

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Personnel Management in Practice

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INTRODUCTION

While much research has been undertaken on the technical aspects of plant propagation, little has been recorded about the equally important aspects of personnel management. Following a study trip to the West Coast of North America to look specifically at personnel management in propagation, an attempt was made to redress this imbalance by reporting my findings to the I.P.P.S.

Using the information and experience gained from my travels in the U.S.A. and from studying and observing personnel management techniques in the U.K., I will endeavor to explain what the benefits can be to staff, management, and the business. Putting personnel management techniques into practice is a challenge. This paper provides an account of how I have applied my findings while employed as a manager in the U.K.

MANAGEMENT STYLE AND STRUCTURE

Observations from my travels to the U.S.A. revealed two main management structures. Although the tiered management structure was in operation in the majority of the 15 nurseries visited, I found it was changing gradually to a flatter management system with fewer top level managers, but more middle managers and supervisors.

In my experience, putting the flatter management structure into practice has been successful providing one can recruit the right people who are suited to the job and to that style of management. Staff at all levels need to be keen and interested, reasonably assertive, good communicators, and be able to supervise and train others. The flatter structure is, in my opinion also a more humanistic structure in practice, because staff are involved at all levels and enjoy being on a more equal footing.

From experience I have found that changing suddenly or too dramatically from a more traditional management structure can have a negative effect. Any change over should be slow, gradual, and well communicated; otherwise you can find yourself in a situation of reduced staff morale, communication break down, and reduced commitment and interest among staff. Make sure you also allow plenty of opportunity for staff feedback about such changes.

RECRUITMENT

Generally speaking, in the U.S.A., staff are recruited by the manager. It is becoming increasingly difficult to find good staff both in the U.K. and in the U.S.A. Nurseries along the West Coast of the U.S.A. are increasingly dependant on Hispanic people to make up the main compliment of the work force. These nurseries recruit from advertisements in local newspapers, referrals recommending relatives or friends looking for work, and recruitment agencies.

In practice I found the second option to be the most successful of the three mentioned. Existing staff don't tend to recommend people unless they are confident that they will be able to perform well, otherwise they will feel responsible if it does not work out.

Recruitment Days. A system I would strongly recommend, based on my own experience, would be to hold recruitment days for specific vacancies. One U.K. nursery, Webbs of Wychbold, found these to be its most successful means of recruiting staff and recommended this system to me. In practice, I have found that staff of good calibre can be recruited when you advertise the position locally, open it up to all age groups, offer flexibility of work hours, and describe clearly what the work entails. It is also important to involve and delegate tasks to all key staff in the weeks leading up to and on the recruitment day.

When using recruitment days I have found that the majority of people who apply do tend to want to do nursery work and some of them have nursery experience. Offering flexibility of work hours means more interested people can apply and candidates can be given the opportunity to try out the tasks in various departments.

In my experience, seasonal staff recruited on recruitment day tend to stay longer, are more reliable, and are happy to return each year, while involvement of existing key staff in the recruitment process, perhaps even giving them the final decision on who they recruit, makes the choice a team effort.

There are some disadvantages when using this recruitment method. For example, the initial setup and organization prior to and on the day is labour intensive and time consuming. New staff may be required for different departments on various recruitment start dates over a period of several weeks. If you hold your recruitment day too early, successful applicants for the later start dates may have found employment elsewhere by the time you want them to start.

TRAINING AND INDUCTION

It is commonly said that staff are the greatest expense in a business but it must be remembered that they are also its greatest asset. Without staff that have been trained to do the job, productivity and quality both suffer. Frequently, there are too few skilled or supervisory level employees to teach and train unskilled staff, so the emphasis should be on teaching unskilled staff the basic skills to do the job. When equipped with the necessary skills they in turn can contribute to the training of new recruits.

The "buddy system" is used to good effect in nurseries I have visited in the U.S.A. It involves pairing an established worker with a new employee. Existing staff working to good standards of safety, quality, productivity, tidiness of work, and individual and team development can train new recruits.

In practice, the training needs of all staff from management to general workers should be taken into account and acted upon. At review time, staff should be encouraged and assisted to evaluate their own learning and development needs and to contribute to planning their future training.

Training for staff can be in the form of specific work activities, formal training either externally or internally, or formal education to achieve qualifications.

The Importance of Induction. Induction is very important, as it is the first real training that new recruits gain on nurseries. I put into practice an induction check list so new recruits are informed about all the relevant details relating to rules, guidelines, and orientation. Employee handbooks are also a very good idea both for helping new recruits become more familiar with the organization and as a reminder for existing staff. These are commonplace on nurseries in the U.S.A. It is important to ensure that such handbooks are regularly updated to remain effective.

ASSESSMENT AND REVIEW

On larger nurseries in the U.S.A. all staff, from managers to general workers, are assessed on an annual basis. Most use the so-called judgmental appraisal system for assessment. This takes into account the assessment of behavioral attributes as well as evidence of performance. This method of appraisal is traditionally carried out by the employee's immediate line manager, the most commonly used appraisal factors being job knowledge or abilities, quality and consistency of work, productivity, interaction with other staff, attendance, and time keeping.

In my experience I have found the self-appraisal system to be less confrontational than the above. In practice I encourage staff to carry out SWOTS (strengths, weaknesses, opportunities, threats) on themselves and I also carried out SWOTS on them. We then meet individually to compare the analyses. This way staff become less stressed and see the process as being more constructive. It is a good way of identifying weaknesses and putting the necessary training in place to improve overall performance.

Part of the review process should be to reward good performance. This can take a number of forms: pay increase, opportunity for promotion, profit share, performance measured bonus, acknowledgment of achievements, support for personal development training.

In my experience, when you put time and investment into good people and they feel supported, appreciated, and fulfilled in their job, they are more inclined to stay. As a manager I do not want to loose my most valuable assets.

COMMUNICATION

Good communication is a vital element in managing staff effectively. It is particularly important to communicate positively or you will "kill the spirit" — the ownership people feel about their work. If you have a problem, something negative to say, turn it into something positive, by coming up with a solution, or a suggestion for one. I have learned a great deal about positive communication from my contacts in the U.S.A., most of which I have been able to put into practice.

We all seek respect, staff just as much as managers, and if managers don't respect their staff they should not expect their staff to respect them. Don't rush to blame staff for things that go wrong, this is negative communication and it affects confidence and morale, which in turn affects targets and quality. Instead try to involve staff at all levels about decisions that affect them or the organisation as a whole. Practice an open door policy and let staff know that you are available to them should the need arise.

MOTIVATION

One of my main reasons for travelling to the U.S.A. was to try to find out how managers motivate their staff and, very importantly, what motivates the managers. The most important reply was, "I love my job, working with plants, and working with colleagues who feel the same way." Managers in horticulture certainly do need to be highly motivated, love what they are doing, and be happy in their work environment.

Motivating staff can be one of the most difficult parts of a manager's job. One common reason for lack of motivation is lack of confidence. Certain staff come across as being awkward and difficult, yet often it is because they are unsure about what is required of them. I have found that informal training sessions help and as confidence grows and staff are more comfortable in their surroundings, they become better motivated.

Money, of course, must not be forgotten as a motivating factor. However, it is by no means the main one. It is always nice to receive a pay increase but job satisfaction goes along way towards creating fulfillment. Most skilled propagators and managers are happy to be paid a fair wage for their skills, knowledge, and experience. Introducing a profit sharing scheme can have a very positive effect not only as a motivation factor but also to give staff a stronger sense of belonging and instill greater commitment. They can "own" a part of the business and it places the importance of the success of the business partly in their hands.

CONCLUSION

Effective communication between management and staff is the key to successful personnel management. Show sensitivity to the needs of staff. If staff know that you are there, not only to manage but also to support them, they in turn and for the most part, can be relied upon to support you. If mutual respect can be established between staff and management the benefits to the business are likely to be significant.

Much of what has been said about personnel management is simple common sense. We can all be guilty of breaching one or more of the basic rules. To avoid this, I believe regular self-assessment is critical to success.

Managing Labour Requirements in Nursery Stock

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INTRODUCTION

There is little doubt that the present difficulties associated with labour resources across the nursery stock industry are a major concern to nursery managers. They have in fact become a global problem and many nurseries now share similar concerns as much of the work remains labour intensive, so attracting considerable materials handling costs. Seasonal tasks such as potting, planting, order collation, and despatch are prime examples. Handling adds cost but adds nothing to profit. A further consideration is that the labour force now available to land-based industries, such as horticulture, has been in decline for some considerable time and there is more competition than ever before for good staff, particularly from the service industries.

Nurserymen now need to compete in an increasingly difficult and challenging global market which is frequently price sensitive. A declining labour force is one of several problems. Import competition remains fierce and to maintain profitability, disciplined cost control without compromising quality or service is necessary. It is a difficult balancing act for many businesses, particularly given the nature of the work, with labour resources frequently occupying a high proportion of the cost base.

PROMOTING HORTICULTURE AS A CAREER

The subject of labour resources embraces a number of issues including education and training. Clearly, there have been frustrations with the quality of graduates and new entrants and closer dialogue between the industry and educational bodies is very welcome. Some businesses have instigated their own in-house induction/ training programmes in response to these difficulties. Budget cut-backs in education have also been a contributory factor, leading to a greater emphasis on numbers, rather than the quality, of graduates.

Linked with education are image, profile, and the need to promote horticulture more vigorously as a rewarding and sustainable career. Clearly, there is a need for the industry to raise and maintain its profile, particularly at grass roots level, in order to establish a larger, better quality labour pool from which it can recruit more readily. Currently, there is a dearth of skilled and middle management personnel which is frustrating to many businesses. It undermines their ability to compete within a highly challenging market.

A further issue is the changing skills mix now required. While traditional skills such as budding and grafting remain important, new skills embracing computer technology, sales and marketing, quality management, and customer service are required to serve an industry which is becoming increasingly sales driven.

Legislation embracing the EU Working Time Directive and minimum wage are also of concern as price sensitivity continues while costs spiral, so placing margins under even greater pressure. Current proposals for energy and pesticide taxes provide further worries and could place additional cost burdens on many businesses so limiting employment prospects. Some businesses, however, are reducing pesticide inputs and costs by adopting a more integrated control strategy and there is increasing pressure from the market to do this.

STRATEGIES FOR THE FUTURE

Looking to the future, there are no easy solutions to many of these difficulties but future strategies will need to focus on three key areas:

1) Maximising the available labour pool through improving the image of horticulture and so broadening its appeal.
2) Improving labour efficiency through work study to develop better handling and transport systems, linked to coordinated nursery layouts.
3) Reducing labour dependency by increased automation and mechanisation.

It is important for the industry to promote itself more dynamically as it has many strengths. It is highly innovative and expanding. Never before have so many plants been grown for the retail and environmental markets. Future growth will provide good opportunities for the right people but the strengths of the industry need to be highlighted to attract good quality recruits. The image of the industry on the continent remains attractive to many Europeans in the trade and the use of foreign labour in the U.K. is likely to increase.

Many nurseries based in continental Europe have invested in increased mechanisation and improved materials handling systems in order to improve labour efficiency and reduce employment costs. Mechanisation can also be used to remove much of the drudgery from nursery work so enhancing its appeal to new entrants. Some nurseries are investing in sophisticated gantry and monorail systems to ease and speed labour intensive tasks, such as order collation and setting down. Such equipment may also embrace irrigation and spray application to create integrated systems with the potential to link with water recycling. Information technology to ease and speed repetitive tasks such as stock control, administration, and record keeping is also becoming more commonplace. Internet trading is likely to expand during the next decade.

Production is likely to follow a more specialised approach in the future in response to market trends and to facilitate greater mechanisation. It will also become more polarised, with larger units servicing the big landscape schemes and multiple retailers using outsourced or contract-grown stock. These units are likely to invest in more integrated systems linking gantries, mobile benches, and potting rigs with better equipment for spray application and water recycling. Sales, marketing, and transport costs may become shared, with the possibility of nurseries combining to set up regionalised distribution and sales centres.

Integrated pest management and plant growth regulators may also provide scope to reduce labour. Forward planning of nursery layouts so they progress in a coordinated way, linked to suitable handling systems, will also be essential if nursery stock units are to remain progressive and competitive. Potting systems are becoming increasingly mobile and mechanised whilst lifting equipment in the field continues to develop.

CONCLUSION

It is unlikely that the industry will ever enjoy the same degree of access to the labour force it once did. However, future prospects are bright for those who are innovative, forward thinking, and well motivated. The emphasis towards environmental issues is likely to accelerate and the garden market seems set to expand as the media profile and popularity of gardening continues to rise. It is important to take advantage of this and promote the positive features of the industry. This, combined with improved levels of labour efficiency, automation, and mechanisation is the way ahead.

The Influence of Government on UK Nursery Stock Propagation and Production

George Noble
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INTRODUCTION

The Government, through the Ministry of Agriculture, Fisheries, and Food (MAFF) has a beneficial interest in plant propagation and production and this can be illustrated with reference to two aspects of MAFF activity. First, there is the policy towards regulation of the sector and, secondly, its efforts through the research and development programme.

GOVERNMENT REGULATION

Much regulation is essential, for example to safeguard animal, public, or plant health or to protect the environment. Above all, Government priority through MAFF legislation is to safeguard the interests of consumers. Consumers need to have confidence in the products which growers place before them. Good regulation enhances consumers' confidence in growers' products and in the regulatory authority. That is the reason for the Pesticides Safety Directorate and for the Food Standards Agency which is shortly to be established.

Food Safety and Environmental Protection thus have priority under the MAFF regulatory programme. But the Ministry is nevertheless concerned to keep regulation to a minimum. The test for good regulation is that it should be transparent, properly targeted, proportionate to the problem, consistent in application, and those of us who make regulations should be fully accountable for them. Wherever possible, except in emergencies, the Ministry consults all those who would be affected by a new regulation and tries to let them know what its impact will be.

These arrangements apply where MAFF designs the policy and the legislation which implements it. It is not quite the same in Europe where the U.K. is one voice in 15. However, MAFF's representatives still seek to get the "better regulation" message across and, once regulations are agreed, the Ministry takes care not to implement beyond what is required. This is not always easy to do. Other member

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These arrangements apply where MAFF designs the policy and the legislation which implements it. It is not quite the same in Europe where the U.K. is one voice in 15. However, MAFF's representatives still seek to get the "better regulation" message across and, once regulations are agreed, the Ministry takes care not to implement beyond what is required. This is not always easy to do. Other member states sometimes have a different understanding of the nature of the problems to be addressed. European agreements on less regulation are not always easy to reach but the U.K. recently achieved such an agreement during the U.K. Presidency on Council Directive 91/682 concerning quality standards for the marketing of ornamental plant material.

Those working in the industry did not like the original directive. It was put into effect by MAFF in a manner which imposed the least possible burden on industry but it remained a problem, because it was highly prescriptive and badly written. The industry and MAFF agreed about the directive. When the Commission nominated the regulation under its SLIM exercise (Simpler Legislation for the Internal Market) MAFF was pleased. The Commission invited five officials from member states (not including the U.K.) and five industry representatives (including one from the U.K.) to a series of meetings in 1996 to consider the need for regulation in this area. The Commission then issued a proposal for simplifying and clarifying the directive in January 1998. The U.K. gave the proposal priority under our Presidency and reached an agreement which was formally adopted at the beginning of the Austrian Presidency as Directive 98/56. It entered into force on 1 July this year.

The new directive now applies to all ornamental plant species, rather than a limited list as before, but it is now confined to propagating material; there is a simplified registration procedure for producers and we generally now have something which industry accepts and agrees to be workable. This success partly arose because of the close consultation with industry doing the negotiations. When it came to implementation, MAFF arranged for the registration of suppliers to fit in with existing plant health registrations and inspection visits are included in existing programmes. It is to be hoped that there will be other similar success stories.

RESEARCH AND DEVELOPMENT POLICY

MAFF has an £11 m research and development budget for horticulture which feeds into the £3.5 m programme undertaken by the Horticulture Development Council. The objectives of MAFF's research and development programme are to encourage a competitive industry, encourage the production of safe and affordable plants, and to enhance the environment.

The programme is one of strategic science which means that MAFF is seeking to understand the complex interactions which are involved in plant growth and development. The programme centres on improving the understanding of mechanisms controlling vegetative propagation including plant/water relations in the establishment of cuttings, the process controlling rooting and subsequent growth, and understanding the qualities of material best suited for rooting substrates.

The MAFF programme on plant propagation at East Malling costs £400,000 per year from a total spent on research and development in hardy nursery stock of £1.5 m. The largest proportion of MAFF's budget is spent in the area of pest and disease resistance and control in order to reduce reliance on chemical control methods.

In addition, a hort-LINK project started in April 1999 on micropropagation of hardy ornamental species. The LINK consortium involves six industrial partners. A further LINK project, concerning improving water use efficiency in hardy nursery stock, is on the way and involves ten industrial partners plus the HDC and the HTA.

The Investors In People Standard

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INTRODUCTION

Investors in People is the UK's national standard which sets a level of good practice for improving an organisation's performance through its people. It offers a framework for integrating human resource strategy with business strategy.

The Standard helps improve business performance and competitiveness, through a planned approach to setting and communicating business objectives and developing people to meet these objectives. The result is that what people can do, and are motivated to do, matches what the organisation needs them to do. The Standard supports individual improvement and development.

It also draws on the experience of some of the U.K.'s most successful organisations, both large and small. It, therefore, provides a comprehensive benchmark of good practice against which any organisation can audit its policies and practice in the development of people.

The Standard assists in making effective use of all resources, by developing a culture of continuous improvement. This drives the organisation to higher levels of performance and enables it to manage competitively in the face of change.

THE BENEFITS

Investors In People works on the premise that "skilled and motivated people work harder and better." It is about results, not procedures. Significant commercial benefits may be gained by the organisations which achieve the Standard. These benefits begin to appear while working towards becoming an Investor In People.

The practical benefits of working towards and achieving the Standard are many. They include:

- Improved earnings, productivity, and profitability.
- Skilled and motivated people work harder and better.
- Productivity will improve. Extra effort will be made to close sales and a positive impact will be seen on the bottom line.
- Reduced costs and wastage.
- Skilled and motivated people constantly examine their work to find new ways of reducing costs and wastage.

Enhanced Quality. Investing in people significantly improves the results of quality programmes, adding considerable value to the International Quality Standard ISO9000 and other total quality initiatives. By meeting the Investors In People Standard, an organisation is putting in place processes which are key to implementing the European Quality Model.

Improved Motivation. Through greater involvement, personal development, and recognition of achievement, motivation is improved. This leads to higher morale, improved retention rates, reduced absenteeism, readier acceptance of change, and identification with the organisation beyond the confines of the job.

Customer Satisfaction. Investing In People is central to helping employees become customer focused. This enables the organisation to meet customers' needs effectively, at a profit.

Public Recognition. Investor In People status brings public recognition for real achievements measured against a rigorous national standard. Being an Investor In People helps to attract the best quality job applicants. It may also provide a reason for customers to choose your organisation's goods and services.

Competitive Advantage. Through improved performance, Investor In People organisations develop a competitive edge which secures their future prosperity.

In addition, working to maintain the Investors In People Standard offers organisations:

- The opportunity to review current policies and practice against a recognised benchmark.
- A framework for planning future strategy and action.
- A structured way to improve the effectiveness of training and development activities.

THE STANDARD

The Investors In People Standard is a cyclical process based on four key principles:

1) Commitment to invest in people to achieve business goals.
2) Planning how skills of individuals and teams are to be developed to achieve these goals.
3) Action to develop and use necessary skills in a well defined and continuing programme.
4) Evaluation of progress towards goals, value achieved, and future needs.

These four principles are broken down into 23 indicators and it is against these that organisations produce evidence for assessment.

ACHIEVING THE STANDARD

Investors In People is both a standard and a process, and becoming an Investor In People involves a number of steps:

- Understanding the Standard and its strategic implications for your organisation and its plans.
- Identifying the gaps between current practice and the requirements of the Standard.
- Making the commitment to meet the Standard, and communicating that commitment to all staff.
- Planning and taking action to bring about changes.
- Bringing together the evidence for assessment against the Standard.
- Recognition as an Investor In People.
- Working to keep the culture of continuous improvement alive.

GETTING STARTED

The Investors In People Standard is delivered through the national network of Training and Enterprise Councils in England and Wales, the Local Enterprise Companies in Scotland, and the Training and Employment Agency in Northern

Ireland. These organisations will provide access to guidance and other support. Many offer financial assistance as well as written materials, networking, and workshops.

What Will It Cost? The only direct cost is that of assessment. This cost will differ for each organisation and will depend mainly on the size and structure of the organisation and the number of employees. Many organisations benefit by focusing their existing training and development expenditure on what the organisation really needs without incurring additional expenditure. Savings and efficiency gains may also be made.

Who Will Be Involved? To become an Investor In People everyone working for the organisation will need to be committed to achieving the Standard. Senior management, union representatives, and all employee groups should take an active part. Initially you will need to gain the commitment of senior management, who in turn will need to approve and communicate the organisation's commitment to its employees and, crucially, to review the outcomes of working to the Standard to see how the business is benefitting. Experience shows that managers from operational, personnel, training, or quality functions are well placed for managing the overall process and sustaining momentum.

How Long Will It Take? The length of time leading up to assessment ranges between 6 and 18 months. The actual time taken will depend, simply, on how much there is to do and how quickly the required changes in the system and attitudes can be effected.

For Further Information. Copies of the Investors In People Standard and more detailed guidance on how to get started with Investors In People are available from your local contact or can be purchased from: Investors In People U.K., 7-10 Chandos Street, London, W1M 9DE. Tel:+44(0)171 467 1900; Fax:+44(0)171 636 2386; http://www.iipuk.co.uk

Using Investors In People at Hillier Nurseries

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INTRODUCTION

When a new member of staff joins Hillier Nurseries they receive, as part of their induction package, a brief explanation of the Investor in People scheme and how it works in practice at Hillier Nurseries. When the induction material was first written, soon after the company achieved the award in January 1993, this was needed because few people had heard of the Investor in People initiative. Today, in the U.K., 7.75 million people work for organisations which have achieved Investors In People.

Hillier Nurseries was fortunate in being offered an early opportunity to obtain the award as part of a pilot scheme involving a small number of businesses in Hampshire. It seemed to be tailor-made for the company as it comprised a framework which would use the various personnel and training initiatives already in place at Hillier, and integrate them with the company's business objectives. It would also provide the scrutiny and deadline of an external assessment.

It took 18 months for the company to be ready for our first assessment. Hillier has 16 retail and production sites scattered across the south of England and it was felt important that the scheme was explained personally to everyone involved. The practical and common sense approach of the scheme made it easy to sell. It is vital that everyone in an organisation, from directors down, is behind the scheme.

THE BUSINESS PLAN

Hillier Nurseries was already developing a 5-year business strategy under the Department of Trade and Industry's Business Planning Initiative and the subsequent rolling Divisional plans have probably been the most beneficial part of the whole Investors In People (I.I.P.) process. A small team, drawn from across Hillier Nurseries, developed a Training and Development policy that set out what staff can expect throughout their career with Hilliers, from induction training onwards, with the aim of developing everyone to their fullest potential and provide the maximum job satisfaction. In addition, the company needed to identify from the business plans what staff development was needed to make the plans work. This formed the basis of detailed departmental plans and budgets. These can and do change during the year to take account of new staff or internal promotions. In cash terms, the company will have spent around £50,000 in this financial year. This is no more than the amount spent before the introduction of I.I.P. but the company believes it will achieve better results for the same amount.

THE ROLE OF I.I.P. FOR THE INDIVIDUAL STAFF MEMBER

Each member of staff should be aware of how they contribute to the overall plan by way of their personal objectives and the importance of their contribution. We do this by regular individual performance reviews when training and development needs can also be identified. Of course, many Hillier staff have been with the company for a long time and are highly skilled in what they do. We do not train for the sake of it. Their needs could be linked to expansion of their role or changes in the way the company does things. New or younger staff will need more training input initially as they learn the skills required to meet the Hillier standard. A lot of development goes on without people realising it is happening. Everyone learns on the job, developing their skills and knowledge or learning from others, visiting other organisations, and attending conferences or trade shows. The list is endless. Training is going on somewhere in the company every day.

REQUIREMENT FOR INTERNAL COMMUNICATIONS

A key requirement of the I.I.P. standard is effective communication. Because of Hillier Nurseries' scattered locations, the company has not found it easy in the past to ensure everyone has access to complete and accurate information. Misunderstandings can even arise when people work side by side. The company believes it has made improvements in keeping all staff regularly informed of progress at company, division, and local level. Team briefings for each nursery section or garden centre are based on a Core Brief which comes from the monthly company board meeting. Newsletters, noticeboards and, now, email are also useful ways of getting the message across.

BENEFITS FOR THE COMPANY

At the company level, the benefits of I.I.P. have mainly resulted from the business planning exercise and seeing many of the targets achieved or surpassed due to better and more focussed management coupled with opportunities for individuals and teams to set their own objectives and initiate their own solutions to problems. There is more flexibility to react more quickly to customers' requirements — an emphasis on improving quality. Overall, there is now a confidence to make capital investment for the future.

CONCLUSION

Is all this training achieving its objectives? Is it value for money? Could it be done differently? These are the questions that are probably the most difficult to answer accurately or immediately — unless it's the gaining of a practical skill that can be put to use instantly. The benefits of a management course can take some time to show in the results but the I.I.P. standard does ask management to evaluate the benefits and, although it's not easy, there is plenty of guidance on sensible ways to do this.

There is nothing particularly novel about the I.I.P. Standard. Most well run organisations use these or similar principles. What is different is that at regular intervals there is an in-depth unbiased external view of how well you train and develop the people who make up your business to make it more productive and profitable.

College-Based Training for the Nursery Stock Industry

Roger Bentley
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INTRODUCTION

Commercial horticultural production in the UK is based on approximately 10,000 holdings employing 60,000 people, including proprietors. There are 25,561,000 working people in the UK so the industry represents about 0.2% of the working population. Ongoing technological advances and large-scale investment in plant propagation over the last 30 years has meant that the industry's need for technically and managerially skilled staff continues to rise. In the period 1950 to 1980 the industry was adequately supplied with staff, recruited locally or via the land-based colleges. More recently there has been a serious shortage of suitable new staff in virtually all areas of production horticulture, with many advertisements for both technical and managerial staff failing to attract the desired applicants and the majority of enquiries to colleges failing to yield any candidates at all. The incentive to attract good staff and develop existing staff to their full potential has never been greater.

TRAINING OPTIONS FOR NEW RECRUITS TO THE INDUSTRY

Degree Courses. For school leavers, or people changing careers from other industries, a wide range of full time degrees (BSc) in horticulture is now available. Most of these have options in both amenity/landscape and crop production, which will give a sound introduction to plant propagation methods even if time limits the student's ability to develop expertise in practical skills. Degree courses are all studied over 3 in-college years. Some degrees offer a sandwich placement which gives the student the chance to acquire practical experience with an industrial employer.

Higher National Diplomas. These are studied over 2 in college years. Higher National Diplomas (HND) in horticultural production (or variations on horticultural production) are available from several of the colleges. Writtle College offers a nursery option which majors on, although is not exclusively confined to, nursery practice. Higher National Diplomas all include a period spent on an industrial placement, although the duration ranges from 1 year to as little as 6 weeks in the spring or summer, depending on the programme selected.

National Diplomas. BTEC (British Technical Education Council) National Diplomas are 2-year college-based courses. The plant propagation and nursery stock content varies with some crop production, amenity and plant production and garden centre management having a substantial amount whereas other amenity and commercial options major on landscape maintenance and edible crop production, respectively.

Pershore and Hindlip College, and Hadlow College, offer a dedicated Nursery Stock option and Merrist Wood College an option in Plant Production and Garden Centre Management. National Diploma courses usually offer a 1-year industrial placement period although this is now invariably optional. One year National

Certificate courses in Crop Production/Nursery Stock Production are available at several colleges and usually reflect the provision offered at National Diploma level.

Entry Qualifications. Usual entry requirements for degrees are two GCE "A" levels. For HNDs the requirement is one GCE "A" level. For the National Diploma it is 4 GCSEs at grade "C" or above[1]. In all cases exceptions may be made for candidates who are over 21 years old offering alternative qualifications which can be deemed to be equivalent.

TRAINING FOR AN EXISTING WORKFORCE

Modern Apprenticeships. This is usually available through the Modern Apprenticeship Scheme, where the local Training and Enterprise Council (TEC) subsidises the training by making an award to the training provider. This averages around £4000 per qualifying Modern Apprentice but the figure varies between different local TECs. A Modern Apprenticeship is available to young people up to the age of 25. A wide range of occupational areas are covered, 60 in all.

A condition of Modern Apprenticeship schemes is that they must include training up to National Vocational Qualification (NVQ, see below) Level 3. An employer can offer a reduced rate of pay to Modern Apprentices during their training and, because the employee is in training, this can legally be below the current National Minimum Wage. However, under the scheme the employer must undertake to give the trainee access to specified NVQ2/NVQ3 training within an agreed period of time and must cover associated costs such as travel to a college to undertake NVQs. The employer is not bound to retain the Modern Apprentice at the end of the training period.

Older Employees. For employees over the age of 25, colleges will usually offer the same NVQ programme but at a fixed tariff which may be paid for by the employer or student. This scheme is sometimes known as Career Link. This is still partly subsidised by Government because the College can access Further Education Funding Council monies but at a much lower rate than for Modern Apprenticeship funding. Short-term training courses for pesticide application, chainsaw use, and fork lift truck operation, to prepare staff for legally required test certification, are available from most of the land-based colleges.

NATIONAL VOCATIONAL QUALIFICATIONS

National Vocational Qualifications are made up of units and there are no time limits, age limits, or entry qualifications imposed by the awarding bodies. They are intended to be undertaken in the workplace or at least a place which simulates a candidate's workplace.

There are two aspects to gaining NVQs. One is the Performance Criteria which is a record of the candidate's ability to perform a set task competently and the other is the Knowledge Specification which is a record of written or oral questions. These questions test the candidate's knowledge which would be required to perform the task. National Vocational Qualifications are very much an active learning partnership between the trainee, employer, and the training provider and some workplace assessment will be normal.

[1] General Certificates of Education at Advanced level are the UK standard academic qualification studied between the ages of 16 and 18. The General Certificate of Education are the UK standard school exams at age 16.

Nurseries training plant propagators are most likely to encounter the NVQ Levels 2 and 3 of the City and Guilds 0135 scheme Intensive Crop Production although an older scheme 0133 Nursery Stock Production is still in use in some centres. The concept of Level 2 is that the candidate shows that they have the ability to do the job whereas Level 3 is intended to reflect an ability to plan and manage the task. Both the NVQ Level 2 and the NVQ Level 3 have six mandatory units and three out of a choice of eight optional units which include: "propagate plants from seed" and "propagate plants by vegetative methods" for the NVQ Level 2; and "plan and manage propagation from seed" and "plan and maintain the production of plants by vegetative methods" in the case of NVQ Level 3.

The choice of units and the fact that candidates are not compelled to take a propagation unit is in line with the NVQ philosophy of open access to anyone working in the industry. For example, someone working on a nursery which grows-on plants bought as liners should not be prevented from qualifying; although his or her certificate will not show any propagation accreditation. It is very much up to individual nurseries to agree the units which they wish their candidates to cover in order to best suit their business requirements.

PROVISION OF IN-HOUSE NVQ TRAINING BY INDIVIDUAL NURSERIES

There is absolutely nothing to prevent an employer giving informal training on an ad hoc basis. Only colleges have access to Further Education Funding Council monies and therefore career link NVQ training, but it is possible for any nursery to undertake its own Modern Apprenticeship training and hence claim funding from its local TEC.

There are several possible sticking points but none is insurmountable. One is that only Awarding Body Accredited Centres can award NVQs. A nursery is unlikely to be able to get true centre accreditation but it could apply to a local college or other training provider to become a sub centre site and thus latch on to their centre accreditation. A local college will probably request a fee per candidate but would in return provide guidance with paperwork as agreed, including help with negotiations with the TEC, registration of the candidate for accreditation, submission of the results to the awarding body for certification, and verification of a sample of both practical assessments and completed NVQ portfolios. The awarding body will insist on a sample of work being internally verified (inspected and approved by a suitably qualified person other than the assessor) in order to ensure an adequate and consistent quality of assessment.

Another possible stumbling block for the in-house trainer is whether the trainer is qualified to assess NVQs. The qualifications for this are Training and Development Lead body (TDLB) D32 (Assess the candidate) and D33 (Assess the candidate using diverse evidence). A nursery will only be able to assess its NVQs in house if a member of staff enrolls on a D32/D33 assessor programme. The D32/33 qualification is also obtained by completion of a portfolio to show that the trainer is a competent assessor. Many colleges offer "D" qualification guidance courses which are normally of 2 or 3 day's duration, plus telephone or visit support. A few TECs refuse to deal directly with production businesses as training providers and will only deal with colleges and other specialist training organisations.

TRAINING TO HIGHER QUALIFICATIONS FOR THE EXISTING WORKFORCE

Some colleges offer BTEC Higher National Certificates in crop production to be studied on a day-release basis over 2 years. These consist of 10 units and have a content which, when combined with work-based projects, is the academic equivalent of a BTEC Higher National Diploma. It is possible, by studying further part time modules, to convert an HNC to an HND if desired. Staff may wish to pursue post HND/HNC part time academic study. Degree courses can be offered at the discretion of awarding universities, typically over 2 days per week over a 2-year period. The availability of such courses will take into account the potential applicant's suitability and the structure of the course, so the possession of an HNC/HND will certainly not guarantee acceptance.

CONCLUSION

Training and education currently available in the United Kingdom appears to be complex in structure and the presence of different Training and Enterprise Councils do mean that access rules are not universal. However, in terms of both location for study, accreditation, and potential progression right up to degree level there is more scope for achievement and recognition for people in employment than at any time in the past.

Horticultural Study by Correspondence

Oliver N. Menhinick
The Horticultural Correspondence College, Little Notton Farmhouse, 16 Lacock, Chippenham, Wiltshire SN15 2BR, U.K.

INTRODUCTION

The first correspondence college was the International Correspondence School which started in 1887 in America. It is now big business and all the colleges not already offering open learning or distance learning packages are catching up as fast as they can. The Horticultural Correspondence College (HCC) in the U.K. was started by a Mr. Ibbett in the early 1930s.

THE HCC CORRESPONDENCE PROGRAMME

Each student member receives lesson texts (usually 10 in all) to work through. These contain both information and questions. Some contain self-assessment material. The courses may commence at any time of the year and the college does not require answers back at specific intervals. The member is invited to send in their worked answers to the set questions. These are marked by their tutor, who returns the work together with a set of specimen answers, a marks profile, and a letter of encouragement. Most student members take about 1 year to complete a course. Help with further information is available from the tutor appointed by letter, and from ourselves via post, telephone, fax, and Internet.

When the student member is half way through there is a review of their progress and at the end of the course the tutor makes his or her recommendations for a grade

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When the student member is half way through there is a review of their progress and at the end of the course the tutor makes his or her recommendations for a grade of certificate. The student member is invited to comment on the course programme at the beginning, the middle, and at the end. This has been very helpful in eliminating weak areas from our delivery and packages.

BENEFITS OF CORRESPONDENCE LEARNING TO EMPLOYEES AND EMPLOYERS

Learning Basic Principles. During the working day employers rarely have time to spend with a staff member to explain how and why it is important to take certain steps. Even the most fundamental factors are frequently not appreciated and these may influence issues including growth rates, plant quality, and the use of resources. A correspondence programme of systematic study, working through texts and occasionally references, can be used to provide a foundation of knowledge.

Appropriate Use of Horticultural Technology. There are similar rhythms for the cropping cycles and activities from seed time to harvest. All horticultural crops have a cycle of growth and development. It is not always easy, with the demands of the working day, to see that there is this common pattern and that a management strategy can be developed to make the best use of the time, equipment, energy, technology, and skills available.

It is often useful on a nursery if members of the craft team are familiar with this kind of thought process. If someone is thinking alongside the management then there has to be a bonus if they are really interested in what is going on; they can be co-operative in different ways including anticipating future needs and in noticing and reporting at the time when there is a chance that something is going badly wrong. While some craft teams may be concerned only with the "Thank God its Friday Pay-day" moment, there may be others who are more closely involved and who have a feeling for a shared objective. These people may be the ones who will ensure that the plant material or other work in hand is left in the best possible order on Friday at the end of their shift.

Aspects of Concern to Management. These may include the importance of following instructions, and of not making changes to rates of application of liquid fertilisers or in recording the use of pesticides, as just two examples. Some employers may find it possible to set aside study time for an employee at specific times but for the majority, correspondence study means staff are able to contribute a full working week. The HCC finds very few of its student members obtain any study time off, except perhaps for examinations and there is very little for their staff manager to do other than to monitor progress from time to time.

Improved Morale. As an individual begins to gain knowledge they gain self-confidence and an appreciation of the value of work done well. Work becomes more interesting and indeed the individual may come to work better prepared to do the job in hand, more fully resourced both in mind and spirit to do the work required — hopefully with a more flexible approach to the need for change, with a faster learning curve and especially where his/her studies have a relationship to the work. To a certain extent knowledge is power and most employers highly value their knowledgeable team members who understand and can express themselves.

It is important that an employer notices when their employees have begun to improve and that the staff member knows how to bring their zeal to the attention of their employer in the most appropriate way. It may or may not be fashionable to work willingly and hard. In a team it may be only the line manager who knows who is delivering the most and it may be that a good worker represents a threat to that person's employment "if they should rise above their station". Most employers are probably very glad to see their staff enthusiastic for study.

THE IMPACT OF CORRESPONDENCE STUDY ON STAFF MOVEMENT IN THE HORTICULTURAL INDUSTRY

The HCC receives many enrollments from individuals who seek to enter horticulture and some undoubtedly do. We only know if they tell us and it has not been our policy to keep a database with this type of information. So far we have not developed a specific course programme on plant propagation but a course is in preparation.

The bulk of our work is for the amateur gardener. Most of the HCC College Members study for a year, either for an examination such as the Royal Horticultural Society's General Examination in Horticulture or for the knowledge that is gained by working to a study programme, for which HCC offers a course completion certificate. A good number continue to study for a further year or more on related courses. The HCC claims that its Course Completion Certificate, coupled with the student's portfolio of work would provide a powerful piece of evidence about the enthusiasm, knowledge, and dedication for that individual. Handed over at interview this material does enable the employer to ask questions and test the insight of the candidate.

For the employer whose staff undertake such a course there is sometimes the fear that it may enable an employee to seek greater rewards elsewhere. This is balanced when an employer advertises for staff and finds suitable candidates who have already benefitted from correspondence study.

COURSE DEVELOPMENT AND ACCREDITATION

The HCC maintains accreditation and membership of the Open and Distance Learning Quality Council. It is costly but provides an external assessment of validity.

HCC commissions new texts from its own tutor group or from other specialists, edited by an external editor and proof reader.

Offering student programmes via the Internet seems the most likely next development.

From Employee to Employer: Experiences of Acquiring a Nursery Business

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INTRODUCTION

Eighteen months ago I left a very good job on a large nursery to buy an existing small nursery. It is approximately 0.5 ha, half of it under protection.

Like many I.P.P.S. members, I went into the nursery business because of a love of plants but as I moved up the career ladder I found myself managing people, becoming increasingly office-bound, and having less to do with plants. Acquiring a nursery of my own seemed a good way of getting back to plants but with the added challenge of running a business.

To build up a nursery from scratch takes time and buying an existing business outright requires capital. I was fortunate to come to an agreement with two of the existing shareholders at Chevin Nurseries: I bought the majority shareholding with the agreement of buying the remaining shares by the end of 2000. Mike Booth, the other shareholder and director, agreed to stay on to help me settle and learn the business. I was very lucky to step into an established business with a good customer base and a good reputation for quality.

The production consists of contract propagation from January to June for a major pot and bedding wholesaler; and growing on of 9-cm basket plants, hanging baskets, pot and patio plants, and hardy fuchsias for local garden centres.

DIFFERENCES IN THE NATURE OF THE JOB

My role is now a much wider one. For example, I plan the production as well as the cashflow; I see customers as well as suppliers; I negotiate wages with the employees and the overdraft with the bank manager. It is more varied and interesting than doing a specific job for a larger nursery.

Chevin Nurseries is a limited company and technically I am still an employee. I do not see the company as mine but as a separate entity with all the people who work for it having a stake in it and I believe that it is right to share the rewards if there are any.

At the same time I am well aware of my investment, the stake that I have in the business and the need to provide a return for my business partner and myself. Perhaps the greatest difference between being employed and running your own business is that in the latter case you are much more directly responsible for you own earnings.

REBUILDING PRODUCTION

Mike Booth was approaching retirement and wanting to sell the business and had been slowing down so we had to plan to build it back up and increase sales, revenue, and profitability. One of the first things I did was put together a computerised budget and cash flow based on the past year's sales and expenditures. I feel that financial planning is very important. It keeps the bank manager happy and it gives me confidence and peace of mind. If you know on a monthly basis where you are with regards to sales and expenditure you can take corrective action before it is too late.

We have found the Nursery Business Improvement Scheme run by the HTA, whereby local nurseries meet quarterly and compare their costs, to be very useful and I would urge I.P.P.S. members to get involved. The more nurseries involved the more useful the scheme will be.

Once a provisional budget was put together, we planned the production, tying it carefully to sales. It is no good deciding to increase the sales budget without making sure there is the time, space, and other resources to achieve the extra production, and that you have a market. Chevin Nurseries does not trade at all and relies exclusively on its own production for its revenue. The main aim of the production strategy was to achieve a faster turn around of crops, growing more in the same space to increase productivity. Standard turnaround for propagation is 8 weeks and the nursery is so full and busy with propagation from March to June that it is always difficult to ensure that the potting for garden centre sales is done on time.

The nursery is well equipped, with two of the three glasshouses having benches with hot water heating, and the bigger glasshouse has mobile benches. There are air heaters and frost protection in two tunnels. In the last year we have invested further in labour saving equipment. For example, we used to deliver in a van fitted out with shelves, but we decided that it was time to move to Danish trolleys and buy a lorry with a tail lift, this has saved us a lot of double handling. We have also bought a Danish trolley transporter to move plants outside and in the tunnels directly onto Danish trolleys.

We have automated the irrigation system and aim to carry this further so that very little hand watering needs to be done, although I believe that you cannot totally eliminate hand watering, particularly for plug production, as it is so important to plant quality.

MANAGING THE EXISTING WORKFORCE

The experience has been in many ways very similar to that of an employee starting a new job. At first Mike Booth was very helpful and made allowances for my mistakes. The staff were cautious and I was aware that they were watching me and probably wondering "does she really know what she is doing?" I also found myself watching Mike Booth, mainly to see how he ran the business. I did not realise at the time but he was aware of it and it created some tension. Just as in a new job, you have to prove yourself and gain respect and it takes time.

When you want to introduce change, you therefore have to do it slowly and cautiously and have a good reason for doing it. This is easily forgotten when you are keen, and you want to make improvements. It is not always easy to ask why something is being done a certain way without making it sound disapproving. I am not a very patient or diplomatic person and this added to the tension. There were many times when one of us has walked off and one memorable occasion when both of us shouted at the other "I've had enough, I'm off." But of course neither of us were off; we have nowhere to go. But after some months, we began to understand each other and to work together and we now get on very well.

I now realise that I am still working with people, so in some ways it is no different from the job I was doing as an employee. Being a small company we are a very skilled and committed team. We all get on well and everybody is willing to contribute comments and advice. We all get involved in most things — taking cuttings, potting, talking to customers.

DISADVANTAGES OF BEING YOUR OWN BOSS

You work long hours and every bank holiday; it is more difficult to delegate because there are so few of you and you have to rely on yourself; you cannot leave jobs that need doing in the hope that somebody else will see to it because most of the time there is nobody else; you cannot pass on responsibility; you make your own mistakes but hopefully you learn from them.

Having two partners in the business helps a lot, there is somebody to bounce ideas on and I can always rely on Mike Booth to bring me back to earth with a bang when some of my ideas are not practical.

THE FUTURE

The main question is how much to expand, and in which direction to expand — propagation or saleable crop. We could sell more if we had the space and we need to increase turnover and profitability. However I am reluctant to employ more staff, loose touch, and have to spend more time in an office. I would like to earn a reasonable living and enjoy the work I do.

CONCLUSION

In conclusion having your own nursery is not for everyone, you need to be bloody-minded and have good nerves. It is stressful and tiring and there has been times when it has seemed too much, but that is no different to most jobs these days. Mostly you are in control and that makes all the difference. There is a lot of satisfaction in seeing a trolley full of good quality plants going out of the door, and to feel responsible and proud of it. You feel even better when you get the cheque in the post.

The Use of Gang Labour for Nursery Stock Production at Darby Nursery Stock Ltd.

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INTRODUCTION

Darby Nursery Stock Ltd. is situated in a region of intensive agriculture and horticulture. Agricultural production is predominantly on arable farms growing cereals, sugar beet, and potatoes. Horticultural production is mainly field-scale vegetable and soft fruit production. Because of this high density of growing, related companies, such as vegetable processors and packers, have also grown up in and around this area.

The labour requirement for this type of industrial production is still relatively high. However the demand is seasonal. Planting and harvest often requires a high labour input. To fulfill this short term need growers will often really on seasonal staff in the form of gang workers.

THE GANG SYSTEM

The gang system started during the 1920s. It helps to fill the gap in the labour market created by this seasonal staff requirement. Individual workers are employed by a central "gang master" who is then employed by the grower to supply the labour for their job. The advantage for the grower is that they only have to contact one person when looking for a large number of seasonal workers. For the workers the advantage is that their gang master will have several contacts with growers and land-based industries that should provide a whole season of work if required.

Darby Nursery Stock Ltd's use of gangs has developed alongside the growth and development of the nursery. The nursery once formed part of Darby Brothers Farms which was established in the 1950s and was originally involved in growing vegetables, such as celery, lettuce, and radishes. As part of this production, processing and packing units were also set up. Darby Brothers then started a fruit propagation unit, producing soft fruit plants for the fruit production industry. The fruit propagation fitted nicely with the vegetable growing giving a year round production process. Shrub propagation started soon afterwards and was linked to the fruit propagation until the development of the garden centre market in the 1960s and 1970s meant a rapid expansion in the nursery's shrub production. This gave rise to Darby Nursery Stock Ltd which has been trading as a separate company ever since.

The nursery sells container-grown plants to garden centres and retail stores through the Anglia Group, a marketing organisation. Darby Nursery Stock propagates 90% of its stock, sticking around 4.5 million cuttings last season. It grows a wide range of plants but specialises in lavenders, conifers, container-grown trees, climbers (particularly clematis), and soft fruit (especially strawberries).

The farm had traditionally used a large amount of gang labour, both on the field and in the processing and packhouse areas. Fruit propagation also requires gang labour during lifting and grading processes. Initially the shrub propagation operation only needed a small labour input. However with the rapid expansion of the nursery, the requirement for seasonal labour also increased. Today the nursery employs up to 10 gangs during the busy spring season. This gives it an extra 200 people to work with and they work in every department on the nursery.

Two different types of gang are used. Firstly there are skilled gangs, used for a certain job such as propagation or potting throughout the season. These gangs are smaller in size and often the gang master works alongside the gang members. They tend to have several long-term members who come back year after year.

Secondly there are larger, less specialised gangs. These gang master might have several buses going out each day to a number of different locations throughout the area. These gangs are used for general work on the nursery such as pruning, weeding, plant moving, etc. One of the main differences between these two gang types is that the smaller skilled gangs are based locally to the nursery and are generally made up of ladies from that area. The larger gangs are based in the big towns and are often made up with students and foreign workers. For Darby Nursery Stock these larger gangs mainly come from Kings Lynn and Norwich areas.

MANAGEMENT OF THE GANGS

When employing an extra 200 workers from several different gangs it is important that there is a method of recording who they are, what they are doing, and how much they are being paid. This sounds easy but the personnel within the individual gangs can change day by day, with several gang members only working part weeks. There is also a legal requirement to record the total payments made or given to each gang master per year (Section 16 *Taxes Management Act* 1970). This information has to be sent to the Inland Revenue Agricultural Compliance Unit.

The information for this is gathered and entered onto a form called the ACU2. This is filled in each week by the gang master and sent back to the nursery. It includes each gang worker's name, their full address, national insurance number, and how much they have earned during that week. They also enter the hours worked each day. At the end of each financial year the nursery sends all of the ACU2s to the Agricultural Compliance Unit along with the covering form the ACU3. To ensure that the ACU2s are returned quickly the nursery will not pay the gang master until the forms are received.

There is also an ACU1 that the nursery has to fill in when it takes on a new gang or an existing gang changes its name. The nursery has developed a Gang Labour Time Sheet which is filled in each day by the foreman for whom the gang has been working. The information gathered on this form is the gang name, the job they have been employed on, wherever it was days work or piece work, and the time spent on this job. If the job was on piece work the rate and total are also written down. The gang labour time sheet is also accompanied with a signing sheet which has to be signed by all the gang workers who have worked that day. The information given on these forms is used to cross check the information that the gang master enters on the ACU2.

Where possible the gangs work on piece work. The rates are set by the managers and are all given as a price per ten. The piece work sheets are used to record this, these are used when filling in the gang labour time sheet, a copy is also given to the gang worker to give to the gang master who uses it when filling the ACU2. All piece work sheets are filed and are used for reference when setting new rates. When work is done on days work, a daily tally sheet can be used to record work rate, this is also used when setting piece work.

A "gang worker skills form" has recently been developed as part of the nursery's health and safety policy. On this several different nursery jobs are listed, such as cane placing and tying, tractor driving, working with a potting machine, etc. Each worker has one of these forms and when they have been trained to do one of the jobs listed, the person doing the training signs the form. This then enables the gang worker to carry out the job. This gives the nursery a record of which gang workers we can use to do certain jobs.

JOBS FOR WHICH GANGS ARE USED

Gangs are used in almost every aspect of production from taking cutting material through to packing the orders just prior to despatch. Whenever gang labour is used the work is overseen by a full-time member of staff, generally a supervisor. This is particularly important when gangs are on piece work because the required standard of work has to be closely monitored and if substandard work is done then the gang is asked to redo the job in their own time. The supervisor is also there to count what has been done during the day and then enter the information on the relevant form. When working on piece work the gang is also required to tidy up at the end of the day and the time spent on this is included in the piece work rate.

Potting. The nursery undertakes both machine and hand potting. Hand potting is generally done from mobile benches situated close to the beds that are to be potted onto. Potting is carried out generally in pairs and the piece work rate includes knocking out and standing down. The total potted each day is divided by two to give each worker their pay for that day. Therefore, the two gang members have to work as a team and we find that most gangs can be subdivided into pairs of workers who will work together.

Machine potting is carried out by a larger team, however the same principle of the total potted divided by the number doing the job is still used when they are potting on piece work. A full-time member of staff is used to control the machine (i.e., to set pot size, drill depth, and speed). They are also responsible for any plant change-overs as well as correctly labelling the plants as they go out of the potting shed. This is important because most gang members have no horticultural background and are not really interested in plants. The machine potting also includes the standing down and the plants stood down are the only plants counted when piece work rates are being worked out. Knocking out and grading is done by a separate team who are also paid by piece work. These piece work rates change with different types of plants, for example more is paid when climbers are potted because they have to be caned before leaving the potting shed. Potting starts in February and continues until June and gang work is used throughout this season. At its peak up to 50 gang workers can be potting on the nursery.

Pruning. This is also carried out by piece work. The rate changes with the type of job required. When pruning on piece work, most gang workers will try to move the plants as little as possible, therefore, when the plants are stood down a special configuration is used enabling someone to work through a bed with out having to move any plants. To give a uniform job only one person per bed is allowed. This also helps the final counting. Sample plants are used to show what is required and these are often done by the manager with the supervisor before the gangs turn up for work.

Moving. When plants have to be moved and spaced this can also be carried out by gang workers on piece work. This is carried out in pairs. They are given a moving sheet that gives information about the plants to be moved, their location, and where they are to be moved to. The number of plants moved has to be entered on this sheet and this information can be used of the piece work price.

Caning and Tying. Caning and tying is generally done in a similar way to pruning in that one person works per bed. The piece work price varies between the type of plant and the amount of growth needing to be tied. An important thing to consider when putting people on piece work is that the equipment that they use should be in good condition. Gang workers will not have any tools and the nursery has to supply all their needs. At Darby Nursery Stock a large stores holds several secateurs and Max Tapeners. These are regularly serviced and sharpened to enable the work to be carried out as fast as possible.

GANG WORK IN PROPAGATION

Last season more than 4 million cuttings were propagated with a full-time staff of only six people. Skilled gang labour is used to supplement the labour requirement during the busy periods. At peak demand there are more than 22 gang workers solely working in propagation. The gang are used in every aspect of propagation from the collection of cutting material through to the moving of cell trays into the liner potting shed. The only jobs that are not on piece work are cuttings collection and tray washing.

The majority of the labour is used for the jobs of cuttings collection and within the cuttings shed. The shed has up to 12 people working within it. The people within the shed are moved about regularly: for example, after a spell in the shed they are then sent out to collect material. This is done to reduce the risk of repetitive strain injury (RSI) and to give all the workers a spell on piece work where they can earn more money. The piece work rate is worked out on the total number of trays completed each day. It is up to each individual worker to keep a count of what they have done each day but the total money is divided by the gang. Tray filling is done separately and this is also done piece work as is taking the trays to the mist from the cuttings shed. When a new worker is taken on by the gang they are given 2 to 3 days in the cutting shed on days pay, this is done to get them up to speed while still maintaining the desired quality. If they still haven't reached the correct number of trays after this trial period then they are not used in the cuttings shed. Each tray is labelled with the plant name, propagation date, and the workers initials, this gives us the ability to track down poor work. The piece work rate differs between different types of plants on an easy, medium, and hard rate. For example, a *Berberis* would be a hard plant while a lavender would be easy. This is based on the speed that the plants can be handled as well as the quality of the material.

The other main job that takes place in propagation is pruning, also on piece work. The cuttings, once weaned, are stopped. Then once the first breaks have started to grow they are mechanically trimmed. The gang works in propagation from February through to October.

Experiences With the Employment of Students From Other Countries

Alan Hargreaves
John Hargreaves and Sons, Gedney, Lincolnshire, U.K.

INTRODUCTION: REQUIREMENTS FOR SEASONAL LABOUR

The business is based near Spalding in the Lincolnshire Fens. It has six departments, each with its own specific labour requirements.

The largest department is Soft Fruit Propagation. This covers traditional field production of strawberry plants, raspberry canes, and other fruit bushes such as gooseberries, currants, and blackberries. Many of these are Ministry Certified cultivars, aimed at fruit farmers, retailers, and other outlets. These are grown on more than 40 ha in South Lincolnshire and West Norfolk. The main labour requirements are for planting, weeding, de-blossoming (a requirement for Ministry Certified strawberry plants), runner training, lifting, grading, and packing for cold storage.

Cross Keys Nursery is a recently developed part of the business which has been set up to grow strawberry plants in modules from misted tips. Many members of I.P.P.S. GB&I Region will be familiar with the Nursery Stock Division which grows a diverse range of high quality container-grown shrubs and fruit plants for garden centres and other retailers. The demands for extra seasonal labour are from propagation, through potting, pinching, and spraying right through to despatch.

The Arable Department grows wheat, and some potatoes, as part of the rotation of land for high-health-status crops. There is no large labour requirement here, except during potato picking and grading in September and October. However a separate fruit farm was set up 6 years ago, to grow strawberries and blackberries for supermarkets. We now grow 40 acres of strawberries, on raised beds, through polythene with T-tape irrigation, as well as in grow bags in French and Spanish tunnels. These are picked from May until October and packed, quality controlled, bar coded, and labeled in our own packhouse. Over 100 extra pickers are needed during the peak fortnight in late June, with approximately 50 needed during the rest of the season. It is vitally important that labour is available at all times, 7 days a week.

SOURCES AND MANAGEMENT OF OVERSEAS STUDENTS

The business has a full-time work force of 35 people, and also advertises locally for extra seasonal help.

However, in recent years foreign students have become an essential part of the work force. The business employs at least 100 at peak times. A student camp has been established, consisting of 24 mobile homes, each holding four or five people. Full planning permission for the camp took more than 2 years to achieve, mainly because of opposition from one family in a cottage on a neighbouring farm, and one local councillor. The camp has shower rooms, recreational facilities, and is attractively landscaped with a bund to hide it from view.

Some 70 of the students are from Eastern Europe, the main countries being Bulgaria, Poland, Slovakia, Ukraine, Russia, Lithuania, Czech Republic, and Estonia. They are recruited through the Harvest Opportunity Permit Scheme (HOPS).

Harvest Opportunity Permit Scheme is one of seven operators under the UK Government-backed Seasonal Agricultural Workers Scheme (SAWS) which was created in 1990. In 1990 5000 SAWS work permits were issued, and by 1997 this allocation had risen to 10,000 work cards. HOPS receives about 38%. CONCORDIA is another well known operator of the scheme. The scheme, administered by the Home Office, enables students from countries outside the European Union to take temporary employment on UK farms during the harvesting season (May to November).

The Home Office has several criteria within which the operators administer the scheme:

- Students should be from outside the Commonwealth or the European Union;
- They should be aged between 18 and 25 years;
- They must return to their University in the same year to continue the same educational course.

The HOPS objectives are to recruit students from Central and Eastern Europe to give them the opportunity to visit the UK, to improve their English language, to "create an understanding between youth of many countries", and to give them the chance to be involved in practical work and the responsibilities of employment and to earn some money.

Other foreign students are from South East Asia, although they are studying at British Universities. We advertise, help them to get work permits in the Job Centres, then provide accommodation for them. We make extra provision for their religious beliefs, for example sourcing meat which has been butchered in their way. We have to show that we are not offering work to people outside the European Community without first advertising in Europe and to British Commonwealth countries. Therefore we advertise in student magazines and, this year, we have employed people from Spain, France, South Africa, New Zealand, and Australia. We also have contact with universities in Europe.

All students are paid at least the national minimum wage. For much of the time they are on piece work rates, and the better workers can, and often do earn more than double their hourly rates. More than £100 per day has been achieved, and more than £450 in one week.

As well as providing good facilities for the students, facilities which are inspected and audited by HOPS to their own exacting standards, the company arranges barbeques, trips to such places as London, Cambridge, theme parks and the seaside, together with the annual company versus student football match.

The Australian Experience of Propagator Training

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INTRODUCTION

There have been many changes in the way the Australian nursery industry trains its propagators and other nursery staff during the past 10 years and there are likely to be continuing changes into the foreseeable future. The industry in both Australia and in Great Britain and Ireland share the challenges of being more receptive and aware of the new skills and knowledge base propagators need. In Australia, the Nursery Industry Association is taking on the responsibility of ensuring that the next generation of propagators is able to produce quality plants in a seemingly more sophisticated and demanding world.

Until a few years ago, the Australian Federal Government fully funded post secondary vocational training, including university courses. This was achieved by funding state-owned training organisations. These organisations designed and accredited their own courses and also offered and controlled qualifications. They had no requirement to liaise with the industry they served.

The graduates of these institutions had a broad theoretical knowledge but there were some in-built inefficiencies which needed addressing, including:

- Lack of industry ownership of the process. The training organisations were not required to seek industry views on training content.
- Lack of equity and moderation between training organisations. Many would not recognise the qualifications of others in the same state which meant that students transferring from one organisation to another were forced to re-learn work they had already completed.
- Decline in uptake of apprenticeships.
- Escalating costs to the state associated with 100% state-funding model.

DEVELOPMENTS TO DATE

In 1989 the Australian Prime Minister instigated the National Training Reform Agenda to address these problems and produce a smarter, better trained, and more modern workforce for the country as a whole.

For example, in Australia this year it is a requirement for gaining a qualification that competency be shown. To accommodate this there is a single National Set of Competencies for horticulture, numbering just over 200 and covering skills from basic worker to manager. They have been developed with industry input and although they are not perfect they do reflect fairly accurately the skills required.

In addition, Australia has a National Horticulture Curriculum which is used by nearly all training organisations. It is now possible for a student to move from one state to another without disadvantage.

A major change has been the introduction of what the Government calls "user choice". This simple title involved the creation of competition among providers of vocational training, not all of whom now receive the high level of public funding they once had. It is now common for training organisations to actively recruit students and to tender for training provision. It is possible that user choice could see the end of some of the longest established training organisations and the rise of privately owned colleges with an interest in profitability.

THE INFLUENCE OF THE NURSERY INDUSTRY ON TRAINING PROVISION

A strong input from the nursery industry is considered to be vital if it is to receive entrants of the right calibre. The Nursery Industry Associations in Australia consist of seven state and territory organisations, affiliated to a national umbrella organisation. Together they have a strong network of industry committees all providing input on training issues, as well as employing a national training manager as an overall co-ordinator.

The Nursery Industry Association (N.I.A.) has established its own training organisation and can offer qualifications in its own right. It delivers training and its presence in the market creates a benchmark on the quality of training delivery. The Association's input is aimed at ensuring that those who seek a qualification end up with skills that are relevant to current industry needs.

The N.I.A. has also instigated programmes to update and advance the professionalism of the industry. It collects an annual levy on sales of containers which is used to fund marketing and research. The research funding is matched by government and is expected to reach Australian$1m in the current financial year. The research that has been funded has resulted in significant cost savings in nursery stock production. Details and results of some of this work can be found on the Association's Internet Web Site (www.niaa.org.au). Workshop notes are also available on CD-ROM disks. Both the web site and the CD-ROM disks help overcome a problem we have in Australia where time and distance for travelling are major barriers to attending courses and workshops to improve skills.

One interesting off-shoot from this research is that the Association is using training workshops as a way to feed technological advances into the industry. Attendance at the workshops earns points (or "marks") towards higher qualifications.

IMPROVING THE PROFESSIONAL IMAGE OF PROPAGATION

Plant propagation and production is yet to be viewed in Australia as a true profession and the Association considers that this perception limits opportunity. It also believes that increasing the perception of professionalism could help lift profitability and become a way of differentiating the high quality producers and retailers.

To address this issue the nursery industry in Australia is establishing a programme that will identify and support professionalism. This programme will be national and will be linked to formal training opportunities. An aim is to have the wider community, as well as the industry, recognise the skills needed to become a professional propagator as well as to give new recruits a career goal to aim for, emphasising that plant propagation and production is a worthwhile career option. The future of our industry rests with encouraging people who can build a skilled and more viable industry.

Marketing Strategies for Small Specialist Growers

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INTRODUCTION

As the manager of a 1.6-ha garden and plant centre I increasingly hear my customers tell me that they "have stopped buying plants at garden centres". This paper looks at who these customers are and why this should be. Obviously the majority of the gardening public will continue to buy plants at garden centres but for small specialist growers, the challenge is to attract those disillusioned garden centre customers and to provide for them the atmosphere, the range of plants, and the novelty they are looking for. In particular I shall consider the role of the display garden in achieving this.

TYPES OF RETAIL PLANT OUTLET

The Development of Garden Centre Chains. In the 1970s and 1980s many garden centres existed as independent entities, a proportion producing some or all of their own stock, for example Church Lawford Garden Centre and Bournville Garden Centre in the West Midlands area. In 1990 Church Lawford was bought by the Kennedy Garden Centre chain to give them 13 outlets. In 1996 Bournville Garden Centre was bought by the Wyevale group and in 1998 they, in turn, bought the Kennedy chain, to give them more than 80 centres throughout the country. This process is set to continue so that eventually most gardeners will buy their plants from two or three national chains in the same way that most of us buy our DIY materials and equipment from chains such as Homebase and B&Q.

Hand in hand with these changes have gone changes in the supply of plants by wholesalers. Firstly the process of centralised purchasing, imposed by the national chains, means that the plant range is limited to that produced by what is often a sole supplier. Secondly the A to Z range of plants is turned into a series of promotional items. This process began with plants such as *Scabious* 'Butterfly Blue' and has extended itself to whole species such as the Gallery Series of lupins and themed packages such as Bransford Nurseries Pots of Gold promotion, which covers a complete range of yellow-flowered/golden foliage shrubs, trees and groundcover plants are sold as a single promotional package. Garden centre plant quality is excellent and availability national, but all these changes mean that customer choice is restricted so that a garden centre in Folkestone is identical to one in Manchester and that the range of plant material follows suit.

Small Specialist Nurseries. Running in parallel with these developments is what has become almost a subculture of small specialist nurseries. These pop into the limelight at the annual gardening shows, such as Chelsea, Malvern, Hampton Court, and Gardeners' World, after which, unless sought out, they will be known only from articles in *The Garden*, or listed as suppliers in *Gardening Which*. It is to such nurseries that people who no longer buy plants at garden centres are turning.

The received wisdom for locating a retail nursery is that it should be accessible to a large customer base, near a town, and visible from a main road. This is where the garden centres are, but not usually the specialist nurseries, which all seem to be in out of the way places, down narrow lanes, and are usually difficult to find. Their customers tend to be dedicated plant enthusiasts who are prepared to seek out such places. Typically such customers will belong to a garden society (either local or RHS) or are perhaps members of The Hardy Plant Society, the Alpine Garden Society, or NCCPG.

The Gap in the Market. I believe that there is a group of customers that lie between the mass market garden centre customers and the out-and-out plant enthusiast and these people could easily be attracted to specialist nurseries. These are people who are not first-time plant buyers and who are looking for something more than the DIY shopping experience being offered by mainstream garden centres. They are the sort of people who go to big gardening shows but who find that this is their only point of access to specialist nurseries. The specialists need somehow to make themselves more accessible.

SPECIALIST MARKETING STRATEGIES

The strategy I suggest, in essence, is to generate a sufficiently high-profile or reputation to attract customers to seek out the nursery. This can be attempted using the following methods:

Shows. From the RHS's Chelsea Flower Show to the much less ambitious Rare and Unusual Plant Fairs, the purpose of taking part in shows has to be publicity and generation of the "wow" factor, so make sure you exhibit your most exciting plants as well as your most profitable lines.

Garden Tourism. This is a developing area which ranges from the highly structured international tours, through organisations, such as Bed & Breakfast for Garden Lovers, to a simple entry in the *Plant Finder,* published by the Royal Horticultural Society. There are many people out for the weekend, a good number of them armed already with the National Garden Scheme's guide to gardens open to the public (the well known Yellow Book), who enjoy the challenge of finding obscure nurseries by looking to see what is listed in the *Plant Finder* for that area.

Books and Articles. Are you a writer as well as a nurseryman? Some magazines are always looking for copy — even if it is only the contents of your catalogue for review. Christopher Lloyd's Great Dixter Nursery profits from the fact that he writes a weekly piece for a national newspaper and Carol Klein's Glebe Cottage Nursery in North Devon must equally benefit from her TV appearances. Beth Chatto's books about her garden in Essex were instrumental in the development of her nursery into what many people claim to be one of the country's best specialist nurseries.

Mail Order and the Internet. Mail order, and its 1990s equivalent of e-commerce, have equal weightings of pros and cons. They overcome the problems of obscure locations and can cover the difficulties of selling very early in the season in February and March. Because mail order customers order from catalogues, the format and look of the catalogue itself takes on a special importance. Some specialist nurseries produce lavish catalogues (Bernwode Plants, Aylesbury), with botanical plates and short essays on plant types (Woottons of Wenhaston, Suffolk), or comprehensive descriptions of obscure plants (Monksilver Nursery, Cambridge), that encourage fireside shopping. The Internet is expected to play an increasingly important role and has the advantage of reaching an international audience and passes on the printing costs to the customer. But the advantages of mail order must be considered against the disadvantages. Not all plants in an order may be ready at the same time for dispatch; a lot of phoning is involved to organise customers to receive the plants; refunds have to be arranged for damaged and lost orders. These common difficulties make mail order a time-consuming, expensive operation.

Innovation, Breeding, and Collecting. All potential customers are excited by something new so many specialist nurseries have made names for themselves by breeding new cultivars or collecting plants form the wild, for example Ashwood Nurseries for breeding *Lewisia, Hellebore*, and *Hepatica,* and the Specialist Plant Unit at Pershore and Hindlip College for the discovery of *Ceanothus* 'Zanzibar'. While the large wholesale nurseries have bulked up and marketed these plants, it is the small specialists that are responsible for these innovations in the first place. In turn many have been able to use their discoveries to arrange financially rewarding deals with the large wholesalers.

The Display Garden. A well laid-out display garden is the ultimate in point-of-sale material, putting the largest coloured label and display board in the shade. Real plants, real size, with real flowers and real smells excite people and that excitement translates into sales. Consciously or unconsciously it is a marketing strategy used by many nurseries, the RHS Garden at Wisley is probably the largest, whose garden displays are bound to stimulate its plant centre sales. One can also think of the Burford Garden and Treasures Nursery at Tenbury Wells, Merriments Garden and Nursery in East Sussex, and the Hiller Garden and Plant Centre near Evesham. The latter is a garden established specifically to generate plant sales, the concept behind it being that everything a customer sees in the garden, plants, fences, seats, ornaments, pots, etc., can also be bought in the sales area. So the customers' experience is not one of "going shopping" as one would if going to a garden centre to buy a specific item, but of being stimulated and excited by an environment — which is also available to take away. It is not aimed at the out-and-out plant enthusiast but at the broader mass of people who have gone beyond their first plant-buying/gardening experience and who want to see more than may be on offer at the garden centre. It is aimed at making specialist products, plants, and ideas more accessible.

THE ADVANTAGES OFFERED BY A DISPLAY GARDEN

Increased Range of Plants. There are a number of spectacular, mainly large plants, that sell very well when the display plant in the garden is in flower, for example *Althaea cannabina, Crambe cordifolia, Verbena bonariensis, Dierama pulcherrimum,* and grass species in general. These plants are not suited to garden centre merchandising because in the pot they are twiggy or coarse-leaved and have no visual impact as young plants. So they have no mass-market exposure — until seen in a display garden.

Improved Ability to Give Advice. A display garden can also provide a real environment where the customer can see exactly what works. Every retailer is familiar with the customer who has a dark, dry, north-facing garden with lots of trees and wants something that will thrive there and provide year-round colour. All that can usually be offered is verbal advice and possibly a printed plant list. The display garden offers a valuable further step. The display garden also becomes an asset that can be used for workshops, tours, and talks. So customers get a broadening, learning experience rather that a sterile, shopping experience.

Greater Opportunities for Linked Sales. A well organised display garden will be full of plant combinations and juxtapositions that create opportunities to sell multiples, e.g.: orange *Crocosmia* 'Lucifer' with purple *Clematis* 'Jackmanii Superba'; pale blue *Perovskia* 'Blue Spire' with the black-foliaged *Aster lateriflorus* 'Prince'.

Ability to Extend Selling Season. Retailers can experience a drop in plant sales in July and August when customers' gardens are full of plants and gardeners go on holiday. But a display garden will attract these very people as tourists in the summer and purchases will often be an impulse affair because the customer has seen something in the garden and "just has to have it".

To make these advantages work for the nurseryman, the obvious extra resources and expenses have to be made available. A 1.5- to 3-ha garden will probably need one full-time and one part-time members of staff to run it although this may be covered by charging an entrance fee. Everything needs to be clearly labeled for customers to know what they are looking at — and in garden this size there may be 1000 to 2000 plant taxa. If customers are to be encouraged to make repeat visits, the garden must change regularly otherwise regular visitors become bored. On a month-to-month basis this can be overcome by issuing a list pointing out plants of particular interest. On a year-to-year basis it means replanting and changing the display to provide totally new items of interest.

CONCLUSION

There is a section of the plant-buying public which is looking for plants, services, and experiences beyond that being provided by garden centres. The specialist nursery, while appealing to plant enthusiasts, may be inaccessible both geographically and in terms of the way the nursery presents itself and sells plants to the public. A display garden can provide a means of opening up the specialist's advantages to a wider public.

Experiences With Direct Sticking

Philip Moreau
Glenbrook Nurseries Ltd, Tuamgraney, Co Clare, Ireland

Nursery-stock prices in Europe have failed to keep pace with the increasing costs of production. Direct sticking of cuttings into cells and pots rather than into trays or beds can reduce labour costs while improving crop quality and uniformity and allows more nurseries to propagate their own liners in order to reduce the production cost of finished plants. At Glenbrook Nurseries, the average price of producing a liner of a subject, such as *Spiraea, Potentilla, Cytisus, Lavandula, Hypericum*, and *Ceanothus*, direct stuck in a P8 pot in the autumn, for topping up into a 2-litre pot in June, is 10.37p. The market price for a similar liner is 40p, therefore, the nursery saves 29.63p. At a production rate of, for example, 500,000 units this would be a £148,150 saving, or percentage wise, selling at £1.20 yielding £600,000 a 24.69% saving.

For crops such as *Viburnum tinus* and its cultivars, *Photinia, Leptospermum, Callistemon*, etc. the costs of producing a quality liner would be 14p, but this would mean sticking in a 108 plug and potting on into a P8 pot after a well developed root has been established, but the sales price would compensate for the extra costs thus the saving would be 39p per unit or £195,000 or 27.85% (based on 500,000 units selling for £700,000 and buying the liner at 53p).

For nurseries selling subjects in P9, 1-litre, or 1.5-litre pots it is quite simple to direct stick cuttings into the saleable pots, but this can and does lead to significant losses; sticking plug-propagated material is best and for the extra small investment an excellent crop can be produced. With the demand for larger size containers of 5 litres and 7 litres such material may be suitable as liners or young plants.

INTRODUCTION

There are two main reasons for direct sticking cuttings in nursery stock production. One reason is that it is a cheap method of producing groundcover type plants for the landscape trade or for the garden centre. Single or multiple cuttings can be inserted in a small pot or container, rooted in situ and sold on in a short time frame, thus making savings on handling, potting expenses, and general overheads.

The second reason is to produce a cost-effective liner for potting on by reducing one or two tasks within the nursery production cycle and it is this aspect that has made a significant impact in the production calendar at Glenbrook Nurseries.

One of the main reasons for this is that, over the past 10 years, the selling price of nursery stock in Europe has been quite stagnant, while the overhead costs have risen with the inflation. It is, therefore, vital for nurseries to adopt better management and more cost-effective production systems to maintain profitability.

DEVELOPMENT OF PRODUCTION SYSTEMS AT GLENBROOK NURSERIES

When I founded Glenbrook Nurseries some 10 years ago we used traditional methods of rooting cuttings using trays or flats filled with a propagation medium consisting of peat and sand (2 : 1, v/v) mix. After rooting these would be knocked out, roots teased apart and potted up into a liner pot, usually 8-cm squares, and grown on for a further period until a good root ball had developed. Depending on the time of year these would either be potted on or grown on until the next season. All this was labour intensive, time consuming, and the percentage losses were high, about 20% overall. These high losses were due to root disturbance, poor root development, and lack of fertiliser. In many cases roots were actually pulled from the cuttings during the teasing out from the flats or trays. We felt that we needed a system that caused less root disturbance and would yield a higher number of better quality liners for potting on into a saleable container.

Production System Costings. Glenbook, in the early days, was growing plants for a wide range of markets but in small numbers. The nursery expanded rapidly, growing some 22,000 units in 1991 to 500,000 today. The system adopted in 1991 is still the system in use today. Cuttings are rooted in low tunnels without heat or any artificial aids. These are situated inside standard single span polytunnels covering 100 m^2 and covered with either transparent or translucent polythene 700 gauge E.V.A. The cost of each tunnel is approximately IR£1000 and the cost is depreciated over 5 years at IR£200 per annum or IR£2 m^{-2} per annum.

Filling each tunnel with 12,000 8-cm pots results in a capital cost of 1.6p per cutting per annum as it is only possible to get one crop of liners per annum out of each tunnel. Within the tunnel there are four beds of 8-cm pots, 11 pots wide at the two edges running down the tunnel and two larger beds 15 pots wide down the centre. The pots are filled using a JAVO potting machine at the rate of 12,000 per day. Each bed is covered with a small tunnel, hoops made from 12-mm conduit or water pipe, fixed into the soil with 15-cm pieces of bamboo and covered with 100-gauge, milky-white polythene. The floor is covered with Mypex to keep a clean environment. Watering, which is done only when necessary, is applied using Dutch pins overhead.

In 1996, 1.2 ha of glasshouses (15 bays each of 3.5 m × 42 m) was acquired and today we use 0.2 ha for liner propagation using the same low tunnel system used in the polytunnels. Liners produced under glass have a lower capital cost compared with those produced under polythene. We can get 225,000 liners into the 0.2 ha. The beds are 15 pots wide and each bay has two beds holding 6000 pots. The capital cost of this glass was IR£50,000 per acre (IR£112,500 ha^{-1}); depreciating over 10 years the capital cost works out at 1.1p per plant per annum.

TIMING OF CUTTINGS

All cuttings are grown without heat. Insertion begins mid to late July and continues on into early January but it would be preferable to finish by mid December to avoid the delayed rooting caused by excessively low winter temperatures.

However, it is not beneficial to start too early, either, as this system is not suitable for very soft material unless extra management time is available to closely monitor temperature control. Heavy shading of the polythene tunnel or glasshouse, with emulsion paint, can be beneficial.

At Glenbrook the first crop of cuttings in mid July are heathers in 150 unit cells, potted up into P8 pots the following spring and then into 2-litre pots. This crop is followed by subjects such as *Potentilla, Santolina, Spiraea, Lavatera, Lavandula, Halimium,* and *Cytisus.*

The plants more suited for insertion in the latter part of the year are *Hebe, Escallonia, Olearia,* and *Griselinia*. All these root very easily even if it is very late in season.

SUBSTRATES AND NUTRITION

Rooting Substrate. A very open, friable substrate is essential for successful rooting. At Glenbrook we aim for an air-filled porosity (AFP) of between 15% and 18%. Since pots and trays are filled mechanically we have to start with a graded peat which, when it passes through the machine, gives us the desired AFP. In order to get this we use a mixture of equal proportions 0 to 16 mm and 6 to 12 mm for cell trays; and 40% 0 to 16 mm plus 60% 12 to 25 mm for pot sizes from 6 cm upwards.

For some subjects, especially heathers and subjects rooting very late in the year, we add 15% medium grade perlite to increase drainage and warmth.

Fertilizers and Pesticides. At Glenbrook, slow-release Osmocote is used in the rooting mix. This ensures there is fertilizer available when the plants are sufficiently rooted in early spring but avoids any problems of salt damage during the rooting period. Some growers prefer liquid feeding in early spring, using nitrogen and potassium only initially and adding phosphate to meet the demand of growth flushes — but this does demand more management.

Table 1. Fertiliser and pesticide incorporation into cuttings substrates at Glenbrook Nurseries.

Calcicoles (plant normally growing on calcareous soils)	Calcifuges (plant not normally growing on calcareous soils)
1.2 kg Osmocote*	1.2 kg Osmocote
2.4 kg ground limestone	1.2 kg ground limestone
750 g Suscon Green**	750 g Suscon Green

*12-14 month Osmocote Plus autumn potting. All figures are per cubic metre.

** Slow-release fertiliser10% w/w Chlorpyrifos.

CUTTTINGS TYPES, HORMONES, FUNGICIDES, AND WORK RATES

Direct sticking allows use of a larger cutting, particularly in P8 pots where it has more space and an airier microclimate. At Glenbrook we use a cutting of about 8 cm but for the later-stuck subjects we use a 10-cm nodal cutting, depending on the subject. For subjects such as *Aucuba, Clematis montana, Viburnum tinus,* and *Cornus alba* cultivars internodal cutting have proved very successful. Hormones are used in a mixture of 8000 ppm IBA and Captan (1 : 1, v/v) to almost all cuttings. After a few days a drench of Carbendazim (Bavistin) is applied to control *Botrytis*.

Work rates for preparation and sticking of direct-stuck cuttings are no different from the conventional methods. At Glenbrook we are currently producing 250 per worker hour but feel this can be improved with closer scrutiny of the work methods, especially for sticking.

AFTERCARE

Once rooting takes place we remove the polythene sheets and let the crop dry to just above wilting to harden the roots and top growth. Trimming is done using an electric hedge trimmer if feasible but for the more prostrate subjects we hand trim to a fist size. For weed control we hand-weed initially but then apply isoxoben (Gallery, Flexidor) at 1 litre ha^{-1}. This herbicide has proved phytotoxic to *Berberis* and *Buddleja* in our experience. Mogeton at the rate of 2.5 g $litre^{-1}$ is sprayed over the crops with no ill effect to control mosses and liverworts.

Downy mildew (*Pseudoperonospora*) can be a problem on some subjects, especially *Hebe*; we spray with fosethyl aluminium (Aliette) at monthly intervals. Keeping the foliage of these susceptible crops dry is very important.

Liners are potted on from mid May to late June into either 2- or 3-litre pots. This system suits the Irish climate because the potting season does not start until mid May, due to the late spring when night frosts can occur. The growing season carries on into October to early November.

Table 2. Production programmes for some species propagated using direct sticking at Glenbrook Nurseries.

	Olearia macrodonta	*Cytisus* ×*praecox* 'Warminster'	*Escallonia*	*Hebe*
Timing	Nov. - Dec.	Aug. - Sept.	Oct. - Nov.	Nov. - Dec.
Pot size	P8	P8	P8	P8
Cut size (cm)	10	10	8	6
Root by	Mar.	Nov. - Dec.	Dec. - Jan.	Feb. - Mar.
Rooting (%)	100	95	100	100

	Viburnum tinus	*Photinia* ×*fraseri* 'Red Robin'	*Camellia*	*Leptospermum*
Timing	Oct. - Nov.	Sept. - Oct.	Aug.	Nov.
Cell	77s	108s	54s	108s
Cutting type	Internodal	Nodal	Nodal	Nodal
Size (cm)	3.75	6	7.5	7.5
Rooted	Feb. - Mar.	Dec. - Jan.	Feb. - Mar.	May - June.
Pot up	P8	P8	1 litre	P8
Pot on date	Oct.	Sept.	Feb.	Sept.
Pot on size	2 litre	2 litre	3 litre	2 litre

Table 3. Comparison of itemised liner production costs for three different production systems on a nursery selling 2-litre and 3-litre containers, not including overheads, which can be written against the selling price. All figures are IR£.

System 1

Rooting cuttings in standard trays July to Jan.; potting into liners Feb. to June; growing on for a further season before potting into 2- or 3-litre container.

Rooting costs	
Tray Preparation (77 cuttings per tray, 26 trays per 2000)	5.00
Peat and sand	6.00
Preparation of cuttings and insertion	80.00
Aftercare	18.00
Pulling out	8.60
Potting up costs	
Peat (fertilized)	25.00
Pots	17.00
Suscon Green	12.00
Potting on Machine	25.60
Aftercare	38.00
Total	235.20
Cost per unit	11.76p

System 2

Direct sticking into fertilised medium in 8-cm pot July to Jan., potting April to June into 2- or 3-litre container.

Pot Filling (2000 pots filled on JAVO Machine)	13.60
Pots (8 x 8 x 8 or 8 x 8 x 7 Soparco)	17.00
Peat (fertilized)	25.00
Suscon Green	12.00
Polythene	3.25
Hoops	0.25
Preparation of cuttings and insertion	80.00
Aftercare	38.00
Total	189.10
Cost per unit incl. 10% losses	10.4p

Production costs are reduced dramatically. In system 1 we needed 12 to 15 months whereas in this system we need only 6 to12 months for our return This system is suitable for: *Potentilla, Spiraea, Cistus, Deutzia, Cotoneaster, Berberis thunbergii* taxa, *Ceanothus, Philadelphus, Rubus, Corokia, Myrtus, Hebe, Lavatera, Escallonia, Phlox, Phygelius, Lavandula, Cytisus, Helianthemum, Santolina, Ulex, Weigela, Clematis, Ozothamnus, Olearia, Hypericum, Lonicera, Griselinia, Fuchsia, Halimium, Caryopteris.*

System 3

Direct sticking into 108 cells Nov. to Jan.; potting up into P8 May to Aug.; growing on for a further period before potting up Feb. to April into 2- or 3-litre container.

Rooting in 108 cells	
Plug trays (20 x 108's)	8.60
Peat (fertilized)	5.00
Suscon Green	2.50
Tray filling	4.25
Polythene	4.25
Hoops	0.20
Preparation of cuttings and insertion	80.00
Aftercare	38.00
Potting on into P8's	
Pots	17.00
Peat fertilized	25.00
Suscon Green	12.00
Labour	25.60
Aftercare	38.00
Total	260.40
Cost per unit incl. 10% for losses	13.5p

This programme suits the larger slower subjects such as: evergreen *Berberis, Leptospermum, Leucothoe, Mahonia, Photinia, Lophomyrtus, Gaultheria* (syn. *Pernettya*), *Osmanthus, Viburnum tinus, Correa, Hydrangea, Choisya, Rhododendron* (evergreen azaleas), *Callistemon, Hedera, Pieris, Erica* (for 2 litres), *Euonymus, Ilex*.

Adrenalin Rush Through the Native Bush: A Mary Helliar Study Tour to New Zealand

Therese Landers
Green Avenue Nurseries, Naas, Co. Kildare, Ireland

INTRODUCTION

Several study tours to New Zealand have been accounted for in past I.P.P.S. papers, many of which I have read and enjoyed. Naturally this account is the most important one of all to me, and I would like to share my love and enthusiasm for the plant life of New Zealand with as many as are interested.

My visit to New Zealand in January of 1999 was made with the intention of seeing the native plants in their natural habitat. Establishing contacts with I.P.P.S. members was also a priority.

My work at the time, as manager of a small liner nursery in Ireland, had brought me into contact with many New Zealand plants, notably *Pittosporum*, *Leptospermum*, *Phormium*, and many of the tussock grasses. I, therefore, had background knowledge of the main plants in the flora. The New Zealand flora is more valued for its foliage than for its flowers and on most plants the flowers are insignificant although usually scented.

ORIGIN OF NEW ZEALAND'S FLORA

Before undertaking the visit I wanted to find out more about the origins of this unique flora. To illustrate its uniqueness, consider the following facts:

- Of New Zealand's 2450 native species, 84% are endemic, i.e., they are found nowhere else in the world.
- And 50% of all New Zealand's plants are dioecious, i.e., they have separate male and female forms.

These traits can be explained by the way the New Zealand flora evolved. Eighty million years ago there was a large super continent in the Southern Hemisphere called Gondwanaland. Due to geological forces, it started to fragment and New Zealand was one of the fragments (Australia and Antarctica were amongst the larger ones).

The landmass we know as New Zealand drifted away on its own. The species of plants and animals that went with it evolved in complete isolation from those left behind on the larger land masses. Some possess features that are only found in fossils elsewhere in the world.

Flowering plants without flamboyant flowers were able to survive because there was less competition for insect pollinators. Also they evolved relationships with insects such as moths which were attracted by scent rather than visual cues.

Another striking feature of the flora is the number of woody species — more than 10% — with a divaricate habit. Divaricate means "stretched apart" and in plants refers to wide-angled spacing of branches. New Zealand has a greater proportion of divaricate plants than any other biogeographical region. In New Zealand species, divarication is accompanied by lack of fully expanded leaves and few flowers near branchlet terminals. In the majority of species, this habit is permanent, whilst in others it occurs in the juvenile stage only.

Well known genera that have divaricate members are *Hebe, Pittosporum, Myrsine, Coprosma,* and *Corokia*. For example, many are familiar with the tangled appearance of *Corokia cotoneaster*. Some botanists believe that the divaricate habit was favoured in New Zealand because of the feeding habits of the moa (a large extinct bird) — the plant presented an exterior of twiggy nonfoliar appearance to deter the browsing birds. Others consider it an adaptation to withstand exposed situations, with the flowers occurring a few centimetres down from the branchlet tips where they are less likely to be damaged by wind or frost. Like many of these long-standing debates, the answer could well be that divarication is the result of a combination of these factors.

DISCOVERING NEW ZEALAND'S NATIVE PLANTS

The real joy of my visit was obtained from walking in the native bush or bushwalking as it is known there. New Zealand has more than 11% of its land devoted to National Parks which are conservation areas.

My trip through both islands enabled me to experience the bush from near tropical to temperate regions. Each area differed greatly in the make-up of its flora. Some important plants are only to be found in small pockets, e.g., the Nikau Palm (*Rhopalostylis sapida*) which is the southern-most palm in the world. It is found in abundance near Punakaiki in the South Island.

Others were ubiquitous, such as the flax-like *Dianella* with its brilliant blue berries. This plant lined the paths on many bush walks. Bushwalking was made all the more enjoyable by the sounds of the bush from the cricket-like cicada to the glorious song of the bellbirds and tuis.

NEW ZEALAND NURSERIES

Many nurseries are devoted to producing native plants. One of the best known and certainly the biggest is Naturally Native in Tauranga in the North Island. Several other smaller producers also stock wide ranges of native plants. I enjoyed my visits to Oratia Nursery in Auckland, Annton Nursery in Hamilton, and C.H. Simpson Nursery in Nelson. I was struck by the dedication of the owners to producing native plants and their knowledge of the plants they grew. Many of the growers do the bulk of their own propagation and personally collect the native seed from selected sites around the country.

In my view, a trip to New Zealand could almost be declared compulsory for anyone interested in its native flora.

I am most grateful to the sponsors of the Mary Helliar Award and the Merlin Trust for their help in making my visit possible.

Full reports on the Mary Helliar study tours are available to sponsors of the GB&I Region's Mary Helliar Travel Scholarship Fund. Please contact the GB&I Region office at 2 Crondall Lane, Farnham, Surrey GU9 7BQ, tel/fax +44(0)1252 725880 for more details.

The Eden Project

Philip McMillan-Browse
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INTRODUCTION

As a new botanical institution, Eden will offer innovative and contemporary responses to the prevailing agronomic, land use, and conservation challenges. These challenges are posed by humankind's impact on the natural world and result from the developing needs of our species. Within this framework, Eden's focus will be on the relationship between humans and plants, although recognising that proposed solutions will have wider implications.

The policy and activity of Eden will be directed by the principles enshrined in the Convention on Biological Diversity (the Rio Convention) and Agenda 21: in turn projects will be designed to support the stated priorities of the IUCN — the World Conservation Union.

At present the mission statement of the Eden Project is "To celebrate plants and promote and explore the balance between conservation and the rational use of plant resources, emphasising the historical and dynamic relationship between humanity and the land, through collaborative local, national, and international programmes of public display and education, applied research, and field projects."

From the outset, the founders of the project decided that the most effective ways to pursue its aims were through increasing public awareness and understanding, and by joining with others to work in the field.

VISITOR ATTRACTION

The site in Cornwall, within a worked-out clay pit of 14 ha at Bodelva, is being developed as a visitor destination; the primary purpose of which is to inform the general public and influence opinion, while ensuring that visitors have a thoroughly entertaining time. It will do this by establishing a novel series of plant displays set in a dramatic social landscape. To reflect the worldwide nature of human dependence on plants, two massive "biomes" are being constructed. One will have the climate of the humid tropics, the other that of the warm temperate or Mediterranean regions of the world.

The plant displays will not be based on traditional taxonomic collections but will reflect wild and man-made assemblages of plants based on geography, ecology, and ethnobotany. A considerable number will be designed to show the crops whose harvests fill the supermarket shelves. They will be designed to intrigue, excite, and inform the visiting public. Some will also provide a useful resource for scientific and extension work while others will show the development of the sustainable use of plant resources through well planned and managed agriculture, horticulture, and forestry.

SCIENCE

Eden's approach to its scientific mission will be collaborative and co-operative and will not subscribe to past prescription. Where feasible it will seek sustainable solutions. This will require a focus on specific problems while at the same time contributing to resolving broader implications which may result from any change effected.

Scientific activities at Eden will be developed from a variety of sources and these will create projects of widely differing complexity and objectives — making use of both basic science (pure and applied) and technology. Much of the extramural activity will inevitably be extension oriented and based on the application of existing science and technology in the resolution of applied and practical challenges in the field.

The practical derivations of scientific activity at Eden will arise from a range of sources (both internal and external). These will generate a series of responses appropriate to the order and scale of the issues identified.

The Living Collections, both in the conservatories and grounds at Eden and within the nursery at nearby Watering Lane, present the challenge of growing an unusually wide range of tropical, warm temperate, and hardy subjects to mature size. The resolution of these challenges will form the basis of "in house" research programmes and, through the publication of the research findings, be of service to others.

Any investigation on the cultivation of the collections will involve soil science; pathology, plant protection (including biological control); mycology and a recognition of the mycorrhizal associations required; together with the challenges created by the physiology of the plants in relation to their successful growth, nutrition, pollination, fertilisation, and fruit development. Eden will also pursue propagation and production studies and will be involved in genetic studies and plant breeding. The collections will also provide the basis for ongoing taxonomic investigations (which form the basis of all authenticated plant research) and will then provide opportunities for refining recording systems.

To achieve this it is intended that the senior curatorial staff of the Living Collections at Eden will have a significant scientific background and will be backed up by an integrated and dedicated specialist scientific staff.

RELATIONSHIPS WITH EXISTING ORGANISATIONS AND INITIATIVES

The role of the Institution will be in pursuing its mission in conjunction with other collaborating bodies (universities, botanic gardens, commercial organisations, etc.) in identifying or working within specific arrangements, in order to fulfil particular projects within the framework of Agenda 21.

Eden will maintain, within its basic funding strategy, a core team of specialists, scientific professionals who will identify and seek funding for particular projects and who will organise or participate within teams to resolve particular problems — but always within an aim to achieve fully ethical and holistic solutions. Holistic approaches to solutions involve not only the resolution of challenges posed by agronomic need and the associated conservation issues but deal with the social, economic, political, and religious imbalances which may be created. Traditionally merely targeting and resolving a challenge produces knock on and side effects which are frequently not addressed.

Inevitably adhering to the requirements of Agenda 21 focuses attention on all areas from local to international involvement.

Involvement locally can be initiated quickly and will provide an immediate area of collaborative activity in the field of conservation. Particular areas of interest include the well being of Atlantic Woodland (a reflection of the international concern at the decline of temperate rainforest), the programme for Lowland Heath conservation, the issues of Cornwall's rare and endangered wild flowers, and the loss of gene pool in cultivated plants — in terms of Cornwall's endemic taxa of fruit and flower bulbs. These issues also interface agronomically with the current position of the agricultural industry in Cornwall and the challenges presented by the present decline in farm incomes. The return to low input - low output systems, with a high value product and the potential for value-added processing becomes a possibility. Sustainable land management of this type will become critical in the maintenance of the traditional forms of farm landscape which are an important part of Cornwall's attraction to tourists.

Nationally it will be possible not only to contribute to the development of these ideas in a wider context but also to act as the local agent for initiatives, such as the proposed Flora Celtica, the development of wider marketing strategies for the local agricultural industry and for cooperation with agricultural or industrial partners to identify immediate and practical projects.

Internationally, Eden will look to provide collaborative and cooperative involvement in projects concerned with sustainable land use and will endeavour to provide holistic solutions. Typically the resolution of a problem will require additional assessments of related impacts and an understanding of how these might be managed.

Eden will have basic laboratory facilities for field investigations. It will not, however, seek to establish expensive, specialist equipment or employ an extensive, permanent scientific staff but it will seek expertise and specialist facility by contractual, collaborative, or co-operative arrangements with partners having the relevant status.

Eden will also provide the opportunity for scientists to visit and study within its facilities, both at Bodelva and at Watering Lane, whether on specific projects or as part of a wider collaborative position.

Because of its commitment to all these facets and the inevitable interactions with the educational programmes and interpretation, the labour force at Eden will be based on a School of Horticulture consisting of student gardeners who will have a strong science base to all their activities.

PROPAGATORS' QUESTION BOX SESSIONS

Two Question Box Sessions were run, during which technical questions posed by members attending the Conference were answered from the floor by other members. The report below is not intended to be a verbatim record but a summary of the questions posed and the points raised.

Readers are reminded that the information aired during the question box sessions does not constitute advice. Readers should use their own judgment and exercise due diligence if acting upon it.

PERSISTENT OR SYSTEMIC PESTICIDES AND INTEGRATED PEST MANAGEMENT

Does anyone have any information about the safety of the aphicide imidacloprid incorporated in compost to beneficial agents used in IPM?
Paul Howling, Howard and Kooij Nurseries

Imidacloprid has generally been regarded as safe with IPM but this season failures have been reported with the use of *Encarsia* (the beneficial organism used to control whitefly). This is unusual and could be an effect of weather conditions or could have been caused by imidacloprid residues.

Imidacloprid has no effect on mites, so should not affect the use of *Phytoseiulus*.

Intercept (which contains imidacloprid) appears to control mealy bug if that pest is concealed in the leaf folds of, for example, *Phormium*, but may also affect the mealybug predator used in IPM.
John Adlam, Dove Associates

What is the activity and persistence of Intercept? If used to control vine weevil, can I also use nematodes?
David Hide, Royal Horticultural Society Gardens, Wisley

SusCon Green (which contains the active ingredient chlorpyriphos) is said to have a 2-year life. Intercept 5 GR, when incorporated in compost, is said to last 12 months from the date of incorporation. A liquid drench of Intercept 70 WG does not last as long. For vine weevil you would need to apply during larval activity, say from March to June and then again in September. If an Intercept drench was applied in spring you could use nematodes in the autumn.
John Adlam

LAVENDERS AND VINE WEEVIL RESISTANCE

We are interested in growing lavender (*Lavandula*) without using SusCon Green. Does anyone know if the high essential oil content in the root is a deterrent to vine weevil?
Patrick Fairweather

We've never found vine weevil in lavender or choisya (*Choisya*) but that is only anecdotal.
Alistair Hazell, Darby Nursery Stock

We find the larvae feed less on aromatic herbs than on other subjects, and there is no sign of adult feeding damage on such plants.
Pandora Thorsby, Yorkstock

EFFECTS OF POTASSIUM ON FLOWERING AND HARDINESS

Does anyone have experience on the benefits of potassium on flowering and hardiness in nursery stock or herbaceous subjects?
Patrick Fairweather, Aline Fairweather Nurseries

We use potassium nitrate for camelias and rhododendrons during August and believe that it is beneficial.
David Hide

Rhododendron sets flower in July so that would be a better time to feed with potassium. It is true that the harder you make the plant the more flower buds you will get next year.

Try drying the plants off and feeding with potash to get improved bud initiation and improved colour. Potash also hardens the cell walls which is good for winter hardiness. Recently we have seen compost temperatures as high as 15°C in November and if you use a controlled-release fertiliser with high nitrogen then you will certainly get very lush growth, too late, which will negate the potash effects.
John Adlam

EXPERIENCES WITH ROOTING HORMONES

Availability of some rooting hormones is becoming restricted in Ireland. What are members' experiences with different products and mixture strengths?
Philip Moreau

A kilo tub of products such as Seradix lasts ages and obviously the strength deteriorates over time. If we've had Seradix No.3 for more than a year we use it as if it was Seradix No.2. Ideally we need to get suppliers to make things like this available in smaller quantities.
Mike Farmer

Indolebutyric acid (IBA) is light sensitive, rather than time sensitive, so if it is being weakened during storage it is because it is being exposed to light. Synergol lasts well as a stock solution in the dark and in a fridge.
John Adlam

Seradix may be withdrawn soon.
Margaret Scott, Horticultural Research International, Efford

I've found IBA is sensitive to both temperature and light. It is worth keeping it in the fridge in the dark.
Greg McPhee, Nursery Industry Association of Australia

CRINODENDRON FROM SEED

Crinodendrons *(Crinodendron)* have set plenty of seed in Cornwall this year. Does anyone have any experience of growing it from seed?
Mike Farmer, Rosewarne, Cornwall

I've found it germinates very easily in the spring after vernalisation, but have not had to give it any other special treatment.
Tom Wood, Oakover Nurseries

We use seed rather than cuttings for this plant because it avoids problems with spider mite being carried over from the stock plants. It takes longer than cuttings but it is easier and you get cleaner plants.
Philip Moreau, Glenbrook Nurseries

As you say there is plenty of seed it would be worth doing some trials so you will know what the optimum method is under your own conditions. Try different cold treatments on small batches in a cold store or fridge and germinate them. There is plenty of time to do this before you have to decide how to plan production of a crop.
Dennis Fordham, Oakover Nurseries

If you collect and sow too early you can get problems with contamination by mould fungi.
Therese Landers, Green Avenue Nurseries

ROOTING CEANOTHUS 'PUGET BLUE'

Does anyone have any tips on rooting *Ceanothus* 'Puget Blue' consistently?
Alan Hargreaves, Hargreaves Plants

We find it roots ok in September and October in Grodan blocks. We water in well but then neglect and they respond well. Don't get it too wet and use a firm, semi-ripe cutting.
David Hide

The source of cuttings material might affect results. One nursery I know had good results using cuttings taken from stock plants in 3-litre containers grown under plastic and rooted in mist in Ellepots — but this would tend to go against what David just said.
Annette Wickham

GROWING *Clematis armandii*

Does anyone have any tips on rooting and growing *C. armandii*?
David Hide

We grow *C. armandii* 'Apple Blossom' from internodal cuttings with one leaf removed, taken in early September.
Margaret Sheward, Avonbank Nurseries, Pershore College

Does anyone know why the leaves of *C. armandii* sometimes become puckered?
Margaret Sheward

The early season use of Flexidor (contains isoxaben) can cause this, or, if you are growing under polythene, it may be an effect of the leaf expanding in temperatures which fluctuate widely between night and day, upsetting the chemical balance in the leaf. You see this in *Rhododendron*, *Mahonia*, and laurels, too.
John Adlam

We used to see it on tea plantations, where it was known as "hot and cold disease".
Pat Scarborough

ROOTING PITTOSPOSRUM

I find *Pittosporum* tricky to root. Does anyone have any tips?
Paul Green, Wyevale Nurseries

Pittosporum grows in flushes and you get good results if you take cuttings from the first flush, once the second flush is finished. Aim to take quite hard growth. Wounding is beneficial but don't use heat. Propagators use heat too much for a great many subjects that don't really need it.
Philip Moreau

In New Zealand growers avoid heat on pittosporum cuttings till they have callused, then use heat. But it is crucial to use strong material, and take from stock plants not from liners. I know growers in New Zealand who get 90% to 100% take even from purple-leaved cultivars.

I agree with Philip's point about flushes. You can tell if the second flush has stopped because if the leaves are folded it is still growing. On small-leaved types, if you can pull the leaves off easily the cutting will have been poor quality anyway.

Direct sticking also works well with pittosporum.
Therese Landers, Green Avenue Nurseries

LEAF DROP IN HOLLY CUTTINGS

Why do holly *(Ilex)* cuttings loose their leaves in some years and not others?
David Hide

It can be related back to the stock plant, especially in a dry year, and there is also an effect of hormone level. It is worth irrigating the stock plants during early growth flushes.
Margaret Scott

ROLE OF MYCORRHIZAE IN PROPAGATION AND CONTAINER PRODUCTION

How much faith should be put in the use of mycorrhizal inocculation in growing media, does anyone have any experience?
Ian Martin, Eden Project, Cornwall

A new 2-year programme of Horticultural Development Council trials has been started on this at Efford. We think some 95% of nursery stock subjects could benefit. A lot of production in the U.S.A. now uses mycorrhizae and there is some evidence it promotes growth and may cut pesticide use. So far there have been a lot of claims but little in the way of independent trials.
Margaret Scott

PREVENTION OF WINDBLOW IN TALL CONTAINER CROPS

Just a tip, really, having tried many different ways of trying to prevent tall container plants being blown over on the nursery. On our standing area we have placed trellis horizontally and supported on plastic pipe so that it is about 2 to 3 cm above the ground to make a grid that the pots are stood down into. Make sure the trellis grid is the right size for the pots you are using.
Robert Hudson, Lilyhurst Plants

Greetings and Introductions

Timothy Brotzman
Brotzman's Nursery, Inc., 6899 chapel Road, East Madison, Ohio 44057 U.S.A.

I will begin by introducing the Local Site Committee consisting of Rod Bailey, Vern Black, Don Cross, John Daniels, Bert Swanson, Dean Engelmann, and Cameron Smith. When you see them thank them for all they have done because you would not have what you have today without their help.

The silent auction will close this evening so you will have plenty of time to make your bids.

Our program chair, Dale Deppe, spent the last year bringing this program together. When you see him, also thank him for a job well done.

This is the fourth year for the poster session and I believe that we are the only region that has one. We have had over 100 posters present and this has allowed members to make presentations who did not have the time to do regular papers or did not wish to present a paper. There are many good ideas presented so take advantage of the posters. It is certainly one of the most positive things this Society has done the past 4 years. It will be available the entire conference. This year's session was chaired by Dan Studeabaker, our Second Vice President.

All of this is glued together by Margot Bridgen who can usually be found at the registration desk.

At this time it is sad to announce that several members of our Society have passed away; they include John Wilde, a Fellow, and Gus Mehlquist, a Fellow and Award of Merit member. May we have a moment of silence for these deceased members.

John Daniels will introduce our first speaker, Dr. Mark Yudof, President, University of Minnesota, who will present the welcoming address.

Seed Dormancy in Commercial Vegetable and Flower Species

Robert L. Geneve
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INTRODUCTION

This paper is a review of seed dormancy in vegetable and flower seeds. Due to page constraints only a portion of it appears here. A complete discussion of this topic including tables on individual species with different dormancy types has been previously published (Geneve, 1998).

Following seed dissemination from the plant, orthodox seeds exhibit one of three conditions. A seed may be nondormant and germinate immediately; it may be nondormant and quiescent; or the seed may be dormant. Quiescent seeds are inhibited from germinating because the environment is unsuitable (i.e., the seed is dry or the temperature is outside the range that permits germination). Dormancy differs from quiescence because dormant seeds fail to germinate even when environmental conditions (water, temperature, and aeration) are suitable for germination.

Seed dormancy is a common condition found in many species. It is an adaptation that allows a species to determine the timing of germination for seeds in a population. Domestication of crop plants has led to the reduction or elimination of seed dormancy to fit cropping schedules. Although this is true of most of the major agronomic crops, many vegetable and flower species still exhibit forms of seed dormancy that impact crop and seed production, and complicate seed testing.

CATEGORIES OF SEED DORMANCY

Propagators of cultivated plants long recognized that germination-delaying phenomena existed in seeds. The first recorded discussion of seed dormancy was by Theophrastus in ~300 B.C. (Evenari, 1984). He recognized that most seeds germinated less after time in storage while others germinated at a higher percentage. An early system of classification was formulated by Crocker (1916), who described seven dormancy types based on treatments used to overcome them. Subsequently, Nikolaeva (1977) defined dormancy based primarily upon physiological controls. More recently, a universal terminology for dormancy was proposed (Lang, 1987) that used the terms eco-, para-, and endo-dormancy to refer to dormancy factors. Baskin and Baskin (1998) have extended the dormancy classifications of Nikoleva to include additional specialty types and forms the basis for the system presented here for horticultural crops.

Major categories are primary and secondary dormancy. Within primary dormancy there are three recognized groups. These include: (1) exogenous; (2) endogenous; and (3) combinational dormancy (Hartmann et al., 1997). Representative vegetable and flower genera for each of these categories are found in Table 1.

Exogenous Dormancy. The tissues enclosing the embryo can impact germination by (1) inhibiting water uptake; (2) providing mechanical restraint to embryo expansion and radicle emergence; (3) modifying gas exchange (i.e., limiting oxygen to the embryo); (4) preventing leaching of inhibitors from the embryo; and (5) supplying inhibitors to the embryo (Bewley and Black, 1994).

Seed coverings that impose exogenous dormancy are the endosperm, perisperm, outer integuments of the seed coat, or the remnant of the fruit pericarp. These may become hard, fibrous, or mucilaginous during dehydration and ripening. The most common form of exogenous dormancy occurs in seeds with "hard" seed coats that become suberized and impervious to water. Hard seeds are characteristic of members of the *Cannaceae, Convolvulaceae, Fabaceae, Geraniaceae,* and *Malvaceae*. Germination in hard seeds can be increased by any method that can soften or "scarify" the covering (Hartmann et al., 1997).

In other species such as cucumber (*Cucumis*) and spinach (*Spinacia*), mucilaginous layers on the seed coverings can restrict gaseous exchange (Bewley and Black 1982). These layers maintain primary dormancy, mainly because this semipermeable nature restricts aeration and inhibitor movement.

Chemicals that accumulate in fruit and seed covering tissues during development and remain with the seed after harvest can also act as germination inhibitors (Evenari, 1949). Fleshy fruits, or juices from them, can strongly inhibit seed germination as in *Cucumis* and *Lycopersicon* species. Some of the substances associated with inhibition are various phenols, coumarin, and abscisic acid (Bewley and Black, 1982). Inhibitors have been found in the seeds of such vegetable and flower families as *Polygonaceae*, *Brassicaceae*, *Chenopodiaceae, Linaceae* (*Linum*), *Lamiaceae (Lavendula)*, *Portulaceae (Portulaca),* and *Violaceae* (Atwater, 1980).

Endogenous Dormancy. Seeds with endogenous dormancy fail to germinate because of factors associated with the embryo. It can be confusing to distinguish between certain types of endogenous dormancy and some forms of exogenous dormancy, because removal of the seed coat (or pericarp) often allows the embryo to germinate in seeds with endogenous dormancy. There are two types of endogenous dormancy – morphological and physiological.

Morphological Dormancy is where the embryo has not completed development at the time the seed is shed from the plant. Seeds with morphological dormancy can have either rudimentary or undeveloped embryos (Atwater, 1980). Species with rudimentary embryos have little more than a proembryo embedded in a massive endosperm. These are found in *Ranunculaceae* (*Anemone*, *Ranunculus*), *Papaveraceae* (*Papaver*, *Romneya),* and *Araliaceae* (*Aralia*, *Fatsia*). Effective aids for inducing germination include (a) exposure to temperatures of <15°C, (b) exposure to alternating temperatures, and (c) treatment with chemical additives such as potassium nitrate or gibberellic acid.

Seeds with undeveloped embryos have embryos that are torpedo shaped and up to one-half the size of the seed cavity. Important families and genera in this category include *Umbelliferae (Daucus), Primulaceae* (*Cyclamen*, *Primula*), and *Gentianaceae* (*Gentiana*). Warm temperatures (> 20°C) favor germination, as does gibberellic acid treatment.

The second type of endogenous dormancy is **physiological dormancy**. This involves physiological changes within the embryo that allows the radicle to escape the restraint of the seed coverings. Physiological dormancy includes non-deep, intermediate, and deep categories. By far, endogenous, non-deep physiological dormancy is the most common form of dormancy found in seeds (Baskin and Baskin, 1998). This type of dormancy includes species that require light or darkness to germinate and species that must undergo an "after-ripening" period of dry storage to lose dormancy.

Seeds that either require light or dark conditions for germination are termed **photodormant**. The basic mechanism of light sensitivity in seeds involves phytochrome (Bewley and Black, 1994; Taylorson and Hendricks, 1977). For some seeds, there is a distinct light and temperature for alleviating photodormancy. Lettuce (*Lactuca*) seeds generally require light to germinate, however, they lose this requirement and can germinate in darkness if the temperature is below 23°C. Seeds may also lose their requirement for light after a period of dry storage.

"After-ripening" is the time required for seeds in dry storage to lose dormancy. It is the general type of primary dormancy found in many freshly harvested seeds of herbaceous plants (Atwater, 1980; AOSA, 1993, Baskin and Baskin, 1998). This type of dormancy is often transitory and disappears during dry storage, so it is generally not a problem by the time the grower sows the seeds. For most cultivated grasses, vegetables, and flower crops, nondeep physiological dormancy may last for 1 to 6 months and disappears with dry storage during normal handling.

Seeds with intermediate and deep physiological dormancy are characterized by a requirement for a 1- to 3-month period (sometimes more) of chilling, while in an imbibed and aerated state. This is a common dormancy type for tree and shrub seeds and some herbaceous plants of the temperate zone (Crocker, 1948). This requirement led to the horticultural practice of "stratification", in which seeds are placed between layers of moist sand or soil in boxes (or in the ground) and exposed to chilling temperatures, either out-of-doors or in refrigerators.

Temperature is the most important factor controlling stratification. The most effective temperature is near freezing (1 to 10°C). The time required to stratify seeds results from the interaction of the genetic characteristics of the seed population, seed development environment, and the stratification environment (i.e., temperature).

Combinational Dormancy. The third category of dormancy is combinational (also called double) dormancy. This dormancy condition combines two (or more) types of primary dormancy. Examples include exo-endodormancy (seed coat dormancy and intermediate physiological dormancy), or morphophysiological dormancy (a rudimentary embryo combined with physiological dormancy). To induce germination, all blocking conditions must be eliminated in proper sequence.

Seeds with **morphophysiological** dormancy may require simply warm (> 15°C) or cold (1 to 10°C) conditions during which time the embryo develops and then breaks physiological dormancy. More complex forms of morphophysiological dormancy require extended cycles of warm and cold temperatures to satisfy dormancy. Seeds with epicotyl dormancy have separate dormancy conditions for the radicle and epicotyl (Baskin and Baskin, 1998; Crocker, 1948; Nikoleava, 1977). These species fall into two subgroups. In one group, only the epicotyl is dormant. Seeds initially germinate during a warm period of 1 to 3 months to produce root and hypocotyl growth but then require 1 to 3 months of chilling to enable the epicotyl to grow. This group includes seeds from various *Lilium* species, *Paeonia*, *Cimicifuga*, and *Asarum*.

In the second group, seeds require a chilling period followed by a warm period for the radicle to grow, then a second cold period to release the epicotyl from dormancy.

Table 1. Catagories of seed dormancy in vegetable and flower seeds.

Types of dormancy	Causes of dormancy	Conditions to break dormancy.	Representative species of flower and vegetables
1. Exogenous dormancy			
Physical	Impermeable seed coat.	Scarification.	*Baptisia*, *Lupinus*
Chemical	Inhibitors in seed coverings.	Removal of seed coverings (fruits). Leaching seeds.	*Beta*, *Iris*
Mechanical	Seed coverings restrict radicle growth.	Removal of seed covering. Cold stratification.	*Lactuca*
2. Endogenous dormancy			
Morphological	The embryo is not fully developed at the time the seed sheds from the plant.	Warm or cold stratification.	
Rudimentary	Small undifferentiated embryo.	Cold stratification and potassium nitrate.	*Anemone, Ranunculus, Daucus, Cyclamen*
Undeveloped	Small differentiated embryo less than ½ size of seed.		
Physiological	Factors within embryo inhibits germination.		
Nondeep	Positively photodormant.	Red light.	*Lactuca*, *Primula*,
	Negatively photodormant.	Darkness.	*Cyclamen*, *Nigella*

	After-ripening.	Short period of dry storage.	*Cucumis, Impatiens*
Intermediate	Embryo germinates if separated from the seed coat.	Moderate periods (up to 8 weeks) of cold stratification.	*Aconitum, Gentiana*
Deep	Embryo does not germinate when removed from seed coat or will form a physiological dwarf.	Long periods (> 8 weeks) of cold stratification.	*Dictamnus*
3. Combinational dormancy	Combinations of different dormancy conditions that must be satisfied sequentially.		
Morphophysiological	Combination of underdeveloped embryo and physiological dormancy.	Cycles of warm and cold stratification.	*Helleborus, Mertensia*
Epicotyl	Radicle is nondormant and growth begins when temperature and water permit, but epicotyl is dormant.	Warm followed by cold stratification.	*Asarum, Paeonia*
Epicotyl and radicle	Radicle is dormant and growth beginsafter chilling stratification treatment, but epicotyl is dormant.	Cold stratification followed by warm followed by a second cold stratification.	*Convallaria, Trillium*
Exo-endodormancy	Combinations of exogenous and endogenous dormancy conditions. Example : physical (hard seed coat) plus intermediate physiological dormancy.	Sequential combinations of dormancy releasing treatments. Example: scarification followed by cold stratification.	No vegetable or flower genera in this category.

4. Secondary dormancy

Thermodormancy	After primary dormancy is relieved, high temperature induces dormancy.	Growth regulators or cold stratification.	*Apium*, *Lactuca*, *Viola*
Conditional dormancy	Change in ability to germinate related to time of the year.	Chilling stratification.	Not applicable for cultivated conditions.

In nature, such seeds require at least two full growing seasons to complete germination. Examples include *Sanguinaria*, *Trillium*, and *Convallaria*. In some cases, a population of seeds can display either simple morphophysiological dormancy or epicotyl morphophysiological dormancy (Barton, 1944).

SECONDARY DORMANCY

In nature, primary dormancy is an adaptation to control the time and conditions for seed germination. Secondary dormancy is a further adaptation to prevent germination of an imbibed seed when environmental conditions are not favorable for seedling growth. These conditions can include unfavorable temperatures, prolonged light or darkness, water stress, or anoxia. These are involved in the seasonal rhythms (conditional dormancy) and prolonged survival of weed seeds in soil banks(Baskin and Baskin, 1998).

For some species, such as lettuce (*Lactuca*), celery (*Apium*), and pansy (*Viola*), germination at high temperatures (> 25°C) can induce **thermodormancy**. Commercially important crops that are prone to thermodormancy (such as summer-sown lettuce or pansy) can be primed prior to sowing to avoid germination problems (Cantliffe, 1991; Carpenter and Boucher, 1991).

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Seed Propagation of *Acer diabolicum*

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INTRODUCTION

The devil maple, *Acer diabolicum*, a species native to Japan, is rarely found in botanic gardens and arboreta in the United States. This rarity is due to its flowering and fruiting characteristics, as well as difficulty in propagation. Since it is a dioecious species, viable seed is usually not available. Devil maple is a member of the rather obscure *Lithocarpa* section in the *Acer* genus, and as a result, cannot be readily propagated via grafting or budding due to a lack of closely related, compatible rootstock species (van Gelderen et al, 1994).

The common name for the species refers to the two horn-like styles that attach to the inner sides of the nutlets between the seed wings (Vertrees, 1978a). The species is perfectly hardy in central Kentucky (Zone 6a) and should be considered for use as a small-sized tree for the homeowner. It has smooth, gray bark reminiscent of beech, and a broad spreading crown profile. The foliage is an appealing deep green in summer; fall foliage coloration is a muted brown. Besides its overall dimensions and apparent hardiness, the greatest ornamental feature of the devil maple are the terminal inflorescences that appear prior to the leaves on male trees. These flowers are a striking red color and are quite noticeable in early May in Kentucky.

In 1964, three trees of *A. diabolicum* were planted at the Bernheim Arboretum and Research Forest. They now average 20 ft tall and 25 to 35 ft wide. Fortunately, the two female and one male trees were planted in close proximity, but only one female produces viable seed. The other female tree flowers approximately 10 days later and, as a result, is out of phase with the male tree. Interestingly, this tree will produce an abundance of parthenocarpic seeds.

Literature indicated that species in the section *Lithocarpa* can require up to 2 or 3 years to germinate (van Gelderen, 1994). A study to investigate the seed germination requirements of this species was initiated in Fall 1998. Results from this study should lead to the development of protocols for producing seedlings that will be screened for fall color potential and/or used as a source of potentially compatible understocks for the male selections.

MATERIALS AND METHODS

A total of 600 seeds were collected on each of three different dates beginning in early September. An additional 150 seeds for each collection date were cut to determine the percentage of filled seed in each lot. Each collection was subsequently divided into a series of five stratification treatments: 3 months cold or 4 months cold, 2 months warm/2 months cold, 2 months warm/3 months cold, and 2 months warm/ 4 months cold. The experimental design for this study was a split-plot arranged in a randomized complete block design with 6 replications, with the stratification treatments considered to be the whole units, and dates of collection as the sub-units.

All seeds were stratified by placing them in polyethylene bags containing moist Canadian peat and sand medium (1 : 1, v/v) for the duration of each treatment period. Warm stratification temperature was approximately 68°F and cold stratification temperature was 40°F. Seeds were subsequently sown at a depth no greater than the width of the seed in flats filled with Metro-Mix® 360. Each flat contained a total of 60 seeds, with 20 seeds sown per collection date for each stratification treatment. Each flat was assigned a random position within each of the 6 replications (blocks) on the greenhouse bench. Temperatures within the greenhouse ranged from 60 to 95°F. Flats were hand watered as needed.

The total number of germinated seedlings was noted at the end of a 30-day period following each sowing date. A germinated seedling was counted based on the presence of true leaves. Percent germination data for each date × treatment × replication combination, was transformed using the arcsin-transformed percent procedure and subjected to analysis of variance (Steele and Torrie, 1960). Treatment mean seperations were tested for significance at $P<0.05$ level following the procedures outlined by Cochoran and Cox (1957).

RESULTS AND DISCUSSION

The percent filled seed, as determined by a cut test of 150 seeds for each collection date, averaged 78%. Despite this potential, the actual germination rate over all collection dates and stratification treatments averaged only 8.6%. Such a minimal result should not be unexpected, however, since species in the *Lithocarpa* section are reported to have the longest dormancy requirements in the *Acer* genus, and may take up to 3 years to germinate (van Gelderen et al., 1994).

The germination rate of devil maple was significantly affected by stratification treatment (T) (Table 1) and date of seed collection (D) (Table 2). In addition, a significant D × T interaction was detected. In general, germination rates decreased for later collection dates for the 3 or 4 month cold stratification treatments. The opposite trend was noticed for the warm/cold stratification treatment data, where germination rates increased with the later collection dates (Table 3). A maximum germination rate of 36% was obtained in this study by collecting seeds in mid-October and placing them in a 2 months warm/ 3 months cold stratification treatment.

Table 1. *Effect of stratification treatments on seed germination of Acer diabolicum*[z].

Treatment	Months warm stratification (no.)	Months cold stratification (no.)	Germination arcsin %[y]
T1		3	13.8 b
T2		4	9.9 b
T3	2	2	10.8 b
T4	2	3	28.1 a
T5	2	4	22.6 a

[y] Values followed by the same letter do not differ at $P< 0.05$.
[z] Germination assessed 30 days after sowing.

Table 2. Effects of seed collection date on germination of *Acer diabolicum*[z] .

Date	Collection date	Germination arcsin %[y]
D1	09/3/98	10.8 b
D2	10/22/98	21.1 a
D3	11/17/98	19.2 a

[y] Values followed by the same letter do not differ at P< 0.05.
[z] Germination assessed 30 days after sowing.

Table 3. Effects of seed collection date and stratification treatment on seed germination of *Acer diabolicum*[z].

Date	Treatment	Germination arcsin %[y]
D1	T1	14.5 cde
D2		18.5 cd
D3		8.6 e
D1	T2	4.3 f
D2		17.3 cde
D3		8.3 ef
D1	T3	4.4 f
D2		11.2 def
D3		16.7 cde
D1	T4	15.6 cde
D2		36.0 a
D3		32.7 a
D1	T5	15.1 cde
D2		22.8 bc
D3		29.8 ab

[y] Values followed by the same letter do not differ at P< 0.05
[z] Germination assessed 30 days after sowing.

Seed Collection Date. Seeds were collected for the study on three different dates beginning in early September. Normal seed fall did not occur until late November in 1998. Early harvest of maple seeds has been cited as one technique to improve germination in some *Acer* species, especially in the Series *Palmata* (Vertrees, 1978b). Early seed collection has also been suggested as a method to overcome dormancy in maples imposed by hard seed coats (Wiegrefe, 1994). In this study, early seed collection in fact resulted in the poorest germination rate (Table 2). Germination was maximized when the seed was collected approximately 1 month before normal seed fall.

Stratification Treatments. The length of stratification, along with temperature, had a significant impact on germination (Table 1). Devil maple apparently requires a combination of warm and cold stratification temperatures to maximize germination, which indicates that the mechanism of seed dormancy in this species may be imposed by both the testa and embryo. Wiegrefe (1994) suggests that testa-imposed dormancy in *Acer* is cold temperature dependent, whereas embryo dormancy is overcome by longerstratification periods when compared to testa-imposed dormant species. In this study, a 2 month warm/3month cold treatment provided the best results over all three seed collection dates.

Devil maple is an obscure species with great potential for surburban landscapes of the MidWest. Its characteristic growth rate, size, and shape, appealing foliage and bark, as well as the spectacular flower display on male trees, are just some of the reasons to justify growing this species. Seed propagation information for the species is lacking, due to scarcity of seed supply. While the present study is by no means conclusive, it does provide some insight into the seed dormancy requirements for the species. It appears that devil maple exhibits a characteristic double dormancy which can be partially overcome by means of combining a warm/cold stratification schedule with a seed harvest date approximately 1 month prior to normal seed fall. Such a prescription may allow the grower to produce a meaningful number of seedlings (35%) within 6 months of seed harvest. It is anticipated that the germination percentage might increase significantly as the stratification schedule is lengthened.

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Biological Remediation of Damping Off on Conifer Seedlings at Meadow Lake Nursery Company

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Seedlots of different conifer species can often be impacted by diseases known collectively as damping off. Anecdotal evidence suggested that the biological fungicide RootShield was performing well in other nursery operations and also that coco coir was, as a seeding mulch, doing wonderful things for flower growers. A replication of standard fungicide treatments and a control were added. It was also decided to trial a seed soak in hydrogen dioxide, the modern equivalent of hydrogen peroxide, used for many years as a seed-born disease sterilant.

The results indicate that certain combinations of the treatments may have commercial application, but that more trials are needed. These particular seedlots apparently exhibited low seed vigor and no matter what treatments were applied, it was a difficult project to redeem.

More work is needed on seed-soaking techniques with hydrogen dioxide. Perhaps soaking seeds in water prior to the dip would have been a better procedure.

INTRODUCTION

Oregon? McMinnville? Where is that? "Why are we here in Minnesota?," you may ask. Nineteen years ago, Todd left Minneapolis to work for Bailey Nursery in Oregon. Within a few years he started backyard experiments in new production methods and liner taxa. He met Cheroyl and together the Ericksons started Meadow Lake Nursery in 1985. The nursery now consists of 500 acres and an annual liner production of 9 million liners.

I am honored to present this paper to the Eastern Region of I.P.P.S. I have added a list of references detailing the choice of seeding method, container, and materials for disease remediation.

Conifers! Meadow Lake grows rootstocks for both the ornamental and fruit-tree industries. We wanted to provide conifers for the ornamental industry geared to provide caliper or height-sized containerized seedlings for winter grafting and growing. The goal is to produce healthy vigorous plants in time for early fall potting or lining out.

I, Mic Armstrong, have been growing conifers for some time. Eastern Region members may remember a presentation I gave in St. Louis, Missouri, in December of 1992 which boasted a title even longer that this one. The aim then was also to reduce losses to the various pathogens that comprise damping off.

Growers like to experiment with new materials or new cost-effective methods to grow healthier plants with less hassle. We design the trial, gather materials, supervise the production, take slide pictures, write notes on the weather and try to eliminate unforeseen variables, and note the dates of various treatments. In addition, we keep the biological parts of the trial separate from chemical treatments and haul nonchlorinated water for biologicals that don't care for chlorine or bromide in the water. We take care that subsequent cultural practices are properly administered, take more pictures, and then when we get a few minutes we try to analyze the results.

METHOD

Two days prior to our scheduled seeding date in early February of 1999, a *Picea abies* seedlot was divided into two parts, one half was soaked in tap water and the other was given a 5 min. soak in 2% Zerotol.

Zerotol is formed by the fusion of hydrogen dioxide (hydrogen peroxide) with peroxyacetic acid. The manufacturer claims it is 10X more active than hydrogen peroxide and contains additives which allow it to remain stable and non-phytotoxic. Many nurseries are using it as softwood cuttings dip to replace fungicidal dips that have a long re-entry interval on the chemical label. Zerotol has a zero re-entry in the United States. It safely breaks down to oxygen and water, however, I would caution that the concentrated product is extremely caustic, therefore, eye and skin protection is essential for all handlers.

The seeds treated in the Zerotol treatment were then flushed in water (a cloth bag works well for the soak), then air-dried on a screen alongside the water-soaked seed on a separate screen. Once surface-dried they were placed into Ziploc bags and refrigerated at 34°F until seeding a couple of days later. In my experience species such as *P. abies* benefit from a water soak (as described) but not from a longer period of cold stratification.

Once the seeding process began on the arrival of our friend from Jiffy Products, things moved fast. We seeded over 100,000 cells that day and our Norway spruce experiment was part of it. We ran the water-soaked *P. abies* lot first, including our trays tagged for trial. Next, the Zerotol-soaked lot went through the machine and the marked trays were also seeded and placed on the same bench as the rest. Later that afternoon I applied the different products on trial.

The trial consisted of 40 trays of 300 pellets, four replications of five on both the Zerotol and water-soaked seed lots. To each of five replications RootShield (*Trichoderma harzianum* Fifai strain KLR-AG2) was applied in labeled quantities and the cells thus marked were drenched and separated from other treatments. Well water was used to dissolve this biological product in order that chlorine would not compromise the initial application. Note: many biologicals are adversely affected by chlorinated water, however manufacturers' protocol rarely mentions this. The second treatment involved pulverizing some coconut coir from a sample brick of dried product. The dust thus produced was broadcast over the top of the 10 trays tagged pink, avoiding other trays destined for noncoir treatments. The idea here was that anecdotal evidence has indicated that coco coir has "anti-damping off" effects and so we considered this worthy of further investigation. To avoid the possibility that the well water used to dissolve the RootShield had its own properties we drenched all other replications with an equal quantity of the same well water.

The final treatment was chemical. The rest of the pellets seeded would also be drenched with a fungicide, in this case Banrot, later that evening. In all future fungicide applications great care was taken to remove the RootShield, coir, and control replications from any danger of fungicidal spray. Frequently moving the treated trays, it was hoped, would effectively randomize the experimental blocks.

Unforeseen variables included the ease with which peat pellets can be either over- or underwatered within a given area if sprinklers are not perfectly tuned. A mouse, apparently heading for the newly seeded *Pinus thunbergii* and *Larix kaempferi* also could be considered as an unexpected environmental factor. We suspect that his effects were minimal to *P. abies* but devastating to the black pine and larch!

As the seeds germinated, general observations were made. Damping off was noticed in all the Norway spruce, both Zerotol-treated and otherwise. Other conifers seeded were also affected to one degree or another. Fungicides such as Chipco, Cleary's, Subdue, and Daconil were applied to all except the RootShield, coco, and control replications which were isolated from sprays.

RESULTS

In this particular trial it was decided that the numbers of plants surviving transplanting to 2¼-inch pots from each of the different treatments would constitute the data. Using a Bouldin & Lawson Transplanter, seedlings were planted onto dibbled trays of Landmark 32 cell 2¼-inch pots. Each tray was labeled for each replication with the appropriate tag printed in the same colored plastic as in the initial experiment.

Table 1. *Picea abies* seeded and transplant data.

Description	Seeded 2/11/99	Transplanted 5/20/99
Control	1500	736 (49)[X]
Coco coir	1500	1216 (81)
Zerotol coco coir	1500	288 (19)
Chemical	1500	820 (55)
Rootshield	1500	992 (66)
Zerotol rootshield	1500	384 (26)
Zerotol control	1500	800 (53)
Zerotol chemical	1500	832 (55)

[X] Number in () = % transplanted

DISCUSSION

It would appear that the two biological methods without the Zerotol-soak (coco and Rootshield) were the best. Visually, however, some damping off was present on all treatments. The application method/rate for treating tiny peat pellets may be critical. The negative interaction with Zerotol observed apparently in coco and RootShield seemed odd. Perhaps we should have imbibed the seed with water prior to the Zerotol dip. Another hypothesis could be coco coir mulch actually prevented seedling desiccation, and any old organic mulch would have helped? One factor that we should have considered is that of seed vigor. Old or poorly stored seed may still be viable, but once germinated it lacks the energy to make a healthy seedling. A high percentage of runty and weirdly branched seedlings is indicative of this phenomenon. The *P. abies* lot chosen for this trial apparently exhibits poor vigor.

Other species seeded on the same day had varying results but some were excellent, i.e., seedlots of good vigor. Over 80% of the single seeded Jiffy cells eventually made 2¼-pots with uniform growth.

Although coco coir on seeds untreated in Zerotol win the "contest", this nursery won't be relying on it as a damping off preventative quite yet. We will, nevertheless, attempt to repeat the experiment with a high vigor seed lot in the Year 2000, perhaps expanding the products to include some new biologicals I have recently acquired.

We will continue to experiment with the Jiffy method of seedling production. The growth and root systems produced by transplanting the juvenile "peat plugs" are phenomenal. In addition, the seeding adaptations allow for high volume production of multiplicity of normally difficult species.

My conclusions to the previous biological trial I alluded to in 1992 at Vans Pines indicated that good cultural practices were more important than any other component. I will continue to trial biological and new chemistry in the pursuit of the best quality seedling and targeted production. However, I doubt if any of them will help if good seed quality and cultural practices are not at the beginning of the recipe.

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PennMulch Use for Seedbeds

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BACKGROUND

Since 1928, Musser Forests has developed primarily as a bare-root seedling and transplant nursery. Sand was an early mulch used over seed to obtain germination. It was shaken through a screen by hand after being wheeled down the path in a wheelbarrow. Later improvements came using a tractor-drawn sanding machine that could be loaded with a high lift and that vibrated its way down the bed. This was also fairly slow, as the hopper needed constant reloading.

In the mid sixties, Musser Forests came into a new era of seed covering with the hydro-seeder. This machine applied the familiar green-dyed silva fibre mulch in a slurry, with starter fertilizer at the staggering rate of 2 to 3 miles of seedbed in an 8-h day. This of course involved a nearby water supply, pumps, and a 100-plus-HP tractor to handle the 4-ton load.

PENNMULCH INTRODUCTION

Just 2 years ago I was introduced to a new product that was developed for the turf industry called PennMulch. PennMulch is made from recycled and shredded newsprint. It is processed into dry compressed pellets that have 1N-3P-1K fertilizer incorporated into them.

Invention and development of the product was by George Hamilton, Agronomy instructor at Penn State's College of Agricultural Sciences. First marketed in 1995, PennMulch protects seedbeds and retains moisture; plus it contains its own fertilizer. Because it's in the form of dry pellets, homeowners will find it much easier to handle than traditional mulches, such as straw or peat. One 6-lb bag covers up to 100 ft^2 because once it's watered, it expands.

MUSSER FORESTS, INC. TRIALS PENNMULCH

Though PennMulch was developed with turf establishment in mind, I was encouraged by Mr. Tim Hurley of PennTurf products to give PennMulch a trial as a seed covering where we normally use the silva fibre mulch. The first trial was in Spring 1997 where side-by-side beds were compared using PennMulch and silva fibre. Each seedbed of 200-ft length was seeded identically using a Gandy drop seeder, sowing Scotch pine (*Pinus sylvestris*) seed. The PennMulch was applied at 42 lb per 100 ft of bed, a rate that appeared to give adequate coverage and closely matched the fertilizer amount applied in the hydro-mulch slurry.

After simultaneous germination of each it was soon readily apparent that the PennMulch afforded a good 10% to 15% greater germination and seedbed density than the silva fibre application.

The seedlings in the PennMulch bed were also about one third taller and stockier at the end of their first growing season. With the benefits readily apparent, Musser Forests, Inc. has gradually phased out the hydro-seeder and this past spring covered all of its seedbeds with the PennMulch.

BENEFITS OF PENNMULCH IN SEEDLING PRODUCTION

One of the greatest advantages of PennMulch for all growers is its ease and economy of application. A $450 model 42 Gandy spreader with a #28 drop pan and a low horsepower inexpensive tractor is all that is needed to keep up with the most expensive 100-HP tractor and hydro-seeder. PennMulch offers a convenient mulch application for the small or larger grower. For smaller areas, it is even convenient to spread by hand from a bucket. Some of its main attributes are its ease in handling and storing, and the bags are waterproof. It is organic, and weed and pathogen free, so there is no worry about introducing problems to a recently sterilized seedbed. When the pellets swell they hold moisture well and slow erosion from raindrop impact. Price of the product is very comparable to the use of silva fibre mulch when labor and equipment overhead are considered.

For conifers and many of the small seeded hardwood species, we use 42 lb of PennMulch per 100 ft of 4-ft wide bed. The average cost of the product is about $10 per 50-lb. bag, or 8.4¢ per lineal foot. The pellets, of course, must receive rain or irrigation to swell and become effective as a mulch, but I don't see this as a hindrance to PennMulch use since the seed itself will need some regular moisture to germinate. The end result is a seedbed of healthy trees.

PENNMULCH SPECIFICATIONS AND APPLICATION

PennMulch is dark green in color and has a bulk density of 35 to 40 lb ft^{-3}. Its moisture content is less than 10% and the product has a minimum absorption potential of 3 times its dry weight. The pellets are of approximately ⅛ inch diameter and ¼ to ¾ inch in length. Fertilizer analysis of PennMulch has been determined to be 1% total nitrogen, 3% available phosphoric acid, and 1% soluble potash. For lawncare application, PennTurf Products, Inc., recommends the following simple instructions: first seed lawn to well cultivated soil; apply PennMulch by hand or with suitable spreader at a rate of 60 to 75 lb per 1000 ft^2, or approximately 55 bags $acre^{-1}$; and for best results, irrigate with 0.2 to 0.4 inches of water. The producer emphasizes not to remove PennMulch after application.

SUMMARY

More than 4 million lb of PennMulch has been sold to turf grass professionals since it was introduced in 1995 and I believe it will prove useful to growers in our nursery seedling industry.

ADDITIONAL INFORMATION

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Even for Perennials, Timing is Everything in Propagation

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INTRODUCTION

Public demand for color seems insatiable. Some have questioned whether the market can absorb all the perennials being produced today. As one wag recently commented, the pie is getting bigger, but the pieces smaller. The only way one can remain competitive in today's booming economy is to bring to market new plants and to more efficiently propagate those already in demand. How? Expand your knowledge base, go to those International Plant Propagator or PPA meetings, and network. So you can quickly propagate and bring to market that new *Dysosma* (*Podophyllum*) you received from a plant hunting expedition in China, or bulk-up the latest yellow *Helleborus* strain. To accomplish this the propagator must apply skill and timing along with a good working knowledge of plant physiology and anatomy.

Perennials are propagated by most of the same methods used for woody ornamentals, but the methods and timing are somewhat different, depending on the plant's timing demands, when you or your labor have the time for propagatioin, as well as the size and time of the year the market wants your propagule.

PROPAGATION METHODS

Seed. Although traditional perennial nurseries propagate a much greater diversity of taxa today, the greatest number of seed-propagated perennials are done by greenhouse growers for the bedding plant market. Here, too, timing is a critical factor. The propagator must weigh factors like need for cold stratification (some perennials do not require one), whether an after ripening period will help to enlarge an immature embryo, or whether just plain room temperature storage will result in more rapid and complete germination. Some germinate best in light, others in the dark. Some like *Platycodon*, *Heuchera*, or *Coreopsis* will flower from seed like annuals (without plants receiving any cold treatment) others like most *Aquilegia*, and *Lupinus* must be germinated, then the small seedlings exposed to cold (vernalizing) temperatures to ensure flowering for sales. In order to schedule these for spring sales, the propagator must locate reliable sources of high quality seed. For spring sales scheduling may begin during the summer of the pervious year.

Hellebores are the rage of the gardening community, but the really great ones are not available in sufficient numbers and may not be for some time. No reliable tissue culture yet (although I understand that it is being done in Japan), division is maddeningly slow, and cutting propagation is not possible. So, that pretty much leaves seed propagation as the only reliable way to grow great, but still not entirely uniform, strains of this outstanding evergreen. Seed collection can be chancy, and if your timing is wrong, the capsules ripen and the seed becomes mouse food in a matter of a few hours. Propagators and seed collectors alike rely on placing muslin bags over the clusters of seed capsules as they approach ripeness in late May or early

June so that when the seed does ripen all drop into the bags. Once collected though, the propagator must be timely and not let the seed dry out. Plant the ripe black seed before the papery membrane attached to the seed coat dries out. Planting in a warm moist medium allows the embryo to continue developing so that it can then be stratified under cool conditions that promote germination either outdoors the following spring, or in the greenhouse during the winter. Another way to propagate hellebores according to Sam Jones, "Mr. Hellebore", from Bishop, Georgia, is to collect ripe seed and sow directly into ground beds. His are shaded in a wooded area on the edge of his nursery. Seeds after-ripen, stratify, and germinated in these beds the following spring. Again, timely collection and quick seeding is still of critical importance.

Division. Division is the traditional way that many perennials are propagated and cloned. Although some can be done almost any month, most division begins in early spring after the ground or pot thaws and continues through the fall months. Timing depends on a number of crop and facility related factors, but most important is to determine when you will sell the propagule and whether is will be sold bare root or in a container.

Probably the most popular perennial is the daylily and one of the easiest to propagate. Although more cultivars, particularly the new "hot" ones are being done in tissue culture, most wholesale growers, gardeners, landscapers, and others propagate by division. *Hemerocallis* is one of those plants that, if necessary, can be propagated almost any month of the year when the ground is not frozen. Propagation begins in the early spring when the fans are just emerging. Plants are lifted, shaken free of soil, and the fans separated either by hand or with the aid of a sharp knife. If you do not have time to propagate them in the spring, then just after bloom in July or August is another good time. In fact, in many ways it's easier because the fans have now grown and the plant has a handle. I do not like to wash fans as they seem to re-establish al little faster in thedirty condition. Probably the second — and the first in shade gardens — most popular perennial is *Hosta*. Again, spring division is best, but division can continue well into the summer. Although propagation can continue into fall, leave enough time for plants to reestablish roots so they do not heave out of the soil the following spring.

Astilbe, *Polygonatum*, German iris, *Dodecatheon*, and herbaceous peonies and a variety of other perennials can be divided in summer.

I divide and pot my bare-root astilbes beginning in March, but if market demand exceeds supply, I re-divide those with multiple eyes in late June and July. This still gives plenty of time for re-establishment for late August sales. Those not sold are held until after the first hard frost and washed for either bare-root sales or winter storage.

If German iris is not done in early spring before growth begins, then wait until mid summer to divide the rhizomes. Lift, remove the soil, and divide so that each rhizome segment has a fan attached to it. Cut back the foliage to facilitate handling and replant so that the rhizome is partially visible. With the onset of mid summer heat, crops like *Dodecatheon* go dormant. After a few weeks of dormancy, *Dodecatheon* crowns are lifted, and the roots separated from the crown. Each large *Dodecatheon* root has a small bud at the junction with the crown that is removed when the root is torn off.

Polygonatum and *Cimicifuga* rhizomes can be lifted, divided, and successfully re-established in early spring but do so before growth is evident, Many *Polygonatum* are imported by bare-root suppliers in the spring. In my experience many of these divisions do not establish and grow very well. In fact, some remain in the pot without any shoot growth until the following spring. For me, the best time is in August, again when plants normally initiate new root growth in response to cooling soil temperatures and renewed moisture. Rhizomes are segmented . Depending on your needs, they can be divided into segments that include a mature, visible bud, or can be cut down into smaller units without a visible bud; one will develop later. Here, each segment is analogous to the node and internode parts of a branch. At this time of the year when the rhizomes are replanted they continue to root and grow in preparation for additional shoot growth the following spring.

Herbaceous peonies should be divided ONLY in late summer or early fall. That is the only time when they "put down" new roots. Buying and trying to re-establish peonies in the spring just invites poor results. In addition, one problem I have seen with fall-potted peonies is that the grower tries to stuff the large tuberous root into too small a pot. Choose a pot large enough that the eyes will be just below the surface of the medium. Gallon containers are just too small for most field-grown roots. Unfortunately, many grafted tree peonies are available in the spring. They too will root in poorly, so, choose a domestic source (there are a few) if possible.

Cuttings. Cutting propagation is a reliable way to mass produce many herbaceous perennials clones. It usually requires greenhouse or outdoor mist systems, although some plants like sedum can be direct stuck into a small container or pot without the aid of mist. Since herbaceous perennials die back to the ground, the seasonal window of gathering cuttings is somewhat restricted compared to rooting woody plants. However, there are some ways to extend that season. For example, placing potted stock plants in the greenhouse to force cutting growth under HID lights. This works well with *Artemisia* 'Silver Mound' or *Scabiosa* 'Butterfly Blue' (the Perennial Plant Association Perennial of the Year for 2000). Stock plants are brought in anytime after January 1 or after they have completed their cold requirement. Although cuttings propagated in this manner are more expensive, it does allow an extended propagation period to meet market demand. For *Artemisia* it is especially useful as rooting decreases rapidly with the onset of hot weather in June. As with "woodies", some perennials root more slowly when they flower. Shearing *Coreopsis* 'Moonbeam' stock plants will produce new cuttings. One of the biggest problems with rooted perennial cuttings comes at transplanting. Here, at least a node or two should be planted below ground to encourage crown development so plants acquire enough storage material for successful overwintering.

Perhaps the lowest tech cutting propagation method I have ever seen was demonstrated by Dale Hendricks at North Creek Nurseries, Landenberg, Pennsylvania. He propagates *Pachysandra procumbens*, normally much more difficult to root than *P. terminalis*, by planting stock plants in raised beds into a loose, friable medium. He waits until August when new growth has hardened and at a time when root growth will soon reactivate. After a soaking rain or, if necessary, irrigation, he grasps new shoots near their base and pulls firmly upward. He is rewarded with well rooted shoots that break free of the stock plant that are then potted into small containers.

Root Cuttings. While rooting vegetative shoot cuttings is done during the growing season, root cuttings are harvested during the dormant season. A range of plants like *Acanthus*, *Anenome*, *Bergenia*, green forms of *Brunnera*, some *Geranium* species and cultivars, Oriental poppy, *Pulmonaria* 'Bertram Anderson', and some *Tricyrtis* can be commercially propagated by this method.

For Oriental poppies, propagation begins in August after they go summer dormant. Plants are dug and placed in cold storage. Large roots — straw size and larger — are cut into segments 2 to 3 inches long and placed into cells or small pots. Here, they produce new shoots that in turn root. Small plants must be protected in frames for the winter. In spring these liners can be planted out to the field, sold, or containerized. *Brunnera* can be done in October and November using the same method, but remember, the great variegated ones can only be propagated by division. For many of the late flowering anenomes, bare root the plants and hold in storage. By late winter roots will start to form shoots, These can be removed still leaving enough of a root system to either sell the plant bare root, or to containerize it. Finally, I propagate *Tricyrtis* from root cuttings (*Tricyrtis* can also be propagated from shoot cuttings in June) from containerized stock. Over winter, the crown will die leaving an in-tact root system. By April plants can be separated from the medium. The large roots will have begun to form new shoots. These can be removed and potted. Do not throw the rest of the root system away. Scatter the remaining roots in a lug or flat. Cover with medium and by May new shoots will begin to appear. Root cuttings are a excellent way to propagate many perennials and, because they are done during the dormant season, help to spread out propagation labor.

Micropropagation. Since micropropagation, usually called tissue culture or TC, is a laboratory procedure, it allows specialist propagators or larger nurseries that have TC labs to propagate any time of the year. Once a culture is established, it can be used to produce plants continually, or held quiescent and used to meet seasonal production demands. In addition to producing pathogen free plants, TC is especially useful for introducing new cultivars. This is one of the ways that some of the new snakeroots like *Cimicifuga* 'Hillside Black Beauty' and 'Brunette' have been popularized in recent years.

Propagating New Plants

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A challenge to all propagators is to receive unfamiliar plants. During the past year, I received these three plants and was told, "see what you can do with these".

The four plants were *Michelia figo*, *Erythrina* ×*bidwillii*, *Pedilanthus tithymaloides*, and *Indigofera kirilowii*. Each presented its own challenges. The first step is to research each plant, where it originates, growth habits, and environmental requirements. The second step is to observe the plant's growing habits (e.g., whether truly evergreen or semievergreen, when it flowers, and stages of growth) in your area. The rooting hormones used are Hormodin #1 and a solution of Dip 'N Grow and water at a ratio of 1 to 20.

The first plant *Michelia figo* or ornamental banana is an evergreen shrub belonging to the magnolia family. It is only hardy to Zone 8. The stem is fleshy, with waxy medium-size leaves with close internodal lengths. It is an excellent candidate for liquid treatment. With sufficient water and adequate drainage, the stems rooted in 3 weeks with few loses.

The second plant, *Erythrina* ×*bidwillii* (hybrid coral beauty), is hardy to Zone 10 to 11, a member of the Fabacea family, and a coarse-textured plant that produces showy red flowers. The stems are quite fibrous and have solid white pith while the new growth is still quite young. When new growth is only 3 inches long and the tips begin to elongate and internodal length is relatively short, the cuttings should be taken. The cutting should have at least two-leaf nodes, one to expose the leaf scar and the other to remain. After trying powder on group Number 1 and liquid on group Number 2, the powder had the greater success. The powder initialized rooting along the treated portion of the stem. The liquid treatment did produce some rooting but stem rot took its toll.

The third plant, *Pedilanthus tithymaloides*, is a succulent native to the Caribbean, Mexico, and Central and South America. The common name is devil's backbone or Jacob's ladder. The foliage structure is architecturally interesting. The flowers are small cherry-red bracts about ½ inch long. These cuttings can be dipped in liquid or powder and set under mist.

The fourth plant, *Indigofera kirilowii* or Chinese indigo, is a deciduous shrub of 3 ft tall with rose-colored flowers. It is hardy to Zone 5. With its compound leaf structure, the new growth is a bright green and ⅛ inch in diameter. The first group dipped in powder took 2 weeks to root. The second group with liquid treatment calloused in 2 weeks but took another week to root sufficiently. Group 1 kept its leaflets better and had less stem rot loses. Both groups needed extra mist in order to keep their leaves but Group 1 was able to withstand the additional moisture better than Group 2.

I suspect with cooler temperatures the liquid would work as well as powder but the new growth is not sufficiently developed until late May to early June with flowers shortly thereafter. The second flush is ready in midsummer when outside temperatures are 90 to 98°F, and are particularly pithy when long enough for cutting.

Getting new plants for propagation is always a challenge. Whether one has years of experience or is a novice, it is something we can all look forward to.

Using Old Stock Plants for New Research on Shading and Stooling

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INTRODUCTION

Stock plants are a valuable resource in woody ornamental plant propagation and nursery production. Stock plants may be specimen trees, shrubs, hedged stock blocks, or specialized plantings used for seed production, stooling, layering, and even root-piece production. Many nurseries have come to appreciate the value of stock plants from the perspective of having better control over the plant propagation process, rather than trying to tie propagation into a production schedule.

Stock plants or blocks have many positive attributes, particularly in comparison with propagating from plants in container or field production. For example, risks such as mixing up cultivars, taking substandard quality cuttings or suffering from a gradual deterioration of plant quality are avoided when propagation occurs from established plants that are well maintained, well labeled, and not part of the plant production schedule (Hartmann et al., 1997). The history of a stock block is known in regards to plant identity, plant age, geographic or commercial source, and propagation (e.g., seed versus asexually propagated, cutting versus tissue culture origin).

Furthermore, the health and vigor of the stock plant can maintained to meet specific plant needs and propagation goals. The use of pest-free propagation material can have a marked effect on production success (Hartmann et al., 1997). Maintaining a pest-free and, in particular, a virus- or bacteria-free stock plant is a more sound integrated pest management (IPM) technique than treating sick plants during production.

Often the needs of the propagator and production manager differ. Production goals include maximizing growth or flowering, while successful propagation may be favored by slower growth rates, lower nitrogen levels, specially timed harvests, and lack of flowering (Hartmann et al., 1997). But most important might be the opportunity to manipulate stock plants for better rooting potential or propagule health. Possibilities include maintaining the juvenility of seed-derived stock plants through hedging or stooling, altering plant nutrition, manipulating light levels and photoperiod, or even forcing plants to time cutting harvests better. The transition of seedling-grown trees and shrubs from the juvenile to adult phenotype, and the genetic changes leading to new cultivars have been studied extensively (Hartmann et al., 1997). Phenotypically juvenile clones can "age" to the adult phenotype over time and cultivars derived from genetic mutations or "sports" can revert to the wild type. Repeated pruning, hedging, or coppicing can delay or prevent these transitions and associated loss of rooting potential or other desired characteristics. This may be particularly important as more blocks are established from tissue-cultured plants, which characteristically root more easily than conventionally propagated plants.

While the mechanism(s) by which nitrogen fertilization reduces rooting potential is not well understood, the practical application of withholding nitrogen from stock

Contribution No. 3820 of the Rhode Island Agriculture Experiment Station.

plants as a means of increasing rooting is ideal for use with established stock plants. Similarly, it is feasible to manipulate the manganese, zinc, or boron nutrition of stock plants to maximize cutting rooting potential (Hartmann et al., 1997). It would be difficult or undesireable to manage production blocks in this way just to increase propagation potential.

Considerable work has been done with the methods of etiolating, shading, and blanching tree and shrubs to increase rooting (Maynard and Bassuk, 1987). Many of the same principles apply to the practices of stooling, layering, and girdling — propagation methods designed for use with stock plants, not production-cycle propagation. Forcing stock plants in greenhouses has been associated with several of the methods mentioned above (particularly etiolation), and is useful for controlling new shoot growth or extending the growing season. Recent advances in greenhouse materials and construction permit the use of temporary or retractable-roof greenhouses to force new growth, perhaps even on plants growing in the field or landscape.

The use of stock plants or hedges as sources of propagation material is an established practice for many in the nursery trade. Considering the myriad advantages of using stock plants it is interesting that so many nurseries still prefer to take propagation material, usually stem cuttings, from plants in production. Drawbacks to the use of stock plants include occupying potentially valuable production space, requiring at least minimal maintenance, and being less well suited to nurseries that change their offerings frequently, because of the time invested in establishing new plant stock blocks.

The propagation trials described herein are part of a ongoing effort to evaluate, using long-established stock plant hedges, methods of increasing rooting potential of difficult-to-root tree and shrub taxa. The research has been conducted in collaboration with Hoogendoorn Nurseries,Inc., Middletown, Rhode Island. Wherever possible, stock plant treatments are carried out only up to the time of cutting harvest, at which point cuttings are collected, prepared, and rooted by nursery staff according to standard nursery practice.

Paperbark maple was chosen because of continued difficulty in obtaining high rooting percentages of softwood stem cuttings. The stooling of Harry Lauder's walkingstick was evaluated from the perspective of getting own-rooted liners, to avoid problems of suckering on grafted plants, and to reduce propagation costs.

MATERIALS AND METHODS

Shading Paperbark Maple. Methods of shading a paperbark maple (*Acer griseum*) hedge were described previously (Maynard, et al., 1998), with the exception that the hedge was covered on 17 May 1999, approximately 1 week after shoots had started to grow. Three thousand five hundred control (not shaded) cuttings, 400 cuttings from 60% shade, and 300 cuttings from 80% shade were collected by nursery staff on 18 June and treated as described previously (Hoogendoorn, 1985; Maynard et al., 1998). Rooting and cutting survival were assessed on 3 Sept. 1999 using 40 cuttings of each type of cutting, randomly sampled from the rooting bed.

Stooling *Corylus avellana* 'Contorta': Effects of Cut Back Height and Stooling Media. Twenty-five-year-old grafted stock plants of *C. avellana* 'Contorta', Harry Lauder's walkingstick, were cut back (stooled) in March 1998 to heights of 3,

Table 1. Rooting of cuttings from light-grown or shaded paperbark maple stems.

Stock plant treatment	Cutting Survival	Rooting (%)	Root Number	Root length
no shade (control)	65±10[x]	51±19	3.2±1	11.6±2.1
60% shade[y]	90±8.2	42±7	2.9±1	9.0±2.6
80% shade	93±9.6	9±12	1[z]	1.7

[X]Data are mean ± s.e.
[Y]Stems were shaded from 17 May to 18 June 1999. Rooting assessed on 3 Sept. 1999.
[Z]Insufficient cuttings rooted to permit estimation of standard error.

Table 2. Stool shoot production and rooting of stooled *Corylus avellana* 'Contorta'. Stock plants 25 years old stooled in March, mounded beginning in June, and harvested in November 1998.

Mounding Medium	Number of stems produced Stooling height (inches)				Rooting percentage Stooling height (inches)			
	3	6	12	Average	3	6	12	Average
2 bark :1 peat :1 sand[z]	8	15	8	10	100	73	100	91
Sand	3	7	11	7	100	100	100	100
1peat :1perlite	11	12	6	10	91	58	100	83
Bark	10	10	2	7	60	90	100	83
Control[y]	18	12	9	13	0	0	0	0
Average	10	11	7	9	88	80	100	89

[z]Mounding medium proportions reported on a volume basis.
[y]Rooting percentage averages across mounding media do not include rooting of control.

6, or 12 inches (7, 14, or 29 cm) from the ground. Three plants of each height were prepared and wild-type suckers were removed, as needed, as new shoots developed. Within each height group single plants were surrounded by wire mesh enclosures [¼-inch (0.6 cm) screen, 1.5 ft (0.46 m) diameter, 2 ft (0.62 m) tall which were filled with one of four media as needed, starting in late June when shoots were 3 to 7 inches (7 to 17 cm) long, to keep up with shoot extension through the growing season. Media evaluated included pine bark; a pine bark, peat, and sand mix (2: 1 : 1, by volume); sand; or a peat and perlite mix (1 : 1, v/v). Stems were harvested in November 1998 and evaluated for shoot number, shoot length, percent rooting, and root number per rooted shoot.

RESULTS AND DISCUSSION

Shading Paperbark Maple. The rooting of cuttings collected from unshaded stems was similar to that reported by Hoogendoorn (1985) and Maynard and coworkers (1998) (Table 1). In contrast with the latter study, cuttings from shoots grown under shade rooted much less. Cuttings from 60% shade rooted about the same as light-grown shoots, while cuttings from heavily shaded shoots rooted poorly. Root numbers per rooted cutting were also lower than previously reported (Maynard, et al., 1998). However, more cuttings died in the rooting bench among cuttings from unshaded stems than those from the shaded treatments (Table 1). One possible explanation for the greater survival of shaded shoots is that cuttings collected from unshaded shoots may have been under greater water stress at the time they were collected.

Stooling *Corylus avellana* 'Contorta': Effects of Cut Back Height and Stooling Media. Stooling height generally did not affect the number of stool shoots produced, rooting percentage of stool shoots, or other rooting parameters (Table 2). Slightly fewer stool shoots were produced on plants cut back to 12 inches (29 cm). More stool shoots were produced on control (nonmounded) plants, particularly on the plant cut back to 3 inches (7 cm). This result suggests that, in the absence of mounding, more severely pruned plants were more stimulated to produce replacement growth. Rooting of mounded shoots generally was high. All of the shoots in plants mounded with sand rooted (Table 2). The mean number of roots on rooted stool shoots was 11, and varied little with treatment. Mean height of rooted stool shoots after removal from the stock plant was 3.8 ft (1.14 m).

CONCLUSION

Continued investigation of the effect of stock plant shading on the rooting of paperbark maple cuttings reveals the importance of timing in applying the shading treatment. While shading did increase cutting survival, the critical window of shading during the first days following bud break may have been missed in the trial reported here. Future trials will focus on evaluating the importance of covering the stock plant prior to bud break.

Commercial stooling of *C. avellana* 'Contorta' at Bountiful Farms, Inc., Woodburn, Oregon is accomplished by cutting own-rooted stock plants back to a height of about 12 inches (29 cm), placing a hog ring around elongating stool shoots, applying a dilute spray of rooting hormone to foliage and stems, mounding with sawdust to a height of 12 to 15 inches (29 to 36 cm) and harvesting rooted shoots in November of the same year. Thousands of own-rooted liners are produced this way each year. Personal observation indicates shoot production and rooting results similar to those observed in the trial reported here. The use of hog rings to girdle the developing shoots facilitates the harvest of rooted stool shoots, but the use of rooting hormone may not be necessary, based on the high rooting percentages we observed. Future trials at Hoogendoorn Nurseries, Inc. will be expanded to permit replication of treatments and to evaluate the effect of girdling, hormone treatment, and sawdust as a mounding medium.

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THURSDAY GENERAL SESSION QUESTION BOX

DAN LONG: Question for Charles Flinn on PennMulsh. Have they guaranteed any minimum level of chemicals from the processing of the newspaper?

CHARLES FLINN: You will have to call the inventor, George Hamilton, at Penn State University; his phone number is 814-865-3007. Mr. Tim Hurley markets the product. His number is 814-234-0391.

VOICE: I think they use vegetable dies so I don't think it is a problem.

RALPH SHUGERT: Question for Mark Coggeshall. Prior to planting your seed, did you conduct any cutting tests?

MARK COGGESHALL: I collected 150 seeds at each test date and conducted a cutting test for viability. Overall it was 78%.

DICK BIR: Did you try any longer than 2 months warm period?

MARK COGGESHALL: No.

SHELLY DILLARD: Did you store the seeds for any length of time or sow them fresh?

MARK COGGESHALL: I collected the seeds for the three dates and stored them in a refrigerator at 38°F and sowed them over a series of different dates.

SHELLY DILLARD: The reason I asked is because maples can develop a secondary dormancy.

BILL BARNES: Would you tell the audience why it is called "diabolicum"?

MARK COGGESHALL: There are to thorn-like styles at the base of the seed.

BILL BARNES: It is hazardous to collect seed without gloves.

EDITOR'S NOTE: A question was raised on which species are taxonomically closely related. The species is in the Section Litocarpa and closely related to *A. sterculiaceum* and *A. sinopurpurascens*.

RICK LOWENDOWSKI: Question for David Beattie. Have you had any luck growing *Caulophyllum thalictroides* sexually.

DAVID BEATTIE: No.

STEPHINE SOLT: Question for Bob Geneve. If the epicotyle emerges after the first cold period but does not grow above the soil is it called combinational dormancy. I am referring to trillium.

BOB GENEVE: Trillium is definitely a combinational dormancy.

STEPHINE SOLT: The reason I ask is that I have done research on it and found that the radical and epicotyl emerge after the first cold period in a petri dish. The cotyledon develops and the seed coat is septorial. In all cases, in over 1000 seeds that I have germinated it occurs. My research is in disagreement with that of Barton from the 1940s.

BOB GENEVE: The best I can do is a seed ecology by Baskin and Baskin. They are at the University of Kentucky and would love to get a call from you.

BARBARA KOLNSBERG: Our germination of *Acer palmatum* is very asynchronous. Can you help any?

BOB GENEVE: I have never germinated that species.

GEORGE OKKEN: We collect the seed and do not let it dry out. We put in a plastic bag and just before it starts to ferment, we sow it.

BILL BARNES: Small seed germinate best, large seeds are recalcitrant.

BARBARA KOLNSBERG: Question for Mark Coggeshall. Have you uesd embryo rescue?

MARK COGGESHALL: No.

BARBARA KOLNSBERG: Question for Charles Flinn. Does the PennMulch have any weed barrier effects?

CHARLES FLINN: The reason they are weed free is because we use methylbromide but are phasing it out. I doubt it has much weed suppressant qualities.

Chlorophyll Fluorescence as a Tool in Propagation

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INTRODUCTION

Failures in the rooting of cuttings can often be attributed to unhealthy or stressed stock plants. Since stress levels detrimental to plant health may be present before they are visible to the naked eye, a method of measuring this stress would be useful in stockplant selection, as well as in monitoring cuttings throughout the propagation process.

Chlorophyll fluorescence is a technique increasingly used to measure plant photosynthetic health. When chlorophyll molecules absorb light in the processes of photosynthesis, a small portion of that light is re-emitted, or fluoresced. Measurement of this fluorescence provides an estimation of photosynthetic efficiency, which is an indirect measure of plant stress (Adams et al., 1990; Genty et al., 1989). Variable fluorescence over maximum fluorescence (F_v/F_m), the measurement used in these studies, has been used extensively in environmental stress studies, including dormancy assessments in douglas fir (*Pseudotsuga menziesii*) (Hawkins and Lister, 1985), Scotch pine (*Pinus sylvestris*), lodgepole pine (*P. contorta*) (Lindgren and Hallgren, 1993), and Norway spruce (*Picea abies*) (Westin et al., 1995) and as an estimate of freeze damage and seedling survival in douglas fir (Fisker et al., 1995). In addition, it has been used to examine light levels in cold storage of white spruce (*P. glauca*) and jack pine (*P. banksiana*) (Camm and Lavender, 1993).

The objective of these studies was to examine chlorophyll fluorescence (F_v/F_m) as a potential tool for stockplant selection, assessment of storage conditions, and measurement of stress over the course of propagation in *Taxus*.

MATERIALS AND METHODS

Nine cultivars of *T.* ×*media* (Brownii, Dark Green Spreader, Densiformis, Densiformis Gem, Hicksii, Bobbink, Runyan, Taunton, and Wardii) were selected to examine cultivar differences, changes in F_v/F_m over the course of propagation, and to compare initial F_v/F_m values with final rooting data. Cuttings were taken in late October from field grown plants at Zelenka Nursery, Grand Haven, Michigan. Each cutting was measured for chlorophyll fluorescence levels, placed in cold storage at 5°C for 32 days, and then stuck at Zelenka (re-cut to 4.5 inches, dipped in Woods Rooting Hormone [IAA 1.03%; NAA 0.66%] at 2800 ppm, and placed in perlite medium, air temperature 18°C, bottom heat 21°C). Cuttings were harvested after 100 days in the propagation bed and rooting percentage, root number, root length, and root dry weight measured. Chlorophyll fluorescence levels were measured monthly.

Four cultivars of *T.* ×*media* (Brownii, Dark Green Spreader, Hicksii, and Wardii) were selected to study storage conditions, as measured by chlorophyll fluorescence. Storage condition treatments consisted of desiccation (low, sealed plastic bag; medium, perforated plastic bag; and high, open plastic bag), duration (34, 70, and 107 days), and temperature (-2.5, 0, 2.5, 5, 10, and 20°C). Propagation was performed as previously described, except for the various storage treatments. Chlorophyll fluorescence was measured at cutting collection and stickingof each duration. Data was collected over two propagation seasons.

RESULTS AND DISCUSSION

Initial chlorophyll fluorescence values (F_v/F_m) ranged from a high 0.833 (relative units) in 'Dark Green Spreader' to a low 0.778 in 'Brownii' (Table 1). Significant differences existed between some cultivars, however, there was much overlapping between them. Fluorescence levels dropped dramatically during cold storage,

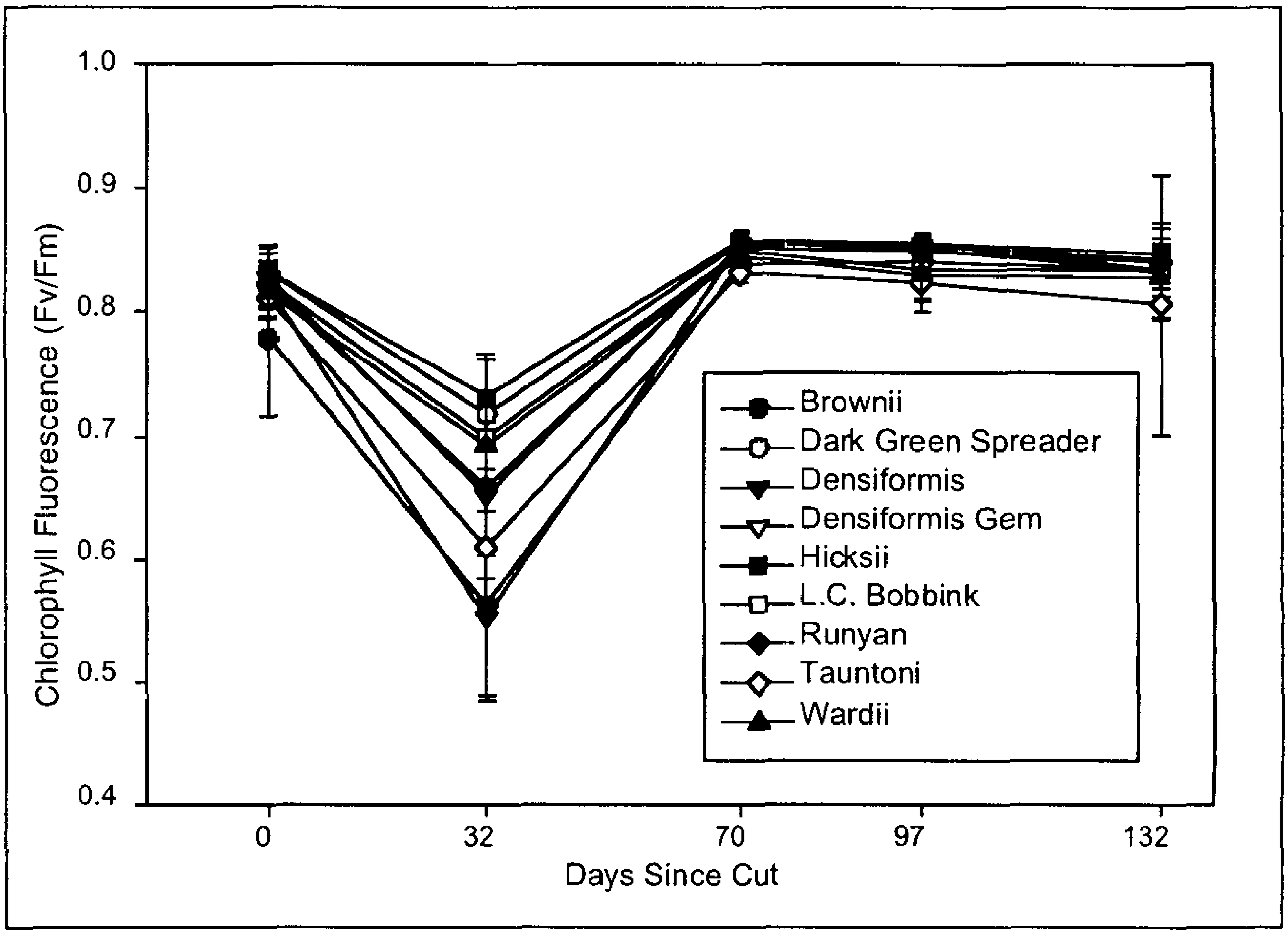

Figure 1. Chlorophyll flourescence in *Taxus* over the course of propagation at Zelenka Nursery 1998-1999 Season.

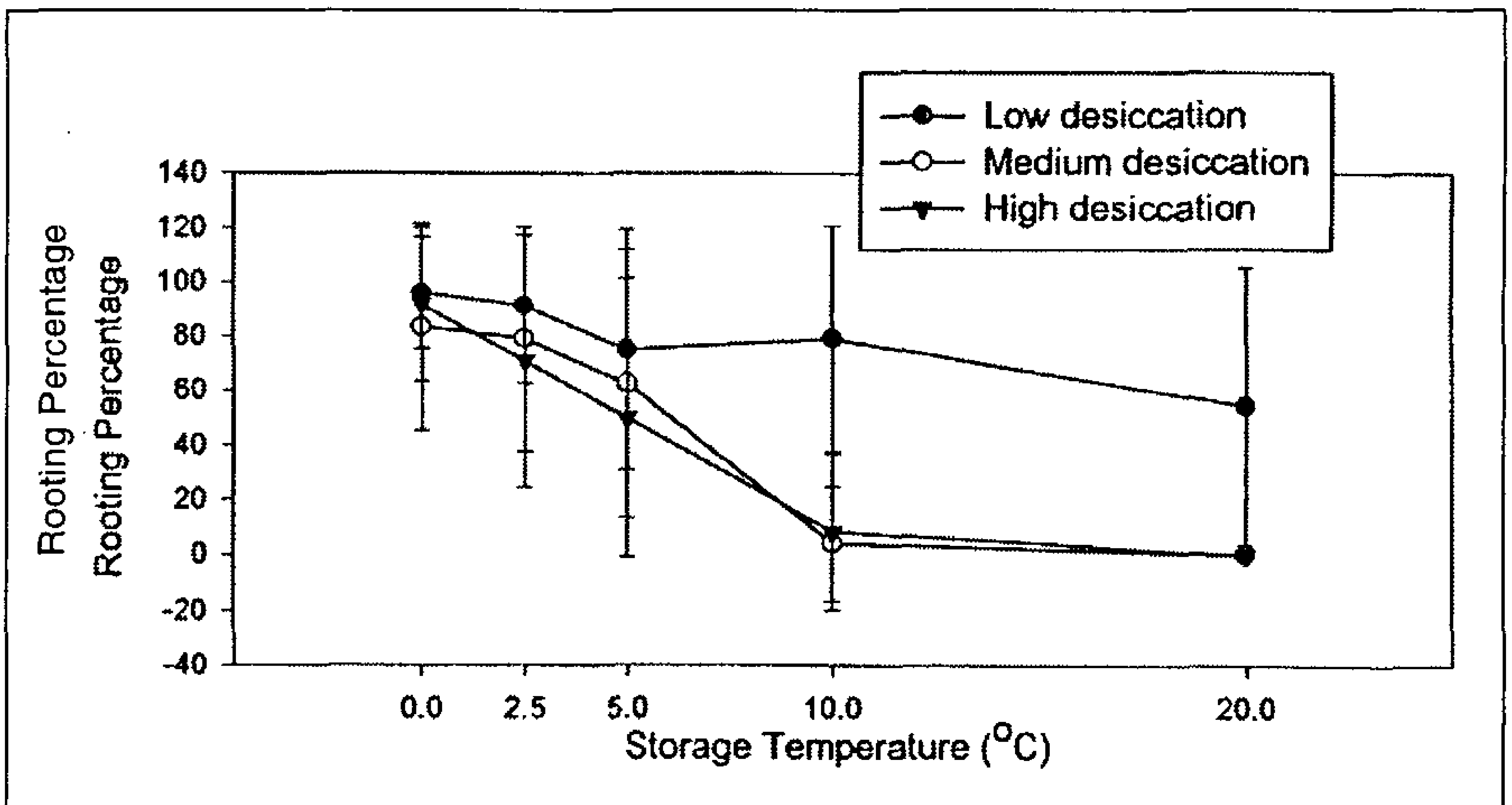

Figure 2. Effect of storage temperature and desiccation on rooting in *Taxus* 'Hicksii' 1997-1998. Storage duration = 34 days

TABLE 1. 1998-1999 Initial chlorophyll fluorescence (F_v/F_m) of 10 cultivars of *Taxus* ×*media* from stock plant material at Zelenka Nursery.

Cultivar	F_v/F_m								
Dark Green Spreader	0.833	a	b	c	d				
Hicksii	0.832	a	b	c	d	e			
Densiformis Gem	0.828	a	b	c	d	e			
L.C. Bobbink	0.825	a	b	c	d	e	f		
Runyan	0.822	a	b	c	d	e	f	g	
Densiformis	0.821		b	c	d	e	f	g	
Wardii	0.814			c	d	e	f	g	
Tauntoni	0.811				d	e	f	g	
Brownii	0.778								h

Mean separation among cultivars by LSD, P 0.05.
Means with the same letter are not significantly different

TABLE 2. 1998 -1999 Rooting percentage of ten cultivars of *Taxus* ×*media* at Zelenka Nursery after 32 days cold storage at 5°C and 100 days in the propagation bed.

Cultivar	Rooting %							
Brownii	96.6	a	b	c				
L.C. Bobbink	95.0	a	b	c	d			
Hicksii	86.7	a	b	c	d	e		
Densiformis Gem	83.3		b	c	d	e	f	
Tauntoni	75.0			c	d	e	f	
Wardii	71.7				d	e	f	
Dark Green Spreader	48.5							g
Runyan	46.7							g
Densiformis	45.0							g

Mean separation among cultivars by LSD, P 0.05.
Means with the same letter are not significantly different

demonstrating dormancy effects, and then rose quickly to pre cold storage levels within a month after sticking (Fig. 1) and remained high until harvest. Rooting percentages ranged from 96.6% ('Brownii') to 45% ('Densiformis') (Table 2). No strong correlations were found between initial F_v/F_m and rooting percentage, root number, root length, or root dry weight.

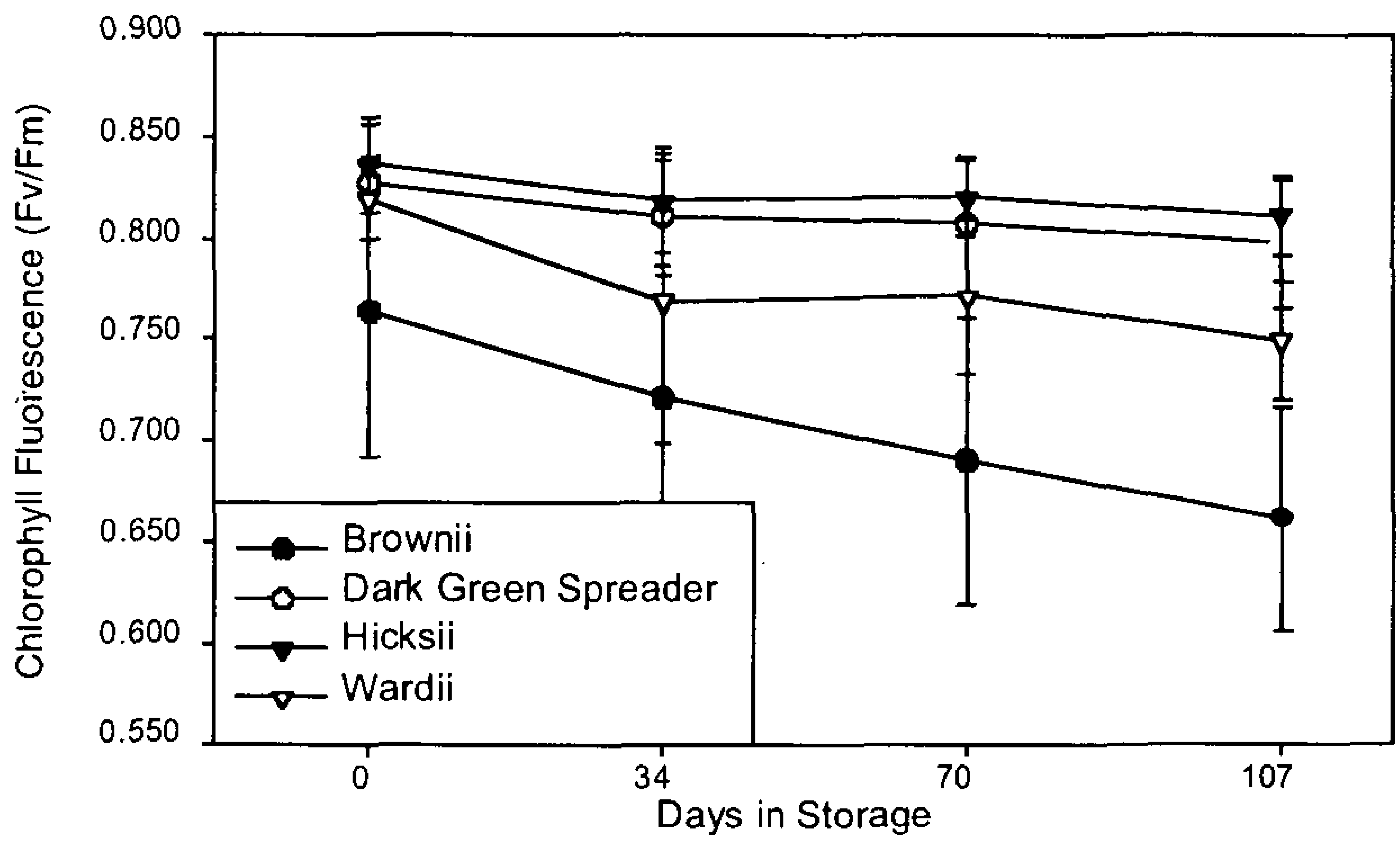

Figure 3. Effect of storage duration on chlorophyll fluorescence (Fv/Fm) of four cultivars of *Taxus*. 1998-1999 Season, storage temperature = -2.5 - 2.5 °C

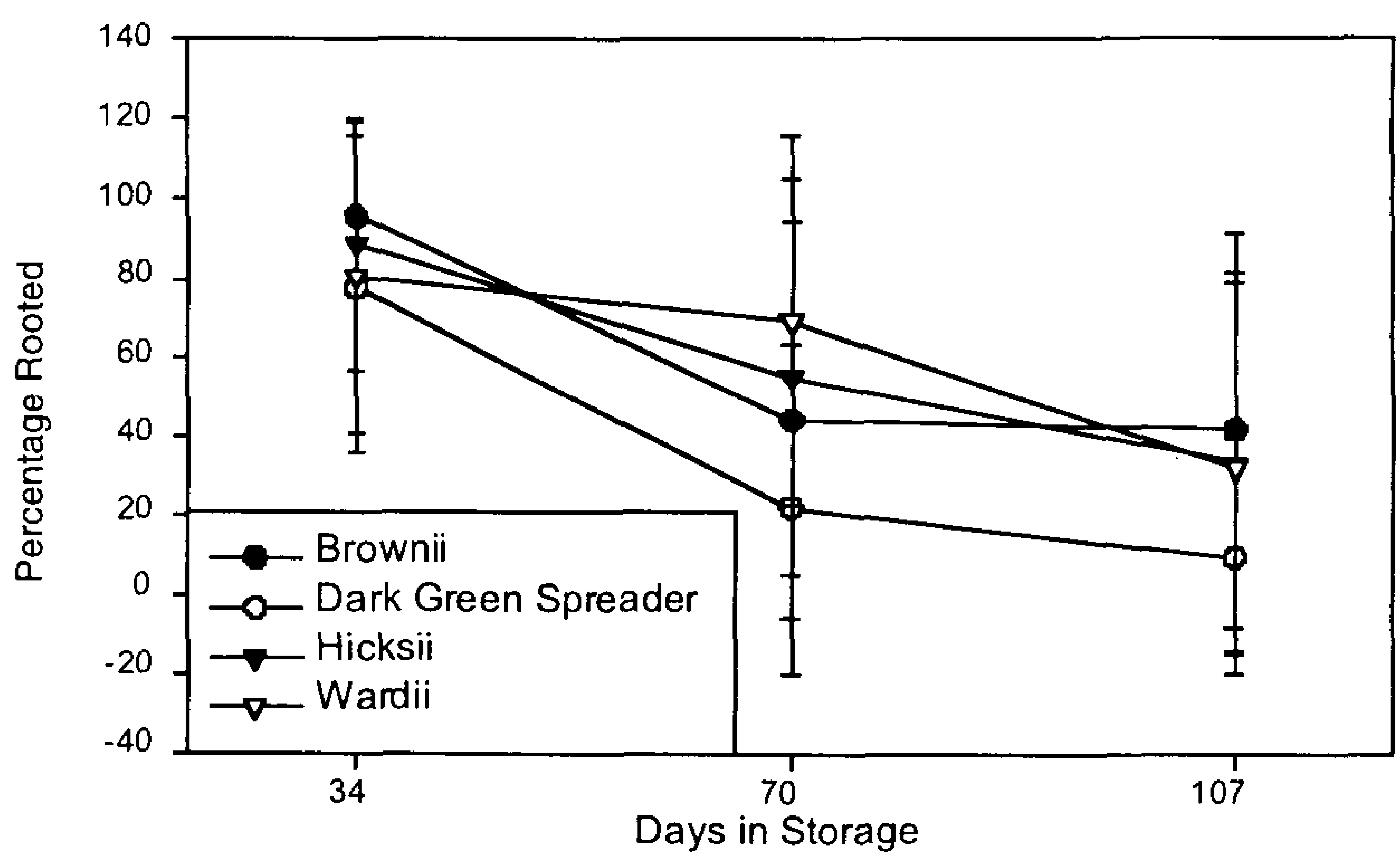

Figure 4. Effect of storage duration on rooting of four cultivars of *Taxus* 1998-1999 Season. Storage temerature = -2.5 - 2.5 °C. Rooting percentages measured 96-99 days after sticking.

High desiccation levels and high temperatures during storage inhibited rooting, however, at low desiccation relatively high rooting occurred at 10°C (Fig. 2). Temperature treatments of 0, 2.5, and 5°C did not result in differing rooting responses, and desiccation did not affect these cooler temperatures. Chlorophyll fluorescence readings were reduced in 20°C treatments but remained indistinguishable for 0 to 10°C treatments. Similar results were obtained for all four cultivars, so only data for 'Hicksii' is presented.

To test effects of storage duration, cuttings were stored for 34, 70, and 170 days at temperatures of -2.5, 0, and 2.5°C. There were no significant differences among temperatures, so data was combined across temperatures. Chlorophyll fluorescence levels did not decline appreciably with longer durations in storage (Fig. 3). Longer storage durations did lead to decreases in rooting percentage (Fig. 4), root number, root length, and root dry weight. Rooting percentages were often halved with a doubling of the storage duration (34 to 70 days). 'Wardii' showed the most initial resistance to extended storage (at 70 days), however, with the longest duration (107 days), it also showed significantly diminished rooting.

CONCLUSIONS

Correlations were not found between initial F_v/F_m and rooting percentage, root number, root length, or root dry weight, indicating that F_v/F_m is not a reliable indicator of stockplant propagation potential. Short storage durations at temperatures ranging from -2.5 to 2.5°C were found to be ideal. Higher rooting could be maintained at 5°C and possibly 10°C when combined with low desiccation. Longer storage durations led to significant decreases in rooting and root quality. F_v/F_m could detect substandard storage conditions only at temperature and desiccation extremes.

Acknowledgment. This experiment was a Michigan State University study funded by: Zelenka Nursery in Grand Haven, MI., International Plant Propagator's Society, Michigan Nursery and Landscape Association, and Michigan Agricultural Experiment Station.

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Alpine and Perennial Propagation Through the Year

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True alpines are small plants from mountainous and other wild places of the earth. In addition, many alpine plants have been selected for superior or unique forms or have been hybridized in culture. Propagation fixes these characteristics and is vital to this collectors' branch of horticulture where a tiny yard may easily contain several hundred kinds of plants. The challenges to propagation are what makes the growing of alpines so fascinating.

Although alpines and dwarf conifers have remained my passion for 35 years, it was the addition of large perennials and shrubs which made it possible to attract a larger pool of customers to our nursery and incidentally introduce them to rock gardening. We propagate 90% of the plants we sell, so this view of our propagation methods covers what we actually do at Rice Creek Gardens throughout the year.

Propagation does not occur in a vacuum. I see propagation, sales, and overhead in dynamic balance, like three sides of a triangle. The propagation side feeds the sales side and they both depend on the stable base of overhead. When any of these sides are too long or too short, a quick response is necessary to keep the business in balance. Ideally, the triangle of propagation, sales, and overhead acts like a fence and protects the business within.

Propagation protects our business by providing true-to-name plants, in reasonable quantity, at the time we want them. We propagate almost entirely in winter and this affects overhead in at least two ways. Strongly constructed greenhouses and large heating bills, which our severe climate demands, are a considerable investment. However, our employees are kept working productively 12 months of the year. The people that grow the plants also sell them, which has been a real advantage for us and our customers.

Display gardens have been an important part of our business for 35 years, both as demonstrations and as sources of propagation materials. Rock gardens, perennials, grasses, shrubs, with ericaceous and shrub rose areas and extensive woodland gardens — including native orchid beds, that serve as research, production, and display gardens — make our nursery unusual.

The propagation year begins in August and September. The last of summer yields soft cuttings on shrubs. They root in flats and are covered loosely with spun-polyester fabric for a few days in a white-plastic-covered greenhouse that is very humid. For example, wisteria roots easily at that time.Cuttings stay in the flats in the greenhouse kept just above freezing, and are left to go dormant until February, when they are potted.

Daylilies, Siberian iris, and peonies are divided in September and October and lined out in fields or potted. In summer, daylilies are either potted or field-dug on demand and sold in plastic bags for immediate planting, where they continue to flourish and bloom.

October sees us taking cuttings from outdoor plants for warm house production of *Alyssum, Arabis, Aubrieta, Iberis, Phlox stolonifera* (creeping phlox), *Saxifraga,* and *Vinca.* These root by early January and are potted in our regular soil mix which contains 15% black peat soil, Fafard 2, perlite, and various macro and micronutrients. Our alpine mix, turface based and also including soil, is used for saxifrages and other mountain plants demanding extra drainage.

One of the most satisfying chores is to take conifer and broadleaf evergreen shrub cuttings in October and November. *Buxus, Calluna, Cornus canadensis, Erica, Euonymus, Genista, Paxistima,* rhododendrons, and *Vaccinium* are successfully rooted at this time. Conifers which root easily include most *Chamaecyparis, Juniperus, Microbiota,* and *Thuja.* They are dipped in Wood's solution at 1 to 5 or even undiluted, stuck in flats containing sphagnum peat and perlite (1 : 2, v/v), placed on the shady north side of a warm greenhouse, and watered throughly but not covered or misted. They go through dormancy and start rooting in March and April, when they are potted in rhododendron soil, containing sphagnum peat, Fafard S2, perlite, and fertilizers.

October also means bringing in stock plants to keep in our "cold" house (32 to 34°F) for at least 6 weeks: *Achillea, Ajuga, Androsace, Anemone, Armeria, Aruncus, Astilbe, Aster, Boltonia, Campanula, Chelone, Cimicifuga, Convallaria, Coreopsis, Dicentra, Eupatorium,* ferns, *Filipendula, Gaillardia* ×*grandiflora* 'Baby Cole', *Galax, Gentiana, Geranium,* grasses, *Hemerocallis, Heuchera, Hosta, Hedyotis* (syn. *Houstonia*), *Iris, Leontopodium, Lobelia, Lysimachia, Mentha, Monarda, Origanum, Penstemon,* garden (*Phlox paniculata*) and woodland phlox, *Physostegia, Potentilla,* named primula, *Rudbeckia, Salvia,* large sedum, *Sisyrinchium, Stachys, Thymus, Tradescantia, Tricyrtis, Petrorhagia* (syn. *Tunica*), *Veronica,* and *Viola.* They are divided and repotted January through March in our regular soil, with extra perlite if needed. Shrubs that need dormancy and will respond with new growth when moved to warmth in January include: *Betula, Buddleja, Calluna, Clethra, Cotoneaster, Epigaea, Gaultheria, Rhododendron* (azalea), miniature roses, *Salix,* and *Spiraea.* They root easily in 1 to 10 Woods solution and in peat and perlite (2 : 1, v/v) medium.

These plants (*Arenaria, Artemisia, Asperula, Bergenia, Chrysanthemum, Dianthus, Draba, Erigeron, Gypsophila, Helianthemum, Hypericum, Lamium, Lavandula, Lewisia, Nepeta, Orostachys, Perovskia, Pulmonaria, Satureja, Saponaria, Saxifraga* (leafy types), small *Sedum,* and *Sempervivum*) go directly to our warm house in the fall for taking of cuttings in December, January, and February. They all prefer our regular container mix.

Opuntia cuttings are taken and left to go dry and dormant at cool temperatures until March, when they are potted and they are ready for sale by May.

November 1 is the date we plan to have all our carry-over of established potted alpines on the ground, covered with insulated plastic sheets. Early spring flowering plants such as *Helleborus, Primula,* and *Saxifraga* need to experience outdoor dormancy or they will flower too early and be less saleable. *Aquilegia, Dianthus,* and *Liatris* are examples of large perennials that will only flower after such full dormant treatment.

November is when we order seeds of perennials for planting in December. *Aquilegia, Althaea, Delphineum, Echinacea, Echinops, Gaillardia, Helenium, Hibiscus, Lilium, Lobelia, Primula,* and *Pulsatilla* are examples. Seed is planted in flats and placed on the cool north side of the greenhouse. Roots are "eased on" to the seeds and cuttings without a great deal of care in this situation.

By the first week in December all cuttings from outdoors are usually stuck. Seed planting is continuing. Stock plants are repotted and the first of the divisions — sempervivums — are placed three to a pot.

Because of our severe climate every inch of heated greenhouse space is used. In our production house plants are arranged on double layers of tables, each about 34 inches high. Flow is critical to our operation. Plants start out on the warm south side where they produce cutting material. The cuttings are dipped in Wood's solution at 1 to 10 and stuck in flats containing our regular soil mix, cut by half with coarse perlite. They then go to the cool north side of the greenhouse where they root in a few weeks. After they are rooted they are potted in 2¼-inch pots and put on the lower, waist-high benches on either side of the center aisle. When they begin to grow and draw toward the light they are moved to the top benches where they are able to thicken up and are fertilized, and pruned if necessary. At a point when they look ¾ ready to sell they are moved to a cool house where they will stay dormant, and often budded for months. We do not move fertilized plants to the cold for 2 weeks to avoid "crashing".

Light is not necessary at this stage for most plants. They do well in a large insulated pole building that is kept at 33°F with a moistened concrete floor and ceiling fans (delphiniums are one of the exceptions). Tables are stacked three high in this building. The floor is covered with potted rhododendrons, free from the vagaries of weather.

In January we begin potting seedlings, the first of the cuttings are rooted, and division starts at the end of the month. Rare seeds arrive all winter from exchanges and they are planted on the cool north side, put outdoors in cold frames or kept just above freezing in our cold house, depending on their germination requirements.

February brings more potting of seedlings and cuttings, and a second round of soft cuttings are taken that root very rapidly.

March is our last month for any serious greenhouse work since the nursery must be readied for opening in mid-April. Bare-root roses arrive at mid month. They are pruned carefully and potted in special "rose soil" with lots of sand and sweated in a white poly-covered greenhouse, and covered lightly with thin sheets of clear plastic. Bare-root perennials arrive about April 1 for potting and are placed outdoors to the south of the pole building.

Once the nursery is open we dig *Asarum europaeum* from our woodland, along with coarse perennials like *Lysimachia clethroides* and *Monarda*. We dig hosta all season from production beds in the woodland, in naturally occuring black peat, which produces large plants from tissue-culture in a matter of weeks.

Try as we might, in spring and summer we don't take time to breathe, much less do propagation. Our selling season is only 5 months long at best, yet we keep busy all year around. Winter propagation season is something we look forward to each year, as we improve our production of our standards, discover new plants to test next season, and propagate new winners from the summer before.

A Lesson in Juvenility

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The important factor of juvenility in the role of plant propagation is well documented in no less than 45 papers to this Society alone. As propagators, we should be using this knowledge to our advantage in all types of propagation, especially vegetatively by cuttings. It is, along with temperature, light, and moisture one of the basic considerations when rooting cuttings. However, since it is not as easy to define and measure as the other factors, the amount or degree of juvenility is sometimes passed over lightly or forgotten entirely. Indeed, its importance in rooting plants does vary widely from genus to genus to the point of not being considered at all. However, not giving juvenility proper consideration can mean the difference between great success or total failure when rooting some plants. Our experience at Appalachian Nurseries with *Aesculus parviflora*, bottlebrush buckeye, is the example I want to relate to you today. In the past, we have tried softwood cuttings, root cuttings, and seeds in an effort to keep up with demand for this great native plant. We were having little and certainly not acceptable success with all of the above methods. Further reading about rooting *Aesculus* revealed nearly all writers emphasizing the use of cutting from young plants or juvenile growth. Since all of our sources of cuttings were from large mature stands, cuttings from young plants were not available. We did have a few of our own large stock plants (7 to 8 ft) with stems ranging in diameter from ½ inch to 2 inches, which finally in desperation we cut to the ground late in Fall 1997. The next spring we were rewarded with a full, thick stool bed of young shoots 12 to 18 inches tall by late May. These we turned into cuttings 10 to 12 inches in length and direct stuck in 3-inch pots filled with composted pine bark and shredded styrene. We used Woods/Dip & Grow at the 1 to 9 rate. The cuttings rooted 80% under mist in a greenhouse in 6 to 8 weeks. Plants were salable the following spring. We repeated the procedure this past spring with cuttings from the same stool block. Rooting was not as good this year at 50% to 60%; however, we attributed those lower percentages to factors other than reduced juvenility. The **TAKE HOME MESSAGE** is this: **ALWAYS** consider age of stock plants and juvenility when selecting a source of cuttings. Don't hesitate to rejuvenate old stock plants or stool beds. This, of course, is nothing new, just basic classic information of which we need to be reminded once again.

How to Propagate and Grow on a Small Scale

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The International Plant Propagators' Society includes members of varying degrees of connection with nursery production. It is safe to assume that all members love plants and have a strong desire to propagate and grow them. In my position as Executive Director ofThe Holden Arboretum I am quite removed from the front lines of horticulture since I spend nearly all of my time at work dealing with administrative matters, real estate, fundraising, personnel issues, and a multitude of other things not related to hands-on plant production. These responsibilities lead to a frustrating personal situation since I still think of myself as a propagator and a grower. How do I cultivate my interest in and increase my knowledge of propagation and growing? I do it like so many others in the same predicament: I operate my own part-time nursery which has the two-fold benefit of satisfying my need to produce plants and hopefully some day, bringing some profit into the picture.

Several considerations must be made before starting this kind of venture and are critical to the success of a small, part-time operation. The first and most important consideration is the commitment of personal time. Even a part-time operation is a 7-day-a-week commitment. Willingness to hire help to cover daily watering is essential if you ever wish to take a vacation or to attend a meeting during the growing season. The next decision is willingness to commit the financial resources to an operation that may be several years away from profitability, if ever. I justify my own use of funds as necessary for my psychological well-being because of the personal satisfaction and stress reduction I receive. I admit that most growers cannot look at it this way but I tend to look at my operation as a hobby that hopesto make money.

Determining what to grow and the type of production (whether in-ground or container) are the next critical considerations. What can you grow well for which an unfilled demand exists? I have found in my situation that native plants, especially the herbaceous and wetland species are in demand, and are becoming more popular all the time. I chose to specialize in native herbaceous species and native medicinal herbs. Aside from a few ground beds, I grow most everything in containers. I have a shortage of good growing ground so container culture works better for me. I have considerable experience, gained by part-time growing over the years, in container growing and have developed by trial and error the growing mixes that work best for my plant types and watering practices. In-ground growing, if you have suitable soils, has an advantage over containers for watering and overwintering, but has the main disadvantages of weed control, shipping, and harvesting.

Propagating and growing on a small scale requires some immediate decisions to be made. Either you grow only a few plants of a wide range of species or many plants of a few. The answer to this dilemma is found in your analysis of the local demand. My own analysis was anecdotal and was made by observing sales at our annual Arboretum plant sale and by talking with avid gardeners. Consequently I grow a total of about 1500-qt pots of 25 to 35 native species per year. This low-volume approach doesn't always work well when trying to meet demand where larger quantities are required. I suspect the most appropriate way to begin is to grow larger quantities with fewer species involved, but that again should be based on analysis of the local market.

Growing facilities are another consideration. Fortunately, poly houses are relatively inexpensive and easy to build and operate. Space considerations forced me, for the time being, to construct a large set of cold frames, instead of a poly house, in which Ido all my seed germination, growing, and subsequent overwintering. This is the second set of cold frames that I have built and I have learned from experience the materials and construction methods that are most successful for me. The cold frames are unheated and are built of 2× treated lumber and lined with rigid insulating foam that is covered on both sides with aluminum foil. The covers are built of 1× treated lumber and glazed with twin-wall polycarbonate panels. Shade is provided by rolled lath salvaged from an old Lord and Burnham greenhouse. Other details of orientation and depth are standard and follow recommendations found in numerous publications.

Another very important consideration is the type of propagation. Because of the part-time nature of the operation and the nature of my facility I have to limit myself to seed propagation (a special interest of mine) and division of existing plants. Propagation by cuttings is not practiced, primarily because of lack of the right equipment, and the fact that the plants that I grow are not necessarily amenable to cuttings. All seeds are germinated in the coldframe as uncovered flats or pots under the sash. Occasionally, plastic domes are placed over flats to maintain moisture.

Growing media are mixed on site in an electric concrete mixer (which I also use to mix concrete) from bagged components obtained from a local greenhouse supply company. Opened bags are stored in plastic trash cans with lids. By maintaining components on site, specific mixes can be created to best suit the needs of a wide range of plants. I don't do enough volume of production to justify bulk deliveries of media components, so cost is necessarily increased to accommodate smaller production. As the size of the operation grows bulk deliveries may be justified with a concomitant reduction in per unit cost.

Another consideration is obtaining the appropriate permits and inspection certificates. By doing this work early in the process you may eliminate delays in selling and shipping. I avoid one big potential problem of shipping to other states by using only soilless mixes. Weed control is accomplished by hand and insect and disease control will be handled by spot treatments if needed. To date, no treatments have been necessary. I believe that insects and diseases have been non-existent due to the rigorous sanitation I practice and the selection of native plants with few, if any, natural pests. Once I begin to sell crops and am required to use chemical pest control I will have to become a licensed pesticide applicator in my state. I have not yet reached this point.

I have yet to sell my first plant. Plants produced to this point have been used in landscaping my home, creating stock blocks for future propagation, donated to The Holden Arboretum annual plant sale, and donated to my church for landscaping and distribution at church events. My first sale will be to a local orchardist who asked to have a specific crop produced. These will be delivered this fall assuming crop success. All other potential sales will be the result of word-of-mouth advertising. A price list is still a few growing seasons away.

The need to propagate and grow plants is deep-rooted to both me and our members. To keep abreast of our industry is important even if we are not directly involved in the commercial end of our profession. Part-time and small-scale growing is an avenue that is both emotionally enriching and potentially financially rewarding. I estimate that my own operation is approximately two or three growing seasons away from the break even point. Since my current objective is personal satisfaction I am not yet overly concerned about profit. However, I will soon reach a point where I must either remain small with little expectation of economic success or I must increase production to a level where profit is assured (with as much assurance as possible in an agricultural operation). However, with the right effort and the commitment oftime and minimal resources, success as a small-scale grower is possible.

Blending Slow-release Fertilizers for Container Nursery Culture

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Two "manufacture-blended" [(test formula 23N-2.6P-7.5K (23N-6P_2O_5-9K_2O) and test formula 19N-2P-6.6K (19N-5P_2O_5-8K_2O), both 8-9 month release type] and two "custom blended" [3-4 month Sierra 17N-2.6P-10K (17N-6P_2O_5-12K_2O) or 8-9 month Sierra 17N-2.6P-8.3K (17N-6P_2O_5-10K_2O)] mixed with quicker-releasing Osmocote [14N-6P-11.6K (14N-14P_2O_5-11.6K_2O)] controlled-release fertilizers were compared with three unblended 3-4 month or 8-9 month standard industry types. Container-grown dogwood (*Cornus alba* 'Argenteo-marginata'), mock orange (*Philadelphus virginalis* 'Minnesota Snowflake'), and weigela (*Weigela florida* 'Variegata Nana') grew similarly or marginally different in two different media with the four best-performing treatments: Test formula 23N-2.6P-7.5K (23N-6P_2O_5-9K_2O); the two Sierra-Osmocote blends; and unblended 3-4 month Sierra. With unblended and blended 3-4 month Sierra, 30% less N was used, and both dogwood and wiegela grew better with the blend.

INTRODUCTION

Many types of controlled- or slow-release fertilizers are available to the nursery industry. The major nutrients in these fertilizers are typically coated. While the type of coating and/or thickness usually determine the release characteristics, mixtures of quicker- and slower-releasing types (custom blends) have been used to alter the release pattern (Lumis et al., 1993; Hicklenton and Cairns, 1992; Murray et al., 1996). In some recent formulations, easily leached nutrients such as N are coated (controlled release) while others such as P and K are blended in but not coated. These "manufacture blends" are less expensive than traditional all-coated types (industry standards) (Hulme, F.D., private communication).

the commercial end of our profession. Part-time and small-scale growing is an avenue that is both emotionally enriching and potentially financially rewarding. I estimate that my own operation is approximately two or three growing seasons away from the break even point. Since my current objective is personal satisfaction I am not yet overly concerned about profit. However, I will soon reach a point where I must either remain small with little expectation of economic success or I must increase production to a level where profit is assured (with as much assurance as possible in an agricultural operation). However, with the right effort and the commitment oftime and minimal resources, success as a small-scale grower is possible.

Blending Slow-release Fertilizers for Container Nursery Culture

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Two "manufacture-blended" [(test formula 23N-2.6P-7.5K (23N-6P_2O_5-9K_2O) and test formula 19N-2P-6.6K (19N-5P_2O_5-8K_2O), both 8-9 month release type] and two "custom blended" [3-4 month Sierra 17N-2.6P-10K (17N-6P_2O_5-12K_2O) or 8-9 month Sierra 17N-2.6P-8.3K (17N-6P_2O_5-10K_2O)] mixed with quicker-releasing Osmocote [14N-6P-11.6K (14N-14P_2O_5-11.6K_2O)] controlled-release fertilizers were compared with three unblended 3-4 month or 8-9 month standard industry types. Container-grown dogwood (*Cornus alba* 'Argenteo-marginata'), mock orange (*Philadelphus virginalis* 'Minnesota Snowflake'), and weigela (*Weigela florida* 'Variegata Nana') grew similarly or marginally different in two different media with the four best-performing treatments: Test formula 23N-2.6P-7.5K (23N-6P_2O_5-9K_2O); the two Sierra-Osmocote blends; and unblended 3-4 month Sierra. With unblended and blended 3-4 month Sierra, 30% less N was used, and both dogwood and wiegela grew better with the blend.

INTRODUCTION

Many types of controlled- or slow-release fertilizers are available to the nursery industry. The major nutrients in these fertilizers are typically coated. While the type of coating and/or thickness usually determine the release characteristics, mixtures of quicker- and slower-releasing types (custom blends) have been used to alter the release pattern (Lumis et al., 1993; Hicklenton and Cairns, 1992; Murray et al., 1996). In some recent formulations, easily leached nutrients such as N are coated (controlled release) while others such as P and K are blended in but not coated. These "manufacture blends" are less expensive than traditional all-coated types (industry standards) (Hulme, F.D., private communication).

This trial compared two manufacture- and two custom-blended slow-release fertilizers with several industry standards using three containerized test species grown in two types of media.

MATERIALS AND METHODS

On 30 May 1996, plug-rooted liners of dogwood, mock orange, and weigela were potted in #2 (2 gal) nursery containers filled with bark and municipal leaf and yard waste compost (1 : 1, v/v) (medium A) or bark, peat, and soil (16 : 3 : 1, by volume) (medium B). Seven slow-release fertilizer treatments (Table 1) were topdressed at a rate of 5.5 g actual N per pot (Treatments 1 to 5) or 3.9 g per pot (Treatments 6 and 7).

Dogwood was spaced 60 cm × 60 cm apart and the other two species 60 cm × 45 cm. Each species was arranged in a separate 2-factor (2 media × 7 fertilizers) factorial design with 4 replications and 4 plants per plot. During the growing season, each container received 1 liter of trickle-irrigated water per container twice daily.

At the start of the experiment, triplicate samples of each unamended medium were analysed for selected nutrients and physical properties (Table 2). Substrate samples were collected from the containers (7- to 12-cm depth) on 30 May (planting), 7 June, 17 July, 20 Aug., and 25 Sept. and analysed for pH and electrical conductivity (EC, a measure of soluble salts concentration) using substrate and water (1 : 2, v/v) extracts. Mid-August leaf samples were analysed for total N, P, K, Ca, Mg, Mn, Fe, and Zn. In mid-September, the shoot (leaves + stems) were removed from each plant and their dry weights determined.

RESULTS AND DISCUSSION

Effect of Media. Notwithstanding an excess of K and Cl in medium B, the chemical composition and physical properties of both media were quite acceptable for nursery container culture (Table 2). In fact, dogwood grew equally well in both media. Weigela and mock orange, however, grew better in medium B, which retained higher levels of soluble salts throughout the season (0.42 dS m^{-1}, mean over six sampling dates) than medium A (0.25 dS m^{-1}).

Effect of Fertilizer. The spring of 1996 was later than normal, cool, and exceptionally wet. Prevailing temperatures during the rest of the season were moderate. Salt levels in the containers were low to moderate (season range, 0.19-1.25 dS m^{-1}). Consequently, all three species grew at most only moderately well with the four best-performing fertilizer treatments [Fig. 1; the 8-9 month test formula 23N-2.6P-7.5K (23N-6P_2O_5-9K_2O (Treatment 4); the 8-9 month Sierra-Osmocote blend (Treatment 5); and the two 3-4 month Sierra treatments, blended (Treatment 6) and unblended (Treatment 7)], *which performed similarly or marginally different, depending on species. With the two* 3-4 month Sierra Treatments 6 and 7, 30% less N was used (Table 2), and the blend was consistently better with two of the three species (dogwood and weigela) (Fig. 1).

Lumis et al. (1993) reported that mock orange and weigela grew best with a T140/40 Nutricote blend compared with unblended Nutricote T140 or 8-9 month Sierra 17N-2.6P-10K (17N-6P_2O_5-10K_2O; spirea grew similarly with T140/40 blended and T140 unblended Nutricote. Murray et al. (1996) obtained larger pot-in-pot shade trees with T270/70 blended Nutricote than with liquid or liquid plus slow-release fertilizers. These results were due largely to more rapid early-season release of nutrients (salts) from the blended fertilizers. Hicklenton and Cairns (1992) also

Table 1. Controlled-release fertilizer and rates applied.

No.	Treatment Fertilizer formulation		Release time (mo)	Topdress rate g pot^{-1z}	Topdress rate Actual N(g pot^{-1})
1	Sierra High N 22-4-8	Industry standard	8-9	25.0	5.5
2	Sierra 17-6-10	Industry standard	8-9	32.4	5.5
3	*Test formula* 19-5-8	Manufacture blend	8-9	28.9	5.5
4	Test formula 23-6-9	Manufacture blend	8-9	23.9	5.5
5	Sierra 17-6-10 (85% N) + Osmocote 14-14-14 (15% N)	Custom blend	8-9/3-4	27.5 + 5.9	5.5
6	Sierra 17-6-12 (85% N) + Osmocote 14-14-14 (15% N)	Custom blend	3-4/3-4	19.5 + 4.2	3.9
7	Sierra 17-6-12	Industry standard	3-4	23.0	3.9

^{z} #2 (2-gal) pot (6-liter actual size).

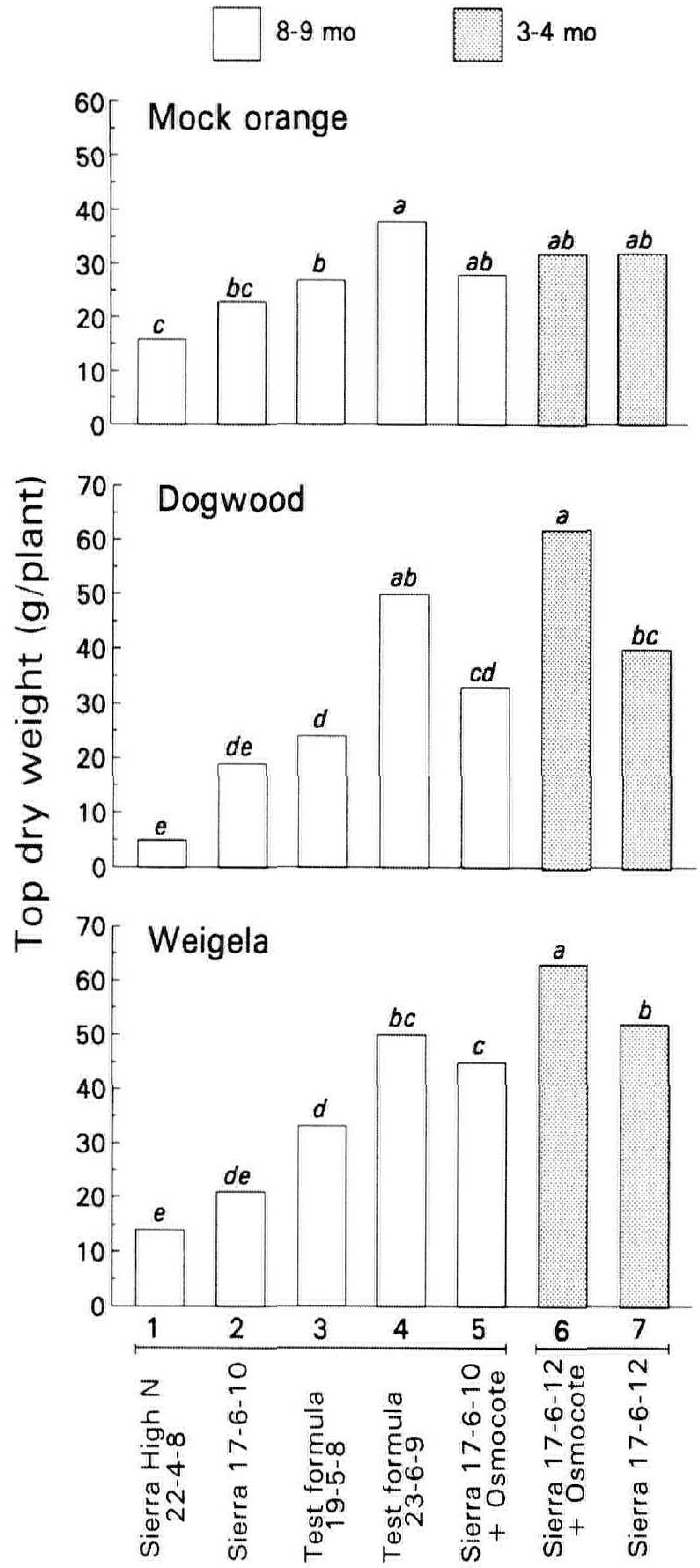

Figure 1. Top dry weight of three containerized nursery crops in response to seven slow-release fertilizer treatments. Data were averaged over two media. There was no fertilizer × media interaction. Comparisons between individual fertilizer treatment means are separated (*a-e*) by LSD at *P* 0.05.

Table 2. Chemical and physical analysis[z] from saturated paste extracts of the two media at the start of the experiment.

Variable	Recommended values	Bark, peat, and soil (16 : 3 : 1, by volume) (medium A)	Bark and compost (1 : 1,v/v) (medium B)
Chemical properties			
pH	5.5-7.0	5.5	6.8
Solublesalts (dS m^{-1})[x]	1.0	0.16	0.56
Nitrate (NO_3^--N, ppm)	100-200	1	1.3
Phosphorous (P, ppm)	6-9	9	7
Potassium (K, ppm)	150-200	40	268
Calcium(Ca, ppm)	200-300	23	63
Magnesium (Mg, ppm)	70-200	17	27
Sodium (Na, ppm)	0-50	21	43
Chloride (Cl, ppm)	0-50	24	242
Iron (Fe, ppm)	0.3-3.0	0.3	1.9
Manganese (Mn, ppm)	0.3-3.0	0.5	1.3
Zinc (Zn, ppm)	0.3-3.0	0.03	0.1
Copper (Cu, ppm)	<0.6	0	0
Physical properties			
Bulk density (g cm^{-3})	0.20-0.75	0.32	0.36
Total pore space (%)	>50	74	67
Air pore space (%)	15-30	37	40
Water pore space (%)	25-35	37	27

[z] Each datum is an average of 3 samples.
[x] Values converted from saturated past extract to 1:2 medium:water extract by a factor of 2.5.

obtained quicker release from blended T40/100 compared with unblended T100 Nutricote. While growth of juniper was unaffected, cotoneaster grew more rapidly at first with the blend but by end-of-season the influence of both treatments was no longer evident.

In this study, salt readings were different (P <0.05) on three of six medium sampling dates: 7 June, range 0.20 to 0.34 dS m^{-1}; 13 June, 0.21 to 0.37; and 17 July, 0.19 to 1.25. Interestingly, end-of-season growth was positively correlated with readings on 7 June [early season, mock orange r=0.596*, n=14 (2 media × 7 fertilizers)] and 17 July (mid season, dogwood r=0.592* and weigela r=0.586*). Raymond et al. (1998) found positive correlations between initial (time of planting) salt values in compost media and growth of each of four container-grown shrubs.

There were some differences in contents of foliar nutrients due to media or fertilizers (data not shown), but variations within species were within limits found normally in container nursery stock (OMAFRA 1997). Highest or near-highest foliar N concentrations in plants from Sierra High N 22N-1.7P-6.6K (22N-$4P_2O_5$-$8K_2O$) (Treatment 1) suggest an imbalance in the release pattern and/or utilization of N. This treatment notably and consistently produced the lowest salt readings and the poorest growth of all three species (Fig. 1).

Acknowledgements. This research was supported in part by The Scotts Company. The compost was obtained from Metro Toronto Keele Valley composting facility.

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Nitrogen Content of *Kalmia* Cuttings and How This Affects the Rooting Ability of Hardwood Cuttings

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Imperial Nurseries has attempted to root *Kalmia latifolia* cultivars using conventional winter hardwood cutting methods. Prior to 1997, cuttings were taken from our Crop 2 plants (3- to 4-year old plants) in mid to late October. They were stuck in our ericaceous rooting medium [peat moss, pine bark mulch, perlite, and styrofoam (6 : 6 : 6 : 1, by volume) in a 16 inch × 12 inch × 2 inch flat 70 cuttings per flat. Bottom heat was maintained at 65 to 72°F using a hot-water tube system on raised beds through out the 4- to 5-month rooting period. The 4- to 6-inch cuttings were dipped in a 2% IBA powder before being stuck into the media. Humidity was maintained using a light mist system during the first month, and only hand misting in the later winter months as sunshine and day length dictated.

Rooting percentages varied considerably from year to year, and from cultivar to cultivar. In 1995, cuttings from five cultivars ranged from 22% to 96% successful rooting, with an overall average of 57% successful rooting. The same five cultivars in 1996 rooted in the range of 18% to 75%, with an average of 53%. From a propagator's point of view, these percentages are discouraging and could definitely be improved upon. In general the plants that did not root showed no signs of failure from a top view of the crops. Inspection at time of transfer revealed little or no callus and blackening of the stem at the basal area where the plants had been dipped into the hormone powder.

In 1997 we attempted to root these cultivars under the same conditions, from similar cutting sources, under the same propagation house environment and rooting hormone as in the past years. However, we took the cuttings in late November using the same type of medium and direct stuck these cuttings into a 72-cell plug tray. Success percentages ranged from 3% to 55%, with an average of 19% overall rooting success.

I consulted with other growers who propagate *Kalmia* cultivars from hardwood cuttings with much more acceptable success percentages. Dr. Richard Jaynes, "*Kalmia* king", recommended Mike Johnson of Summerhill Nursery in Connecticut as a successful propagator of hardwood *Kalmia* cultivars. Mike was kind enough to provide me with his ideas, observations, and tested methods for achieving acceptable success rates. Two of his methods struck me as different from ours. Mike took his cuttings in mid to late January, after the cutting source had gone through 6 or more weeks of winter dormancy, and his cutting source was juvenile liner stock from the previous years successfully rooted liners.

Another idea, which may contribute to poor percentage rooting, entered my thought process on this subject. I began to think that a cutting's nitrogen (N) level may be a contributing factor after reading Dr. Jaynes' books on *Kalmia* and thinking back to a seminar I had attended in Canada in 1997 sponsored by IQDHO of Quebec.

That winter, we were experiencing difficulty with rooting of *Rhododendron* 'Boursault' a conventionally "easy" crop to root (93% to 97% average take rate). Approximately half of a propagation house, (15,000 cuttings) of 'Boursault' were excessively green in leaf color at the time of sticking. As other crops of 'Boursault' began to callus and set some roots, this crop showed little or no signs of callus or root formation. After approximately a 2-month period in the propagation environment, the cuttings began to blacken and lose turgor. There was no evidence of any fungal pathogen. Further analysis of these cuttings, through the help of the Connecticut Agricultural Experiment Station, revealed that there were no pathogens involved in their failure, or any symptoms of herbicide damage, only secondary fungal activity. A speaker at the IQDHO seminar, Dr. Jacques-Andre Rioux, described some similar experiences in his nursery in attempting to root ericaceous crops. Further analysis on his part suggested that the failures were due to a high level of N in the cutting tissue.

I later questioned him as to whether or not he was aware of any research that could pinpoint what level of N in plant tissue would give optimal rooting percentages. He was unaware of any such research or documentation. Hence my idea to pursue this aspect further.

I attempted a small trial of rooting *Kalmia* cultivars from hardwood cuttings later in the same season (Winter 1997/1998) with our direct stick to 72-cell plug tray. I unfortunately approached this from a "lay person's" point of view rather than a scientific point of view. I took these cuttings on 15 Jan. 1998 from the previous years successful crop that had been stepped up to a pint liner. I had also purposely starved this crop of fertilizer, with the last application of quick release 24N-7P-8K at a 5 lbs N 1000 ft^{-2} rate on 28 July 1997. I did not measure the N content of these plants but they were visibly yellowed from lack of nutrients. I placed these cuttings in 72-cell plug trays in the same propagating house as our November cutting crop. Of the four cultivars that I had stuck, my percentages of success ranged from 18% to 87%, with an overall average success of 65%. Three of the cultivars had a 70% success rate or better. From this small rather unscientific trial I was encouraged by these results. I am not certain which of these factors, juvenile cutting stock, cutting timing, or N content played a more significant role in rooting success.

I decided to pursue this experiment further and solicited Dr. Martin Gent of the New Haven Connecticut Agricultural Experiment Station to conduct a trial on a more

Table 1. Percent of cuttings rooted after nitrogen fertilization.

	Percent of cuttings rooted				
	"Low nitrogen" cuttings: nitrogen fertilizer applied (ppm)				"High nitrogen"
Cultivar	0	20	40	80	control
Minuet	71.5	74.3	77.1	71.3	4.3
Carousel	25.7	25.7	36.3	11.4	12.8
Sarah	28.6	40.0	20.0	0.0	0.0
Olympic Fire	77.1	70.0	78.6	11.4	12.8
Cultivar aver.	50.7	52.5	53.0	23.5	7.5

quantitative basis. Four cultivars were chosen for our cutting source, again using 1-year-old pint-sized liners. These cultivars were in various nutritional states. The liners originating from tissue culture had higher nitrogen content than those originating from cuttings. Dr. Gent fertilized the liners from cuttings (low-N) with four nitrogen levels to vary the nitrogen in the tissue of each cultivar (see protocol for fertilizing) for 7 weeks. Cuttings were taken from these four fertilization levels of all cultivars on 9 Feb. 1999 and placed in 72-cell trays in the same propagation house and conditions as in the previous years. An additional two trays of each cultivar were stuck from cuttings from liners of tissue-culture plants (high-N).

These cuttings were analyzed in May 1999 for their rooting percentages. The rooting results indicated that the concentration of N fertilizer did have an effect on rooting (Table 1).

'Carousel' did not root well at any rate of fertilizer concentration, because the low-N plants had as much N as the control group of the other cultivars. 'Sarah' did not root well because many plants died. Rooting of 'Minuet' was good at all N levels, but much better than the control plants. 'Olympic Fire' showed the most marked response to N fertilizer, particularly between 40 and 80 ppm N. Changes due to N fertilization level in the percentage of rooting occurred most significantly between the 40 and 80 ppm levels (Table 1). As the levels of N increased beyond 40 ppm, the percentage of root formation dropped rather dramatically. This suggests that higher concentrations of N in plant tissue have a detrimental effect on the ability of *Kalmia* cuttings to root.

How will these results help our industry take the guess work out of cutting viability and success rates? Obviously larger, more controlled fertilization rate studies need to be conducted to better assess what level of N fertilizer will give the best level of N in the plant tissue for optimal rooting percentages.

Currently, Dr. Gent and myself are repeating this experiment, using *Kalmia* cultivars at controlled feeding rates throughout the growing season. Prior to sticking cuttings this coming winter, we will again measure the N content of these various levels of N-treated cultivars and again assess their rooting success. On a grander scale, I like to envision our wholesale nursery industry utilizing this kind of knowledge with large cutting numbers of ericaceous plant material. Perhaps, in the future, a cutting can be analyzed under field conditions for its N content; in a simple process such as a nitrate electrode system, something like a "Cardy" meter. The measurement can then help us determine whether or not to utilize the crop for cutting stock. This fine tuning of the "guess work" involved in taking cuttings can save valuable time and labor dollars and also help assure that production plan numbers are met within the proper growing season.

This information may or may not apply to your nursery growing operations, or it may very well be thought of as a "pipe dream". I invite anyone who may be interested in this kind of research or feels that this idea is worth pursuing, to join myself and/or Dr. Gent in further analyzing and utilizing this type of venture.

PROTOCOL FOR FEEDING AND SAMPLING *KALMIA* FROM IMPERIAL NURSERIES 1999

- Plants delivered on 17 Dec. 98.
- Low-N plants were 1-year old propagated from cuttings. High-N plants were propagated from tissue culture.

- Four cultivars of *Kalmia latifolia*: Carousel, Minuet, Olympic Fire, and Sarah
- Eight plants of each cultivar and each N treatment were harvested. Stems were cut at soil level.
- Leaves were cut off stems and leaves were frozen and freeze dried.
- Except for 'Carousel', high-N plants weighed twice as much as low-N plants. Leaf weights were about 2 and 1 gram per plant, respectively. 'Carousel' did not look N-starved and leaf weights were similar for high- and low-N plants. For 'Minuet' and 'Sarah', N supply affected stem weights relatively more than leaf weights. Samples of 0.25 gram of dried, ground plant material were digested and total N was measured with Nessler reagent.
- High-N plants had about 40 mg N per gram leaf, while except for 'Carousel', low-N plants had less than 20 mg N per gram leaf. Stems of high-N plants had 17 mg N per gram while low-N plants had 10 mg N per gram (Table 2).

Table 2. Total nitrogen in leaves and stems before fertilization treatment expressed as mg nitrogen per gram dry weigh. High-nitrogen plant parts were from tissue-cultured plants and low-nitrogen plants were 1-year-old propagated from cuttings.

Part	Cultivar	Treatment High nitrogen	Low nitrogen
Leaf	Carousel	37.1	36.7
	Minuet	32.7	18.8
	Olympic	46.4	17.4
	Sarah	43.4	19.5
Leaf total		39.9	23.1
Stem	Carousel	15.6	13.2
	Minuet	14.6	10.3
	Olympic	16.8	9.2
	Sarah	19.9	10.3
Stem total		16.8	10.7

Starting on 4 Jan. 1999, the low-N plants were fed twice a week with a complete nutrient solution that contained all essential nutrients in ratios equivalent to half-strength Hoagland's solution, except for nitrate. Nitrate concentrations were: 0, 20, 40, to 80 ppm nitrate-N. Each plant received 50 ml, or 0.05 liter per feeding, and with 10 feedings over 5 weeks, a total of 0.5 liter of solution. Thus a plant weighing 1 g originally at 20 mg N per gram leaf, should contain 40 milligrams N if plants took up all the N supplied in the 80 ppm treatment.

Eight plants of each feeding treatment and each cultivar were harvested on 9 Feb. These plants were freeze dried and analyzed as before. The 15 remaining plants were returned to Imperial Nursery to be used as a source of cuttings.

Pot-in-Pot System: A Container-Grown-in-the-Ground Approach for Diverse Crops

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In the pot-in-pot (PIP) system, essentially a containerized plant is placed into a socket pot that is permanently buried in the soil. The plant grown in this manner can simply be harvested by lifting it out of the permanently buried pot. These plants will require irrigation during the active growth period and sufficient site drainage. In many regions of the United States, the expensive cost of providing overwintering structures is eliminated using this principle. The PIP method is an effective means to grow 3- to 20-gal containerized trees, evergreens, and deciduous shrubs.

Installation of a PIP growing area is not very complicated process. First determine items to be grown, the size container and the row spacing for the items. Select a site that is suitable for the crop. The site should have available water source and can be sloped or relatively flat. If drain tiles are to be installed stony ground may make trenching rather difficult. We grow all of our PIP items in bed configuration sites. Our rows are either 200 or 300 ft long, depending on the site; the beds are 24 ft wide providing for either 10 or 20 rows per bed. The base site is either shallowly rotivated or disked to flatter the uneven high spots. After leveling the site, we measure and mark row spacing. We are obsessive about row straightness and use a string line to guide the walk-behind trencher. The trench is approximately 5 inches wide and 4 inches deeper than the selected socket pot. Next, the 4-inch drainpipe is placed in the trench. We then use shovels to widen the spots for each of the socket pots. The pots are placed and back filled before we move to the next row. When all rows are set we spread the excess soil throughout the site (allow for some settling overtop of the drain tile). We generally allow the loosened soil to setup before we install the weed barrier. Rainfall or overhead irrigation will help compress the soil around the pots. To install the weed barrier we pin it in place right over the entire bed site. We then use a razor knife to cut an X over top of the socket pot. Next we lift the pot from the soil and through the hole in the weed barrier. This allows us to tuck the flaps of barrier down in the hole and the pot is then replaced anchoring the weed barrier tightly to the soil. After securing the weed barrier, we install the irrigation system. We use either inline drip irrigation system or overhead impulse type sprinklers. Basically the PIP area is then ready for use.

ADVANTAGES VS. DISADVANTAGES OF PIP SYSTEM

Advantages.

- Root zone insulation from extreme temperature variations
- Reduction of water usage.
- Suitable for trickle applications.
- Elimination of blow-down problem.
- Year-round harvest ability.
- A "neighbor friendly" system.
- Less capital intensive, construction, and maintenance reduction.

Disadvantages.

1) Lack of flexibility in spacing.
2) Initial labor-intensive set up.
3) Exposure to winter winds.
4) All plant care performed outdoors.
5) Container-grown plants rooting into soil.
6) Heavy-soil type limitations.

CHARACTERISTICS FOR CROP SELECTION

1) Deciduous shrub, conifer, or selective evergreen shrubs with desiccation-resistant foliage.
2) Upright or semi-upright growth habit.
3) Fibrous root structure.
4) Hardiness zone fit.

ITEMS SUCESSFULLY GROWN

Rhododendron (azalea-deciduous)	*Itea*
*Buddleja**	*Juniperus*
Caryopteris	*Microbiota decussata*
Chamaecyparis	*Pinus*
*Cornus**	*Potentilla*
*Forsythia**	*Prunus*
ornamental grasses	*Rhododendron*
Hibiscus (althea)	*Spiraea*
Hydrangea	*Syringa*
Ilex	*Weigela*

*Items have aggressive rooting characteristics and require copper coated barrier to minimize root anchoring.

COSTS

Anticipated Setup Costs.

1) Container cost:		
	3 gal injection mold	$.64 each
	5-gal "seconds"	$.49 each
2) Equipment rental:		
	ditch-witch trencher	$140.00 per day
	gravely mounted auger	$85.00 per day
3) 4-inch ADS drain pipe 100 ft^{-1}:		$25.60 per roll
4) Weed barrier 7500 ft^2 at $0.05 per ft^2		$363.40
5) Bark mulch $yard^3$		$4.00 to $10.00
6) Labor 236 h for 942 containers complete with drainage, irrigation, weed barrier, and mulch		
7) Spray stakes 3.2 gph		$0.47 each
8) Weed check sheets (3-year life)		$0.44 each

Container Sizes.

- 3-gal poly-tainer 3A and classic 1000.
- 5-gal poly-tainer 7S and classic 2800.
- 15-gal poly-tainer 15S and classic 4000.

These containers provide nice nesting configuration with the liner pot sitting at the bottom of the socket pot. Several pot manufacturers provide information matching liner pot and socket pot sizes for PIP installations.

ACTUAL COSTS

For 22 ft × 200 ft = 4400 ft^2 site (1000 containers) $4704.09 or $0.86 per ft^2.

Comparative site with a poly structure would cost $6909.40 or $1.21 to $1.45 per ft^2 with additional yearly expenses of $338.00 for new poly recovering and general repair.

CONCLUSION

I believe that PIP does provide an economical and viable option to maximize production space beyond the normal scope of expanding structure-covered sites.

A Dynamic Control System for Scheduling Mist Propagation in Poinsettia Cuttings

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INTRODUCTION

Major greenhouse crops, (poinsettia, chrysanthemum, and geranium), as well as many woody nursery crops are propagated by softwood cuttings. The typical propagation system used to root cuttings is open bench misting. Although, cuttings from many species are remarkably tolerant of variable environments in the mist bench, mist propagation as currently employed can be an inefficient use of inputs such as water and electricity. This is the consequence of static control systems for controlling the interval between misting events. In some cases, inappropriate control of misting intervals can reduce or delay root formation by allowing cuttings to wilt, leaching nutrients from the leaf, or saturating the medium with water. In contrast, dynamic systems for controlling mist rely on plant or environmental signals to estimate the water status of cuttings. Several alternatives to static control have been developed including simulated mechanical or electronic leaves, light sensors, and humidistats (Hartmann et al., 1997). The objective of the current study was to evaluate an evapotranspiration model (Zolnier et al., 1998) for scheduling misting for poinsettia cuttings under summer greenhouse conditions.

Commercial poinsettia production starts with propagation of terminal cuttings taken from stock plants during midsummer in the United States. Summer season greenhouse environments are typically most severe because of high solar radiation, temperature, and air vapor pressure deficit (VPD). Because poinsettia terminal cuttings are initially unrooted, the propagation effort is focused on providing an optimal environment for the cuttings until they develop roots, typically 3 to 4 weeks. Water status of the cuttings must be maintained by maximizing water uptake and providing mechanisms to limit transpirational water loss (Mudge et al., 1995). Techniques such as intermittent mist, fogging systems, and shading control (Hartmann et al., 1997) that control VPD (Gates et al., 1998) can be used. VPD is the difference between the vapor pressure in the leaf (V_{leaf}) and the vapor pressure of water in the air (V_{air}) (Fig. 1). Vapor pressure deficit is the driving force for water loss from leaves. Because cuttings are initially unrooted, the propagator must limit transpiration. Fogging systems, humidity tents, and enclosed misting increase V_{air}, while open bench misting impacts V_{leaf} by water evaporating from the leaf surface, thereby reducing V_{air} and increasing V_{leaf}. Note that VPD of air is commonly used as a substitute for VPD leaf – air. This is acceptable so long as leaf temperature does not vary from air temperature by more than a few degrees.

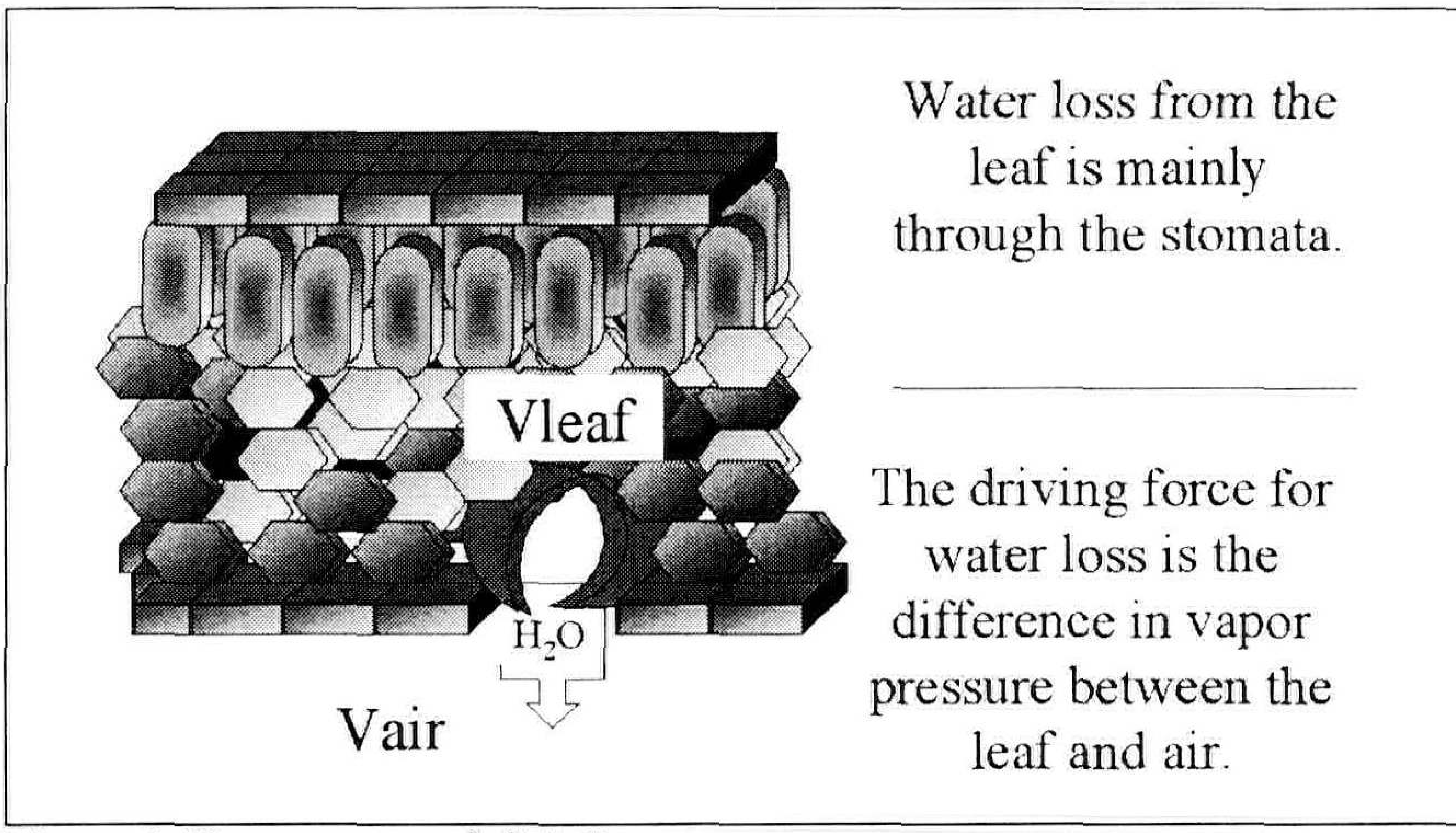

Figure 1. Vapor pressure deficit diagram.

Recently, we have devised a dynamic misting control strategy for poinsettia propagation (Zolnier et al., 1998). Evaporation from cuttings is estimated from an energy balance (the Penman-Monteith equation) using parameters obtained from carefully controlled growth chamber experiments and online measurements of canopy temperature, air temperature and relative humidity, and light intensity (Zolnier et al., 1998). Mist is only activated when predicted evaporation reduces stored water in the canopy to below a threshold quantity.

MATERIALS AND METHODS

Stockplants and Cuttings. Poinsettia (*Euphorbia pulcherrima* 'Freedom') stock plants were maintained under standard greenhouse conditions and prevented from flowering by daylength control. Terminal cuttings (9 cm long) were treated with IBA (1000 ppm quick dip) and stuck in peat and perlite (1 : 1, v/v) medium.

Mist Chambers. Cutting were misted by four Netafilm nozzles suspended above the bench adjusted for uniform coverage (Fig. 2). Four individual mist chambers (1.5 m × 3 m) were independently controlled by computer. Two chambers were statically controlled for mist at 5 sec every 5 min. The remaining two chambers were dynamically controlled using the evapotranspiration model (Zolnier et al., 1998). The computer recorded temperatures, misting times and calculated V_{air} every minute. Root number and length was recorded after 21 days.

RESULTS AND DISCUSSION

The major difference between the two systems of mist control was the amount of water used. There was a 38% reduction in misting using the dynamic control system. This reduction in water usage should have resulted in a less wet propagation medium and could account for the differences seen in root length and diameter for the dynamically controlled cuttings. In general, the dynamic system of control misted more frequently during sunny conditions, and less frequently during

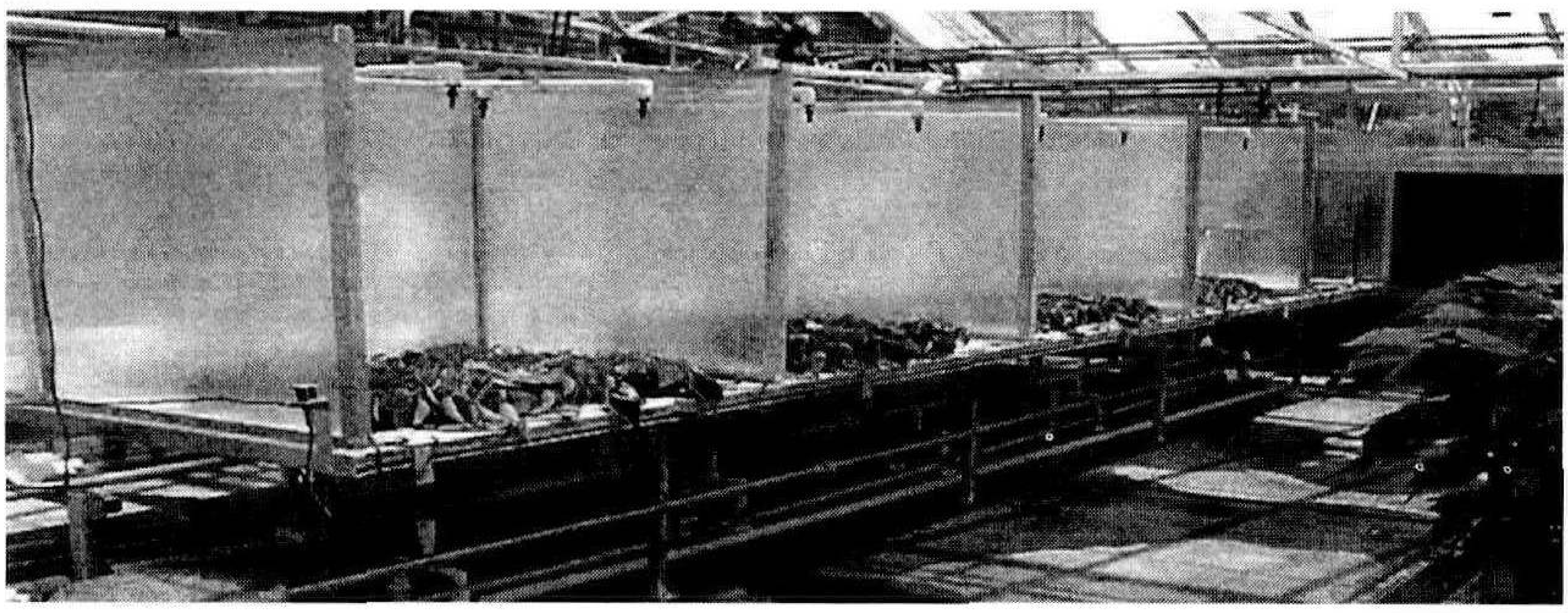

Figure 2. Mist chamber layout.

morning,evening, and cloudy times. This is illustrated by the number of times mist was activated during a typical sunny or partly cloudy day.

The number of roots per cutting did not vary between systems of mist control (static = 47.0; dynamic = 47.3 roots per cutting). There was also no difference in relative water content of the cuttings (a measure of water stress). Differences were seen in overall root length (static = 209; dynamic = 249 cm per cutting) and root dry weight (static = 89.0; dynamic = 101 mg per cutting). The percentage of fine roots (<0.8mm) was 24.5% greater in the cuttings controlled by the dynamic system. Poinsettias are the highest value pot crop in the United States. Propagation is from softwood cuttings that are usually rooted under mist using static time control of fixed or traveling nozzles. While some growers may adjust this mist interval manually as water status in the cuttings warrant, timely adjustment is certainly not prevalent. Indeed, no clear criteria exist for assessing what constitutes proper misting adjustment, other than observing wilted cuttings. Thus, the on/off interval is selected to satisfy extreme midday conditions, and consequently excess water consumption occurs during cloudy days, mornings, evenings and in some cases during night time. Excess water also reduces O_2 availability in the roots of newly propagated cuttings. Growers are hesitant to make adjustments toward water conservation, because forgetting to re-adjust for high radiant conditions can quickly result in a lost crop. The mean wholesale value of poinsettias sold in 1997 was about $3.70 per potted plant (USDA, 1998); it is common for propagators to have tens of thousands of terminal cuttings under propagation at one time. Mistakes during propagation can have serious economic impact. The model tested in this paper is one approach to dynamic mist control. It has proven to be a good predictor of misting frequency for poinsettia propagation. Additional testing will be required to optimize this system for poinsettia and to extend it to the general propagation of other crops.

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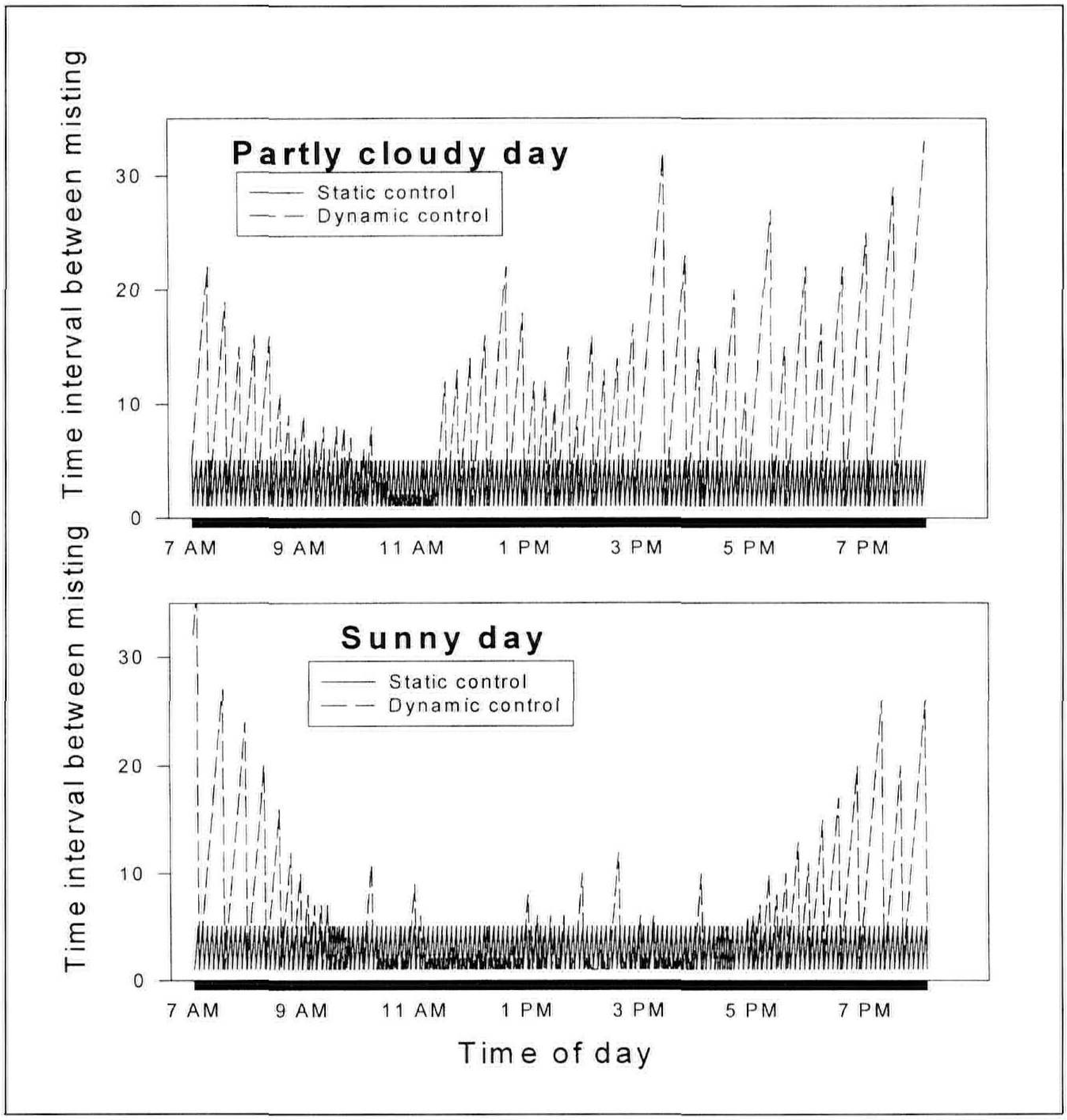

Figure 3. Frequency of misting during a sunny day and shady day under dynamic control.

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Affects of Container Size and Shape on the Rooting of Cuttings

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INTRODUCTION AND OBJECTIVES

After many years of work with rooting cuttings of both perennials and woody plants I have formed some opinions on what works, however, not all of these hunches and intuitions are accurate.

We should reexamine our convictions from time to time to insure their accuracy. One such hunch is to suppose that deep celled pots are superior to those of lessor volume or depth. I am not alone with this idea as a recent conversation with the vice president of production at a major nursery will attest when he suggested the very same thing! What we both believed to be true did not tell the whole story and the data presented here suggest that other factors in addition to volume and depth play a major role in the successful rooting of cuttings in plugs.

MATERIALS AND METHODS

Individual pots and vacuum-formed trays commonly found in suppliers catalogs were the subject of this study. Table 1 outlines the particulars with respect to physical shape and size. The study was designed so that only pot size and shape were the varying factors and all other factors were kept as standards. Three species were selected as test plants based upon varying degrees of rooting potential.

Experience has shown that *Callicarpa dichotoma* 'Alba' to be an exceptionally easy plant to root and most closely mimics perennials in terms of ease of production. It was thought that an easy-to-root plant might not show appreciable differences due to container variations.

Hydrangea macrophylla 'Tokyo Delight' was chosen because it is somewhat harder to root than *Callicarpa* and previous work has shown some degree of sensitivity to container size and shape.

The third test subject was *Acer rubrum* 'Franksred' Red Sunset® red maple. Woody plants in general are more reluctant to root than more herbaceous material and *A. rubrum* was selected because it can be rooted but requires more time and effort; the supposition being that a more difficult-to-root plant might show a larger sensitivity to container size and shape variation. The medium selected was Progro Perennial Mix, a proprietary mix of Sphagnum peat moss, composted pine bark, composted peanut hulls, and 5% sand. The mix also contains a starter fertilizer with trace elements and has a pH of 5.4 to 5.9.

Cuttings of *C. dichotoma* 'Alba' were about 5 cm long, those of *H. macrophylla* 'Tokyo Delight' were 15 cm long, and those of *A. rubrum* 'Franksred' Red Sunset® red maple were approximately 35 cm long. All cuttings were treated with Dip 'N Gro rooting compound diluted to a rate of 1 : 10 with water. This equates to a solution of1000 ppm IBA and 500 ppm NAA. The *Callicarpa* and *Hydrangea* cuttings were not wounded, those of *A. rubrum* were wounded on two sides by dragging across a horizontally mounted blade resulting in a shallow scrape along each side. Cuttings were inserted up to the first set of leaves with at least one set of nodes beneath the soil surface. This left a basal end of 1.5 to 2 cm in the soil for the *Callicarpa* and the *Hydrangea* and 2 to 3 cm basal end on the *A. rubrum*. Mist was provided every 15 min with a 30-sec burst. All the cuttings were rooted in a 70% milky-poly-covered house with no bottom heat or forced ventilation.

Cuttings were stuck in lots of 50 of which five were selected for evaluation after being assigned a random number. The entire block of a single species was removed for evaluation once it was determined that at least 80% of the cuttings in any one of the test treatments was rooted. The 80% evaluation mark was determined by checking individual trays and counting the "pulls" verses the "tug backs"; tug backs indicating a positive rooting response. The intent was to capture the rooting process early on in order to clearly see the differences, if any, due to the containers.

Had the cuttings been allowed more time to develop the most obvious and early differences in rooting might be obscured by the lesser rooted plants being given extra time to catch up.

Evaluations were based upon the length of the longest root, root number and where applicable, rooting percentage. If rooting percentage was not listed in the following charts, it was because there was no difference at the time of evaluation.

RESULTS

Callicarpa dichotoma 'Alba' rooted earliest and with the greatest of ease (Table 2). As was expected and subsequently verified those cuttings in 32-celled square pots with a rating of a 5 were superior to the other trays. The 50 squares were a close second if not equal to the 32s with a rating of a 5 as well, but varied slightly with shorter root lengths. This was followed by 70 squares which were adequate with an over all rating of 2, beyond this point round 50 cells and 70 cells were poor with very short root lengths which gave a rating of 1. The 50 round cells showed both a reduced level of root length and number of roots, whereas the round 70 cells showed only reduced root length, with root numbers that were comparable to the other cells.

Hydrangea macrophylla 'Tokyo Delight' (Table 3) showed a similar pattern with respect to cell shape as the *Callicarpa*. Again, the 32 squares earned high marks with a rating of a 5, followed by 50 squares with a rating of a 4, and 70 squares coming in at a 3. Once again, the 50 and 70 roundcells, were poorest, both earned a 1. Here the important criteria was the number of roots as rooting percentage and root length did not indicate significant differences amongst the containers.

Acer rubrum 'Franksred' Red Sunset® red maple (Table 4) followed the trend of performing best in 32 squares, however, this trend was not repeated in 50 squares nor in the 70 squares, with ratings of 5, 1, 2 respectively. Round cells (50s and 70s) provided a rating of 2. In this test the 50 squares yielded the poorest results with the exception of rooting percentage, which was comparable to that of 70-deep round cells. Rooting percentage was poorest in 50 rounds and in 70 squares. Root quality was comparable between 32 squares and 50 rounds but 50 rounds did not provide the higher rooting percentages that 32 squares allowed. Root quality was poorest in 50 squares, 70 squares, and 70 rounds.

Table 1. Pot volume and depth.

Size	Volume (cc)	Depth (mm)	Rating[Z]
32 squares	240	85	5
50 squares	80	55	4, 5 (1)
70 squares	50	50	2 to 3
50 round	60	55	1 to 3
70 round	50	60	1 to 3

[Z]5 is highest, 1 is lowest.

Table 2. *Callicarpa dichotoma* 'Alba' rooting results.

Size	Rating	Root length (mm)	Roots (no.)
32 squares	5	15	25
50 squares	5	8	21
70 squares	2	10	26
50 round	1	2	16
70 round	1	2	23

[Z]5 is highest, 1 is lowest.

DISCUSSION

All of the species clearly demonstrated the superiority of 32 squares over the other types of rooting cells. It is also apparent that square cell types have advantages over round cell types regardless of cell size as volume or depth. Since *Callicarpa* and *Hydrangea* are easy-to-root plants it is possible that the speed at which they root compensates for problems that depth and volume might cause. Specifically, they root too fast for depth and volume to be a factor. However, in both of those species, cell shape does seem to influence rooting by influencing the rooting time. Perhaps this occurs by altering the physics of water and air flow through the cell. *Acer rubrum* being much slower to root, 21 days vs. 10 days for *Callicarpa* and 14 days for *Hydrangea*, seems highly sensitive to volume and depth differences and this over rides the difficulties presented by differing cell shape. Here too, oxygen diffusion within the rooting media may be significantly altered by the depth and volume of the pots. It would seem that a woody plant such as *A. rubrum* can not be effectively produced in anything but containers with larger volumes and depth.

Another factor possibly affecting rooting is the close proximity of the cuttings in the blow-molded trays. This causes for a serious overlap of leaves, particularly in larger types of cuttings, such as *A. rubrum* and *Hydrangea*. This greatly cuts down

Table 3. *Hydrangea macrophylla* 'Tokyo Delight' rooting results.

Size	Rating	Root length	Roots (no.)
32 squars	5[y]	nsd[z]	>100
50 squars	4	nsd	>10>100
70 round	1	nsd	approx. 50

[Z]5 is highest, 1 is lowest.
[Z]nsd = no significant difference.

Table 4. *Acer rubrum* 'Franksred' Red Sunset ® red maple rooting results.

Size	Rating	Root length (mm)	Roots (no.)	Rooted (%)
32 squares	5	25	10	98
50 squares	1	3	4	81
70 squares	2	12	5	72
50 round	3	17	11	60
70 round	2	14	6	80

[Z]5 is highest, 1 is lowest.

on the amount of light available to any one particular cutting save for those on the outside edges. It also reduces coverage of the mist for those cuttings on the interior of the trays and provides an area of little or no air movement, possibly resulting in fungal problems.

CONCLUSIONS

Conclusions would be to recommend the use of 32-celled squares approaching volume of 200 cc for the rooting of woody plant species. If for some reason an insert cell-rooting system is needed due to space allocations then it is suggested that square cells be given consideration over round cells. It is clear that round cells allow for root formation but they cause serious impediments with respect to accentuating rooting and root quality. The rooting of cuttings is a time-sensitive process, seasons change and rooting conditions within a season change dramatically. Use of cell inserts that do not allow the propagator to maximize production through shorter propagation times can be costly. By taking advantage of the decreased rooting times for square cells over round cells the propagator can conceivably get an extra crop for the year over the same space.

Liner Bed Production of Boxwood

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Warner Kingwood Nurseries, Inc., 37611 Pleasant Valley Road, Willoughby Hills, Ohio 44094 U.S.A.

With the increased popularity of *Buxus* (boxwood) cultivars in the landscape industry and the corresponding increase in wholesale production, we at Warner Nurseries have an economical production system using field-grown liner beds. There is nothing revolutionary about our system, however, several key processes allow us to gain maximum growth with minimal time and expense.

The first key is cutting size. Cuttings are taken in September and October using a 3- to 4-inch many branched cutting from 2-year liners. When rooted these cuttings already have a well formed habit. Cuttings are dipped in a 2500 ppm KIBA solution for 5 sec. They are then stuck in a 9 inch × 13 inch × 3 inch propagation flat into an equal peat and perlite mix (1 : 1, v/v). Flats are given hot-water bottom heat at 70 to 72°F with light mist.

Western Lake County has heavy soils so we utilize raised beds for all liner production. Beds are formed with a standard 5-ft bed maker. All beds are dressed with 2 to 3 inches of a peat and pine-bark mix. This adds organic matter and prevents soil surface drying. The beds are then hand raked and hand planted. The second key item is that we water plants immediately after planting either with overhead irrigation or hand watering with a hose. The third key element is spacing. Ten rows across a 60-inch bed allows 6 inches between rows and plants are spaced 6 inches in the row. This allows 1 ft^2 per plant which gives us maximum density with no crowding or misshapen plants.

The first winter the boxwood are covered with wire hoops and white poly film. This prevents physical damage from snow or desiccation from wind. The beds are uncovered in the spring, trimmed and fertilized with a season-long slow-release fertilizer. Irrigation occurs twice per week or as needed. By the second winter plants are full enough and have enough roots; they are not covered. After a flush of growth the second spring the liners are ready for transplanting. Most plants will have good root to shoot proportions and will be a full bodied 10 inch × 10-inch plant. We do not want a skinny liner. The liners are field planted and will be harvested as B&B plants in 2 years or canned into 2-gal containers and shipped after one growing season. We are producing salable B&B within 4½ years from a cutting and a salable 2 gal within 3½ years from a cutting due to these key processes in our production system.

Winter Survival: Creative Ways of Protecting Plants in the Northeast

Mike Emmons
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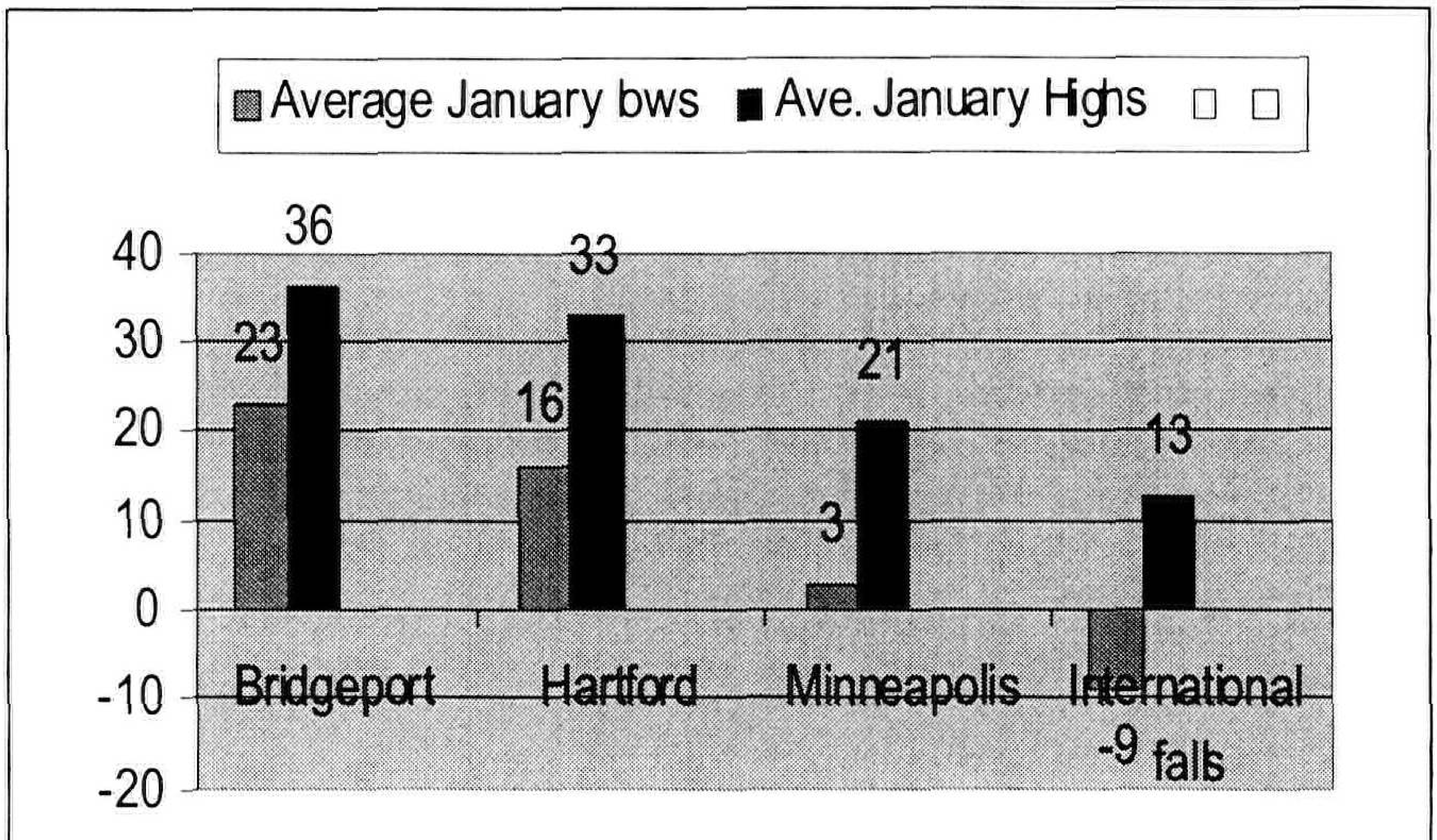
Coming from southern New England to Minnesota to talk about protecting plants from the extremes of winter might be perceived by some to be foolish or even a bit cocky. It would be like a Floridian telling a New Englander how to dress for bad weather. It's not advised. However, cold is a relative term. What we in Connecticut might construe as bitter cold the people in the upper Midwest might refer to as Indian summer.

As the figure below shows Connecticut indeed has a much more temperate climate than Minnesota. We can, however, have extremes in our temperatures. During the 1990s, all but two of our winters have been at or below normal levels. How do you determine how to prepare for a winter in southern New England? Well there is the Farmers Almanac, the woolly bear, El Nino, La Nina, how many nuts are on the trees, etc. Then there is the more scientific approach where the weather meteorologists give their predictions and than you wait and see how wrong they are. Realistically the best you can do is prepare for the worst and hope for the best. And that is what I would like to share with you today.

Because the great creator never intended to have plants grown with their roots in the air and because that is exactly what we are doing in a container nursery we must find a way to protect them from the extremes, especially exposure to extremely low temperatures. The retired Dr. Havis of the University of Massachusetts pioneered some of the first research involving root kill temperatures of woody ornamentals. Utilizing that research we can get a pretty good idea as to which plants need minimal winter protection and those that require a greater degree of protection than what can be provided by a single sheet of overwintering film.



The first group of plants has, through trial and error, demonstrated no need for any kind of winter protection in southern New England. These plants are simply left outside without any kind of winter protection. The containers are merely collapsed pot to pot and left to the elements. Some plants grown by Prides Corner that fit into this category are:

- *Cornus alba* 'Argenteo-marginata'
- *Cornus sericea* (syn. *stolonifera*)
- *Cornus sericea* 'Flaviramea'
- *Potentilla fruticosa* and cultivars
- *Salix discolor*
- *Lonicera tatarica* 'Arnold's Red'
- Any tree grown pot in pot

A quick word about trees grown pot in pot. There are some real advantages to growing trees this way. First is that they simply don't blow over under windy conditions. Because the roots are not exposed to a hot container during the summer months there is no root kill on the south side. Finally, because the buried container is larger and wider than the pot the tree is grown in there is good insulation of the root system during the winter allowing the trees to be overwintered in place.

Approximately 70% of all the nursery stock grown by Pride's Corner Farms (PCF) is overwintered conventionally in overwintering structures using opaque plastic to protect the plants from the winter environment. They are merely 14-ft wide structures that are manufactured in house. Because of record snow levels during two of the winters in the early 1990s we have converted from a traditional quonset-style structure to a gothic style. This new design sheds snow loads much better and believe it or not seems to take the wind better as well

The simplest form of winter protection is to cover them with a single sheet of white co-poly. Even this method has been critiqued and adjusted by us over the years. Originally our plastic was wrapped on a piece of faring strip and attached to the house using 8d duplex nails. Although the plastic is firmly attached there are spaces between the baseboards and the ground that cold air can seep into, especially when the wind is blowing. We overcame this by simply laying the sides onto the ground creating a skirt that seals the house more completely. This alone makes a huge difference in how well a house overwinters. Most plants that have a root kill temperature of 15 to 20^{o}F or less usually do not need any additional winter protection other than this. Shrubs such as H-1 and H-2 *Rhododendron*, *Viburnum*, *Spiraea*, deciduous azaleas, and *Juniperus* just to name a few are some groups of plants that fall into this category.

Then there are the plants that either from time to time or on a consistant basis need additional winter protection to ensure there winter survival. Through the years PCF has identified and targeted these plants so that they can get special treatment. The process is simple in that an additional layer of poly is placed into the house to be used as a blanket to create a warmer environment that has a higher relative humidity. As simple as it sounds the process is not and it requires that certain criteria be met in the installation process and when the plants are covered.

Plants that require a poly blanket are determined at or before the time they are first potted. By doing this they can be put into the house a certain way. That is, first we do not put these plants down at the end of a house. The coldest part of any overwintering structure is at the ends so we begin and end the plants 10 ft from these ends. We also must take into consideration the space the poly blanket takes up so we leave an area approximately 6 inches wide along the inside of the baseboard. The blanket is then placed before the house plastic is put on. This makes it much easier to cover the plants and the quality of the job is much better which is essential to how the blanket will perform.

Timing is also important in knowing when to apply. If applied too early diseases due to excess moisture can be a problem. Applying too late and damage could already have been done. The weather is watched very carefully and when a significant cold outbreak is anticipated we will begin to cover. Historically the timing of this is usually around Christmas. After the blanket is put on, the plants are checked periodically to see how they are doing. Moisture levels are checked as well as checking to see if bait put out to control rodents have been eaten. This is a warm secure environment for these four legged eating machines and they can quickly devastate a crop if not kept in check. Also checking to make sure that the blanket is on securely is important. The one sure-fire way to know this is to look at the condensation on the underside of the blanket. If it is completely covered you have a good seal. If there are dry areas on the underside of the plastic there is cold air seeping in from the outer portion of the house and therefore needs attention.

This form of winter protection is vital to a number of important crops we grow. Plants such as evergreen *Ilex* (holly), *Magnolia*, *Pieris*, *Cotoneaster*, *Buddleja*, and evergreen azaleas to name just a few, need this additional protection to ensure they survive our winters in Connecticut. We would not even attempt to grow these plants unless we were able to protect them this way.

A second group of plants requires winter protection but not necessarily in an overwintering structure. Some of our needle evergreen material have been found to do quite well when protected with what we call micro film. The material is ¼- inch thick foam with a 2-mil opaque film embossed on the outside. The material is 12 ft wide and up to 100 ft long. Because the material is put right over the top of the plants there is very little ambient air, therefore, the environment underneath remains remarkably stable with little fluctuations in temperature. We often will overwinter plants we know will do well in this environment when there aren't enough overwintering structures for all the plants in the nursery. Some of the drawbacks of this system are that the plants are inaccessible and they are difficult to monitor through the course of the winter. If there is a snow load you can forget getting a peek inside. Also, because of the way the plants are packed it is once again very important to make sure they are protected from rodents. One very nice thing about this system is that if the plants are covered moist they do not dry out at all as the soil maintains a high moisture content throughout the overwintering period.

These are just a few techniques we have developed to overwinter our containerized plants. To some these extra steps might seem a bit tedious or even unwarranted. Our research and findings are the results of trial and error; lots and lots of errors. I can assure all of you that these techniques do in fact work and work very well. I have simplified stating these techniques, as the time allotted does not allow me to be more specific. I will make myself available afterwards to anyone who would like to talk some shop with me. Growing plants is truly a labor of love. Under intense growing conditions practical techniques to take care of them are vital. In the spirit of seeking and sharing I hope this information will be of benefit.

Making Tissue Culture Pay

Tom Pinney Jr.
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INTRODUCTION

We use tissue culture primarily in the propagation of new cultivars of *Betula* which need to be asexually reproduced. During the past 11 years we have sold 193,000 tissue-cultured 'Crimson Frost' and Royal Frost™ birch. These have all been produced in our own lab, rooted, and grown on for sale as liners. Our costing systems reveals that the sale of these tissue-cultured plants adds to our profitability.

FACTORS INVOLVED IN MAKING OUR TISSUE-CULTURE SYSTEM A PROFITABLE VENTURE

Selection. Since we are known for our quality birch liners, tissue culture became a way for us to quickly introduce new improved birch cultivars. It is much faster than the traditional budding and easier for us to manage than standard cuttings. It fits our scheme of producing quality 1-year containerized liners 18 to 24 inches.

Rooting. We use unrooted microcuttings. Twenty five are stuck in a 4-inch, soilless-mix square pot and placed in a growth chamber for initial rooting. As they begin to root they are moved to polytents inside a greenhouse where they are grown to transplanting size.

51 Cell. The 1 to 1½-inch rooted cuttings are transplanted into a 51-cell tray (each cell 1¾ inch diameter × 3½ inch deep) and grown 4 to 8 weeks at which time they are 4 to 6 inches in height. They are then transplanted into a 3½ inch × 3½ inch × 5 inch deep pot.

3½ inch × 5 inch Square Pots. Nine of these individual pots are spaced alternately in an 18-unit-deep socketed tray so as to allow for proper density of the crop. They are grown 8 to 12 weeks to an 18- to 24-inch size with an approximate ¼-inch-caliper stem.

Timing. We manage our scheduling so that the majority of the plants in the 51-cell trays are ready for transplanting in May and June. Lab production is scheduled accordingly. We also do a late production from the lab which is rooted and held over winter as dormant plants in the 4-inch-square rooting pots.

Root Configuration. Both the 51-cell unit and 3½ inch × 5 inch square deep unit has grooves to prevent root curling. The 51-cell unit is designed and used so that the roots on the bottom are air pruned. We are experimenting with copper-treated units to develop a more natural root system.

Overwintering. The liners are allowed to harden off naturally during October and November. The greenhouses are covered with a 70% opaque poly for winter. The polyhouses are not heated. When temperatures rises above 55°F the structures are ventilated. When the plants are dormant they are graded and consolidated filling each socket in the 18-unit tray.

Crop Cycle. Depending on the time of the year the microcuttings are produced, the production cycle varies from 9 to 18 months.

Shipment. Liners are available to ship from September through mid-May. Small orders or orders from outside our general 1000-mile delivery range are shipped UPS, while larger amounts are usually delivered by our shelved, refrigerated, and air-ride semi trailers.

We are applying the same basic system of rooting microcuttings to lilacs and other species where profitable. Most of these microcuttings are being purchased from commercial labs.

SUMMARY

In summary, tissue culture has become an integral part of our production scheme. It has allowed us to quickly introduce new cultivars requiring asexual reproduction into the market place at a profit and maintain our niche in the production of quality liners.

Two Ways to Crack the Nut — *Aesculus parviflora*

Alan M. Jones
Manor View Farm, Inc., 15601 Manor Road, Monkton, Maryland 21111 U.S.A.

INTRODUCTION

Aesculus parviflora, bottlebrush buckeye, is a native shrub that grows 8 to 10 ft tall and 8 to 12 ft wide. While being native to much of the southeastern U.S.A., it is hardy in much of the eastern United States as far north as Zone 4. Panicles of large white flowers, 6 to 12 inches long are carried in profusion above the foliage in midsummer (in the mid Atlantic states usually in early to mid July). The plant prefers a moist well drained soil, but will adapt to lesser conditions. As this past summer has shown it is very drought tolerant once established. *Aesculus parviflora* grows well in full sun or shade.

Plants in the landscape are pest free and appear to be highly resistant to deer browsing.

Because of all these attributes the demand for *A. parviflora* has been huge, but there is a problem, the supply has not been able to keep up with the demand.

In a presentation, given to this group in Philadelphia in 1994, Dick Bir talked about "Why Some Natives Aren't Mainstream...Yet". He talked about the need for the plant to have market appeal and to be marketable; it must also be possible to produce the plant profitably. How many of us grow plants we like that are not really profitable.

Interestingly, he discussed *Fothergilla* as a native that was not widely known and had the reputation for being difficult to propagate. He also stated that in the near future, *Fothergilla* would be better known and more widely available. Guess what? Five years later *Fothergilla* is now listed in most container nurseries catalogs and considered a staple production item at many nurseries. The propagation problems once associated with the plant have been overcome with the selection of easier-to-root cultivars such as *F.* 'Mount Airy'.

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Those who listened to Dick Bir in 1994 and got *Fothergilla* into production have been well rewarded.

We have not been so lucky with *A. parviflora*, 5 years later we still have a shortage of plants and no easy-to-root cultivars, despite the fact we have a plant with market appeal and one that is easily marketable.

Why is this still a problem? In a word, propagation has been the problem.

For a number of years I have been propagating and growing *A. parviflora* and have watched with interest the work Bill Barnes and Dick Bir have carried out with timing and hormone trials. I have also followed the methods used and discussed by the *Aesculus* King, Phil King of Greenwood Propagation.

We have not solved all the problems, but we are finally producing larger quantities of liners by attacking the problem from two directions.

SEED AND CUTTING PROPAGATION

Both these methods have problems and limitations. However, by establishing stock plants at the nursery and searching for established plantings in public and private gardens, we now have a reasonable source for seed and cutting collections. I am still amazed how many large plants exist in older private gardens. A few years ago we let our landscape customers know that we were looking for plantings of *A. parviflora* and ended up being told of a number of local gardens that had large plants; we now collect seed from them. I also found a large plant growing on the side of a recently established rail trail, a biking and walking trail established along a site of a former railroad track. You never know when you are going to find the plant so you need to keep your eyes open.

Seed Production. *Aesculus parviflora* is not known for producing large quantities of seed on a regular basis. Various suggestions have been offered for the irregular seed set, it is generally believed that cross pollination and a long and warm growing season is needed for viable seed production. Various kinds of butterflies, bees, bumblebees, and wasps all appear to help pollinate the flowers. We have tried to track the seed production levels of a number of plants and have not found any consistent pattern to seed production. This year the seed set is better than average, we had a hot and very dry summer so that may have helped. But we have had good seed production in cooler and wetter summers. What is confusing is that one plant can have a heavy seed set and the plant next to it has a poor seed set.

This is one seed that can fool you if you are unaware of how to handle it. It takes knowledge, speed, and awareness to collect the seed on time and beat the forces that are working against you.

The seed is usually ready for collection in late September. The fruits are loosely attached to the old flower stalk and drop to the ground easily once the seed ripens. Timing your collection is critical because if the seed is allowed to drop to the ground it can be eaten by mice or carried away by squirrels. The seed has a very short period of viability so if not collected and processed quickly it can dry out.

Treatment of Seeds. Once collected the seed needs to be sown immediately, as the radicle will emerge within a few days of collecting. In a few weeks the food reserve in the cotyledons are exhausted by the rapid development of the large, carrot-like root system.

We place the seed in a bag of slightly damp peat moss and perlite, and check the seed daily, as soon as the radicle starts to show we sow the seed. We take this extra step as it guarantees that the radicle is straight and pointing down when planted; if the seed is sown prior to the radicle showing a curled root could occur. We sow the seed in flats or crates filled with regular potting compost and place them in a cool greenhouse. We like to use a mesh-bottom flat so that the root will air prune when it reaches the bottom of the flat and will, therefore, not produce a long taproot.

The most critical thing at this stage is to protect the seed from mice. If the seed is not protected in some way the mice will eat all the seed within a few weeks. We cover the seed flats with wire mesh. Protecting the seed cannot be understated; it's amazing the speed at which the mice move in.

Once sown the radicle grows rapidly and becomes well established. It is critical not to over water this crop as the seed and root can rot very easily. Once the radicle is established, it is not unusual for a shoot of about ½ inch to grow, this usually then goes dormant.

We overwinter the plants in a frost-free environment to provide the seedling with a stress-free winter. In early spring we remove the seedlings from the flat and pot them into a 3-inch pot. At this point they are just a short thick root and a very short stem. The potted seedlings are then kept in a warm house until fully rooted in about 4 weeks.

The problems associated with seedling production are not over yet. Anywhere from 10% to 20% of the seedlings can be albino. At first everyone is interested in these unusual looking plants, but without chlorophyll the plants cannot survive for very long and slowly die. It is generally considered that inbreeding causes this problem. The large plants of *A. parivflora* spread by sucker growth and the clump is usually one clone.

Interestingly, I have not seen as large a percentage of albino seedlings with *A. parviflora* f. *serotina* (a later-flowering form).

THE OTHER WAY TO CRACK THE NUT

Cuttings. In the late 1970s research (Dirr and Burd, 1997) indicated that rooting of softwood cuttings had great potential. In 1976, 80% rooting was obtained using 1000 ppm IBA in an alcohol quick dip, but in 1997, this same treatment produced no rooting while a 5000 ppm IBA quick dip produced 60% rooting. These differences were attributed to the rapid maturation of the cutting wood. In 1994 Dick Bir and Bill Barnes carried out extensive trials to try and overcome the problemof when and how to treat cuttings of *A. parviflora*.

Their results were presented to the Southern Region of I.P.P.S. in 1994. We took their work and put it into a commercial situation.

Their results indicated that seasonal timing is very important and that rooting was best within the first 6 weeks after bud break. They also found that auxins were not essential for rooting, but significantly enhanced rooting percentages.

We have been planting stock plants for a number of years so it has become easier to collect larger quantities of cuttings. We used to try to have it both ways, take cuttings and leave enough flowering shoots to provide us with hopefully some seed. Having improved the percentage take on our cuttings, we don't gamble with seed on nursery-grown stock plants. The sources we have located in private gardens provide us with most of our seed while the field-grown stock plants provide us with our cuttings.

The key to rooting *A. parviflora* from cuttings is juvenility, timing, and adequate stock plants — sounds familiar. Since our stock plants are all young and are cut back each year we are only collecting juvenile wood. With older clumps collecting the sucker growth will also provide suitable wood. As much by accident than by design we now collect cuttings from sucker growth that has grown up from a number of trees we dug and sold a few years ago.

Since timing is critical we watch for bud break, which is usually about 1 April in our area. This means we aim to collect cuttings around 15 May – 6 weeks after bud break.

At about Week 4 we start to check the wood to see how it is developing and at about Week 6 the wood is usually ready to collect.

We cut the wood early in the morning and process the cuttings immediately. The cuttings are made using clippers, the cutting is usually a two-node cutting with a cut made below the lower node and one pair of leaves left at the upper node.

The leaf area is reduced by 65% to 70%. If the internodes are very long we will make a single-node cutting. We grade cuttings by size so that large cuttings are stuck together and small cuttings are stuck together.

Prepared cuttings are given a quick dip of 2500 ppm of KIBA, stuck in 3-inch pots filled with a mixture Scotts 510 mix and perlite (1 : 1, v/v). The cuttings are placed in a mist house and a high level of humidity is maintained for the first 2 weeks. Within a couple of weeks you will be able to tell if the cuttings are going to root, defoliate, or rot. After about 4 to 5 weeks the cuttings are wellenough rooted to leave the mist house and be hardened off and fertilized. We normally get a good flush of growth during the summer months on each cutting.

We have tried higher rates of KIBA and obtained lower rooting percentages. In fact for many other plants that we were experiencing inconsistent rooting percentages, we lowered the KIBA rate and greatly improved rooting percentages.

The rooting percentages for *A. parviflora* are usually in the 80% range, except for this year when they dropped to 60% due to the extreme summer heat. Two days after we stuck the cuttings this year the temperature went to over 90°F and stayed there for a couple of weeks, the cuttings did not enjoy it.

Each year we evaluate what we did and how it worked, in the hope of improving the crop the following year. If it had not been for the research work that Dick Bir and company did a few years ago we would still be guessing when to take the cuttings and wondering why we failed.

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FRIDAY GENERAL SESSION QUESTION BOX

PAUL READ: Question for Tom Pinney. I am interest in knowing about your birch tissue culture. What is your plant material, timing, etc.? Also do you do recycling?

TOM PINNEY: I would be more comfortable having Ron Amos answer that question.

RON AMOS: It is all shoot-tip culture from plants forced in the greenhouse. After harvest a certain number are utilized for new cultures. The basal shoot mass is not recycled as we are afraid of what might happen.

BILL BARNES: Tom Pinney described putting the explants in a growth chamber, can you describe that chamber for us?

TOM PINNEY: We constructed a shelf and put lights on it with the ballasts outside. We then drape it with plastic. The containers are covered for humidity control.

TIM WOOD: Question for Bob Geneve. Does a different model have to be developed for each species?

BOB GENEVE: Yes. There is, however, basically one parameter that would have to be established for each species. You have to establish canopy resistance which is the resistance of water leaving the leaf. We are looking to see if we can do that on a more global scale. For example, one category might be low canopy resistance and the other could be high.

TIM WOOD: Question for Brad Rowe. I know that the correlation was not high, but there were differences between cultivars. Would it be possible to distinguish cultivars from each other?

BRAD ROWE: I do not think that would be reliable.

Irrigation System Upgrades

Daniel R. Long
The Conard-Pyle Co., 372 Rose Hill Road, West Grove, Pennsylvania 19390 U.S.A.

The Conard-Pyle Company has been propagating plants for many decades. Over the many years the department has grown little by little to 14 acres under cover. One of the difficulties encountered with growth is the need to add onto the existing structure while incorporating new systems at the same time. Often the result is awkward and cumbersome.

Starting about 3½ years ago, the company began a program to upgrade irrigation throughout the department. The first major step was to find and install a state-of-the-art control system for environment and irrigation. It would have to replace all the old control devices as well as expand with us into the next millennium. The Argus Control System was chosen for its versatility, expandability, and excellent software. The first phase was installed in late Spring 1997 to include most of the full-heat propagation houses and the outside mist huts. The second phase was begun in Spring 1999. When completed, the system will have control over all aspects of environment and irrigation throughout the department. It will have replaced seven controllers and dozens of thermostats. Every day we realize new advantages of centralized control and software designed to optimize equipment. We also have the opportunity to access the system from home. This allows for faster response as well as avoiding unnecessary trips to the nursery at night.

The next large upgrade involved the heart of the irrigation system; the well and pump house. Much of the equipment was in disrepair or functioning poorly. The well is capable of 200 gal min^{-1} but the water has high iron. Liquid chlorine was injected just upstream from a pair of filters to precipitate and trap the iron. The main pump was turned on manually whenever irrigation was needed or the cistern emptied. Secondary pumps ran mist and inside water from the cistern. If not carefully monitored, the main pump would overpressurize the lines which created fatigue and breakage regularly. The chlorine injection wasn't accurate and was not given enough reaction time prior to filtration. The filters were also aging and required attention daily. The metal fittings and valves inside the pump house were corroded and leaky as well. The fertilizer and chemical injector was balky and expensive to repair also.

While searching for economical ways to make the system work, we came across several alternatives that made us decide to replumb the entire pump house. First, we installed a pressure control valve and eliminated the need to turn the pump on and off. This also stopped the damaging pressure spikes. We learned, however, that upstream pressures were high enough that we had to replace any plastic pipe between the well and the valve. We also replaced the old steel pipe in the well itself as a precaution. The end result of this upgrade is total freedom to run any volume of water from a single hose to several houses at once. The next big change came when we switched from chlorination and filtration to sequestering our iron. Using a bypass injector, we add a concentrated sequestering agent to the line and spin the water through several small filters to distribute the agent before the iron does any harm in the system. The first injector we bought was not capable of handling our operating pressures. The supplier replaced it with a sturdier unit that required only minor modifications to serve our needs. The sequestering agent's formula is proprietary but itis based on the same principal used to make iron available in fertilizers.

The last change we made inside the pump house was to replace the fertilizer injector. We had access to four large Dosatron injectors no longer in use at our Maryland farm. We chose to install two of these in parallel to maintain our full flow capacity. Repair parts and the other two units are kept on standby. While installing these injectors, the remaining metal fittings and valves were replaced. Schedule 80 PVC was used wherever possible. We also installed a backflow prevention device to comply with pesticide labels and local regulations. Later we added a flow meter to monitor our usage for our records. Some changes, however, have not worked out. The solenoid valves we installed in line to switch from plain water to fertigation proved too slow and couldn't handle our varying flow rates effectively. We are currently investigating alternatives to gain better control of our fertilizer usage. The ultimate goal is exact house-by-house control as needed.

To further ensure an uninterrupted supply of water, we investigated two wells on the property that had been abandoned years before. One had poor recovery but the other produced a steady 25 gal min^{-1} of very good water. We now pump from this well directly into our cistern to supply water inside our full-heat houses for irrigation and mist. We also chose to use the main well to supply outside mist since that system is now under consistent pressure. This relieves the burden on the cistern and its pumps. The small well and municipal water provide ample backup in case of pump failure or other emergencies with the main well and pump house.

Another concern with the system was the nozzles used throughout the nursery. We had no resource for purchasing new ones of the same type and others had proven inferior. We are currently replacing inside nozzles with Senninger T-Spray nozzles. This gives us a reserve of the old type for outside irrigation.

At the same time we are investigating completely different irrigation systems as well. We have incorporated Netafim microsprinklers for mist and irrigation in our newest full-heat greenhouse. This also required modification of the delivery system for the selection of clear water or fertigation water. While some details still need to be worked out, overall the system serves very well.

Not all of the changes have involved automated systems. We have two employees dedicated to irrigation and mist. Many of the upgrades have made their responsibilities more manageable. Some changes were made to help them directly. Simple things like keeping an organized stock of parts and having the proper tools on hand can mean the difference between a quick repair and a day-long hassle. Other simple changes like a utility sink instead of a hose on the ground boost morale and help them to be efficient.

We have also begun hanging hoses with pulleys on cables wherever possible throughout the nursery. The savings on labor and damaged plants from dragging hoses are worth the investment. Hoses on the ground are also a safety hazard and a plant disease vector.

The result of all these improvements is better water delivered more efficiently and consistently with less labor. This allows the irrigation team to spend less time managing equipment and more time monitoring the plants. We will continue to seek out new ways to change and upgrade our irrigation system in an effort to improve quality and reduce losses throughout the nursery.

Propagating the Hardy Kiwis

Robert Osborne
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INTRODUCTION

All of us are familiar with the brown fuzzy kiwis that the New Zealanders did such a wonderful job marketing to North Americans. It has become a staple fruit that is now raised in warmer regions throughout the world. Not as many, however, are aware that there are many species of kiwi (genus *Actinidia*) and that some of these kiwis are extremely hardy.

We first became aware of the hardy species in the early 1980s. We were actively seeking fruits that could survive winter temperatures of -35 to -40°C (-40°F) and that could ripen their fruit in a growing period that averages only slightly more than 100 frost-free days. The two species that interested us most were *A. arguta,* commonly called the hardy kiwi, and *A. kolomikta,* the arctic kiwi. These species are native to northeastern Asia in the region between northern China and the Sakhalin peninsula of Russia. The weather conditions of this area are very similar to our own in the maritime provinces of eastern Canada.

We were able to access some very interesting cultivars of *A. kolomikta* that had been developed out of breeding research in Russia. These cultivars were chosen for productivity, hardiness, fruit size, and quality. Some of the cultivars we planted included 'Krupnopladnaya', 'Pozdanaya', 'Nahodka', 'Aromatnaya', 'Matovaya', and 'Sentyabraskaya'. We also planted the cultivar 'Arnold Arboretum' from the Arnold Arboretum in Jamaica Plains, Massachusetts. Because this species is dioecious (needing both male and female plants to set fruit) we also planted a selected male clone for pollination.

This species has thrived at our location since we first put in our mother plants. Life has not always been easy for them. They are planted in full sun, facing south on a slight slope that is open to strong winds from nearly every direction. It is a good site for testing hardiness. They have endured temperatures of -40°C and little or no snow cover with no appreciable winterkill. Our later plantings were placed in locations more amenable to survival. We have chosen sites that are partially shaded so that the ground is cooler and moister, conditions more like the understory conditions in their native habitats. Once they climb into sunlight, they fruit heavily. We usually expect fruiting from new plants within 2 to 3 years. Once in a fruiting state, they produce annually and heavily every year. The new leaves in spring are frost tender, so siting is important. Once they climb up the supports provided, they are less likely to suffer severe frost damage because their leaves are high enough to escape the coldest temperatures, which are usually at ground level.

We originally planted six cultivars of the second species, *A. arguta*. Here the survival rate was not quite as good. The first winter we lost a numbered cultivar developed at the University of Michigan and a selection from the Research Station at Geneva, New York. We also lost the well known cultivar 'Ananasnaya', believed to be a cross between *A. arguta* and *A. kolomikta*. The survivors, which have thrived since planting, include 'Dumbarton Oaks', which had been growing at the Dumbarton Oaks garden near Washington D.C., 'Meader #1', developed by Dr. Meader of New Hampshire, and a male variety of unknown origin.

This species is more vigorous than *A. kolomikta* and has a glossy green leaf that is quite different from the matte green leaves of *A. kolomikta.* In other respects they behave similarly. This species takes 5 to 6 years to begin producing fruit. The cultivars we have kept have survived the same winter conditions as mentioned above.

These two species are important new introductions to northern horticulture. Not only is their fruit delicious but the twining vines are stunning plants. *Actinidia arguta* has clean glossy foliage that stays in excellent condition until it is killed by hard frosts in the fall. The foliage of *A. kolomikta* is fascinating because of the variegation that occurs during and after flowering. The male plants and many of the females become variegated with patches of white and pink appearing throughout the plant, hence one of its common names, the tri-color kiwi. These vines are extremely vigorous and there are now vines growing near us that have reached the top of a three story building.

The fruits of both species are outstanding. The flavor is very like the fuzzy kiwi (*A. deliciosa)* and is perhaps even sweeter. Many have said they prefer the flavor of the hardy kiwis. The fruit is generally about 25 mm (1 inch) in length and 12 to 15mm (½ to ⅝ inch) in width. They are grass-green and hairless. You pop them in your mouth like a grape. Mature vines can easily produce several kilos of fruit.

MATERIALS AND METHODS

We propagate both species of hardy kiwi using the same methods. In early spring we harvest hardwood cuttings from vigorous 1-year growth. We use 1 to 2 nodes per cutting and dip the base of the cutting in a #3 Seradix rooting hormone. Care must be taken that proper polarity is maintained as the polarity of nodes without leaves is not always apparent to the untrained eye. We use a rooting medium of perlite and screened peat (4 : 1, v/v). Nutricote 14N-14P-14K 100-day slow-release fertilizer is also incorporated at the rate of 0.5 litres yd^{-3} medium. These are placed in flats of 32-vinyl pots (2¼ inch × 2¼ inch × 4 inch). The flats are watered in well and then placed in a house humidified by a Mee high pressure fog unit. Bottom heat of 25°C is maintained until callousing, then lowered to 20°C until they are removed from the house. Rooting generally occurs in 14 to 16 days. The trays are removed when two out of three pots show roots coming through the drainage holes. The rooted cuttings are hardened off for 1 week and then potted into 1-gal pots complete with a stake. By early summer the plants are salable.

The second method of propagation uses softwood cuttings, preferably taken in early summer when the wood is slightly stiffened, although we have taken cuttings as late in the season as July with good results. Summer cuttings are rooted on the floor of the house with no bottom heat and are given a #1 Seradix hormone treatment, but are otherwise treated in exactly the same manner as the hardwood cuttings.

RESULTS

We have had excellent success with the hardy kiwis. Softwood cuttings have provided the best results with most crops rooting nearly 100%. Hardwood cuttings and softwood cutting crops taken late in the season will not be quite as successful, but we expect at least 80% take or better. It should be noted, however, that a rooting medium with low porosity or overly wet conditions in the house can cause rotting. This may account for some reports I have read complaining of poor success in rooting these species.

DISCUSSION

Although the hardy kiwis have been growing in North America for nearly a century, there are still only a limited number of nurseries growing the improved cultivars. Those nurserymen growing in the colder regions should consider this crop. The market for these vines is potentially immense. The exotic nature of the plants fascinates a public jaded by "the commonplace" in horticulture. Once we have convinced our customers that these kiwi are truly hardy, we have not had any problems selling the plants. Our biggest challenge has been to hold onto the vines long enough to get them to size. The desirability of the hardy kiwi vines, combined with their relative ease of propagation, presents an ideal opportunity to provide a fascinating new group of plants to the public.

Light Light Light

Daniel Kuczmarski
The Flower, Tree & Shrub Co., P.O. Box 235 Elsberry, Missouri 63343 U.S.A.

INTRODUCTION

This presentation is a review of a novel and effective way to provide light to plants to facilitate optimum growth and quality, while trying to reduce operating costs.

Quality plant growth requires water, nutrients, media, proper temperatures, an environment free from pests and pathogens, and light in proper quantity and of sufficient quality. Light is the energy source essential for survival and proper growth. Typically on the 21st day of June the maximum light in terms of quality, quantity, and duration is available via the sun alone. On the 21st day of December there just is not enough light to achieve the same result. Also, proper light enables maximum quality potential barring other limiting factors.

I have observed and participated in efforts where plant quality has been compromised due to insufficient light. Because of this, I have sought to find methods to improve lighting systems but remain cost effective.

In addition to the direct experiences I have acquired lots of antidotal evidence of the value of things, like moving shade houses, which have yielded crops of unsurpassed quality. The wave concept has the analogy of a sunny day with cumulus clouds intermittently providing a cooling shade as they drift over the crops.

METHODS

Experiments were conducted during the growing period of 15 Oct. 1998 through 15 March 1999. The greenhouse was maintained at a daytime temperature of 78°F, and a night time temperature of 68°F. Photoperiod was 16 h light and 8 h dark. Lights were on from 5 AM through 9 PM.

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In addition to the direct experiences I have acquired lots of antidotal evidence of the value of things, like moving shade houses, which have yielded crops of unsurpassed quality. The wave concept has the analogy of a sunny day with cumulus clouds intermittently providing a cooling shade as they drift over the crops.

METHODS

Experiments were conducted during the growing period of 15 Oct. 1998 through 15 March 1999. The greenhouse was maintained at a daytime temperature of 78°F, and a night time temperature of 68°F. Photoperiod was 16 h light and 8 h dark. Lights were on from 5 AM through 9 PM.

Determining the "right" number of lights for a stationary configuration was difficult. Based on general recommendations it seemed like one light per 56 ft^2 was appropriate.

Agrosun bulbs (430 W), which are hybrid bulbs, were used. They have both sodium and metal halide elements which increase the amount of red light being delivered.

The point of this submission of information is that the lighting system was set up based on industry recommendations and practical budgetary considerations. Using this set up there was improvement over ambient conditions but plants were not growing as hoped!

LIGHT SYSTEM

Two light bridges were used for evaluation. The two bridges are nominally 18 ft apart and have a travel of 17 ft to cover an area the length of 36 ft with uniform light. There is light coverage beyond that distance, but attenuation is significant beyond that point.

RESULTS

For green beans, internodal distance was greatest for plants grown under ambient light, intermediate for plants grown under stationary light, and least for plants under the moving light system. Stem diameter measurements are greatest in reverse order.

With tomatoes stem diameter is greatest for plants grown under the moving lights, intermediate for the stationary lights, and least under ambient conditions. Leaf and leaflet length were greatest with the moving light system, intermediate for the stationary lights, and least for the ambient light. Plant leaf number was greatest with the moving light system, intermediate for the stationary lights, and least for the ambient light only plant.

Ajuga, under the same conditions, exhibited dramatically greater growth in size and also rate under the moving lights as compared to ambient light conditions.

Propagation of Selected Perennials

Kenneth Roe
Greenleaf Gardens, Yellow Springs, Ohio 45387 U.S.A.

Greenleaf Gardens is a small family-owned wholesale perennial nursery in Yellow Springs, Ohio. The nursery specializes in growing over 800 taxa of herbaceous and woody perennials. The plant material is grown in quart and gallon containers and sold to garden center and landscape customers in the greater region of southwestern Ohio. We propagate material by seed, softwood cuttings, root cuttings, and divisions.

I would like to share with the Society just a few of our technologies and practices we use to achieve a more synchronous crop. A few of the tools we use in our seed operations include hand-held seeders, strainer, spray bottles, PG6000 media, and flats.

One way we achieve synchronous stands in our seed flats is to soak seed that exhibit exogenous dormancy (if hard seed coated) in polyethylene glycol (PEG6000). PEG6000 acts as a softener with *Baptisia, Lathyrus, Lupinus,* and *Thermopsis*. The PEG6000 is dissolved 1 tablespoon liter^{-1} warm water. The seed is soaked for 1 to 3 h, then strained, dried, and placed in the refrigerator. These seed are sown as soon as possible.

Another group of seed is soaked in warm water with PEG6000, rinsed, strained, and placed in plastic bags with moist vermiculite. These seed are allowed to pregerminate in the refrigerator. When the radicle appears in a majority the seed is sown and placed under mist. Once true leaves appear and the seedlings are rooted to the bottom of the flat, the trays are removed and hardened off. *Delphinium* is an example of a genera handled in this way just as soon as seed is received. Seed viability with these genera declines by the month if left untended. Another group of seed handled this way is the "frost germinators". Trays of bagged primed seed can be moved back and forth between warm greenhouse benches and the refrigerator until the appearance of the radicle; at which time the seed is sown. Genera in this group include *Dicentra exina* and *Clematis paniculata.*

Most seed are simply sown and placed under mist with no pretreatment required. Attention must be payed to the physiological dormancy of the genera and if a cover of vermiculite, media, or sand is required, or no cover. These requirements are listed in many good seed catalogs. These seed are sown and placed under mist. Once true leaves and rooting are observed the flats are removed and hardened off.

Seedlings are moved up to 2-inch plug tray and grown on and then upgraded to quarts and gallons for sale.

Plants are established the summer and autumn before selling and overwintered in unheated poly huts. Cultural care includes water, fertilizer, and herbicide at the appropriate time.

Propagation of French Hybrid Lilacs

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INTRODUCTION

Lilacs have traditionally been the cornerstone of many landscapes throughout the midwest. The colorful and fragrant flowers were a subtle reminder that the spring season was in full swing. The ever-changing family of lilacs offers numerous cultivars with a wide selection of shape, size, flower color, and leaf texture. The emphasis of this paper will be on *Syringa vulgaris* and the propagation of cultivars using softwood cuttings stuck directly into the soil. The amended soil used is formed into temporary beds using lumber to keep them in place and throughout this paper will be referred to as ground beds.

We at Scarff's Nursery have built a consistent and ever increasing request for large lilacs to be used in landscapes mainly on the East Coast. We are presently growing 10 cultivars and planning to add more. In order to supply the market we needed to produce a liner quickly and transplant it to produce a finished product in 5 years. There were many options to consider when producing the liners including grafting, buying in tissue culture plugs, and propagating softwood cuttings. We chose the last option because it was economical and fit into our production program. The following paper will provide procedures and cultural practices we use to produce a quality lilac liner.

GROUND BED PREPARATION

The area used for our ground beds consists of approximately ½ acre. We alternate the beds every other year as the liners are grown as a 2-year crop. When the ground is idle it is kept weed free and is amended with recycled potting media, perlite, and comtil.

Bed preparation begins in mid-April with a final herbicide application being sprayed to kill any lingering weeds. After 5 days the soil is rotivated using a Howard rotivator. The beds are laid out using irrigation risers as focal points so at a later time 2-inch irrigation pipe can be set down between the beds. The beds are 105 ft in length and 5 ft wide with 24-inch aisles between them. We connect two of the beds together with a hoop thus forming a 12 ft wide temporary hoop house to overwinter the newly rooted plants. The 5-ft beds accommodate our undercutter when harvest occurs. The old beds are dismantled and the same shade cloth, hoops, re-bar and lumber is used to build the new ones. Irrigation is set up for frost control once the shade cloth has been removed.

The beds are formed by hand and lumber moved in complete sections. The lumber used is CCA treated 2 inch × 6 inch × 16 ft boards connected with metal truss plates and held in place with 18-inch stakes made from re-bar. The soil depth is set 2 inches from the top of the boards as sand is used to level them off. The sand used is a washed sand and #9 gravel mix (7 : 3, v/v). This top layer of sand makes the dibble board pattern easier to read and allows the cuttings to stand upright making them easier to stick. Once the beds are framed and sand is added they are sprayed with Vapam, a soil fumigant. The Vapam is drenched in and the beds are covered with clear plastic and left for 3 days. The soil temperature must reach 70°F to activate the fumigant.

After the soil has been sterilized the plastic is removed, beds are raked to aerate the soil, and the hoops are set in place. A 75% shade cloth is placed over the hoops. The mist system is then put in, using 1-inch poly tubing, 3-ft stakes, Eddy mist nozzles, and a Davis 812 controller. The whole bed preparation process should be completed by mid-May.

STICKING SOFTWOOD CUTTINGS

The window of opportunity for taking softwood cuttings of *S. vulgaris* can be very limited. The weather is the biggest factor, which regulates the growth of the 2-year-old stock plants. The10-inch tip cuttings are taken mid to late May when the new growth is still fleshy and hasn't started to harden off. The cuttings are trimmed to a uniform length of 7 inches, lower leaves stripped off, and upper leaves clipped to allow air and light movement. They are then quick-dipped in a Woods rooting hormone that was diluted 1 : 4 using distilled water. The cuttings are transported in wet burlap and stuck 20 to a row using a dibble board to set the pattern. A 6-inch space is left between cultivars with a label at each end. Each bed holds approximately 7500 cuttings, making a total of 15,000 per hoop house. As the bed is progressively filled it should be covered with a clear 4-mil poly sheet.

The mist system is set to come on for 8 sec every 8 min; this may vary under full sun or cloudy days. It begins at 10:00 AM and shuts down at 6:00 PM. Once the hoop house is completed, the poly is drawn over it and sealed up. This creates intense humidity and protects the mist and plants from wind drifts. In 4 weeks the cuttings should start to callus and send out initials. At this time the poly can be vented to help reduce extreme hot temperatures. In 6 weeks the cuttings should be rooted and the mist reduced to harden off the cuttings. After 8 to 10 weeks the plants are drenched with a fungicide and fertilized with two applications of 10N-52P-10K. At this time the poly is removed and the shade cloth kept intact.

CULTURE, OVERWINTERING, AND HARVEST

The cuttings are trimmed to a height of 12 inches in August and are hand weeded as no herbicide is applied. After the plants are weaned from the mist, they are irrigated overhead with Rainbird 25 heads off a 2-inch aluminum irrigation pipe. The plants are kept moist and every 2 weeks an application of 21N-7P-7K liquid fertilizer is applied until the end of August. At that time the shade cloth is removed to harden the plants off for winter. In December the hoops are covered with a single layer of 4-mil white plastic. They are heavily baited with both granular and bar rodent bait and moth balls. Depending on temperatures, the last step before closing them for winter is to cover each bed with Gilbond, a brand name poly-foam winter protection blanket.

The following spring the blankets are removed and hoop houses left open so the liners break dormancy in a timely manner. The white poly protects them from frost until irrigation lines are set up. The second year plants are irrigated with Rainbird 25 heads off a 2-inch aluminum irrigation pipe. They are fertilized every 10 days with Plantex 21N-7P-7K liquid fertilizer. Cuttings are taken off them in May and then they are trimmed to a height of 14 inches. Cuttings are sprayed every 2 weeks with an insecticide/fungicide mix. In November when they have lost their leaves they are harvested with a Egedal undercutter. Cuttings are transported to cold storage where they are root pruned, graded, and packed accordingly by taxa to sit through the winter season. In the spring they are planted on 40-inch spaces.

CONCLUSION

By implementing the above procedures we have found a satisfactory rooting percentage for propagating French hybrid lilacs Each year the percentage varies, but we still have found this ground bed method the most economical way to produce quality lilac liners. After 2 years in our ground beds and 3 years in the field we have been able to harvest a 3- to 4-ft lilac ready to ship to our customers We are continually striving to increase the rooting percentage by making subtle changes, but by following the procedures in this paper, lilacs can be successfully propagated by softwood cuttings and grown on to a large quality specimen shrub.

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The Educational System in Denmark

Uffe F. Jensen

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I would like to thank IPPS Scandinavia who made this trip possible for me and Eastern Region for letting me speak at their annual meeting. My presentation will focus on horticultural education in Denmark and I will discuss the following categories

- Primary, secondary, and high school.
- Basic education groups
- Higher education groups.
- Education at university level

PRIMARY, SECONDARY, AND HIGH SCHOOL

Danish children start at primary school when they are 7 years old and almost 98% of them enroll in preschool classes 1 year before They attend school for 9 or 10 years; only 45% attend the last year. It is optional for pupils to finish primary school by taking examinations in the most important disciplines. English is taught from the 4th year, and German or French from the 7th year Most children go to public schools that are free and paid by the government After finishing primary and lower secondary school approximately 45% of the pupils enroll in upper secondary school or high school.

BASIC EDUCATION GROUPS

Some basic education groups can be attended directly after primary and lower secondary school whereas others require upper secondary school. Basic education groups are provided by institutions such as technical and business colleges and by institutions with university status.

Technical colleges are basically divided into four groups according to sector·

- Technical colleges (trades and industries and service trades).
- Business colleges (commerce and administration)

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- Technical colleges (trades and industries and service trades).
- Business colleges (commerce and administration)

- Agricultural colleges (agriculture and horticulture).
- Social and health care colleges (public social and health care).

It is at the technical colleges that the basic training for horticulture starts. The training lasts for 4 years, 1 year is spent at college and 3 years are spent in nurseries or greenhouse companies. During school periods the student has to learn the following: computer studies, natural sciences (mathematics and chemistry), research methodology, languages (English), ecology, crop production, botany, plant production, plant nutrition, soil science, horticultural practices, production planning, pest control, quality control, and trade knowledge. He/she also has course assignment and a final project to complete.

HIGHER EDUCATIONS

After basic training in horticulture which lasts 4 years, you can enroll in the Production Manager or the Horticultural Technicians education which takes 2 years.

Aim. The aim of the 2-year technicians education course is to provide students with a thorough theoretical knowledge and a range of necessary skills in the areas of crop production, business, and management techniques so that on completion of the course the student has a sound professional foundation for undertaking a range of responsible roles in various branches of the horticultural industry.

Participants. The course is primarily for qualified skilled gardeners who wish to expand their skills and theoretical knowledge with a view to:

- Working as production manager in a variety of horticultural enterprises.
- Buying their own horticultural enterprise.
- Employment in a business or service company related to the horticultural industry.
- Employment in government institutions involved with research or inspection, etc.
- Teaching at a horticultural college.

The Course. The course takes 2 years and consists of four semesters. The school year starts each year at the beginning of August and finishes mid-June. At the end of each semester, there are written and/or oral examinations in some of the subjects which have been taught. In addition, during each semester a written assignment is prepared and this is presented and defended at the examination. During the final semester a project is undertaken which involves a written report about a practical or theoretical subject relating to the course. After passing the examination and completing the obligatory written assignments satisfactorily, the student receives a diploma.

EDUCATION AT UNIVERSITY LEVEL

When students have earned their degree from upper secondary school they can attend the Agricultural University in Copenhagen or one of the other universities in Denmark. At the Agricultural University you can earn a bachelor or master degree in horticulture within 3 or 5 years, respectively.

N-6-Benzyladenine Increases Lateral Offshoots in a Number of Perennial Species

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A study was conducted testing the effects of N-6-benzyladenine (BA) on a number of perennial species. Eighteen perennials were screened for BA's effect on the number of lateral offshoots and overall foliage appearance. Eighty-nine percent of the perennials tested in the screen had significantly more offshoots when treated with 1000 ppm BA ($P<.05$). In addition, two perennials, *Persicaria amplexicaulus* 'Taurus' and *Veronica gentianoides* 'Barbara Sherwood' were treated with 0, 1000, 2000, and 4000 ppm BA. Mean number of offshoots and overall foliage appearance were analyzed and rooting analyses of offshoots and overall growth were studied. Benzyladenine significantly increased the number of lateral offshoots in both plants tested ($P<.001$). However, there was no significant difference in the number of lateral offshoots in the 1000, 2000, and 4000 ppm treatments. As concentration of BA increased, leaf size and height decreased in *Veronica gentianoides* 'Barbara Sherwood' while width increased. Petiole length and height decreased as BA concentration increased in *Persicaria amplexicaulus* 'Taurus.' Results suggested that BA releases lateral bud dormancy and increases the number of lateral offshoots in a number of different perennial species. Although increasing concentration of BA had an effect on overall plant growth in *Veronica gentianoides* 'Barbara Sherwood' and *Persicaria amplexicaulus* 'Taurus,' the number of lateral offshoots did not increase significantly above 1000 ppm BA.

INTRODUCTION

There are several perennials sold at Green Leaf Enterprises that are difficult to produce efficiently because of the small number of offshoots the plant produces each year. The minimal number of offshoots produced by some plants is a result of slow growth or the nature of the plant's growth. Therefore, many plants are produced in tissue culture or propagated only once or twice a year. This causes an increase in cost for Green Leaf and our customers. Finding a way to treat these "problem" plants or to significantly increase the number of cuttings for any plants produced at Green Leaf was our goal in this experiment.

In the past, cytokinins have been used to increase lateral breaks in woody plants (Henny, 1986 and Wang, 1987), promote bud formation in woody plants (Mulgrew and Williams, 1985), and induce lateral branching in poinsettias and geraniums (*Pelargonium*) (Carpenter et al., 1971 and Carpenter and Carlson, 1972). In addition, cytokinins such as benzyladenine (BA) are commonly used today in tissue-culture production to induce shoot proliferation during the multiplication stage.

The apical dominance in a plant is determined by the relationship of cytokinins to auxins. Auxins are antagonistic to cytokinins, inhibiting the development of lateral buds. Benzyladenine allows lateral buds to develop that have been otherwise suppressed by an auxin (Garner et. al., 1997a). Recently, BA has been found to increase the number of offshoots in a number of hosta cultivars when applied exogenously (Keever, 1994; Garner et. al., 1997; and Keever and Brass, 1998). Our interest lies in BA's effect on a number of different perennials that are produced at Green Leaf Enterprises. The objective of the study was to evaluate the effects of BA on lateral offshoots, foliage, and overall growth. Based on previous studies, we expect to see an increase in the number of lateral breaks as the concentration of BA increases. We also expect BA to decrease leaf size and affect overall growth by decreasing height and increasing width (Keever, 1994).

MATERIALS AND METHODS

Plant Materials.

Brunnera macrophylla
Campanula persicifolia 'Chettle Charm'
Coreopsis Flying Saucer™ tickweed
Eryngium 'Sapphire Blue'
Filipendula 'Midwest Dream'
Gaillardia ×*grandiflora* 'Baby Cole'
Geranium ×*cantabrigiense* 'Karmina'
Heuchera micrantha var. *diversifolia* 'Absi', Bressingham Bronze™ alumroot
Hibiscus 'Blue River II'
Iberis sempervirens 'Purity'
Lithodora diffusa 'Grace Ward'
Persicaria amplexicaulus 'Taurus'
Physostegia virginiana subsp. *speciosa* 'Variegata'
Polemonium caeruleum 'Blanjou', Brise d'Anjou™ Jacob's ladder
Pulmonaria 'Little Star'
Stokesia laevis 'Silver Moon'
Tiarella ×*hybrida*
Veronica gentianoides 'Barbara Sherwood'

Screening Process. Plants were initially screened for a response to BA. Twenty-four juvenile plants without lateral breaks were potted in 3.5-inch pots in March through July 1999. Plants were potted in Fafard 1P potting mix. Twelve plants were treated with no hormone (control) and 12 plants were treated with a 1000 ppm N-6-benzyladenine (BA) solution. A surfactant was added to the solution at 1 ml gal^{-1}. Firstly, the foliage was sprayed with the BA until runoff and then the crown was saturated. After 30 days, the number of lateral breaks and the foliage quality were graded for each plant. The foliage quality was determined by using assigned numbers to describe the appearance of the foliage (0-dead; 1-dying, diseased, or desiccated; 2-chlorotic; and 3-healthy). If there was a significant difference in the number of lateral breaks between treated and non-treated plants, the crop was put into an experiment using various concentrations of BA. After trialing several plants and observing BA's effect on internode length; height measurements were included in the screen. Over the 30-day growing period, plants were watered with a 200 ppm of 20N-10P-20K liquid fertilizer with micronutrients and grown in a double poly greenhouse with glaze.

Experimental Design. Eighteen juvenile plants without lateral breaks were potted up into 3.5-inch pots using Fafard 1P potting mix. Plants for the *E.* 'Sapphire Blue,' *P.* 'Taurus,' and *V.* 'Barbara Sherwood' experiment were taken from the cuttings rooted down in the screening process. Nine plants of each crop were treated with 1000 ppm, 2000 ppm, 4000 ppm, or no treatment (control). Lateral breaks were counted and the foliage quality was rated after 30 days.

In the second part of the experiment, 12 cuttings were taken from the plants in each treatment when available (the control in some crops did not show lateral breaks.) If plants had no lateral breaks, the mother plants were used for rooting success analyses. Cuttings were treated with the appropriate rate of indole 3-butryic acid, potassium salt (IBA-K) that is used during production and stuck in saleable flats. After sticking, cuttings were treated with a Subdue Max/Clearys 3336 FL drench as directed by the label. After 15 days, rooting success was measured. Three factors determined the plantlet's rooting success: root rate, root number, and foliage quality. Root rate was determined by assigning the cuttings numbers (0-dead, 1-no callus, 2-callus, and 3-roots greater than 2 mm). The number of roots was counted and foliage rate was determined by assigning numbers based on foliage appearance (0-dead; 1-dying, diseased, or desiccated; 2-chlorotic; and 3-healthy).

RESULTS

Screen. There was no significant difference in the number of lateral breaks when *C.* 'Chettle Charm' and *L.* 'Grace Ward' were treated with 1000 ppm BA. *Coreopsis* Flying Saucer™ *coreopsis*, *E.* 'Sapphire Blue,' *G. ×grandiflora* 'Baby Cole,' *P.* 'Taurus,' *V.* 'Barbara Sherwood,' *H.* 'Bressingham Bronze,' *B. macrophylla*, *G. ×cantabrigiense* 'Karmina,' *P. caeruleum* 'Blanjou', Brise d'Anjou™ Jacob's ladder, *S.* 'Silver Moon,' *I. sempervirens* 'Purity,' *F.* 'Midwest Dream,' *H.* 'Blue River II,' *P.* 'Little Star,' *P.* 'Variegata,' and *T. ×hybrida* all exhibited significantly more lateral breaks when treated with 1000 ppm BA. Benzyladenine appeared to have an effect on the growth habits in most of the plants screened. Smaller leaves were observed in *E.* 'Sapphire Blue' and *V.* 'Barbara Sherwood' plants that were treated with BA. When *G. ×grandiflora* 'Baby Cole' was treated with BA, plants remained in a juvenile stage; BA-treated plants had smooth leaves, nontreated plants had jagged leaves. Overall canopy height of BA-treated *P.* 'Taurus' plants was approximately 20% less than in the control. Petiole length appeared to be shorter in plants that were treated and the breaks of *P.* 'Taurus' were more swollen and thicker at the base than the plants not treated with BA. Again, *H.* 'Bressingham Bronze' and *C.* Flying Saucer™ coreopsis plants treated with BA were shorter and more compact than plants in the control. No plants showed any phytotoxicity to the foliage when treated with BA during the screen. Some cuttings were taken from plants that were "cuttable" after 30 days to qualitatively observe whether rooting might have been affected. There was no difference in rooting between treated and untreated cuttings of *P.* 'Taurus,' *E.* 'Sapphire Blue,' *V.* 'Barbara Sherwood,' and *H.* 'Bressingham Bronze' after 30 days.

Optimal BA Rate. There was a significant difference in the number of lateral breaks when *P.* 'Taurus' was treated with 0, 1000, 2000, and 4000 ppm BA ($P<.001$). A large increase in the number of lateral breaks from the control to the 1000 ppm treatment was found. After 1000 ppm, the number of lateral breaks leveled off and started to decrease at 4000 ppm (Fig. 1). However, there was no significant difference between the 1000, 2000, and 4000 ppm treatments. In addition, there was no significant difference in foliage quality between treatments. We qualitatively observed a decrease in petiole length and leaf size as the concentration of BA increased.

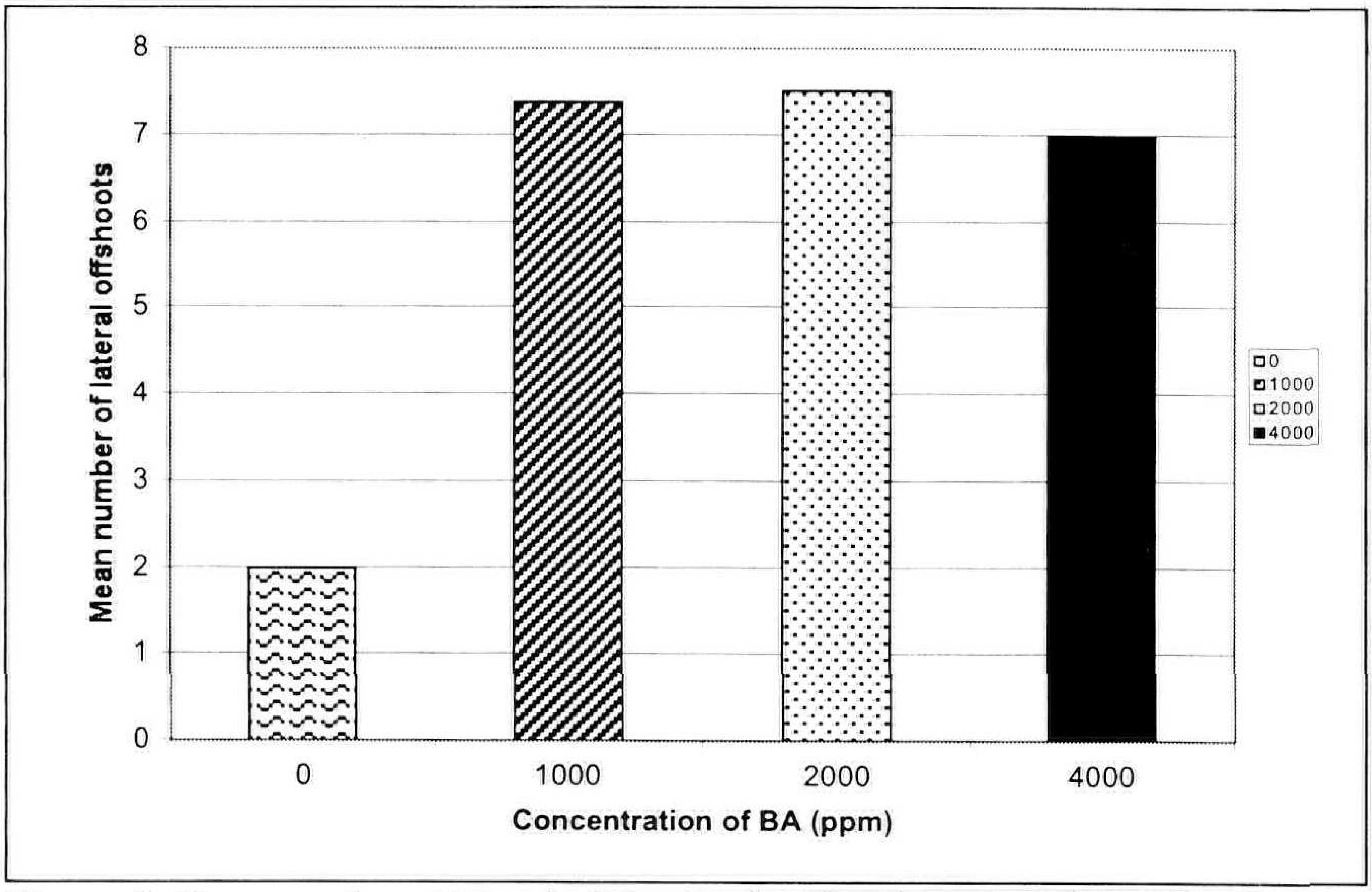

Figure 1. Mean number of lateral offshoots when *Persicaria amplexicaulus* 'Taurus' was treated with various concentrations of benzyladenine.

Veronica gentianoides 'Barbara Sherwood' performed similarly when treated with 0, 1000, 2000, and 4000 ppm BA. There was a significant effect of BA on the number of lateral breaks in eachtreatment (P<.001). From the control to 1000 ppm, there was a sharp increase in the number of lateral breaks. After 1000 ppm, the number of lateral breaks leveled off (Fig. 2). There was no significant difference in the number of lateral breaks between the 1000, 2000, and 4000 ppm treatments, nor was there a significant difference in foliage quality between all of the treatments. Plants became more compact and had decreased leaf size as the concentration of BA increased. Cuttings were not immediately taken when the data was collected because there was not enough of a conversion zone present after 30 days for successful rooting. Currently, cuttings in each treatment under mist do not appear to be rooting differently.

Gaillardia ×grandiflora 'Baby Cole,' *P. caeruleum* 'Blanjou', Brise d'Anjou™ Jacob's ladder, and *H.* 'Bressingham Bronze' which were treated with 1000, 2000, and 4000 ppm BA during July and August did not perform well. High temperatures caused leaf burn and eventually death in all treated plants while plants in the control had normal growth. *Persicaria amplexicaulus* 'Taurus' plants treated with BA had approximately 25% to 50% smaller root masses than nontreated plants. Phytotoxicity to the foliage and a reduction in root mass was not observed in the *G.*

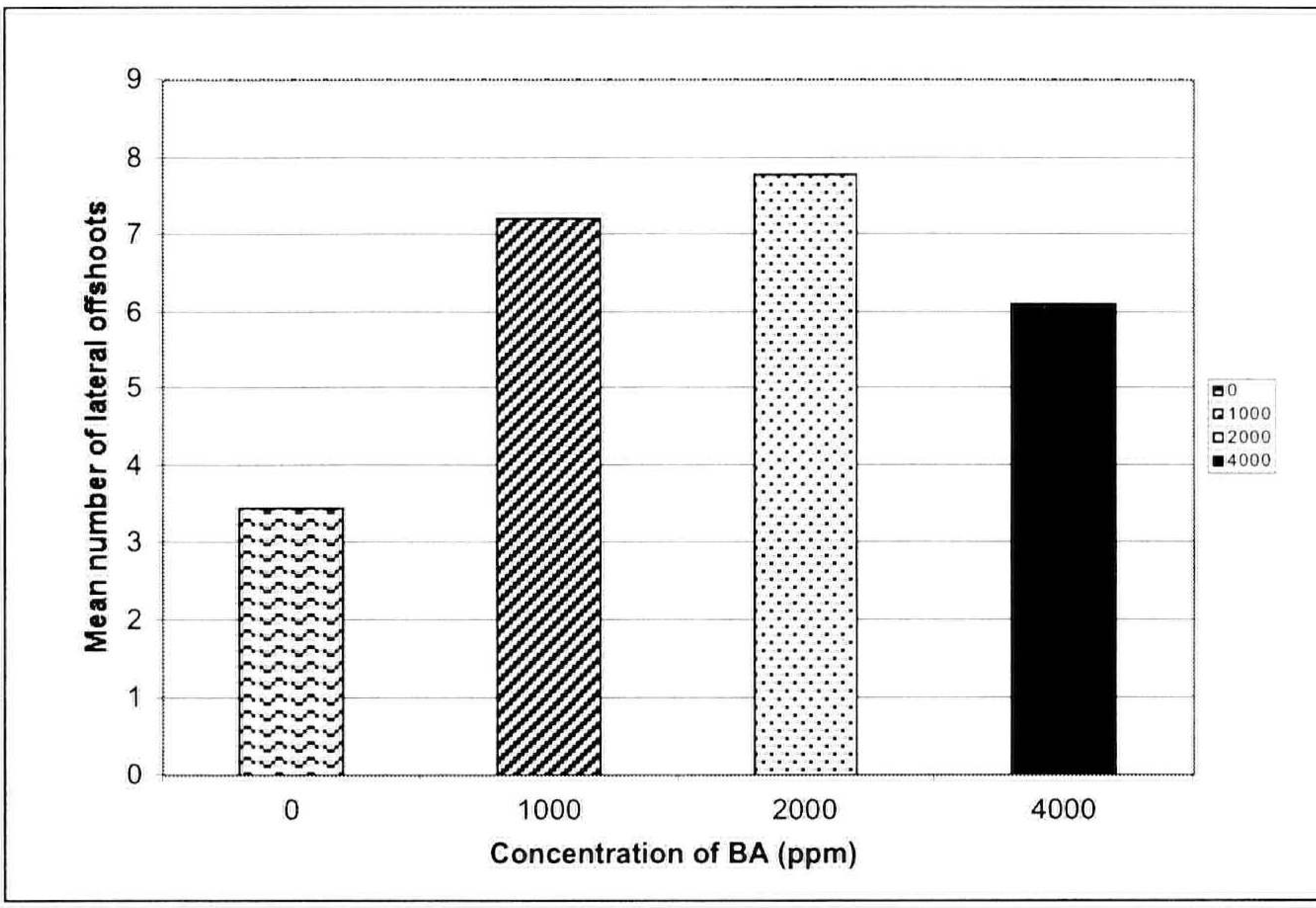

Figure 2. Mean number of lateral offshoots when *Veronica gentianoides* 'Barbara Sherwood' was treated with various concentrations of benzyladenine.

×*grandiflora* 'Baby Cole', *P. caeruleum* 'Blanjou', Brise d'Anjou™ Jacob's ladder, *H.* 'Bressingham Bronze,' and *P.* 'Taurus' screen in Sept. 1999.

DISCUSSION

Screen. As expected, BA had an effect on the number of lateral offshoots for the majority of the plants tested (Garner et al., 1997b). All plants that naturally break from the ground except *C.* 'Chettle Charm' had significantly greater offsets when treated with BA. The 1000 ppm treatment was effective in releasing lateral buds from apical dominance for *E.* 'Sapphire Blue,' *C.* Flying Saucer™ coreopsis, *G.* ×*grandiflora* 'Baby Cole,' *P.* 'Taurus,' *V.* 'Barbara Sherwood,' *H.* 'Bressingham Bronze,' *B. macrophylla*, *G.* ×*cantabrigiense* 'Karmina,' *P. caeruleum* 'Blanjou', Brise d'Anjou™ Jacob's ladder, *S.* 'Silver Moon,' *I. sempervirens* 'Purity,' *F.* 'Midwest Dream,' *P.* 'Little Star,' *H.* 'Blue River II,' and *P.* 'Variegata.' Not only were there significantly more offshoots when treated with BA, the lateral breaks were more uniform than in the control treatment. This could mean less production time spent grading cuttings and improving cell flat uniformity. Petiole length was decreased in *P.* 'Taurus' making the plants more attractive and easier to hold (would require less mechanical pruning). In addition to the increased number of lateral breaks in BA-treated plants, the cuttings when placed under intermittent mist rooted without any noticeable differences (Keever, 1994).

Optimal BA Treatment. According to our initial studies, the lowest concentration of BA, which was effective at releasing lateral bud dormancy and increasing the number of lateral offshoots was 1000 ppm. We hope to continue studies at lower concentrations of BA since the chemical is relatively expensive. As in other studies, phytotoxicity was observed in the foliage when temperatures were unusually high (Keever, 1994). From our experience applying BA during the summer, we have observed that many plants are temperature sensitive to BA. Plants that were treated grew best when BA was applied at temperatures 30°C or below. In addition, plants treated with 4000 ppm BA appeared over treated. Lateral buds had begun to develop but offshoots were so small plants required more growing time before cuttings were available.

Based on the screening process, there is a great potential for increasing production by applying BA to stock plants. We hope to continue our studies to find optimal rates of application that cost Green Leaf the least amount of money.

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Economical Low Pressure Fog System

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INTRODUCTION

The objective of creating a low-pressure fog system is to achieve an ideal rooting environment in which plant evapotranspiration is minimized without saturating the rooting medium.

DISCUSSION

By combining fog and intermittent mist, a decrease in misting is realized due to the humidity contribution of the fog. The fogging system being presented utilizes compressed air (35 to 55 psi) supplied at the nozzle orifice to shear the water droplets as they emerge.

Fog systems that supplement intermittent mist have been shown to:

- Boost percentages of difficult-to-root cultivars.
- Reduce nutrient leaching from foliage.
- Reduce carbonate and iron residue on foliage.

Low-pressure fog systems have several advantages, such as:

- Considerably less expensive than high pressure systems.
- Nozzle maintenance is reduced.
- Safer operating systems.

SYSTEM DESIGN

The rooting chamber at D&B Plants consists of a 32 ft × 98 ft × 12 ft gutter-connect bay, in which approximately 400,000 cuttings are rooted in five or six rotations. Materials used in the construction of the rooting chamber as shown in Table 1.

Two small vents on the north wall and an exhaust fan on the south wall operate at 85°F and 92°F, respectively. There is no shading provided on the double poly structure.

Four Spraying Systems nozzles #SP-1180.JPG (Figure 1) are 12 ft off the ground and supplied with well water at 45 to 60 psi. A 6-hp air compressor is located outside the greenhouse and serves as an air station for the nursery.

Figure 1. Nozzle from Spraying Systems #SP-1180.JPG. Contact 1-800-95-SPRAY or www.spray.com

Table 1. Materials used in construction of the rooting chamber.

Spraying Systems nozzle #SP-1180.JPG	4 @ $38.00	$152.00
PVC pipe/fittings	$35.00	
Copper pipe/fittings	$45.00	$165.00
Solenoid valves (4)	$85.00	
Recycled mist control unit	$00.00	
(Suggested) 24-h timer and 60-min time clock		$150.00
6-hp air compressor		$600.00
Total		$1,067.00

RESULTS

After 3 years of operation several concerns and advantages are apparent.

Concerns:

- Increased pressure on the water supply is needed to eliminate back feed. Water pressure must be greater than air pressure.
- Low-pressure fog requires a dedicated water and air system to ensure proper function. Other prolonged uses for the water or air supply interrupted efficient fogging.
- Water droplets "wet" some areas unevenly.
- Excess water dripping under nozzle created washout or saturation problems.

Advantages:

- Increased rooting percentages on difficult-to-root taxa.
- Reduction in rooting time. Crop rooting times requiring 20 to 25 days were as much as 5 days shorter.
- Increased vigor. Actively growing softwood cuttings continued to grow during rooting.
- Reduced acclimation period following rooting. Before the introduction of a fogging system, cuttings taken from the mist chamber would often require a substantial amount of time under high shade and frequent low fertilizing. This transition period has been reduced or eliminated.

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Developing New Woody Landscape Plants

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There is tremendous potential for developing superior new landscape plants. New plants create excitement for gardeners. They are the new models for the landscape industry. Breeding, evaluation, selection, and introduction of new plants is a long term process and requires considerable resources. However, nurseries can be involved in plant selection and introduction without devoting a lot of additional resources. To be successful in selecting and introducing new plants a person needs to have a strong interest in plants, have knowledge of existing cultivars of the species of interest, be observant, and hope for some luck. Thus most nurseries can be involved. In fact the vast majority of new plants introduced into the nursery trade come from introductions by nurseries. Production nurseries have the advantage in selecting superior individual plants in that they are normally growing large populations of plants as part of their normal production. If nursery employees are observant during their normal production practices, they can spot the individual plants that are distinctly different from the majority of plants in a population. These can then be tagged and propagated for further evaluation and possible introduction. Thus there is little additional expense. A researcher at a nonprofit institution can not afford to grow comparable-sized populations. Thus they need to expend their efforts on populations that possess much greater diversity than usually grown in a nursery production field. However, at the same time nonprofit institutions can devote the resources required to do controlled breeding if that is their mission. They are not required to make a profit to stay in business. The chance for success in selecting superior individual plants is dependent on the amount of variability in a plant population and the size of the population. Thus the chance of finding that superior individual in a highly variable population of 100 plants may equal that of finding a superior mutant plant in a population of several million plants that are clonally propagated. In comparison of different types of populations for the amount of genetic diversity, and thus, the potential for selection of a new plant, a population of asexually propagated plants would have much less diversity than any seed-produced population. A seedling population from a single seed source would have less diversity than a population of a species that resulted from natural pollination when more than one seed source was growing in close proximity since there would be potential for crossing between the populations. Controlled crosses of a species between selected plants from different parts of the species native range would result in much greater diversity. Collection of naturally pollinated seed of a species growing in close proximity to other species that overlap in bloom time can produce some interspecies hybrids in the resulting population which adds greatly to the diversity of the population and thus the opportunity to select new plants. Controlled crosses between two compatible species would give the greatest degree of diversity and seed from the second generation would have the most variability. One way to produce interspecies hybrids between two compatible species that overlap in bloom period is to plant a single plant or clone of the plants together and let them naturally cross pollinate. Insects are much more efficient pollinators than we are. If the plant that is chosen as the female parent is self incompatible, then all resultings seedlings would be of hybrid origin unless apomixis is involved. Hybrid populations can be produced rather efficiently by planting plants of species desired as parents together and letting the insects or wind do the pollination assuming that the plants are compatible and bloom period overlaps.

BREEDING OF WOODY LANDSCAPE PLANTS AT THE UNIVERSITY OF MINNESOTA

The University of Minnesota has had an active project in breeding, evaluation, and selection of woody landscape plants for a number of years. The plant introduction part of the project has successfully developed and introduced a number of plants. New introductions result from selection of superior plants from native or planted populations, plants from seed-lots obtained from other arboreta or plant exploration expeditions internationally, and from progeny from controlled hybridization efforts. One of the major breeding efforts has been the development of the hardy deciduous azaleas. These are known as the 'Lights' series of azaleas. Cultivars introduced include: 'Pink Lights', 'Rosy Lights', 'White Lights', 'Orchid Lights', 'Spicy Lights', Golden Lights', 'Mandarin Lights', and 'Lemon Lights' Other plants introduced in the past 15 to 20 years include: *Acer rubrum* Northwood® PP5053 red maple, *A. rubrum* 'Autumn Spire', *Aesculus* ×*arnoldiana* 'Autumn Splendor', *Cornus sericea* 'Cardinal', *Exochorda serratifolia* 'Northern Pearls', *Forsythia* 'Northern Sun', *Gymnocladus dioica* 'Stately Manor', *Lonicera* 'Freedom', *L.* 'Honeyrose', *Phellodendron* 'His Majesty', *Pinus resinosa* 'Wisota', *Prunus nigra* 'Princess Kay', and *Viburnum* 'Emerald Triumph',

Current breeding emphasis includes breeding activities with deciduous azaleas, *Viburnum*, *A. rubrum*, and interspecific hybridization with *A. saccharinum*, shrub roses, and intergeneric hybridization between *Sorbus* and closely related genera.

Goals of the azalea breeding program include developing hardy plants with other flower colors, especially reds, and breeding to combine cold hardiness with resistance to powdery mildew and in general better foliage qualities. Two additional cultivars have been selected for introduction. The first selection is a tricolor with white, pink, and yellow flowers and the second selection has pink flowers.

The shrub-rose-breeding efforts were started several years ago. In addition to hybridization activities, evaluation of a broad range of cultivars and species for disease resistance, flower color, quality, degree of repeat bloom, cold hardiness, plant size, form, etc. has been emphasized. Goal of the breeding effort is to develop disease resistant, repeat-flowering plants with good cold tolerance.

Breeding activities with *Viburnum* has been limited to interspecific hybridization within the section Lantana. Goal is to develop small, compact plants with glossy dark green foliage. Several selections look quite promising. These are results from crosses between earlier selections. Most of our selections trace their background to hybrids between *V.* 'Alleghany' × *V. burejaeticum*. *Viburnum* 'Alleghany' introduced by the National Arboretum is a hybrid between *V. lantana* and *V. rhytidophyllum*.

Goals of the hybridization efforts with *A. rubrum* and interspecies hybridization with *A. saccharinum* are to develop cold-hardy cultivars with good fall color and other aesthetic qualities and better tolerance to soil-related stresses such as drought, poor soil fertility, etc. Northern sources are being used as *A. rubrum* parents. Selections from hybrids between *A. saccharinum* 'Wieri Laciniatum' and *A. rubrum* 'Autumn Spire' PP7803 look promising.

Viburnums That Have Prospered at and Around the Arnold Arboretum and the Threat of the Viburnum Leaf Beetle

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INTRODUCTION

With over 150 different species and countless cultivars of *Viburnum* presently known and new species being found in China, Nepal, and Bhutan on a consistent basis, we are very fortunate to have such a large and diverse group of plants to enjoy in our gardens.

Viburnums, as with all plants, need proper cultural conditions to prosper. One of the main ingredients to good health is an adequate moisture supply to maintain these densely leafed and full-sized shrubs and small trees. Over the past decade it has been the exception and not the rule to have consistent moisture by way of precipitation through the growing season. The majority of the past decade has been spent dealing with either a 2- to 3-month dry period through the heat of the summer or a full growing season drought. The Arnold Arboretum has limited irrigation options across its 265-acre sight. The main *Viburnum* collection receives supplemental water but not enough to alleviate the drought effects. There are a few individual species that have done better than others in their ability to maintain their ornamental characteristics with our drought conditions. These include: *V. lantanoides* (syn. *alnifolium*),*V. bitchiuense, V. farreri* 'Candidissimum', *V.* ×*lobophyllum* 'Oneida', *V.* 'Pragense', V. sargentii, and *V. sieboldii.*

This is not intended to be a complete listing nor are those plants listed unaffected by the dry conditions, but a list of plants that still maintain their ornamental quality and have produced well for us.

VIBURNUM LEAF BEETLE (*Pyrrhalta Viburni*)

This beetle is closely related to the elm leaf beetle, *Pyrrhalta luteola.* It is limiting its feeding to viburnums, with a preference for; *V. opulus, V. trilobum, V. sargentii, V. lantana, V. dentatum* complex, *V. acerifolium, V. lentago*, and *V. prunifolium.* It's showing less interest in those viburnums that have a felty and or heavy pubescence to the leaf: *V. carlesii, V.* ×*burkwoodii, V.* ×*carlecephalum, V.* ×*juddii, V. sieboldii, V. rhytidophyllum, V.* ×*rhytidophylloides, V. setigerum*, and *V. plicatum* have been damaged but to a much less severe degree than the others. The signs of infestation are often first noticed by the skeletonizing of the leaves. Both the adult and the larvae are heavy feeders, stripping all the leaf material and leaving only the major veins and midrib. Along Lake Ontario the beetle has decimated the native populations of *V. dentatum* in many areas. Those viburnum planted in the shade have been noticed to be more susceptible to the beetle then those found in a higher light area, possibly due to a thinner cuticle layer.

The viburnum leaf beetle is native to central Europe and was first reported in North America in 1947 along the Niagara peninsula in Ontario. It is thought to have come into the country on nursery stock. It seemed to disappear for awhile and then reappeared in 1955 in Font Hill, Ontario, and then again in 1978 in Montreal and

Quebec City, Quebec, and Ottawa, Ontario. First breeding populations were recorded in 1978 in the Ottawa – Hull area, where it caused severe damage to viburnums there. It wasn't seen in the U.S.A. until 1996 when E. Richard Hoebeke, associate curator of the Cornell entomology collection, first discovered the beetle in Monroe, Orleans, Niagara, Cayuga, and Jefferson counties. The five counties are all found along Lake Ontario from Niagara to Cayuga New York. In 1998 the beetle was also seen in St. Lawrence, Oswego, Ontario, Wayne, and Genesse counties. In 1999 it has been sighted in Tompkins and Chautauqua as well as several other counties of New York bringing the total to 25 counties with the beetle present. Hoebeke put out an alert to all Cornell Cooperative Extension offices in 1998 for any and all sightings to date. The Master Gardener's Hotline at Cornell is averaging 30 calls a day concerning the beetle.

The beetle is presently in the Canadian Maritime Provinces of Nova Scotia, New Brunswick, and Prince Edward Island. It is also spreading quickly along the St. Lawrence Seaway to the shores of Lake Ontario and Lake Erie. During the I.P.P.S. Annual Meeting tours to the Niagara Parks' Botanical Garden the beetle damage was present on *V. opulus* and *V. lentago*. The Niagara Parks' Botanical Garden tried to control the beetle by pruning the egg masses off in late winter but have such a high population of the insect that they feel they are not able to control the beetle damage. The viburnum leaf beetle is also at Royal Botanical Garden, Hamilton, where it has yet to be a major problem.

In Maine it has been seen around the Portland area for the past 8 to 9 years. Initially it is thought to have appeared near Old Orchard Beach and has moved 15 to 20 miles inland from the coast but is still centered on Portland in southern Maine. It has also been seen north of a line connecting Rumford, to Farmington, east to Bangor and then to Mt. Desert Island on the coast. The beetle has spread quickly down the State Highway system consuming the *V. trilobum* used as bank plantings. It is seen in large numbers in remote woodland and in cultivated areas.

The beetle overwinters as egg masses found on the upper portion of the stems. In early May the egg masses begin to swell as the temperatures rise. The caps over the egg masses will slough off and the larvae then begin to hatch and feed on the newly emerged viburnum leaves. The larvae are quite mobile, dark brown to a pale green in color and very small in size, yet may group in large numbers. The larvae begin to feed right away and will make small pinholes in the leaves. Eventually the damage looks like the leaves have been riddled with buckshot. The larvae will mature at a ¼ inches in length and appear green and brown in color. In June the damage to the leaves has progressed to the point at which the leaves are mostly skeletonized. In a heavy infestation season the larvae can strip a mature plant in a matter of 3 to 4 days. The larval stage will last 8 to 10 weeks long.

Later in June the larvae drop to the ground and begin to pupate in the soil. The process of pupation will take about 10 days. In late June to early July the beetle will emerge and begin to feed. They can fly well and will readily seek out the preferred viburnums to infest. They are very specific in their feeding habits avoiding leaves of other genera within the *Caprifoliaceae* even if they are mixed in with the viburnum. The adults are about the size of a large kitchen match head (4.5 to 6.5 mm) in length and a coffee brown in color. The adults will stay active feeding until frost. The adults feed as strongly as the larvae and will often remove the whole second flush of growth within days of emerging. The ability of both the larval and adult stages to feed heavily on the host plants and severely reduce its ability to put on growth and store nutrients can cause the viburnum to loss vigor and perish in a year or two.

The female can lay her eggs from late summer until the first frost. The female will chew a squarish-shaped hole or slit into the upper portion of the stem and deposit several eggs into it. The egg masses are arranged in a straight line and are covered over with a mixture of chewed wood and excrement forming a black cap for protection. She may lay as many as 500 eggs a season. The adults begin to breed as soon as they emerge in July and this activity continues through to frost.

The beetle is very active and at times hard to see. It will roll off the leaf and drop to the ground or fly away when disturbed.

There are a few ways to control the beetle. Through the winter and into early in spring look for the overwintering egg masses. These can be pruned or scrapped off before the larvae hatches. If you can remove the eggs before hatching that is best. If you are too late to remove the egg masses it is best to treat the larvae while it is still very small.

According to Cornell Cooperative Extension the larvae and beetle can be controlled with a numberof pesticides, however, an additional difficulty comes in the form of incomplete labeling on these products and the need to add the viburnum beetle to the list of targeted insects to be controlled.

Paul Weston and Brian Eshenaur have been conducting studies of possible control mechanisms for the larvae and beetle, including several pesticide trials within the viburnum collection at Highland Park in Rochester, New York. They hope to be able to advise people on the best controls in a year or so.

A key source of current information is the integrated pest management newsletter for trees and shrubs produced by Cornell's Cooperative Extension, called *Branching Out*. It is published every 2 weeks from April through June and then every 3 weeks July through September. Subscription is $35 a year. The address to subscribe is: Branching Out, Department of Plant Pathology, Cornell University, 334 Plant Science Building, Ithaca, N.Y. 14853-4203 U.S.A.

Many thanks to the following who gave freely of their time and/or information to the assemblage of this paper:

Canada

- Christopher Kessel, OMAFRA (Ontario Ministry of Agriculture, Food and Rural Affairs) Nursery crop specialist, Univ. of Guelph, OMAFRA web site (http://www.gov.on.ca:80/OMAFRA/english/crops/facts/vbl.htm).
- Scott Olan, COPF (Canadian Ornamental Pest Foundation) .
- Bruce Peart and David Schmidt, Royal Botanical Garden, Hamilton, Ontario.

New York

- Brian Eshenaur, Monroe County, Cornell Cooperative Extension.
- Blaine P. Friedlander, Cornell News Service, Cornell number for fact sheet (716) 461-1000.
- E. Richard Hoebeke, Dept. of Entomology, Comstock Hall, Cornell Univ. Ithaca, N.Y. 14853. Tel: (617) 255-6530 and Fax (607) 255-0939.

- Thomas S. Pollock, Superintendent of Horticulture, Monroe County. (Rochester Parks).
- Howard H. Lyon, Biological Photographer (ret.), Dept of Plant Pathology, Cornell University
- Paul Weston, Dept. of Entomology, Cornell Univ., Ithaca N.Y.

Maine

- Jeff O'Donnel, O'Donnel Nursery in Maine.
- Richard Dearborn, State of Maine Dept. of Conservation, Insect and Disease Lab. Tel: (207) 287-2431, Fax: (207) 287-2432.

Massachussetts

- Bob Childs, Ma. Coop Extension, State Entomologist, Urban Forestry Diagnostic Lab. Tel: (413) 545-1053.

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New and Unusual Perennials at Bluebird Nursery

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Bluebird Nursery, Inc., 519 Bryan St., Clarkson, Nebraska 68629 U.S.A.

I would like to start by introducing one of the most ancient seed producing plants that we grow.

Ephedra minuta (miniature joint fir) forms a dense mound of leafless blue-green stems to 10 inches and prefers well drained sites and full sun. It is hardy in Nebraska, with no winter protection. Zone 4/5.

***Dianthus* 'Dale Lindgren'** is a sport of *D.* 'Prairie Pink', and is named in honor of Dale Lindgren of the University of Nebraska. It has 18-inch stems, blue-green foliage, and delicate pink semidouble flowers all season. Zone 5.

Clematis fremontii (Fremont's crowfoot) has stout erect stems to 2 ft supporting lavender-purple bell flowers. It is a summer bloomer, native to the plains states. Zone 4.

Clematis fruticosa (Mongolian gold) is a shrub reaching 3½ ft tall. It's native to Inner Mongolia, and has yellow flowers in the summer and persistent seed heads in late summer to fall. It is a 1999 Great Plant for the Great Plains winner.

Spiranthes cernua (ladies' tresses) is a U.S. native found from the Plaines States to the East Coast, preferring damp organic soils. Diminutive plants form spires of porcelain white sweet-scented flowers in the late summer. It can be grown from seed using standard laboratory techniques for orchid seed culture or grown vegetatively. It forms advantageous shoots on the root tips.

***Geranium ×cantabrigiense* 'Karmina'** has 1-ft mounds of fragrant stems and leaves covered by intense pink flowers in the early summer and sporadically thereafter. The foliage turns to shades of red during the cooler weather of fall.

***Penstemon* 'Mexicale', Pikes Peak Purple™ penstemon** is an interspecies hybrid by Bruce Meyers. It has narrow dark green leaves that form attractive mounds to 15 inches and has violet-purple flowers. It is Zone 4b, and a 1999 Plant Select®.

***Hibiscus* Baltimore hybrids** range from white to red, are 4 to 6 ft tall, and have flowers ranging in size from 6 to 10 inches in diameter. We have made a seedling selection with intense pink flowers and small red eye, 10 inches in diameter.

***Aster alpinus* 'Cotton Candy'** has double pink flowers, and is a seedling selection of *A. alpinus* 'Marchenland'. It forms 12-inch plants and is an early to mid summer bloomer.

***Aster fendleri* 'My Antonia'** has pure white flowers with yellow centers in mid to late summer. The 12-inch plants have glossy dark green leaves. It is a 1999 Great Plants for the Great Plains winner. Zone 4.

***×Pardancanda norrisii* hybrids**, through the last 15 years of hybridizing and selection, several new seed strains and clones have been made over the last several years.

×***Pardancanda norrisii*** **'Sangria'** is an 18-inch plant with heavier, slightly twisted foliage and increased flower count and size. The flower color is an interesting blend of purples with a tough of gold in the sepals.

×***Pardancanda*** **Dazzler Series** is a seedling strain very similar to 'Sangria' in plant and flowering habit It grows 12 to 20 inches in height, with colors ranging from pinks with yellow margins, to darkest purples and near reds, very few with spotting. Another even smaller seedling strain is in the works.

Veronica **'Goodness Grows'** is a release from Goodness Grows Nursery. Spikes of violet-blue flowers, 1 to 1½ ft tall, have an extended bloom season May through frost.

Stokesia laevis **'Mary Gregory'** is a 2-ft plant loaded with 2-inch creamy-yellow flowers in mid summer. It is a Niche Gardens introduction.

Rudbeckia missouriensis **(Missouri black-eyed susan)** has 12-inch mounds of fuzzy foliage topped by bouquets of bright yellow flowers. Zone 6

Sambucus is a shrub that fits well into the perennial garden. The height can be reduced by cutting back the old canes in the early spring. Zone 4

Sambucus nigra **'Pulverulenta'** has green foliage splashed with white specks, starting out nearly white in the spring.

Sambucus nigra **'Madonna'** has bold golden margins, slightly shorter than typical *S. nigra*

Sambucus racemosa **'Plumosa Aurea'** has finely cut leaflets that mature from bright yellow in the spring to lime green in the summer to yellow with a touch of bronze in the fall along with bright red berries.

Ipomoea batatas. There has been an increasing demand for tender perennials, especially the ornamental sweet potato, *I. batatas* They make fast growing ground covers, and prefer the heat of summer to grow. Zone 10

'Blacky' has dark cut foliage to 10 inches tall 'Marguarita' has chartreuse foliage, and 'Pink Frost' has white and green foliage with a violet-pink blush

Lysimachia punctata **'Alexanders' PP#10598** is a Plant Haven, England introduction. The 3-ft plants have cream-green variegated leaves that develop a pink blush during the cooler months of fall and spring. It has golden-yellow, star-shaped flowers in the leaf axils. Zone 5

Oenothera macrocarpa selection (possibly subsp *oklahomensis*). This plant was found in central Oklahoma, it is vigorous and adaptable, and was found growing on an extremely poor site under drought conditions, but it was completely covered by large bright yellow flowers Under normal garden soil conditions, it's a little more open in habit allowing its unusual red stems to be even more obvious. Zone 4

Callirhoe alcaeoides **'Logan Calhoun'** is 8 to 12 inches tall and up to 4 ft in diameter. This native plant is covered by sparkling white flowers throughout most of the summer, and is named in honor of the discoverer, the late Logan Calhoun. Zone 4

Due to the increasing interest in miniatures for troughs and rock gardens we are always looking for new "little jewels". To determine the actual hardiness is very difficult since more are lost during the damp cool weather of fall and spring

***Lewisia* 'George Henley'** is a typical alpine plant forming a 6-inch rosette of fleshy leaves with magenta-red flowers in midsummer It is listed as a Zone 6 plant, but it has been persistent in my Zone 4b garden

Drosanthemum hispidum is a close relative to the *Delosperma*, this miniature forms a dense clump of fleshy leaves covered nearly all summer long with purple-red flowers

New and Usual Conifer Cultivars

Jim Smith
Blue Sterling Nursery, Bridgeton, New Jersey 08302 U S A

The term "new" is a relative one when dwarf or garden conifers are involved When I use the term "new" it will mean popular or newly acquired by the trade, since collectors usually have this material long before it ever makes it into commercial production Conifers for the garden can come from many sources They can start from a graft of a witches broom, seed from a broom, a chance seedling, or a sport on a plant. The main thing to keep in mind when talking about dwarf conifers is the length of time something can be referred to as new. We all know of the work that Dr. Sidney Waxman has done at the University of Connecticut on broom seedlings. He has introduced many very nice landscape conifers to the industry. This takes quite a long time evaluating each plant to make sure it has a differing characteristic form the next one and then many more years to distribute to the trade, in some cases it can take 20 years or more. Many of these plants are first evaluated by collectors and shared or traded Sometimes a selection can be around for many, many years before it is commercially accepted. So the word "new" is also being used as "collector new" and "industry new"

Which then brings up the classification of sizes The American Conifer Society has established a guide to help eliminate the confusion around the term dwarf conifer They actually prefer to use "garden conifer"

- **MINIATURE**. Grows less than 3 inches a year or will reach around 2 to 3 ft in 10 years Example is *Chamaecyparis obtusa* 'Nana'.
- **DWARF.** Grows around 3 to 6 inches a year or will reach about 3 to 6 ft in 10 years. Example is *Pinus strobus* 'Blue Shag'
- **INTERMEDIATE**. Will grow about 6 to 12 inches a year or will be about 6 to 15 ft in 10 years. Example is *Chamaecyparis pisifera* 'Gold Thread'
- **LARGE.** Grows more than 12 inches a year and will be around 15 ft in 10 years. Example is *Cedrus atlantica* 'Glauca'.

Miniatures are perfect for the trough or patio garden since they will almost never outgrow the space allotted for them. Dwarfs are great in shallow borders or lower level foundation plantings. Intermediates will tend to outgrow the space if not used properly Large should be used only as specimens or where plenty of room is given

One thing to keep in mind when landscaping with conifers is to keep the growth rate in perspective By using the proper plant in the correct location many years of enjoyment can be had

***Lewisia* 'George Henley'** is a typical alpine plant forming a 6-inch rosette of fleshy leaves with magenta-red flowers in midsummer. It is listed as a Zone 6 plant, but it has been persistent in my Zone 4b garden.

Drosanthemum hispidum is a close relative to the *Delosperma*, this miniature forms a dense clump of fleshy leaves covered nearly all summer long with purple-red flowers.

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Jim Smith
Blue Sterling Nursery, Bridgeton, New Jersey 08302 U.S.A.

The term "new" is a relative one when dwarf or garden conifers are involved. When I use the term "new" it will mean popular or newly acquired by the trade, since collectors usually have this material long before it ever makes it into commercial production. Conifers for the garden can come from many sources. They can start from a graft of a witches broom, seed from a broom, a chance seedling, or a sport on a plant. The main thing to keep in mind when talking about dwarf conifers is the length of time something can be referred to as new. We all know of the work that Dr. Sidney Waxman has done at the University of Connecticut on broom seedlings. He has introduced many very nice landscape conifers to the industry. This takes quite a long time evaluating each plant to make sure it has a differing characteristic form the next one and then many more years to distribute to the trade, in some cases it can take 20 years or more. Many of these plants are first evaluated by collectors and shared or traded. Sometimes a selection can be around for many, many years before it is commercially accepted. So the word "new" is also being used as "collector new" and "industry new".

Which then brings up the classification of sizes. The American Conifer Society has established a guide to help eliminate the confusion around the term dwarf conifer. They actually prefer to use "garden conifer".

- **MINIATURE**. Grows less than 3 inches a year or will reach around 2 to 3 ft in 10 years. Example is *Chamaecyparis obtusa* 'Nana'.
- **DWARF.** Grows around 3 to 6 inches a year or will reach about 3 to 6 ft in 10 years. Example is *Pinus strobus* 'Blue Shag'.
- **INTERMEDIATE**. Will grow about 6 to 12 inches a year or will be about 6 to 15 ft in 10 years. Example is *Chamaecyparis pisifera* 'Gold Thread'.
- **LARGE.** Grows more than 12 inches a year and will be around 15 ft in 10 years. Example is *Cedrus atlantica* 'Glauca'.

Miniatures are perfect for the trough or patio garden since they will almost never outgrow the space allotted for them. Dwarfs are great in shallow borders or lower level foundation plantings. Intermediates will tend to outgrow the space if not used properly. Large should be used only as specimens or where plenty of room is given.

One thing to keep in mind when landscaping with conifers is to keep the growth rate in perspective. By using the proper plant in the correct location many years of enjoyment can be had.

THE FOLLOWING ARE SOME EXCITING PLANTS

Some are dwarf and some large. Some are new and some are quite old.

***Calocedrus decurrens* 'Gnome'.** Very dense and slower growing than the species.

***Cedrus deodara* 'Divinely Blue'.** A fantastic blue semiprostrate deodar cedar that is growing at the U.S. National Arboretum in D.C. It was named by Don Howse after Bill Devine of Maryland who found it.

Cephalotaxus *harringtonia* 'Fastigiata'. This old favorite is also making a second hit due to its deer resistance. It was introduced in 1913 from Japan and has dark green foliage with a good upright form.

***Cephalotaxus harringtonia* 'Korean Gold'.** Here is a great selection from 1984 that was brought back by Barry Yinger, then of Brookside Gardens in Maryland. It is a golden-yellow selection with a dense upright habit. It is still very difficult to find commercially.

***Chamaecyparis lawsoniana* 'Barabit's Globe'.** This is a selection from Elemer Barabitts of Hungary. It has a nice semi-weeping globose-to-later-conical habit with a good silver-blue-green color. It has been in production since 1965.

***Chamaecyparis obtusa* 'Elmwood'.** Here is a tight compact golden ball that looks fantastic anywhere in the landscape.

***Chamaecyparis obtusa* 'Repens'.** This is an old selection that is also making a comeback. It grows low and wide with a nice dense, close-grouped medium green foliage. It was introduced from Holland in 1949.

***Chamaecyparis nootkatensis* 'Green Arrow'.** Here is a nootka cypress that really makes a statement. The weeping foliage is more bluish than green at least in the east. It has a nice tight, strongly vertical habit that shoots for the sky.

***Chamaecyparis obtusa* 'Golden Whorl'.** It is similar to *C. obtusa* 'Torulosa' but it has a great golden-yellow color year round.

***Chamaecyparis obtusa* 'Split Rock'.** Here we have a nice plant that has the bluest foliage of any Hinoki cypress I have seen to date. It came from Split Rock Nursery in New Jersey around 1983.

***Chamaecyparis pisifera* 'Curly Tops'.** Here is a sport of the well known boulevard cypress that grows into a rounded to conical shape. It has bright blue needles that curl around the stem (similar to *Cryptomeria japonica* 'Spiralis') revealing the silvery underside. It is from Yamina Nursery in Australia and first released in 1989.

***Chamaecyparis pisifera* 'True Blue'.** Here is another new 'Boulevard' type. It will grow into a neat round ball that is quite dense. The color is excellent!

***Chamaecyparis thyoides* 'Rubicon' (syn. 'Red Star').** This could also be sold as 'Rubicon' but either way it is a real nice upright grower. The foliage changes from a real nice gray-blue-green to a fantastic shade of purple in the fall and winter. This has been around since 1984 as 'Red Star' and 1972 as 'Rubicon', but just became popular in the last 4 years.

***Picea abies* 'Acrocona'.** Here is another old cultivar from around 1890 that exhibits beautiful red cones at the tips of the branches.

***Picea abies* 'Pusch'.** This is a relatively new arrival to the states, found in 1987 in Berlin, Germany. It has the attractive red cones on the tips but it is a dwarf form in all respects.

***Picea abies* 'Witch's Brood'.** This one starts out its life as a flat globe but becomes conical with age. It is very slow growing. It is from the late Link Foster who grew it from a broom seedling and gave it to Don Smith of Watnong Nursery in New Jersey. It has nice light green foliage. Around from 1983.

***Picea glauca* 'Pendula'.** This one is even older but to many that tour our nursery it is a new selection. It is from 1867 and has a bluish gray color and a very nice tight pendulous habit.

***Picea omorika* 'Hexenbesen'.** This one has also been around since 1989 and is quite slow. It will start out as a low globe and then turn into a low broad cone.

***Picea omorika* 'Minima'.** This one is great for the patio or trough garden. The name has been changed to 'Minimax' and it has been around since 1979.

***Picea omorika* 'Pendula Bruns'.** It has very dense tightly pendulous branches that literally hug the trunk. It came from Germany somewhere around 1955.

***Picea omorika* 'Pimoko'.** Here is a selection that was found as a witches broom in 1984. It has a nice globose habit and the two-toned color of *P. omorika*.

***Picea omorika* 'Treblitsch'.** Again this one was found in 1987 in Germany. It is a very compact cushion that is different from other *P. omorika* taxa by having straight branches with a coarse needles that run perpendicular.

***Picea orientalis* 'Mount Vernon'.** This one is an extremely slow-growing, tight bun with dark green foliage. Around since 1985.

***Picea orientalis* 'Professor Langnor'.** It is a very tight miniature selection with light green color. Great for a trough garden.

***Picea orientalis* 'Silver Seedling'.** This one will make a small tree with sulfur-white foliage. It must have protection from the sun. It grows about 2 to 4 inches per year. A release from Konijn Nursery of Holland around 1990.

***Picea orientalis* 'Tom Thumb'.** Here is a cool miniature that is similar to Mt. Vernon but keeps a great golden-yellow color year round. Introduced by Joel Spingarn in 1990.

***Picea pungens* 'Glauca Prostrata'.** Here is an old favorite making a great comeback. It was around since about 1906 and has great blue color. Its spreading compact habit makes it a winner. Sometimes it can throw a leader that can be easily be pruned back.

***Picea pungens* 'The Blues'.** This is an exciting new weeping form that has fantastic blue color and an excellent weeping habit.

***Picea pungens* 'Walnut Glen'.** Here is a Colorado blue spruce with a nice golden-yellow color on new foliage. It was selected in the U.S.A. in 1985. It does need shade in the afternoon sun or it will burn.

***Pinus banksiana* 'Schoodic'.** Here is one from the Arnold Arboretum in 1979 that has a prostrate mat-like habit with short needles. It is now becoming more popular.

***Pinus densiflora* 'Oculus-draconis'.** The dragons eye pine is also from around 1890 and some people still are not familiar with it so to them it is new.

***Pinus densiflora* 'Pendula'.** This old selection from around 1890 is becoming popular again I feel because it can be used in many locations. It makes a great ground cover or if staked up it will provide the waterfall effect in the garden.

***Pinus flexilis* 'Campy'.** Here is another selection from Jerry Morris. It is very slow growing and is perfect for the patio garden.

***Pinus flexilis* 'Ririe'.** This one is an extreme miniature version of the limber pine. It was found by Jerry Morris in Colorado.

***Pinus koraiensis* 'Jack Corbit'.** This one is a variegated Korean pine with a nice habit. Around since 1986 and still almost impossible to locate.

***Pinus mugo* 'Mitsch Mini'.** It is a very low-spreading plant with twisted green needles and long buds in the winter. Has been around since 1989.

***Pinus parviflora* 'Cleary'.** This is a nice selection that has excellent silver-blue foliage with a nice compact upright habit.

***Pinus parviflora* 'Tani Mano Uki'**. The name means "snow on the mountain". This cultivar makes a nice bush with white variegation on the dark green foliage. The candles in spring also turn a shade of pink and add extra interest. It was a selection from Kristick Nursery in Wellsville, Pennsylvania in 1990.

***Pinus resinosa* 'Don Smith'.** Here is an excellent low-growing dwarf flat-topped form that was found by J. Leonard Bailey and distributed by Watnong Nursery in New Jersey. It has been around since 1984.

Pseudolarix amabilis. This selection is not new, nor is it a dwarf, but I thought I would include it here because so many are not familiar with it. It will become a rather large tree with nice green needles that change to a fantastic golden-yellow fall color. When people see this one at the nursery they always buy some because of the excitement. It was introduced from China around 1919.

Sciadopitys *verticillata* 'Triploid'. This one has needles that are three times as wide as the species and also has good color.

***Thuja plicata* 'Doone Valley'.** Here is a slow-growing cultivar with a conical habit and golden foliage. It was a selection of R.S. Corley from the United Kingdom in 1970 but is still relatively unknown in the trade.

New Plant Introductions from Bailey Nurseries

Debbie Lonnee
Bailey Nurseries, Inc., 1325 Bailey Road, St. Paul, Minnesota 55119 U.S.A.

At Bailey Nurseries, we are always looking for new and interesting trees, shrubs, evergreens, roses, and perennials to add to our product line. We work with a number of different arboreta, university breeding programs, and private breeders and we find plants within our own production plantings as well as having our own rose breeding program at our West Coast operation in Oregon. We have a number of new selections slated for release in Spring 2000 to present to you.

SPRING 2000 RELEASES: WOODY PLANTS

***Syringa* 'Bailbelle' Tinkerbelle™ lilac (PPAF).** This is, I think, our most exciting new introduction for the coming year. Tinkerbelle™ lilac is the first in a series of lilacs named the Fairytale Series that we are introducing. Coming from the work of Dr. Neal Holland, from Sheyenne Gardens in Harwood, North Dakota, (and retired professor of Horticulture at North Dakota State University) it is the result of a cross between *S. meyeri* var. *spontanea* 'Palibin' and *S. pubescens* subsp. *microphylla* 'Superba'. The color range in the resulting seedling population varied from a near white to a dark red bud with pink flowers. A number of selections have been made, tested, and are in propagation. Tinkerbelle™ lilac is officially being released in Spring 2000. Two more unnamed selections will be released starting in Spring 2002. We have patented and trademarked Tinkerbelle™ lilac and have sublicensed a number of propagators.

The growth habit of Tinkerbelle™ lilac is similar to that of dwarf Korean lilac, the plant itself will reach a mature height of 5 to 6 ft and spread of 4 to 5 ft. The flower buds are a beautiful wine-red that open to a deep pink and have a spicy fragrance.

***Berberis* 'Bailsel' Golden Carousel® barberry.** This was a selection from a seedling population of *B. koreana* made here in our seedbeds at Bailey Nurseries. We feel it was a naturally occurring cross between *B. koreana* and B. *thunbergii* 'Aurea' in our seed block.

It has golden-yellow leaves that will fade through the end of the growing season, and has nice red fall color. The plant has an upright growth habit, growing to 4 to 5 ft in height and 3 to 4 ft at maturity. We have found that it is best planted in a site where it receives some light shade to keep the leaves from burning.

***Rhododendron* 'Lemon Lights', lemon lights azalea.** This is the newest introduction from the azalea breeding program at the University of Minnesota under the direction of Dr. Harold Pellett.The flower color on 'Lemon Lights' is quite striking – it is almost a bi-color with the throat of the flower being a dark yellow and the outer edges of the petals being a lighter yellow color. The plant will reach a mature height of 4 to 5 ft and spread of 3 to 4 ft and has excellent maroon fall color and much improved resistance to powdery mildew.

***Juniperus horizontalis* 'Blue Prince', blue prince juniper PP10134.** This is a new creeping juniper introduced by Van Vloten Nursery in Alberta, Canada. A low, compact prostrate plant characterized by an incredible blue hue to the foliage, it will drape well over timber or rock walls. Reaches a height of 6 inches and spreads to 3 to 5 ft and is hardy from Zones 3 to 7. Bailey Nurseries has the United States patent on this plant.

***Lonicera* 'Mandarin', Mandarin honeysuckle PPAF.** A hardy new vine from the breeding program at the University of British Columbia. 'Mandarin' blooms in late spring through summer with large clusters of orange flowers which have a yellow center that are really showy on this vining plant. The foliage emerges in the spring with a coppery-brown hue that matures to a glossy dark green. It is a vigorous grower and will reach a mature height of up to 20 ft. Bailey Nurseries has the United States patent on this plant.

***Rosa* 'Hope for Humanity'.** A new rose in the Parkland series from the Morden Research Center in Canada, named in commemoration of the 100th anniversary of the Canadian Red Cross Society. This dieback-type shrub rose blooms throughout the growing season with hybrid-tea-like flower buds that are a deep wine-red. The growth habit is upright, reaching a mature height of 2 ft with good resistance to powdery mildew. Hardy to Zone 3.

***Rosa* 'De Montarville' PPAF.** We have a number of new Explorer roses from the breeding program at Ottawa, Canada to introduce this year. Bailey Nurseries holds the United States patent on all these rose cultivars. 'DeMontarville' is a dieback type with glossy foliage and beautiful pink flowers borne in clusters of one to four blooms with buds very much resembling a hybrid tea, although smaller. Initially, the flower buds are a dark red, and then open to a medium pink and finally fade to a mottled pink when fully open. Quite an interesting metamorphosis of the flowers! The plant foliage is very resistant to powdery mildew and is tolerant of black spot. These are being propagated on their own roots.

***Rosa* 'William Booth' PPAF.** This Explorer rose has an interesting plant habit in that it is quite spreading and trailing. It grows to a height of 4 to 5 ft and can easily spread to 8 ft wide, making it a good candidate for ground cover situations. The flower buds are initially a deep red color which changes to a medium red as the flower bud opens and finally fades to a light red in the fully opened flower. It is an everblooming type. The flowers are borne in clusters of 8 to 10 and are single with five petals. The plant itself is highly disease resistant.

***Acer saccharum* 'Bailsta', Fall Fiesta™ sugar maple.** We introduced this plant to our customers in Spring 1999, but I felt it was worthwhile to present to you today. This cultivar was selected from a field of seedling sugar maples in our fields in Oregon, and we are very proud of it. It has beautiful, thick, leathery glossy green foliage that is very resistant to leaf tatter. It is a vigorous grower, and has excellent fall color in shades of yellow, orange, and red. We bud this tree onto sugar maple understock.

AND NOW A LOOK TO THE FUTURE . . .

Very quickly, I wanted to give you a glimpse of some of the plants we are working on for future introduction, including some selections from our rose breeding program.

WOODY PLANTS.

***Rhus typhina* 'Laciniata' Selection.** We found this yellow-leaved sport/mutation of *R. typhina* 'Laciniata' in the field, and are in the process of propagating, naming, and trademarking it. We hope to have bareroot plants available within a year or two.

Morden Parkland Roses. We have two new Morden roses in propagation for future years. 'Morden Sunrise' has unusual flowers of yellow edged in orange and we've just this year received propagation stock, so we are a number of years away from introduction. 'Morden Snowbeauty' will be available in Spring 2001, and has white single flowers atop glossy green foliage and is an everblooming type.

Explorer Roses. In future years, we will introduce 'Marie Victorin', a pink dieback-type repeat bloomer with peachy-pink-colored flowers.

The Bailey Nursery Rose Breeding Program. In 1991 we initiated a rose breeding program at our Yamhill, Oregon facility. Led by breeder Ping Lim, we're at the stage of entering both hybrid tea types and a number of hardy shrub roses in the All American Selections, and continue to make crosses in search of hardy shrub roses for Midwestern Gardens. We are also working with breeder Bill Radler, in Milwaukee, Wisconsin and are testing some of his hardy shrub roses here in Minnesota.

'Love and Peace'. This hybrid tea rose is a beautiful red and yellow bicolor and we think it's a winner!

Perennials. And, last but not least, we have another dwarf *Monarda* that will be introduced in Spring 2001. Many of you know *Monarda* 'Petite Delight', from the *Monarda* breeding program at Morden Research Station in Canada, which we introduced a number of years ago. It was a real breakthrough in dwarf size and disease resistance. We are now in the process of propagating (by tissue culture) the second in this series, named *Monarda* 'Petite Wonder' PPAF. It is also dwarf in stature, almost 2 inches shorter than 'Petite Delight', and blooms with a beautiful clear pink flower. We own the United States patent on these *Monarda* cultivars and hope to have more cultivars to introduce in future years. The hope is that Morden can continue breeding to develop a dwarf white and a dwarf red. Keep your fingers crossed! We have sub-licensed a number of growers across the country who are producing these *Monarda* cultivars.

NEW PLANT FORUM

Compiled and Moderated by Jack Alexander

Presenters:

Jim Ault, Chicago Botanic Garden, 1000 Lake Cook Road, Glencoe, Illinois 60022 U.S.A.
Rhus copallina var. *latifolia* 'Morton', Prairie Flame™ shining sumac
Acer miyabei 'Morton', State Street® Miyabe maple

Bill Barnes, Lorax Farms, 2319 Evergreen Ave., Warrington, Pennsylvania 18976 U.S.A.
Hibiscus 'Lohengrin'
Hibiscus 'Tosca'
Ilex 'Clusterberry'

Alan Jones, Manor view Farm, Monkton, Maryland 21111 U.S.A.
Caryopteris ×clandonensis 'First Choice' PPAF
Lagerstroemia 'Chickasaw'
Lagerstroemia 'Pocomoke'

Tim McGinty, The Conard-Pyle Co., 372 Rosehill Road, West Grove, Pennsylvania 19390 U.S.A.
Ilex 'Centennial Girl'
Rhododendron 'Purple Passion' Highland™ rhododendron PP 9981
Rosa 'Knockout' PPAF, Canadian PBRAF

Clement Paquette, Pepinieri Mont-Yamaska, St-Paul d'Abbotsford, Quebec, Canada
Spiraea japonica Golden Elf™ PPAF

Tom Pinney Jr., Evergreen Nursery Co., Inc., 5027 County TT, Sturgeon Bay, Wisconsin 54235-8899
Betula papyrifera 'Renci', Renaissance Reflections™ paper birch
Betula papyrifera 'Cenci', Renaissance Compact™ paper birch
Betula papyrifera 'Uenci', Renaissance Upright™ paper birch
Betula papyrifera 'Oenci', Renaissance Oasis™ paper birch

Michael Yanny, Johnson's Nursery, Inc., W180 N6275 Marcy Road, Menomonee Falls, Wisconsin 53051
Malus toringo subsp. *sargentii* 'Select A' Firebird™ crabapple PPAF

PLANTS:

***Acer miyabei* 'Morton', State Street® Miyabe maple**. A clonal selection of a little-known Asian species, this deciduous shade tree has an excellent branching character, uniform broad-pyramidal habit, superior heat/drought tolerance, clean dark green foliage, and good yellow fall color. Of medium growth, it will eventually reach 60 ft in height with a 50-ft spread at maturity. State Street® Miyabe maple is a more cold-hardy alternative to *A. campestre* (hedge maple) in northern growing conditions, and a more heat/drought-resistant alternative to *A. platanoides* (Norway maple) further south. Adapts to a broad range of soil types and site conditions. Very tolerant of salt and pollution. Its attractiveness, excellent adaptability, and stress tolerance provides for a broad range of landscape applications in commercial, residential, and urban sites. Easily transplanted either B&B or from a container. Hardy to at least USDA Zone 4. Selected from the collections of The Morton Arboretum, Lisle, Illinois. The parent tree was accessioned and planted in 1929, and has thrived and developed into a magnificent specimen. A Chicagoland Grows Plant Introduction Program selection.

RENAISSANCE (SERIES) PAPER BIRCH

- Highly resistant to bronze birch borer.
- 30 years of hybridization, testing, and selection.
- Testing done in Wisconsin and Ohio.

Betula papyrifera **'Renci', Renaissance Reflections™ paper birch**

- Appears to have the normal growth habit of species.
- Nonexfoliating clean white bark.
- Fall color yellow.
- Available Spring 2000 in 3.5-inch square pot.

Betula papyrifera **'Cenci', Renaissance Compact™ paper birch**

- Tight compact pyramid form.
- Exfoliating sheets of clean white bark.
- Semiglossy rich green foliage.
- Fall color yellow.
- Available spring 2001 in 3.5-inch square pot.

Betula papyrifera **'Uenci', Renaissance Upright™ paper birch**

- Narrow pyramid with strong central leader.
- Semi-exfoliating clean white bark exposing cinnamon under layer.
- Semiglossy green foliage.
- Available for Spring 2001 in 3.5-inch square pot (limited quantity may be available for Spring 2000).

Betula papyrifera **'Oenci', Renaissance Oasis™ paper birch**

- Appears to have normal growth habit of species.
- Retains good green foliage during drought periods.
- Nonexfoliating clean white bark.
- Yellow fall color.
- Available for spring 2001 in 3.5-inch square pot.

Caryopteris ×clandonensis **'First Choice' PPAF**

A new compact form of *Caryopteris* from English breeder Peter Catt of Lis Forest Nursery. The inky-blue buds open to large rich cobalt-blue flowers in profusion on erect stems. Rounded habit 3 ft × 3 ft, 'First Choice' requires less pruning than other caryopteris on the market and does not have the floppy habit most cultivars exhibit. Hardy to Zone 5.

***Hibiscus* 'Tosca'** and ***H.* 'Lohengrin'**. These are sister seedlings of a hybrid between *H. syriacus* and *H. paramutabilis*. Both plants are seedless and offer continuous bloom throughout the summer. Easily propagated from softwood cuttings. Hardy to Zone 5.

***Ilex* 'Centennial Girl'**

- A naturally pyramidal holly from Kathleen Meserve.
- Hardy from Zones 5 to 8.
- At maturity 15 ft tall and 6 ft wide.
- Deep green satin foliage, bright red berries that persist well into spring.
- Propagates very well from cuttings.
- Makes up quickly in production and requires very little shearing.

***Ilex* 'Clusterberry'**. This *Ilex* is a complex hybrid that was released by the U.S. National Arboretum about 15 years ago. Surprisingly it has not caught on with the horticulture industry but it should. It is a very compact plant with thick, heavy, glossy dark green leaves. Its name 'Clusterberry' comes from the manner in which the bright red fruit forms in small clusters in the same manner as cherry tomatoes. It can be propagated via cuttings in mid fall or in winter. It is a little harder to propagate than some other *Ilex* which might explain its limited distribution. Hardy to Zone 6 and possibly Zone 5. It is very drought tolerant and seems immune to most pests.

***Lagerstroemia* 'Chickasaw'**. This introduction from the National Arboretum is the first true miniature crapemyrtle growing 2 ft × 2½ ft after 7 years. A small, densely branched, compact plant with foliage that is glossy dark green with maroon new growth. The flowers are lavender to pinkish-lavender from midsummer to frost. 'Chickasaw' is highly tolerant to powdery mildew. Reliably top hardy to Zone 7, root hardy to Zone 6.

***Lagerstroemia* 'Pocomoke'**. This introduction from the National Arboretum is in the miniature hybrid series. It is similar to *L.* 'Chickasaw' but has large, deep rose-pink flowers.

***Malus toringo* subsp. *sargentii* 'Select A' Firebird™ crabapple PPAF**
Malus toringo subsp. *sargentii* 'Select A' Firebird™ crabapple PPAF originated from open-pollinated seed collected in 1980 by Michael Yanny at Johnson's Nursery, Inc., Menomonee Falls, Wisconsin. It was selected from a block of about 300 seedling plants.

'Select A' showed superior fruiting qualities early on in the selection process. It has small, red crabapples slightly less than ½ inches in diameter. Unlike most *M. sargentii* selections which have small, red fruits that quickly soften in the autumn after a few hard frosts and are taken by birds, 'Select A' fruits remain hard and colorful late into the winter. It's ornamental fruit quality and persistence is better or equal to that of Malus 'Donald Wyman' and approaching but not equal to Malus 'Red Jewel', in Wisconsin.

'Select A' is a small-scale plant similar to its parent *M. sargentii*, though a more compact version. It grows more upright than the species when young eventually spreading out to 8 ft wide by 5 ft tall after about 18 years.

'Select A' shows much more of a tendency towards annual flowering and fruiting than its parent. Red flower buds open to sweet smelling 1-inch diameter, snow-white flowers at the time *Viburnum carlesii* is in full bloom.

It has excellent resistance to apple scab disease. Fireblight has not infected it.

'Select A' is a patented plant, requiring licensing. Growers interested in becoming licensed should contact: Michael Yanny, Plant Propagator at Johnson's Nursery, W180 N6275 Marcy Road, Menomonee Falls, Wisconsin 53051.

***Rhododendron* 'Purple Passion' Highland™ rhododendron PP 9981**

- The first in a ruggedly hardy series of large-leaved evergreen rhododendrons.
- Created and selected by Robert Blough on a wind-swept slope in western Pennsylvania.
- The original plant has survived -29°F without any leaf burn, bud kill, or other die back.
- It is one of the deepest purple rhododendrons on the market.
- Hardy to Zones 4 to 7. Mature height 6 ft × 4 ft wide.
- Maintains foliage to the base of the plant in container culture.
- Very heavy flower set. We have counted as many as 45 buds on a 3-gal plant.

***Rhus copallina* var. *latifolia* 'Morton', Prairie Flame™ shining sumac.** A clonal selection of a native plant, this deciduous, multistemmed shrub has a dwarf compact habit, clean dark green glossy foliage, attractive flowers, and a brilliant red-orange fall color. A dioecious species, this male clone produces attractive greenish-yellow flowers in late July to early August, when few other shrubs are in bloom. No fruit are produced. The plant matures at 4 ft to 6 ft in height and spreads laterally from root suckers, eventually forming a broad dense colony. Useful for naturalizing/colonizing on open slopes, road cuts, and other exposed areas; well adapted to harsh, dry habitats with nutrient-poor but well drained soils. In the formal landscape, excellent as an accent plant with evergreens, or as a companion to other shrubs or perennials. Full sun for optimal growth and fall color. Best planted from a container. Hardy to at least U.S.D.A. Zone 5a. The plant was selected from the collections of The Morton Arboretum, Lisle, Illinois, but originated from seed collected in the Iroquois County, Illinois, Conservation Area. A Chicagoland Grows Plant Introduction Program selection.

***Rosa* 'Knockout' PPAF, Canadian PBRAF**

- 2000 AARS winner. Developed by William Radler, a rosarian formerly with the Bourner Botanical Garden.
- Thrives from Manitoba to Texas.
- It is a blooming machine, producing a profusion of cherry-red blossoms. The plant is self cleaning.
- Three-foot-tall mounding habit.
- Drought tolerant once established.
- Mite resistant and not preferred by Japanese beetles.
- It's going to set the standard in blackspot resistance; it doesn't get it.
- A good production plant. It does best on its own roots.

***Spiraea japonica* Golden Elf™ PPAF.** A new and unique golden spiraea that grows 6 to 8 inches tall and spreads 18 to 24 inches. The rich golden leaves provide a carpet of color all summer long. The flowers are insignificant. Requires full sun to maintain gold color. It has not shown any signs of summer leaf burn even in the hot Georgia summers. The rich golden leaves provide a carpet of color all summer. Hardy to Zone 4. An introduction from Mont-Yamaska Nursery, Quebec, Canada.

QUESTION BOX

MODERATAED BY RALPH SHUGERT AND BRUCE BRIGGS

RALPH SHUGERT: Question for Charles Flinn. Does Penn Mulch provide you with any weed control? I noted your germinated beds were weed free.

CHARLES FLINN: The beds are weed free because they are fumigated and a pre-emergence herbicide, Goal, is applied.

RALPH SHUGERT: Question for Charles Flinn. Is it possible that the paper product could blow away after it is hydrated if allowed to dry out before germination has taken place.

CHARLES FLINN: No, it becomes a fine crumpled mass.

RALPH SHUGERT: Question for Charles Flinn. Have you seen any weed control from the Penn Mulch product compared to other bed techniques you use?

CHARLES FLINN: No.

BRUCE BRIGGS: Question for Mic Armstrong. Hydrogen dioxide (Zerotol), are there other reports of its use?

MIC ARMSTRONG: Hydrogen peroxide and hydrogen dioxide are basically the same thing. Apparently they treat hydrogen peroxide with perioacetic acid and that makes it stronger. We use it as a softwood cutting dip at 2%.

BRUCE BRIGGS: There is some research being done in the West on the potential control of mosses and liverworts. There is hope that it can be put into the mist system to control fungi.

DEB McCOWN: I sent the label to my pathologist and he questioned the longevity once it is mixed. Once mixed it can not be stored.

TIM McGINTY. Zerotol is the other name. We have been using it as a spray before our mist comes on and have seen a marked reduction in *Rhizoctonia*.

BRUCE BRIGGS: How do you propagate *Picea glauca* 'Conica'; time of year, type of wood, soil mix, hormone, watering, summer or winter, and bottom heat.

BRUCE BRIGGS: I got the following from one of Dave Bakker's sons. Take the cuttings just after summer growth is finished and are just ready to make the second flush. Do not take any of the needles off, leave the heal on, mist. Medium has 10% perlite and sand.

RALPH SHUGERT: Many years ago I rooted it from late June/July cuttings, very short, 2 to 2½ inches, no strip or hormone, sand ground beds in a shade house (50%), with the beds covered with 50% shade and then burlap that was watered daily. Techniques vary widely with that plant.

RALPH SHUGERT: Question for Mark Coggeshall. Did you try longer than 2 months warm before your cold treatment?

MARK COGGESHALL: No only 2 months.

RALPH SHUGERT: Question for Mark Coggeshall. Have you tried propagating *Acer diabolicum* from cuttings? If so what were the methods and results.

MARK COGGESHALL: No.

JACK ALEXANDER: I have tried to root cuttings and thought that was why it was called "diabolicum". You get little hairs in your hands and they remain for quite a while. It is worse than fiberglass insulation. The hairs are under the leaves and on the stems. They disappear later in the summer. We had a very low rooting success rate.

RALPH SHUGERT: Question for Mark Coggeshall. Have you ever attempted a technique known as "embryo rescue" to assist germination of *A. diabolicum*?

MARK COGGESHALL: No.

RALPH SHUGERT: Could Deb McCown explain what embryo rescue is?

DEB MCCOWN: My husband is doing crosses in the genus *Viburnum* and some of the embryos formed do not do well. So they excise embryos and put them on a nutrient medium under sterile conditions.

JIM AULT: Susan Wiegrefe of the Morton Arboretum is doing embryo rescue with maple crosses to speed the germination.

DICK ZIMMERMAN: It has been used extensively in fruit breeding with early ripening nectarines and peaches. Rutgers has done it extensively.

BRUCE BRIGGS: Question for Shelton Singletary. Where do you get BA? How much does itcost?

SHELTON SINGLETARY: From Plant Wise Labs, Lexington, Kentucky (800-334-4962). It cost about $160 a quart. It is not commercially labeled. We are trying to get a label for it.

DICK ZIMMERMAN: Sigma Chemical Co. or any similar chemical supply company.

BILL BARNES: Abbot Laboratories sells it and it is called ProShear. Usually applied between 500 and 2000 ppm.

BRUCE BRIGGS: Question for Michael Byers. What herbicides do you use on the *Buxus* transplant beds? Have you found *Buxus* to be more prone to herbicide injury than most other woody shrubs?

ED LOSELY: We had a bad experience with Factor. It tended to girdle the stems at the ground level.

DICK BIR: Ed, why are you not using Caseron or Surflan?

ED LOSELY: We have had similar problems with other plants and Caseron. In our soils Surflan seems to have a much longer residual than indicated. This longer residual inhibits root growth with a number of subsequent crops.

DICK BIR: Our soils are heavier and it has been used at 4 lb acre^{-1}. I have never seen damage on American boxwood. Surflan has worked fine for us also.

RALPH SHUGERT: We are growing boxwood in liner beds for 2 years before container and field production. Rout (100 lb acre^{-1}) has been used in our boxwood container production for 15 years with no phytotoxity. Gallery and Surflan are used for our field-grown boxwood. In the field Gallery and Surflan are 50% cheaper on our sands than Caseron.

ED LOSELY: Tim Brotzman was the first to alert us to the problem of surflan on rhododendrons on our sandy soils.

TIM BROTZMAN: We were using 1 lb active on our sandy soils and it did appear to penetrate deeper than expected.

DAVE BEATTIE: Unless they have changed the formulation you cannot use Caseron in the summer.

BRUCE BRIGGS: If spurge is out of control, what herbicide can help regain control in a container nursery with woody ornamentals and perennials?

RALPH SHUGERT: In North Carolina with perennials you would wait until the plants are completely dormant — with no green tips at all. A total of nine genera including hosta, hemerocallis, and peony, were tested and Diquot over the top worked. I repeat — the plants must be dormant.

RALPH SHUGERT: In the fall of 1998 I sowed *Cornus florida* seed which I collected from around the area in 1996. As of today these plants have reached a little over half the size they usually reach. I also seeded *C. kousa* var. *chinensis* at the same time; seeds collected also in 1996, and these plants are of normal size. The seeds were kept in plastic baggies in a refrigerator. Is it possible the lack of growth is due to the age of the seeds?

BILL BARNES: Age can affect, *C. florida*, it must be fresh. *Cornus kousa* is more user friendly.

RALPH SHUGERT: Does anyone have a suggestion for germinating *Cornus alternifolia*? We planted ours after collection, fleshy coating removed. A germination of 0% occurred. Will it come up next year?

CHARLES TUBESING: This dogwood requires a warm then cold period. Best to store dry until May or June of the next year and then sow. It will germinate the following spring. For the person who wrote the question, just wait and they should germinate the second spring. Keep the beds clean of weeds.

RALPH SHUGERT: What ever you do, don't ever sow seed without soaking it overnight. It cost nothing.

BRUCE BRIGGS: I've had difficulty successfully budding mature, native specimens of sugar maple (*Acer saccharum*). I've been budding onto 2-year-old seedlings in mid to late July (in Minnesota) using a T-bud technique. I know that the age of these specimens might be a limiting factor, but I'm wondering if anyone can offer any tips or special tricks for budding sugar maple. Also, is there any progress in tissue culture or cutting propagation of this species?

TIM BROTZMAN: My biggest losses have come from verticillium wilt with sugar maple grafts. Prehaps that is the cause of the failure.

RALPH SHUGERT: Obviously Bailey's is very successful with *Rhus aromatica* 'Gro-Low'. Could they share their methods; e.g., timing, type of cutting, hormone, mist frequency, etc.

PHIL KING: Best luck is with the softest cuttings you can stick. They do not like high humidity, keep them on the dry side, avoid fog. 'Gro-Low' should look like they have fall color (from the stress) in the bed if they are hard cuttings when rooting. You will lose some but most will root. Hormone is 500 to 1000 ppm.

VERN BLACK: The biggest thing is taking cuttings from 1- to 2-year-old plants. Stick in sand beds, take them in June, 750 ppm IBA, careful with mist, and dry down in the evenings.

RALPH SHUGERT: How do you propagate *Schizophragma* 'Moonlight'?

BILL BARNES: Cutting has to be a lime-green color (soft), if brownish it is to hard. Hormone is not important (2000 ppm liquid dip will do), mist, and peat and perlite medium.

BRUCE BRIGGS: Are all roots juvenile? How do you convert a plant back to a juvenile state?

DICK ZIMMERMAN: That is difficult to answer. It is know that you can cut back plants close to the ground to produce cuttings that are easy to root. It might also depend on what roots you are talking about and how far away from the crown they are. Heavy pruning and hedging are used to maintain the plants in a condition favoring rooting. An example is East Malling where they maintained their understocks hedges for *Malus* (apple) rootstocks and root the apples by hardwood cuttings.

MIKE PRICE: I talked earlier today on lilacs. I take cuttings from 1- and 2-year-old plants in the field.

RALPH SHUGERT: Is anyone using Wilt-Pruf or know of anyone as a control for rose (*Rosa*) blackspot?

MIKE KOLACZEWSKI: Five or 6 years ago in California they showed that it was a good agent against blackspot. Anyone can call or fax me and I will fax them the research.

Micro-Positional Differences in Cutting Origin Influence Propagation of *Quercus rubra*

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Grafting and rooting trials followed shoot formation and rooting ability of individual buds from a mature northern red oak. Sixty-four matched pairs of dormant twigs were chosen with a total of 701 buds identified by position along each parent twig. Apical bud clusters and individual lateral buds from one randomly selected twig of each pair were grafted onto potted nothern red oak seedlings and stimulated to develop shoots. Buds from the paired counterparts were left on the tree (in situ) to develop normally.

In situ, shoots developed from 100%, 75% and 18% of terminal buds (Position I), lateral buds within the distal 1/3 of the twig (Position II), and lateral buds within the proximal 2/3 of the twig (Position III), respectively. When grafted, shoots developed from 39%, 54%, and 42% of the buds from the same positions, respectively. Therefore, shoots from grafted and in situ buds originated from two positionally different bud populations. All shoots were subjected to a rooting trial. Overall, cuttings from grafts had greater rooting (48%) than cuttings developed in situ (14%). However, for grafted and in situ bud pairs which both produced shoots, rooting success was similar. Rooting was not influenced by twig position or origin for in situ shoots. For cuttings from grafts, rooting was significantly related to position on the twig with 25%, 46%, and 67% success for Positions I, II, and III, respectively.

Though it is well known that rooting differs for shoots from widely varying crown positions, these results suggest that rooting differs on a much smaller scale, among buds along a twig. Results suggest that buds which normally develop into shoots in situ are not as competent to root (and perhaps more determined in their developmental fate) as those at more proximal portions of twigs that usually maintain dormancy in situ but form shoots when grafted. Although increased rooting through grafting is often attributed to physiological or ontogenetical rejuvenation by juvenile rootstock, these results suggest that grafting may serve to select for buds with high rooting potential by allowing their development into shoots and indirectly select against buds with low rooting potential through reduced shoot development.

INTRODUCTION

Inducing adventitious roots on cuttings of northern red oak (*Quercus rubra* L.) and many woody plant species is often attainable when the ortet is juvenile but exceedingly difficult when mature. Rooting success of tissues originating from mature plants has been shown to be enhanced if scions are first grafted onto seedling rootstocks, and cuttings are taken from the graft. Accordingly, it has been suggested that grafting rejuvenates mature tissues. However, the true effect of grafting remains unclear.

Prior grafting and rooting trials by the author have shown that bud-grafting mature northern red oak (NRO) onto seedlings produced cuttings with increased rooting and more juvenile-like leaf morphology, suggesting partial rejuvenation of mature tissues. However, these cuttings from mature grafts exhibited other mature characteristics such as low numbers of roots per cutting, limited flushing, and reduced post-rooting growth. Also, more horizontal or branch-like plagiotropic growth of rooted cuttings from grafts indicated that increased rooting in grafts may also be attributable to predetermined differences between axillary buds used in grafting and terminal buds that form most shoots that develop in situ.

Rooting can vary considerably for cuttings arising from widely differing crown positions of woody plants where maturation gradients (cyclophysis) may exist (Copes 1992; Ridding 1976). Black (1972) working with 24-year-old *Pseudotsuga menziesii* (Mirb.) Franco, did not find rooting differences due to cyclophysis, but did find topophytic (branch order) differences. Rooting differences in branch order were also found in *Sequoia sempervirens* (D. Don) Endl. plants that had been maintained in a hedged condition (Power et al., 1988). Presumably, variability in rooting success may occur on a smaller scale, such as among buds (meristems) along a twig.

Considering this, the effect of grafting on rooting may not be manifested through a physiologically or ontogenetically rejuvenating change of existing buds. Rather, grafting may increase rooting by allowing the development of a greater proportion of shoots from axillary buds that are inherently more rootable.

MATERIALS AND METHODS

In late Winter 1992, a mature open-grown seed-producing NRO tree 13 m tall and 39 cm in diameter at 1.3 m above the ground was chosen for the study. On the tree, 64 matched pairs of dormant twigs were chosen based on similar crown position, twig size, and number and type of buds/twig. For reference, a twig refers to the dormant shoot formed in the previous growing season that bears dormant terminal and axillary buds. A shoot refers to the leafy extension growth from buds that broke in Spring 1992. Shoots were used to collect cuttings for the rooting trial and are referred to as in situ shoots or graft shoots, respectively, according to whether they formed in place or after the buds were grafted onto seedling rootstocks. Overall, 701 buds were identified by parent twig and position along the twig. Twig length (TL) was measured (mm) from the base of the apical bud to the apical bud scale scar of the previous shoot growth extension. For each bud, the distance (mm) from the base of the apical bud (DA) was also recorded. The relative position (RP) of each bud was determined by DA/TL.

One randomly selected twig of each pair was selected to remain on the tree and the buds developed normally in situ. The twigs paired counterparts were removed from the tree and the buds were grafted onto potted NRO seedling rootstocks in a greenhouse in early April. For these twigs, all axillary buds positioned at least 5 mm below the apical bud were individually T-budded (Hartmann and Kester, 1983). Apical and closely subtending axillary buds within the 5 mm of apex were grafted as one scion using a side veneer graft (Hartmann and Kester, 1983). In all, 296 single buds and 64 apical scions were grafted. The grafting method for the apical scions did not allow for the development of the axillary buds in the distal 5 mm of the twigs. Because of this, the in situ counterparts in this region were excluded from the study.

Approximately 5 weeks after grafting, the seedling rootstocks were removed above the grafts in order to stimulate shoot development of the grafted buds in synchrony with those remaining on the tree. Each in situ and grafted bud was checked and shoot formation was recorded in early June. Shoots from one-half of the twig pairs were randomly chosen for use in another study. Remaining shoots were subjected to a rooting trial reported in this paper.

For the rooting trial, collections of softwood cuttings were made over consecutive days in mid June after shoots had fully expanded and prior to initiation of a new flush of growth. All leaves except three at the apex were removed from cuttings. The basal end of each cutting was freshly trimmed and dipped in a solution of 10,000 ppm 1H-indolebutyric acid (IBA) and ethanol for 5 sec and allowed to dry. While drying, the leaves were trimmed in half perpendicular to the midvein. Cuttings were inserted 3 cm deep into moist medium (perlite, peat, and coarse white sand [1 : 1 : 1, by volume]) in 115 cc Ray Leach Super Stubby Cells™ (Steuwe and Sons, Corvallis, Oregon). Cuttings were watered and randomly placed within the rooting chamber.

The rooting chamber consisted of separate 1-m-tall box-shaped frames of polyvinyl chloride pipe on three adjacent 1.7-m × 3.0-m roller benches. One sheet of clear 6-mil polyethylene covered all three frames, forming one large chamber. Intermittent fog was directed into the chamber by four ultrasonic humidifiers (Sunbeam model 667, Laurel, Mississippi) placed outside of the tent near the corners. Whitewash was applied on the greenhouse to reduce solar irradiance and heating inside the chamber. Benomyl (Benlate at 2.4 g $liter^{-1}$) was sprayed on the leaves at least once every month during the rooting trial. After 95 days, the cuttings were examined for root formation.

Data collection included the relative position of each bud along each twig, whether the buds formed a shoot in situ or after grafting, and if so, whether the shoots rooted in the rooting trial. First-year acorns were located in the approximate middle ⅓ section of nearly every twig (relative position 0.33 to 0.67 units). These developing acorns excluded graftable vegetative buds at these positions. Because of this natural division of vegetative buds along the twigs, results are summarized by three positions: the terminal (Position I), the distal ⅓ of the twig excluding the terminal ($0.00 <$ relative position ≤ 0.33, or Position II), and the proximal ⅔ of the twig ($0.33 <$ relative position ≤ 1.00, or Position III).

Chi-square analysis was used to test for significant relationships between the treatments at the P=0.05 level (Roscoe, 1975). Specific pairwise comparisons in shoot production and rooting among bud position (I, II, III) and among bud treatment (grafted or in situ) were made at the P=0.05 level using CONTRAST a computer program (Hines and Sauer, 1989) based on a chi-square procedure described by Sauer and Williams (1989).

RESULTS

Shoot Production. Shoots formed from 59% of the buds left to develop *in situ*, and shoot development was dependent (P<0.001) on bud position of origin when considering all positions simultaneously. In situ, all Position I, most Position II, and a few Position III budsformed shoots (Table I). All specific pairwise comparisons (Positions I vs II, I vs. III, and II vs III) showed that the number of shoots differed

Table 1. A comparison of the percentage of buds producing shoots in situ or in response to grafting, by position of bud origin on the twig. See text for position designations.

Twig Position	Buds on in situ twigs (n)	Buds producing shoots in situ[1] (%)	Buds grafted (n)	Buds producing shoots when grafted[1] (%)	Comparing in situ and grafted shoot production by position[2]
Position I	64	100.0 a	64	39.1y	*
Position II	166	74.7 b	138	54.3 x	*
Position III	130	17.7 c	139	42.4 xy	*
All Positions	360	58.6	341	46.6	*

[1]Shoot formation values in the same column with the same letter are not significantly different at the p=0.05 level based on pairwise comparisons using CONTRAST.

[2]Comparisons by position denoted with * are significantly different at p=0.05 using CONTRAST.

at all positions for buds developed in situ . However, when grafted, shoot production was somewhat reduced at 47% and was independent (P=0.055) of position when considering all positions simultaneously. When grafted, specific pairwise comparisons among positions showed that only Positions I vs II differed (Table I).

Comparing in situ and grafted treatments at each position, shoot production was greater (P<0.001) for in situ buds than grafted buds at Positions I and II. However, at Position III, shoot production was greater (P<0.001) for grafted buds compared to those buds left to develop in situ.

Rooting. Shoots formed from grafts rooted more (P<0.001) frequently (48%) than shoots formed in situ (14%) over all positions (Table II). However, considering only the 35 grafted and in situ bud pairs for which both buds of each pair had produced shoots, rooting success was marginally higher for graft shoots vs in situ shoots (43% vs 23%) but the difference was not statistically significant (P=0.068). For grafted buds that produced a shoot whose in situ bud counterpart failed to, rooting was 58% (n=19). For in situ buds that produced shoots whose grafted bud counterpart failed to produce a shoot, rooting was 11% (n=47).

For in situ shoots, rooting was not related (P=0.594) to bud position. However, for graft shoots, rooting was (P=0.044) related to position with 25%, 46%, and 67% of the shoots rooting at Positions I, II, and III, respectively (Table II). Rooting was higher for graft shoots vs in situ shoots at Position II and Position III (P<0.002 and P<0.001, respectively), but not at Position I (P=0.300).

DISCUSSION

When left to develop in situ, shoots formed mostly from the more distal buds, Positions I and II, as is typical of decurrent species with proleptic shoot development (Brown et al. 1967). Of the total number of shoots produced in situ, 30% originated from terminal meristems (Position I) only 11% were from the proximal ⅔ of the twig (Position III). However, when grafted and removed from the influence of apical control, buds originating formed shoots at more comparable percentages at all three positions. Therefore, shoots from Position I buds accounted for a smaller proportion (16%) and shoots from Position III buds accounted for a larger proportion (37%) of total shoots within the grafted population compared to the in situpopulation. Thus, shoots from grafts originated from a positionally different population of buds, generally less terminal and more proximal, than those formed in situ.

Rooting for shoots from grafts was greater than for those formed in situ, and the difference increased with increasing distance from the terminal. However, shoots of both treatments arose from different populations of buds. When considering a priori matched bud populations, where both matched bud pairs resulted in shoots, rooting success was not statistically greater for graft shoots.

Grafting allowed more shoot formation from buds originating from the proximal ⅔ of the twig than was the case in situ. These grafted Position III shoots had the highest rooting success (67%) compared to all other treatment combinations. Of the graft shoots, Position I shoots were the poorest rooters. There were also relatively few Position I shoots in the grafted population (n=12) compared to the in situ population (n=28) because grafting effectively eliminated many of these shoots (61%) by failing to form a successful graft union. In contrast, all Position I buds formed shoots in situ. Thus, in this study, the principal effect of grafting on rooting

Table 2. Adventitious rooting response of shoots formed in situ or after grafting by original bud position. See text for position designations.

Shoot cutting origin	Cuttings from in situ buds (n)	Rooting of in situ cuttings[1] (%)	Cuttings from grafts (n)	Rooting of grafted cuttings[1] (%)	Comparing rooting of cuttings originating in situ and from grafts by position[2]
Position I	28	10.7 a	12	25.0 x	ns
Position II	58	17.2 a	41	46.3 xy	*
Position III	11	9.1 a	18	66.7 y	*
All positions	97	14.4	71	47.8	*

[1] Rooting values in the same column with the same letter are not significantly different at the $p=0.05$ level based on pairwise comparisons using CONTRAST.

[2] Comparisons denoted with * are significantly different at $p=0.05$ using CONTRAST.

success may be viewed as a form of selection; selecting for buds that form shoots which root in high percentages and selecting against buds whose shoots root in low percentages.

Rooting was greater for shoots from Positions II and III when grafted, as compared to in situ, but not significantly so for Position I (terminal shoots). Also, where both members of matched bud pairs developed into shoots, rooting was no different. Thus, there was no evidence that grafting provided an exogenous effect to enhance rooting or rejuvenate individual meristems and their resulting shoots. Therefore, grafting's main effect in this study was to cause the preferential growth of shoots from meristems with an endogenous high capacity for adventitious root formation.

Thus for NRO the population of meristems with high adventitious root formation potential tends to remain dormant unless stimulated to grow by grafting. This is a more accurate description of the effect of grafting than "rejuvenation". Rooting can differ for shoots from different locations within the crown of the tree (Copes, 1992; Nautiyal et al., 1992; van den Driessche, 1983). Rooting also is affected by smaller scale branch order differences (Black, 1972; Power et al., 1988). Since crown architecture is the ultimate expression of differential development of terminal and axillary meristems, it is logical to conclude that rooting potential on a microscale (as shown in this study) is another expression of the same phenomenon at the macroscale.

If this is a general phenomenon, then other cultural treatments that increase rooting may also be due to meristem selection. This is especially true of hedging, or the severe and repeated pruning of stems from a plant, which has been shown to enhance rooting success in many species (Black, 1972; Copes, 1983; Copes, 1992; Howard et al., 1989; van den Driessche, 1983). Black and Copes have suggested that hedging stimulates rejuvenation or reinvigoration. However, Clark (1981) and Franclet (1983) suggested that the effect of hedging may be to induce the production of shoots which remain stable and juvenile and possess a high endogenous capacity for root formation. The results of this study support the latter interpretation. In other words, hedging may affect the overall rooting of a clone by reducing the proportion of terminal (Position I) and distally located axillary meristems that produce shoots which are poor rooters. And simultaneously, allowing a greater proportion of proximally located axillary meristems to form shoots (with high endogenous adventitious rooting capacity) that, if left unhedged, remain dormant. Similarly, this interpretation could be applied to serial propagation or even tissue culture treatments, which may serve to select out (epigenetically) difficult-to-root meristems from within a clone and concurrently select for, by their continued propagation, those which root readily.

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Spent Mushroom Substrate as a Soil Amendment for Ornamental Plants

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Fresh spent mushroom substrate (SMS) as a medium amendment for containerized nursery crop production is a promising alternative to disposal of this co-product of mushroom production. Fresh SMS is the material that is removed from a mushroom house and used without further weathering. The two objectives of this study include: (1) identification of key factors involved in its successful use and (2) demonstration of effective use of SMS in plant nurseries.

The plant material includes both bedding plants and woody perennial species. Results demonstrate that the key limiting factor in the use of SMS for plant production is high soluble salts (>30 mmho cm^{-1}). Leaching can reduce these high soluble-salt levels. In addition, special consideration needs to be given to the reduction in potted media volume over time due to the continued decomposition that occurs during plant production. Spent mushroom substrate as the sole growing medium was not as effective as when SMS was amended with a nursery growing mix (pine bark, peat, and gravel). Both *Tagetes* 'Yellow Girl' and *Spiraea* ×*vanhouttei* were grown in 0%, 25%, 50%, 75%, and 100% mixtures of SMS and a nursery potting mix. Both species grew well in SMS and nursery growing (pine bark, peat, and gravel) (1 : 1, v/v) mix.

INTRODUCTION

Chester County, Pennsylvania is the center of mushroom production in the United States (Kelsey, 1996). The majority of the spent mushroom substrate (SMS), a co-product of mushroom production is high in salts, unsightly, odoriferous, and a potential surface and groundwater contaminant. Currently, SMS is piled and weathered in fields at depths no greater than 3 ft per EPA regulation (Kelsey, 1996).

Spent mushroom substrate can be used as an amendment in potting media at nurseries and greenhouses. However, high salt levels found in SMS present significant challenges in growing plants if not managed properly (Szmidt, 1995). Recommendations have involved the long term field weathering of SMS as a means of mitigating the salt effect. Chong and Hauersma (1997) recently reported leaching of fresh material immediately following removal from the mushroom house, or at least prior to planting, can lower the soluble salts to acceptable levels for growing plants (<3,000 mmhos).

Spent mushroom substrate is not physically stable. The material remains biotically active for a period with temperature, moisture, and composition determining the rate of decomposition. Decomposition results in an overall increase in bulk density over the span of a growing season (Gerritis, 1994). This increase results in reduced aeration that can lead to undesirable growth effects and disease problems.

Today, when the idea of recycling by-products and acting in an environmentally conscious manner is encouraged, if not demanded, the utilization of SMS in an environmentally sound method has become necessary.

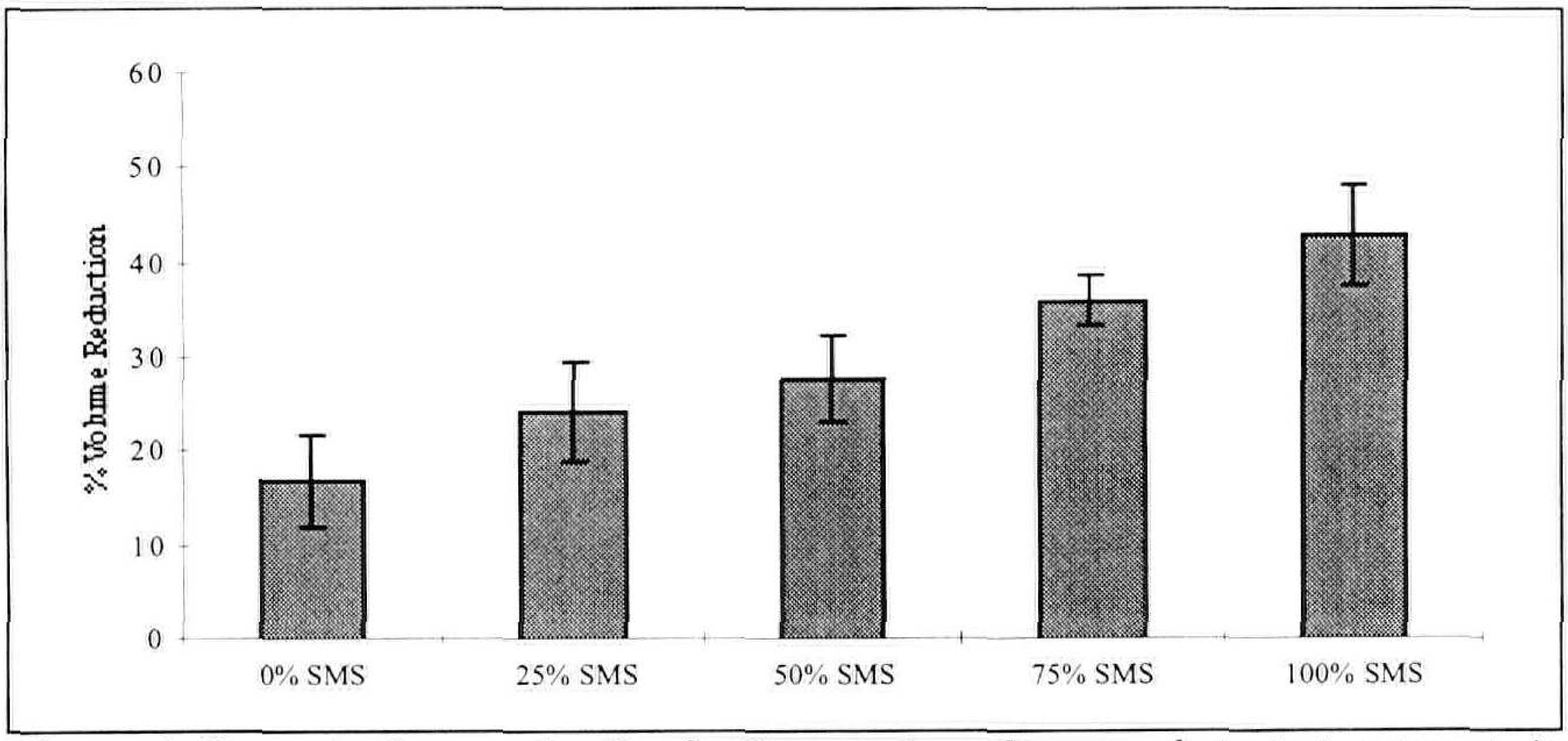

Figure 1. Percent volume reduction for five spent mushroom substrate treatments in 3-gal pots with *Spiraea* ×*vanhouttei*.

MATERIALS AND METHODS

Objective 1. Spent mushroom substrate was obtained from three different mushroom growers. For each trial, the SMS from each source was individually mixed with a pine-bark-based growing mix (pine bark, peat, and gravel, by volume) at rates of 0%, 25%, 50%, 75%, and 100%.

Marigolds were grown in greenhouses at University Park, Pennsylvania. Three replications, four subsamples from three sources and five ratios for each source were arranged in a randomized complete block design. The SMS was leached to reduce the soluble salts to levels below 3 mmho cm^{-1}. One marigold seedling was transplanted into pre-mixed medium in a 4-inch pot. Marigolds were irrigated as needed to maintain moist conditions and fertilized with 21N-7P-7K at 250 ppm N at each irrigation. Greenhouse temperatures were set at a minimum of 60°F at night and ventilation beginning at 70°F during the day. At the end of an 8-week period, fresh and dry weights were recorded.

Figure 2. *Tagetes* 'Yellow Girl' marigolds grown in 0% to 100% spent mushroom-substrate-amended media.

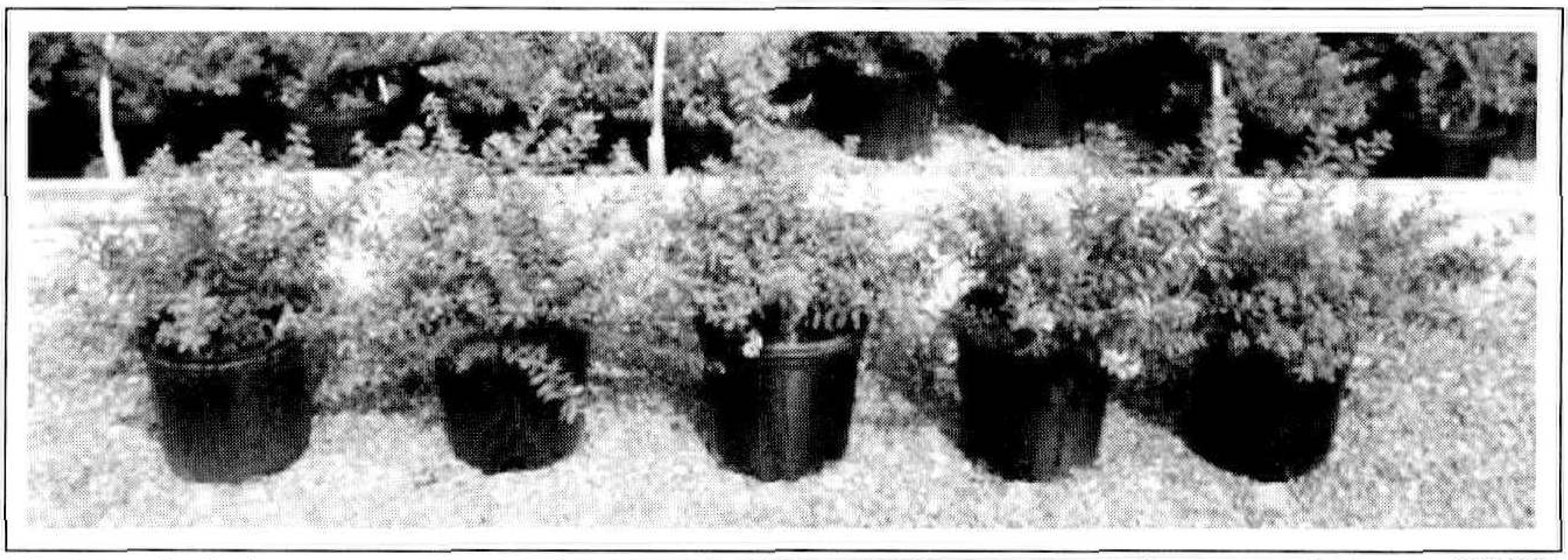

Figure 3. *Spiraea* ×*vanhouttei* grown in 0% to 100% spent mushroom substrate (SMS) amended media at Hansen Nurseries.

Spiraea plants were grown at Hansen Nursery, Sassamansville, Pennsylvania. Spent mushroom substrate from one source was mixed with the pine-bark-based medium at rates of 0%, 25%, 50%, 75%, and 100%. Each mix was potted in 3-gal containers, replicated 15 times, and arranged in a completely randomized design. Plants were irrigated with an overhead spray system and fertilized with 18N-6P-12K Osmocote (3 tbsp per pot). At the end of the cropping season, nondestructive measurements including height, widest width, and the ninety degree width were taken and averaged to create a growth index.

Objective 2. In planting *Spiraea* in 3-gal pots at Hansen Nursery, the medium was made level with the pot rim. Volume reduction was measured as the depth that the medium had shrunk from the pot rim after a given period of time.

RESULTS

Spent mushroom substrate tends to shrink over time as it continues to decompose. It has been found that the degree of shrinkage follows a straight-line relationship with increasing ratios of SMS : pine-bark-based medium. In situations where SMS constitutes the entire medium, reduction in volume can approach 25% to 30% (Fig. 1). The excessive salt levels associated with SMS can be reduced with approximately 4 to 5 leachings, each equivalent to the volume of water held in the container.

In experiments conducted on *Tagetes* 'Yellow Girl' marigolds, media ratios of 25% to 50% SMS produced plants superior to those grown in standard nursery pine bark, peat, and gravel medium (Fig. 2).

In experiments conducted at Hansen Nurseries, *S.* ×*vanhouttei* showed no visible difference in growth response between the various SMS treatments. This trial demonstrates that a nursery grower is able to incorporate SMS successfully into a container production operation (Fig. 3).

SUMMARY

- Marigolds showed a positive response at SMS levels between 25% to 75%.
- Spirea showed no visible difference in growth response.
- Volume reduction was linearly proportional to an increasing SMS content.

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Chong, C. and **B. Hamersma.** 1997. Container growing with spent mushroom compost. Mush. News Vol. 45 No. 11, 12-14.

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Kelsey, T, W. Timothy, and **L. Singletary.** 1996. Conflict at the rural/urban interface: mushroom farms and composting in a suburbanizing environment. Compost Sci. Util., Summer 89-96.

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Comparison of Propagation Mixes

Cathy Kowalczyk and Carolyn Mihalega
Willoway Nurseries, Inc., 4534 Center Road., Avon, Ohio 44011 U.S.A.

The propagation department at Willoway Nurseries in Avon, Ohio is always trying different techniques to increase rooting percentages and rooting quality. With well over 1 million cuttings propagated annually, timing as well as different methods of cutting preparation, including IBA treatments, are always evaluated in order to obtain the best results.

This year we decided to trial a coir medium for some of our hard-to-root species as well as those species that take longer periods of time to root. The mix we used was Sun Gro Horticulture coir mix available in 3-ft^3 loose bags. The components of this mix are simply coir pith and coarse perlite (3 : 1, v/v).

Coir is a waste product of the coconut industry and is produced in Sri Lanka, the Philippines, Indonesia, Mexico, and parts of the Caribbean and South America. Sri Lanka is the leading processor of coir product and is reportedly one of the most reliable and consistent sources. Coir produced there also has the lowest electrical conductivity. Coir is the name given to the fibrous material of the coconut fruit. Coconut husks are ground and the long fibers are screened out. The long fibers are used in the manufacturing of such products as brushes, floor mats, hanging basket liners, and automobile seat and mattress stuffing. After the long fibers are extracted, the coir dust (called pith) is used to produce horticultural growing mixes.

Coir mixes have many desirable properties. These mixes wet rapidly and uniformly. Drying of coir media is also very uniform and requires less watering after root development. These mixes retain high porosity which in turn improves root development and quality. The pH range of coir is between 5.6 to 6.5. Electrical conductivity can range from 0.3 to 2.9 mmhos cm^{-1}. Electrical conductivity is the most important factor that producers and coir users must consider.

Coir has a slightly lower nutrient holding capacity than Canadian sphagnum peat moss. Fertilizer programs may need adjusting when using this product.

Our "in house" propagation mix works well for most of the cuttings that we propagate. Its components are sphagnum peat moss, styrofoam, hardwood bark, sand, haydite (compressed shale product) (5 : 2.5 : 1 : 1 : 0.5, by volume) and 7#

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agricultural lime per yard. Certain species are also rooted with our sand/perlite mix. The coir mix gave us another opportunity to improve our rooting percentages and root quality on hard-to-root species and those species that require a greaterlength of time to root. The Sun Gro Horticulture coir/perlite mix was very successful on *Syringa, Magnolia, Viburnum* (fragrant), *Rhus,* and *Berberis* to mention a few. Many species rooted up to 3 to 4 weeks quicker in the coir mix than our propagation mix, allowing those cuttings to be transplanted earlier.

The coir and perlite mix was a bit more costly than our "in house" propagation mix. However, the rooting response that was achieved outweighed the extra expense. The coir fiber is also sold in bulk, as a compressed brick, so it is possible to make your own mix. It has been reported, however, that this "raw" material is very difficult to break up and mix with other components, such as perlite. It is more economical to purchase it as a commercial mix such as the coir and perlite (3 : 1, v/v) that we used in our trials. Many other formulations, using different media components are commercially available as well.

Cocount-Coir-Based Media Versus Peat-Based Media for Propagation of Woody Ornamentals

Jeffrey Stoven and Heather Kooima
Bailey Nurseries, Inc., 6750 103rd St. South, Cottage Grove, Minnesota 55016 U.S.A.

This trial was conducted in order to determine if coconut-coir-based media makes a significant difference in the propagation of *Juniperus* versus the standard growers media containing peat.

INTRODUCTION AND METHODS

Woody ornamentals such as the *Juniperus* species, have several that are both easy and difficult to root. One cultivar from each of these two categories was tested. Several varying amounts of coir were used in the media trials. Each medium contained a different amount of perlite.

The media were as follows:

- MetroMix and perlite
- Coconut coir
- Coconut coir and perlite (3 : 1, v/v)
- Coir and perlite (1 : 1, v/v)

The juniper cuttings were stuck and rooted for approximately 10 weeks. After this time, the cuttings were evaluated for root growth. They were removed from their trays and the medium was washed off. Cuttings were divided into three groups: no callus, callous only, and callous and roots.

RESULTS

The results were impressive. The rooting that was planted in the peat-based standard media and coconut-coir-based media were more successful. 'Maney' had agricultural lime per yard. Certain species are also rooted with our sand/perlite mix. The coir mix gave us another opportunity to improve our rooting percentages and root quality on hard-to-root species and those species that require a greaterlength of time to root. The Sun Gro Horticulture coir/perlite mix was very successful on *Syringa, Magnolia, Viburnum* (fragrant), *Rhus*, and *Berberis* to mention a few. Many species rooted up to 3 to 4 weeks quicker in the coir mix than our propagation mix, allowing those cuttings to be transplanted earlier.

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RESULTS

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Table 1. Effect of media type on the rooting of *Juniperus chinensis* 'Maney'.

Treatment	Uncallused	Callused only	Callused and rooted
Standard	67	30	3
Coir (100%)	15	79	6
Coir (75%) + perlite (25%)	37	43	20
Coir (50%) + perlite (50%)	35	35	30

Table 2. Effect of media type on the rooting of *Juniperus horizontalis* 'Hughes'.

Treatment	Uncallused	Callused only	Callused and rooted
Standard	20	7	73
Coir (100%)	3	17	80
Coir (75%) + perlite (25%)	1	24	75
Coir (50%) + perlite (50%)	3	32	65

a 100% increase in the number of cuttings with callous and root formation (Table 1). The highest percentage with callus and roots was 30% for *J. chinensis* 'Maney'. This was exceptional being this is a difficult species to root. In the *J. horizontalis* 'Hughes' cultivar the increase ranged from 80% typically rooted to 97% with callus and roots (Table 2).

Perlite seems to have a varying effect on the rooting of junipers. In the difficult-to-root 'Maney', the perlite and coir medium (1 : 1, v/v), appears to have the best rooting percentage. With 'Hughes' the 100% coir without perlite had the highest percentage of callus and roots alone. Therefore, the level of perlite added to the medium makes an impact with the different cultivars.

CONCLUSION

This trial took place during the winter months with a rooting temperature of 75°F and an air temperature of 40°F. These results could vary during the other seasons. Perlite level influenced the rooting of the cultivars and should be looked at in more detail. Coconut coir did increase the rooting of these juniper cultivars. More trials should be conducted to determine the right level of coconut coir. The end result could make a positive impact in the production of woody ornamentals.

Composting at Weston Nurseries

Jon Knight, Mike Mannero, and Dana Baron
Weston Nurseries, Inc., Route 135, P.O. Box 186, Hopkinton, Massachusetts 01748 U.S.A.

Weston Nursery started composting leaf and yard waste in the 1960s. The owners believed in the importance and value of the finished product. In the 1960s the nursery purchased all of its leaves from a local municipality. The leaves were then trucked onsite and composted. The finished product was then used in the container mix and field production.

Weston Nursery started to accept leaves and yard waste on site in the mid 1990s when towns were mandated by state authorities to stop dumping leaves, grass clippings, etc. into landfills. During this period the nursery recognized a need to staff the leaf collection site. It was at this time that Weston Nurseries instituted a tipping fee to offset the cost of staffing.

Until recently the nursery accepted leaf and yard waste only. In 1997 the nursery recognized a demand to accept brush. Since its initiation, the compost site accepts approximately 1500 yards of brush annually. A tipping fee of $7.50 is charged per yard.

CUSTOMER BASE

The compost facility is open to all landscapers and area residents. The commercial accounts (landscapers, municipalities, etc.) are all charged tipping fees. Local area residents can use the facility free of charge.

TIPPING FEES

Table 1 shows yardage and income for 1998.

- Brush - $7.50 per yard
- Leaves and yard waste - $4.50 per yard

Table 1. Yardage and Income for 1998.

Brush 1500 yards @ $7.50 per yard	$11,250
Leaf and yard waste 6000 yards @ $4.50 per yard	$27,000
Total	$38,250

COMPOST MANAGEMENT

The leaf and yard waste material, is put into windrows. The size of the windrows varies, but in general they are around 150 to 200 ft long and about 9 to 10 ft high. The material is turned periodically until the composting process is completed. This generally takes up to a year to complete. When the composting process is completed the finished product is screened and utilized by the nursery in several ways:

- Container mix
- Field preparation
- Bulk sales

The brush is pushed up into large piles. When the piles reach a certain size we outsource a tub grinder to reduce the piles. The tub grinder turns the brush into a coarse wood chip product, which then needs to be composted before it is ready for use.

COMPOST USED AT WESTON NURSERIES

Container Soil Mixes.

- Shrub mix: bark, compost, and sand (3 : 1 : 1, by volume)
- Ericaceous mix: bark, compost, and stone chips (4 : 1 : 1, by volume).

Field Operations. Compost is applied at a rate of 135 yards per acre. This is equivalent to a depth of 1 inch.

Bulk Sales.

- Wholesale customers.
- Retail customers.

Six-row Perennial Planter

Paul Zelenka Jr.
Zelenka Nursery Inc., 16127 Winans St., Grand Haven, Michigan 49417-0001 U.S.A.

In 1998 Zelenka Nursery Inc. met with Holland Transplanter of Holland, Michigan, to design a mechanical means of planting bare-root perennial divisions. Up to this point we had only had limited success with our transplanter. Holland Transplanter and the Zelenka staff met several times and through trial and error came up with a 6-row planter which met our needs.

The planter was needed to plant hosta, daylilies, grasses, peony, and astilbe but still be flexible enough to plant *Taxus* rooted cuttings, *Buxus* cells, and even seedlings if required. This flexibility was a must after speaking with many growers who had perennial planters gathering dust. Also the bed width needed to fit our land use, harvest equipment, pruning riggs, and spray equipment. The biggest obstacles were: a pocket which could grip a small or nonexistent stem and the irregular shape of many root systems. A pocket was designed with a rubber yoke to hold a division below the soil level. Also two metal fingers supported the roots and guided them into the soil. The irregular root shape was accommodated by a wider and deeper shoe.

Other amenities were also added: larger bins and a shelf to hold reserve plants, hydraulic wheels to adjust for uneven beds and to aid in transporting, bench seats to accommodate taller workers, two heavy duty counters, and soil guides to ensure even soil packing.

After almost a year of talking and planning we took delivery in March 1999. After working out a few bugs this machine increased our planting rate in excess of 125% over hand planting of perennials. It has also increased our units per acre from 35,000 to 50,000 units per acre. It has allowed us to mechanically plant 95% of our bare-root divisions. About 5% are still hand planted due to severely irregular root shapes. *Taxus*, *Buxus*, and seedlings planted without a hitch.

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In conclussion, this planter has met our expectations and will for many years to come. I would like to thank Victor Villadsen, Judy Tourner, Jamie Hernandez, and the staff at Holland Transplanter in the preparation of this poster display.

Six-row planter specifics:

- Manufacturer: Holland Transplanter
- Uses: Plants a wide variety of bare-root perennials and rooted cuttings.
- Dimensions: 221 inches long × 100 inches wide
- Spacing: 6 rows 10 inches × 9.5 inches (can be adjusted by adding or removing pockets) 60-inch bed
- Units per acre: 50,000
- Units per hour: 2450 to 2800
- Tractor: 65 hp or larger with stepped-down transmission
- People: 8
- Cost: 14,500(Tractor not include)
- Comments: Designed to plant bareroot perennials. Prior to this unit most perennials were hand planted. Planting rate has improved 125%.

Plant Propagation Education — A Community College Approach

Normand Hotte
Algonquin College, 1385 Woodroffe Ave., Nepean Otario K2G IV8 Canada

We are a community college in Nepean, Ontario, Canada (near Ottawa — Canadian Zone 5a) that offers a 2-year Diploma course in Horticulture and Landscaping. Our students graduate as Horticulture Technicians. Although much of the nursery business is conducted in the southern regions of our province, we do not overlook this aspect of horticulture in training and educating our students, as many of them will venture to seek employment in the larger nurseries after graduating. Thus, our approach to training students in the field of plant propagation focuses primarily on the nursery industry in eastern North America.

Although the plant propagation course is conducted in the winter semester of the first year, attention is given to propagation throughout the 2-year program in courses such as Herbaceous Plants 1 and 2, Woody Plants 1 and 2, and Greenhouse Applied 1 and 2. As students become familiar with plant identification, they are also taught cultural requirements including specific propagation techniques of the plants. For example, during a Woody Plants 1 class, *Caragana arborescens* 'Pendula' will be talked about as being a grafted plant, and the terminology of grafting is first introduced. Later in the plant propagation class, grafting of ornamental trees and shrubs will be shown in class through the use of slides taken at various nurseries throughout southern Ontario and Eastern United States. The students will then perform various styles of grafting in the propagation lab and grow the propagated plants in the greenhouse until time to plant in the nursery. Much of the grafting that we do is on *Malus* rootstock, where we bud ornamental crabapple cultivars by either

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T-budding or by chip budding onto potted and actively growing *M. antanovka* or *M. baccata* rootstock. This is done in February using dormant scionwood collected in December and stored in our refrigeration units at 32 to 36°F. We have also bench grafted upright juniper cultivars using the side veneer graft onto *Juniperus* ×*media* 'Hetzii' 1-year hardwood cuttings, which the students rooted the previous winter. Our second year Greenhouse Applied 1 class will T-bud in September a range of nursery stock such as *Gleditsia tricanthos var. inermis* 'Shademaster' and 'Sunburst' and will also graft in early spring other rootstock in the nursery.

Space in the 4000 ft^2 greenhouse is limited during the winter semester for all the student projects. Timing and careful juggling of crops is critical for success. We have four greenhouse sections each aprox. 1000 ft^2, one section dedicated to propagation. This area is equipped with misting lines down each bench and controlled by a digital HARDI misting controller, hot-water underbench heating pipes, and independent environmental temperature control. We can root a large range of cuttings including evergreen hardwood cuttings, herbaceous, and softwood cuttings. Students are encouraged to take cuttings from as many plants as they wish, usually learning by trial and error that for example, Boston ferns (*Nephrolepsi exaltata* 'Bostoniensis') will not root from leaf cuttings.

Seeds are purchased from suppliers throughout the world as we attempt to increase our plant collections on campus. Our bedding plant seeds are purchased from Stokes Seeds Ltd. in St.Catherines, Ontario. The students appreciate the cultural information written on the back of each seed packet while we can order many taxa of seeds in small quantities. After germination and transplanting is done by the propagation students, the seedlings are grown in the greenhouses in spring and planted out by the student summer staff so that the plants are fully displayed at the start of semester in the fall for new and returning students to learn.

The Combined Proceedings of the International Plant Propagators is the basis for the readings and research material that our students use for their projects. This year, the Continuing Education class had to research a topic within the Proceedings and prepare a 15-min presentation on their findings. Our collection in the Resource Center is incomplete as we are missing some earlier volumes. There is a complete set of the Combined Proceedings locally at the Central Experimental Farm in Ottawa that our students have access to.

From time to time, an event presents itself which we feel would be of benefit to our students. For example, last February, we bussed a group of students to Drummondville, Quebec to attend a 2-day conference on plant propagation held by the "Institut Quebecois du Developpement de Horticulture Ornemantale" which is run along the same lines as the International Plant Propagators Society annual conference. Our students are encouraged to join the I.P.P.S. and at last year's annual conference in Toronto, Canada, a number of our students were in attendance.

The Use of Second Generation Cuttings to Increase the Rooting and Quality of Micropropagated Elms

Deborah D. McCown
Knight Hollow Nursery, Inc., 3333 Atom Road, Middleton, Wisconsin 53562 U.S.A.

INTRODUCTION

Knight Hollow Nursery has been micropropagating selections in the genus *Ulmus* for over 15 years. We have always found elms growing in vitro problematic. Shoot proliferation is poor and generally single-node pieces are required to obtain bud break. This multiplication protocol requires a significant amount of tedious labor for each subculture. Additionally, in vitro elm shoots produce large numbers of "blind" buds, nonviable buds in the leaf axils, thus complicating multiplication using nodal explants. The shoots that are produced in microculture are slender, almost thread-like. Consequently, the rooting success of microcuttings is variable with a 50% rooting/acclimation success being considered a good response. Time required to root, acclimate, and grow elms using microcuttings to a shippable size is approximately 12 weeks.

Many of the elm propagules we produce are shipped into states with strict import limitations. Plants must be micropropagated and grown in a greenhouse or other facility that is protected from insects from 1 June through the first killing frost. Because of the difficulties in elm micropropagation and such interstate shipping limitations, we needed to explore other methods of generating high quality elm cuttings.

USE OF ROOTED MICROCUTTINGS AS STOCK

Microcuttings of elm cultivars stuck en mass in flats rooted non-uniformly (Fig. 1). Rooting success varied from approximately 35% to perhaps 50%.

Figure 1. Response of microcuttings of *Ulmus parvifolia* 'Emer II', Allee™ elm (PP# 7552).

Three hundred cuttings were stuck in Pro-Mix BX in a standard 1020 flat. Cuttings were stuck in late August and moved to a greenhouse in mid November. Photograph was taken when microcuttings were moved from our rooting facility to the greenhouse.

The flats of rooted micropropagules were then moved to a greenhouse that was minimally heated in the winter months with night temperatures set at 35°F. Since *U. parvifolia* is a southern elm, we determined 600 h of temperatures below 40°F was probably sufficient to break dormancy. At the end of the 600 h of chilling (last year, this occurred by the 3rd week of January), flats were then moved to a greenhouse with a minimum daytime temperature of 60°F and a nighttime temperature of 45°F. After the surviving plants in these flats produced a new growth flush, 2-inch (5-cm) cuttings were harvested periodically and stuck in flats using the same procedures as originally used for the microcuttings. Due to the branching characteristic of juvenile elms, more cuttings than were originally planted in each flat could be harvested. Generally, we got a 4- to 5-fold increase in number of harvested cuttings over the number of surviving plants in each flat.

Experience from several years of trying to root elm cuttings taught us that we would again get variable results unless we treated the second generation cuttings with rooting hormone. A Dip 'n Grow treatment at a 30% dilution rate gave us the favorable results (Fig. 2).

Figure 2. Growth of newly rooted elm cuttings that originated from flats of rooted microcuttings (as in Fig. 1).

All rooting occurred under 24-h artificial light with bottom heat. Daytime temperatures were 68°F; nighttime temperatures were a minimum of 50°F. Three hundred cuttings were stuck per flat.

Cuttings rooted quickly; root initials were visible in less that 1 week. Cuttings were shippable in 3 to 4 weeks at which time they were 3 to 4 inches (10 cm) tall and fully acclimated to normal humidity. Quality grading yielded 275 shippable cuttings out of a flat of 300 cuttings stuck, or a 92% yield.

CONCLUSIONS

The basic conclusion is that microcuttings of elm are of low quality and generally produce variable rooting and acclimation results. However, the surviving micropropagated plants make excellent stock for a new generation of cuttings. Such "second generation" cuttings will root with high success and produce quality propagules within a month.

Cercidiphyllum japonicum 'Amazing Grace' a New Weeping Katsura Selection From Theodore Klein

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Cercidiphyllum japonicum 'Amazing Grace' is a weeping form of katsura tree which has recently been released to the marketplace. The primary features which set apart this selection from the typical weeping form are plant size, branching, and fall foliage color.

The typical *C. japonicum* 'Pendulum' grows from 15 to 25 ft tall and unless staked and heavily pruned, will form a dense tangled mass of weeping branches. 'Amazing Grace' forms a larger spreading specimen up to approximately 40 ft tall or more with an equal or greater spread. The plant will form a sturdy graceful but ascending main trunk with only minor support initially. Branching is far more open than 'Pendula' and produces a superb specimen in the landscape.

Foliage color in *C. japonicum* 'Amazing Grace' is a soft blue-green in the summer, changing to a bright golden-yellow in fall. This is in contrast to the typical *C. japonicum* 'Pendulum' which often fails to produce much in the way of fall foliage color.

This new release is a selection of the late Theodore Klein of Crestwood, Kentucky who also released *Cersis canadensis* 'Silver Cloud' and *Ilex opaca* cultivars 'Judy Evans' and 'Virginia Giant'. *Cercidiphyllum japonicum* 'Amazing Grace' was discovered around 1960 as a chance seedling in an Indiana nursery. Two of the original plants produced are at Bernheim Arboretum and Cave Hill Cemetery in Louisville, Kentucky. The plant is easily produced by budding onto seedling rootstock. A 6- to 7-ft-tall budded whip is easily produced in one season under Kentucky growing conditions. Budwood is available from Bernheim in limited quantities.

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Hosta Propagation

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INTRODUCTION

Hostas are a group of popular shade tolerant herbaceous perennials known more for their foliage effects than for their flowering characteristics. Increased market demand by consumers due in part to the long market window of a plant sold primarily for its attractive foliage, and the number of cultivars available, has resulted in limited supplies of popular cultivars.

Hosta taxa are commonly propagated by division or tissue culture. Sexual propagation is used by hybridizers to develop new cultivars, but is not a commercially viable propagation method because seed propagation does not produce a plant identical to the parent. Hostas are slow growing (Armitage, 1997) and simple division does not produce adequate numbers of new plants. "Mowing" and "the Ross method" (Grenfell, 1996) and the application of benzyladenine (BA) (Garner, et al., 1995, 1996, 1997; Hoover, et al., 1998; Keever, 1995; Keever, et al., 1995a and 1995b; Keever and Bass, 1998; Schultz, et al.,1998) increase the number of offsets resulting in a greater number of divisions that are identical to the mother plant. Tissue-culture propagation has produced large numbers of plants, but its use as a propagation technique requires careful monitoring in both the technique and evaluating the product of that technique.

DIVISION

Division is the primary means of propagating hosta. Field-grown plants are traditionally dug and divided in the spring when the shoots are dormant or less that 1 inch (2.5 cm) (Nau, 1996). The third spring of growth is when the greatest number of divisions occurs (Aden, 1990a). Most think of division as the separating of shoots with roots, but it is possible to remove the terminal shoot or dormant bud and further divide to a plant having a single lateral bud and a root or rhizome (Summers, 1969). As this results in significant wounds there is an increased chance of disease.

Amateur gardeners divide in the spring, but to maintain a good landscape appearance, may separate the division away from the mother plant with a sharp trowel or knife without removing the mother plant from its site. Even though spring division is considered the optimum time to produce a quality containerized plant for market in a relatively short time of 2 to 5 weeks (Nau, 1996), nurseries may divide to fill an order anytime (Summers, 1969). It seems hostas are frequently divided from late winter through fall (Davis, 1998). Diana Grenfell recommends removal of leaves from plants divided in the summer (Grenfell, 1996). David Beattie recommends a reduction in leaf area and shade whenever dividing after the leaves have fully expanded (Beattie, 1996). Older plants tend to be more difficult to divide (Gear, 1996). While young plants and certain cultivars are easily pulled apart, knives or pruners are sometimes needed to cut divisions apart. Selecting large vigorous plants to maintain as mother plants (Davis, 1998) rather than smaller plants typically used (Keever et al., 1995b) will result in more divisions, as will proper care and providing a good growing environment.

TECHNIQUES TO INCREASE THE NUMBER OF DIVISIONS

Hosta do not naturally produce a large number of shoots that can be harvested. This limitation has forced the development of several methods to increase the number of potential divisions. The objective of increasing the number of divisions is to be able to sell more plants but increasing the size of plants in the landscape is desirable as well.

The first methods to increase the number of divisions is "mowing" the plants down to approximately 0.5 inches (1.25 cm) during the summer forcing buds to break and increasing the number of shoots. The second, "Ross-izing" or the "Ross method", is described as cutting through the stem just above the basal plate down through the basal plate to the roots and then making a similar cut at 90° to the first, essentially quartering the plant in the late spring or early summer (Ross, 1982, Zumbar, 1991). Additional shoots will develop at the cuts. The third method is to apply benzyladenine, a cytokinin, as a foliar spray or drench to the plants (Garner, et al.,1995, 1996, 1997; Hoover, et al., 1998; Keever, 1995; Keever, et al., 1995a and 1995b; Keever and Bass, 1998; Schultz, et al.,1998) to increase offset formation. In several studies the application of BA resulted in offset formation when the controls produced no offsets. Researchers have used the synthetic cytokinin Pro-shear (BA) in several of their studies and found it to be effective in increasing the number of offsets formed, but consistent results have not been found for all cultivars (Garner, et al.,1995).

N-6-benzylaminopurine (BAP) has been shown to be effective in increasing offsets in 11 hosta cultivars (Hoover et al., 1998). The presence of offsets at the time of BA application resulted in fewer offsets being produced compared to plants with no offsets at the time of a BA application (Keever and Brass, 1998; Keever, et al., (1995b) reported that the stage of development of the offsets resulting from cytokinin treatments affected the rooting of the stem cuttings. Those offsets with two or more leaves unfurled rooted more readily that those with less unfurled leaves. It would appear that a research program developed around BA treatments to increase offset formation would benefit *Hosta* propagators.

SEED PROPAGATION

Hosta species can be propagated by seed. However, sexual propagation is mostly limited to producing plants from seed resulting from selected crosses by hosta hybridizers. Methods of hybridizing hosta, including: selecting parents, the handling and storage of pollen, making the cross, and producing plants from seed are described in *The Gardener's Guide to Growing Hosta* by Diana Grenfell (1996) and *The Hosta Book*, Second Edition edited and compiled by Paul Aden (1990b). Rarely does a good variegated hosta cultivar result from uncontrolled pollination (Micheletti, 1996).

Once seed has been produced it can be directly planted or stored in a cool dry environment for a short term or in a refrigerator for a longer term. Hosta seed viability varies greatly (Aden, 1990b). Direct seeding of important crosses would be recommended until a hybridizer becomes familar with the seed characteristics of his/her crosses.

Seeds are broadcast on a fine textured medium, keep moist, and at 60 to 75°F (16 to 24°C) in order to achieve good germination. Light will be needed once the true leaves appear. Hybridizers and amateur gardeners alike must be diligent in culling out the unacceptable seedlings. The use of hosta standards (similar cultivars currently available) for comparison will help in the selection of quality species plants and new cultivars.

TISSUE CULTURE

Considering the slow production of plants by division, it became inevitable that tissue culture would (and does) play a critical role in the propagation of hosta. Tissue culture has made it possible for hosta to be in every landscape. Many new cultivars are propagated by tissue culture. A recurring criticism of tissue culture for hosta propagation has been the production of plants that are not true to type and the older the culture gets the more likely there will be "sports". Meyer (1980) found that when 'Francis Williams', a popular cultivar, was propagated by tissue culture only 45% of the plants produced were variegated, with the rest being 45% a gold sport and 10% a green sport. These kinds of early results with tissue culture of hosta were discouraging and resulted in resistance to tissue-cultured plants in the market.In order to have a successful tissue-culture program with hosta it is important to be able to identify the form of the cultivar at roguing. The purchaser of tissue cultured plants should be able to evaluate the plants they receive to ensure the plants they invest in are true to cultivar. It can take 4 to 5 years before *Hosta* taxa reach maturity of form and color (Armitage, 1997). Establishing standards (plants known to be true to the cultivar grown to the same stage of development) to use to compare plants at different stages of growth in order to rogue several times through the production cycle is important. The source of the tissue to be cultured, florets, flower scapes, or shoot tips can make a difference in maintenance of parent plant characteristics, as can environmental treatments (Papachatzi, et al., 1981). Certain environments and production factors can affect the variegation or form of a plant in nursery production or in the landscape. A loss of variegation can occur in areas of high temperatures when nitrogen fertilizers are used (Armitage, 1997) causing plants to be mistakenly thought not to be true to type. Considering the precise and fastidious care required to propagate hosta in tissue culture the commercial success of this technique is a tribute to those propagators that produce vigorous, disease-free, true-to-name plants.

CONCLUSIONS

Tissue-culture techniques will continue to be refined by both large and small commercial laboratories to eliminate deviant plants from the production cycle and, ultimately, from getting to the consumer. Division will be the propagation method of choice for hosta, especially for small nurseries and specialty nurseries that sell a few plants of many different cultivars. It would seem that treatments and cultural practices that increase offset formation would benefit the propagator, the nursery grower, and the landscaper.

It would be interesting to know if commercial propagators and nurserymen have adopted the application of cytokinin products to increase hosta offset formation.

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Evaluation of Root Exudate Production in Six Sorghum Accessions: Chemistry and Root Morphology Studies

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Sorghum (*Sorghum bicolor*) has been used for several decades as a cover crop during crop rotation in nursery production. Sorghum is one of a number of plant species which produce natural products involved in pest management. Sorgoleone production in sorghum has been identified as a component of the exudate associated with the inhibition of other plant (weed) growth.

A detailed study was performed in order to compare root-exudate production and chemistry in six different sorghum accessions (SX - 15, SX - 17, 855F, 8446, Della, and johnsongrass). Comparisons were based on the quantity of root exudates produced and related chemical constituents within each extract. In order to provide mass quantities of root exudates, a novel system of root-exudate collection was developed using a capillary-mat system for seedling growth. Six sorghum accessions were then grown on this system and roots exudates were collected, dried, and weighed. Components of these root exudates were then separated via reverse-phase HPLC, with UV detection set at 280 nm. Each accession differed with respect to the quantity of root exudate produced. Moreover, the amount of each chemical constituent produced varied by sorghum accession. To further understand how the root exudates of sorghum are produced, gross root morphological studies utilizing light microscopy and CryoSEM were performed. These two techniques revealed that root exudates are produced and released by root hairs. Ultrastructure studies were performed using transmission electron microscopy and showed that root exudates are being deposited between the plasmamembrane and the cell wall before secretion of the hydrophobic droplets by the root hairs. Intracellularly, exudate production appears to originate in the endoplasmic reticulum.

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Seed Vigor Testing Using Computer-aided Image Analysis

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INTRODUCTION

Standardized seed vigor tests must be developed for greenhouse-grown flower species. Current vigor tests used to evaluate large-seeded agronomic crops are generally not useful for evaluating smaller-seeded flower species. One alternative is to use radicle length in seedlings grown under controlled environments as an indicator of seed vigor. For that purpose a seed vigor test was developed that uses digital images taken using a flat bed scanner to measure radicle length in small-seeded flower species. The superior resolution of the flat bed scanner for collecting images has allowed for easy computer-aided measurements of the small seedling parts seen in flower species. A novel, clear substrate that provides similar moisture holding properties to standard germination blotters used by commercial seed analysts has allowed for quick image acquisition without removing seedlings from the Petri dish. In addition, improved commercially available software allows for accurate analysis of radicle length regardless of growth orientation or radicle overlap in the Petri dish; thus avoiding the need to grow seedlings on an oriented, slant-board. Correlations between seedling growth (radicle length, total seedling

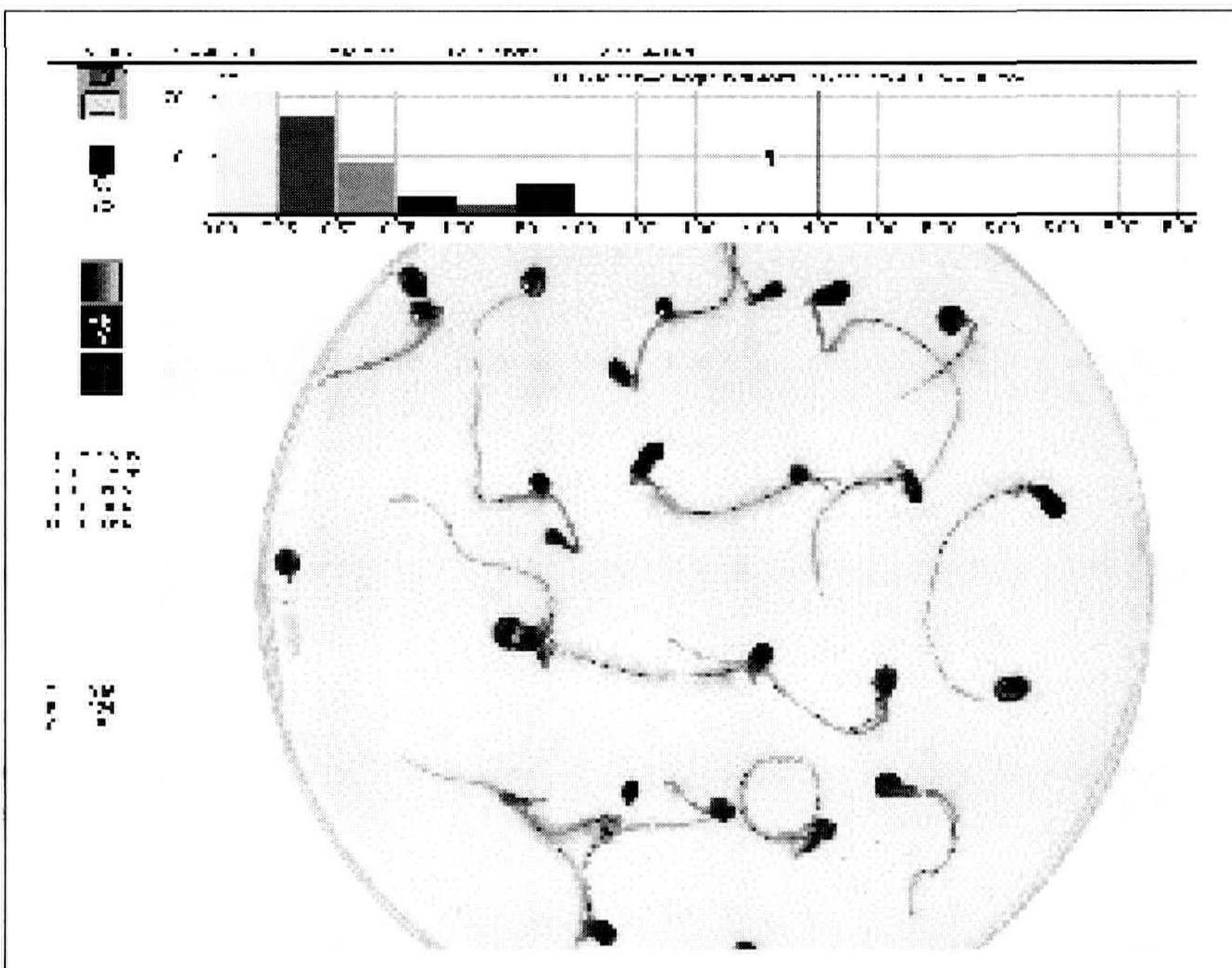

Figure 1. Typical digital image of impatiens. The computer traces the seedling parts.

length, total seedling area) with other vigor tests (saturated salts accelerated aging) and greenhouse plug flat emergence show this method to hold promise as a standardized vigor test.

METHODS

Seeds were germinated on either blotter paper, germination paper, or a clear medium in petri dishes. Seedling length was measured using digital images captured on a flat bed scanner and analysis software from Regents called Rhizo.

RESULTS

A key aspect of this research was to develop a germination medium that is clear to allow flat bed scans of germinating seeds in the Petri dish. Figure 1 shows a typical flat bed scan through this clear medium.

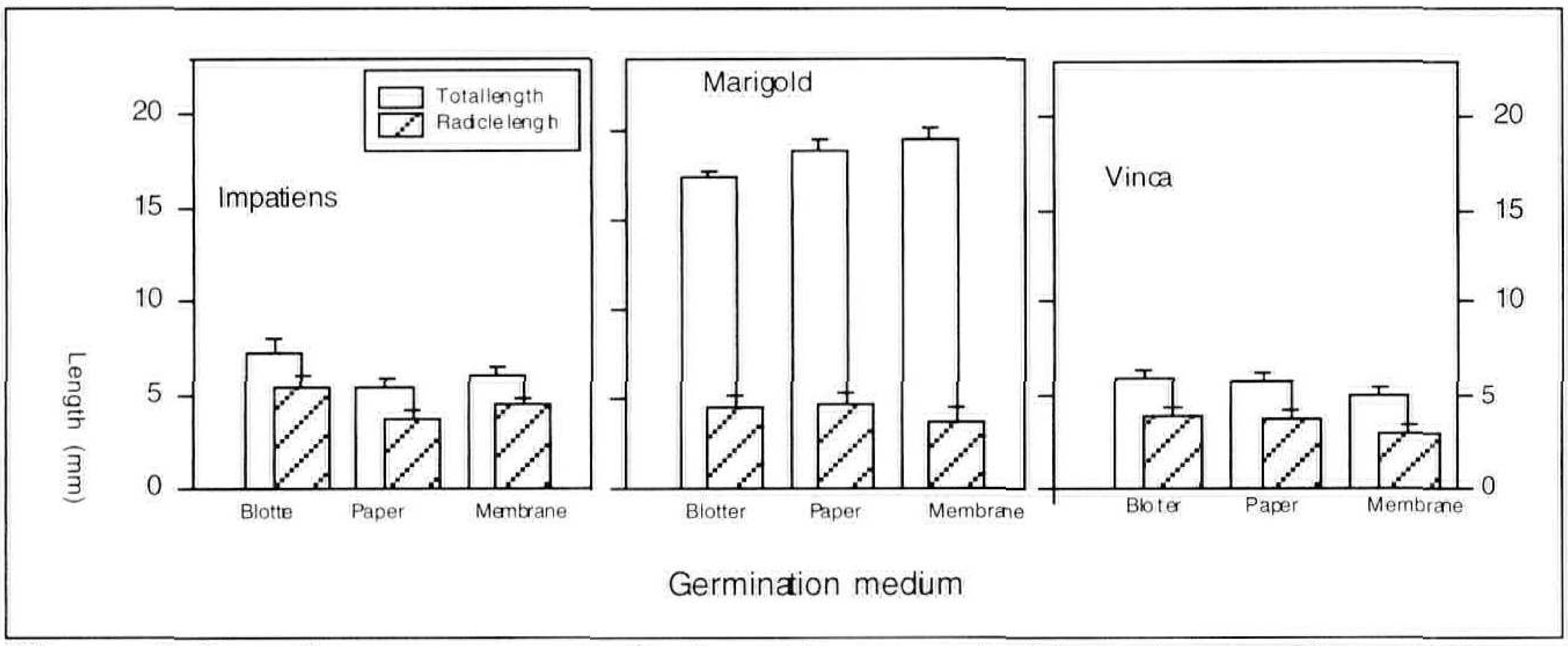

Figure 2. Length measurements for impatiens, marigold or vinca on three different germination media.

In addition, it was shown that seeds of impatiens, vinca, and marigold all germinated in a similarfashion on all three germination media evaluated (Fig. 2).

Computer-aided imagery was used to measure radicle lengths after 7 days in a petri dish standard germination test and correlate that length with other measures of seed vigor. For two seed lots of *Viola ×wittrockiana*, pansy, radicle length was consistent with the vigor status of the seed lot (Table 1).

Table 1.

Seed lot	Standard germination (%)	Germination rate	Radicle length	Greenhouse plug test (%)
1	77	13	14	59
2	87	15	19	93

This system is an improvement over other attempts to use computer-aided assessment of digital images because it provides digital images that do not vary due to external lighting; it uses software that can evaluate radicle length in a Petri dish assay that does not require a slant-board for straight radicle growth; it relies on standard germination techniques used by every seed lab; it uses a clear substrate to replace the opaque blotter to allow digital images to be taken within the Petri dish; and accurate measurements of seedling parts is performed in under 2 minutes per Petri dish.

Acknowledgments. This work was supported by a grant from the Gloeckner Foundation and seed provided by Goldsmith Seeds, Inc.

Use of Compressed Hardwood Sawdust Pellets as a Weed Control Mechanism for Container Plants

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INTRODUCTION

Weed control in container plants can be a daunting task. Nurseries which only grow one type of plant can easily find suitable chemical herbicides for effective weed control. However, smaller more specialized nurseries, such as Lorax Farms, with literally hundreds of different species must carefully considered the choice of herbicides. Alternative methods do exist and the theory is straight forward. Many of our most annoying weeds depend upon light for adequate seed germination — excluding the light automatically stops seed germination. The late Jim Cross of Environmental Nurseries used pine straw as a mulch for container plants, others in my experience have used cocoa shells a costly but effective mulch material. In both cases the mulches were effective at inhibiting light from reaching the weed seeds. Articles in *American Nurseryman* and the *Journal of Environmental Horticulture* suggests that pelletized paper might make for an effective mulch (Smith, 1998 and Smith et al., 1998). While the literature suggests that it is effective, the pelletized paper, like the cocoa shells, is expensive and it shares a lack of availability with pine straw in the Northeastern part of the U.S.A. Pelletized wood is readily available and seemed to be a reasonable alternative to the previously mentioned materials

METHODS

Fifty hybrid *Hemerocallis* plants with clean soil and no weeds were treated with the volume equivalent of 400 cc of hardwood pellets by spreading the pellets evenly over the soil. Alternatively, an equal number of *Hemerocallis* plants with clean soil were selected as a control with no other additives. The pellets were watered soon after they were applied and expanded approximately three-fold. After 3 months of normal growing conditions outdoors the plants were tabulated for weed control. For the plants treated with the pellet mulch there was no indication of reduced growth or

This system is an improvement over other attempts to use computer-aided assessment of digital images because it provides digital images that do not vary due to external lighting; it uses software that can evaluate radicle length in a Petri dish assay that does not require a slant-board for straight radicle growth; it relies on standard germination techniques used by every seed lab; it uses a clear substrate to replace the opaque blotter to allow digital images to be taken within the Petri dish; and accurate measurements of seedling parts is performed in under 2 minutes per Petri dish.

Acknowledgments. This work was supported by a grant from the Gloeckner Foundation and seed provided by Goldsmith Seeds, Inc.

Use of Compressed Hardwood Sawdust Pellets as a Weed Control Mechanism for Container Plants

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INTRODUCTION

Weed control in container plants can be a daunting task. Nurseries which only grow one type of plant can easily find suitable chemical herbicides for effective weed control. However, smaller more specialized nurseries, such as Lorax Farms, with literally hundreds of different species must carefully considered the choice of herbicides. Alternative methods do exist and the theory is straight forward. Many of our most annoying weeds depend upon light for adequate seed germination — excluding the light automatically stops seed germination. The late Jim Cross of Environmental Nurseries used pine straw as a mulch for container plants, others in my experience have used cocoa shells a costly but effective mulch material. In both cases the mulches were effective at inhibiting light from reaching the weed seeds. Articles in *American Nurseryman* and the *Journal of Environmental Horticulture* suggests that pelletized paper might make for an effective mulch (Smith, 1998 and Smith et al., 1998). While the literature suggests that it is effective, the pelletized paper, like the cocoa shells, is expensive and it shares a lack of availability with pine straw in the Northeastern part of the U.S.A. Pelletized wood is readily available and seemed to be a reasonable alternative to the previously mentioned materials

METHODS

Fifty hybrid *Hemerocallis* plants with clean soil and no weeds were treated with the volume equivalent of 400 cc of hardwood pellets by spreading the pellets evenly over the soil. Alternatively, an equal number of *Hemerocallis* plants with clean soil were selected as a control with no other additives. The pellets were watered soon after they were applied and expanded approximately three-fold. After 3 months of normal growing conditions outdoors the plants were tabulated for weed control. For the plants treated with the pellet mulch there was no indication of reduced growth or toxicity due to the mulch. All plants bloomed and grew normally. In this particular test, fertilizer was applied as a liquid feed at 400 ppm monthly.

RESULTS

At the conclusion of the test period the following data was recorded:

1) Nine plants were selected at random from a block of 50 of nontreated containers. Result: Total weeds = 47.
2) Nine plants were selected at random from a block of 50 treated with hardwood pellets as mulch. Result: Total weeds = 7.

DISCUSSION

As the results show weed control with the pelletized woods was quite good. Treated plants had less than one weed per container, whereas, nontreated plants had an average weed population of greater than five weeds per pot. The treated plants show a weed reduction of close to 85%.

Equally surprising was that the pellets did not remain as pellets but instead break down upon the application of water to form a barrier of sawdust that completely covers the soil surface. Once degraded the sawdust barrier remains intact as a mass and almost completely inhibiting light from reaching the soil surface. It is also interesting to note that few new weeds seem to be able to gain a foothold in the sawdust barrier as it turns a deep brown to almost black up oxidation with the air. This color change may account for the lack of wind blown seeds becoming established.

From this test it appears that the wood pellets are safe and effective at reducing weed populations from becoming established in container plants.

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Utilizing Insect Traps and IPM in Plant Propagation

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INTRODUCTION

Integrated pest management, IPM, is being accepted by more and more nursery professionals, as another tool in daily nursery practices. The cost of various chemicals, liability of worker exposure, environmental concerns, and other considerations, have led nursery professionals to seek more economical alternatives of insect or other vector control and elimination.

Mention the term IPM and people look at you like you are speaking a foreign language. These various procedures offer safer and less toxic ways to deal with vectors of infestation and disease. The use of insect traps will allow the nursery operator or propagator to make more accurate determination of what insect is causing damage to a particular crop or plant. This further helps to determine which product or course of action to follow to effect either reduction or elimination of a given pest.

Let's examine several ways that traps can be utilized in the nursery by the propagator. First, there is the issue of a chemical control agent. Simply applying insecticide every other Tuesday, does not guarantee elimination of an insect problem. As we have seen, timing the application of a product with either insect emergence or the presence of an insect, is a better method of control. Using a trap to locate the vector or the numbers, or even the sexes present, will determine your course of action. If you are using biological control methods, the trapping information will help to better target the release of parasitic or predatory insects to help control an insect outbreak.

As an example, I have several residential garden clients who have rose gardens and ornamental crab apples, in their landscapes. Setting out Japanese beetle traps before adult emergence will help to determine the density of that particular population. In 2 cases, I have reduced the amount of insecticide applied, due to effective trapping. I have for several years, used the Trece™ Japanese beetle trap, which combines a pheromone and scent lure on the top of the trap jar. In the severest case, I was collecting upwards of 80 adults a day from a 1500 ft^2 garden. This was over a period of about 45 days. In this case, I used about 2 pints of Dursban™ insecticide, which was applied to the plants that showed the worst feeding damage. Before using traps in combination with dusts, the amount of insecticide would have been five times greater.

This brings up another point. You can use traps in your stock blocks or display beds to help monitor the presence of insects. This becomes crucial when plants are coming into fruit or when cuttings will be ready for processing. Leaves and stems that are chewed up or damaged by egg laying are not suitable for cutting production. Once you have trained a crew or grower what to look for, they can walk the blocks with a sprayer for spot treatments. They can even collect the insects out of the traps to determine a population count. This further helps to keep costs under control which of course makes the bottom line look good as well. Insect traps will work around the clock. When you go home at night, many insects emerge from hiding to begin feeding.

The well known pest of rhododendrons, the black vine weevil, is almost impossible to spot during the daytime. Trapping for these nocturnal pests helps the nursery operator to "see" what's going on when no one is at the shop. Many beetles, moths, and wasps are not out during the daytime. We know that they are in the nursery or greenhouse by the evidence of the damage they leave behind.

Traps will also help you to see other things around your nursery as well. An example would be the presence of whitefly on yellow sticky traps, but not on plants in the greenhouse or containers. Do you have weeds growing along or in the gravel or soil of your production area? Left to multiply, the weeds and the whitefly will soon be everywhere. You can also set out traps along common hedge rows, or in tree stands adjacent to your operation. Woody plants like box elder, silver maple, honeysuckle, and others attract certain pests, which if not detected could move into your property and cause damage.

Consult with your agriculture extension agent or nursery inspector to determine what insects are likely to be found in your area. Then you can make the right choice in the type of trap you will need. These traps generally come with lures which are either sex pheromones or scent-based. The type of insect you are dealing with, will dictate the type of attractant that you will be using. You must also take into account the placement of the trap. This is crucial in attracting the greatest number of insects. They may be placed either in front of or behind crops. In some cases, the traps must be among the plants or even below them, subterranean, in order to catch insects.

Insects traps in most cases are not stand alone products. They are, however, an integral part of a nursery operator's tool kit to control and eliminate insect pests. When used effectively, they will help you to gain better control over not only insect vectors, but also operating costs, environmental concerns, and promote a better quality product for your operation. Which of course, will provide you with a successful and profitable business.

The horticulture industry is competitive, like any other business. By using all the tools at your disposal, you will be able to compete with all the other propagators who are in the same arena as you are.

Many Uses for Polyproplene Fabric

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FROST PROTECTION IN SEEDBEDS

After seeds germinate in the spring, and prior to a killing freeze, we cover sensitive species with 1.5-oz yd^{-2} fabric. These days we can cover six seedbeds at a time. The material is supported on galvanized steel rods, bent into a curve, and pushed into the ground on either side of the seedbed. The edges of the cloth are held in place with sufficient soil to prevent wind damage. These row covers are removed in early summer after all danger of frost has passed and the growing season begins.

ROOTING TISSUE-CULTURED PLANTLETS

Some tissue-culture plantlets such as lilacs are rooted at the nursery. Unrooted microplants are received from the lab in tubs of agar. These "cuttings" are removed from the tub, basal ends are lightly dipped in Hormodin # 1, then planted in plug trays filled with Sunshine Mix #5. The plug trays are placed on benches over moistened capillary matting, then lightly covered with 0.5-oz yd^{-2} fabric. Fungicides for *Botrytis*, etc., are applied later in the day over the top of the moistened fabric. The acclimation tunnel is covered with plastic and shade. An occasional light mist is all that may be needed for a week or two. When the plants are rooted, the fabric is removed and, over time, the plugs are weaned from the acclimation tent.

SEED PRETREATMENT BAGS

Certain seeds need germination inhibitors "flushed out" with a long, aerated water soak. One way to do this is to toss them in a pond. Seeds are weighed out in seedbed quantities, then wrapped and tied in a piece of 0.5-oz yd^{-2} fabric. A plastic gunny sack is weighted with a piece of steel, and enough seed for several seedbeds is placed in the bag which is then tied off. A cable tied to a piece of log chain is sent to the bottom. Bags are wired on to the cable, then turned with a pole every couple of days. Protect as needed from varmints. After 3 weeks the beds are seeded, in this case with *Fraxinus pennsylvanica*, and mulched with sawdust.

Monarda Mildew Resistance

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"UNDER OUR CONDITIONS" should be at the top of every plant disease-resistance trial report. We learn in our first plant pathology class that the amount of disease on a plant depends upon disease pressure. Disease pressure depends upon local growing conditions. However, it has become all too convenient to view the results of a plant disease resistance study . . . often because their results were conveniently printed in a table . . . and cite these results as if the same plant will respond the same way everywhere.

The bee balm resistance studies referred to here are the result of similar tests at two dramatically different sites, the Chicago Botanic Garden in Illinois and in the North Carolina Mountains. The tests were similar except that plants in Chicago were irrigated "as needed" while those in NC received over an inch of rainfall per week as well as almost daily morning fog during June, July and August.

Table 1. Early bloom season (8 June 1998) *Monarda* cultivar taxa ratings from North Carolina.

Highly resistant (40% to 50% defoliation)		
Claire Grace	Marshall's Delight	Stone's Throw Pink
Moderately resistant (50% to 60% defoliation)		
Beauty of Cobham	Blaustrumpf (syn. Blue Stocking)	Cambridge Scarlet
Comanche	Mahogany	Vintage Wine
Poorly resistant (over 60% defoliation)		
Cerise	Cherokee	Colrain Red
Croftway Pink	Elsie's Lavender	Gardenview Scarlet
Jacob Cline	Jean Stewart	Loddon Crown
Monarda didyma	Raspberry Wine	Sagittarius
Scorpion (syn. Scorpio)	Schneewittchen (syn. Snow White)	Violet Queen

Table 2. Late bloom season (27 July 1998) *Monarda* taxa mildew ratings from North Carolina.

Highly resistant (60% to 70% defoliation)		
Beauty of Cobham	Blue Stocking Blaustrumpf (syn.)	Cambridge Scarlet
Elsie's Lavender	Mahogany	Marshall's Delight
	Vintage Wine	
Moderately resistant (70% to 80% defoliation)		
Cerise	Cherokee	Claire Grace
Colrain Red	Comanche	Croftway Pink
Gardenview Scarlet	Jacob Cline	Jean Stewart
Loddon Crown	Raspberry Wine	Sagittarius
Scorpion (Scorpio)	Stone's Throw Pink	Violet Queen
Poorly resistant (over 80% defoliation)		
Monarda didyma	Schneewittchen (syn. Snow White)	

Table 3. *Monarda* taxa mildew ratings from Chicago Botanic Garden.

Highly resistant (under 25% infection/defoliation)		
Blue Wreath	Colrain Red	Falls of Hill's Creek
Gardenview Scarlet	Marshall's Delight	Ohio Glow
Raspberry Wine	Rose Queen	Violet Queen
Moderately resistant (26% to 50% infection/defoliation)		
Aquarius	Blue Stocking	Thundercloud
Feuerschopf(syn. Firecrown)	Kardinal	Petite Delight
Prärienacht (syn. Prairie Night)	Schneewittchen (syn. Snow White)	Souris
Squaw	Stone's Throw Pink	Sunset
	Monarda didyma	
Poorly resistant (over 51% infection/defoliation)		
Adam	Beauty of Cobham	Cambridge Scarlet
Croftway Pink	Claire Grace	Granite Pink
Mahogany	Mrs. Perry	Panorama
Präriefeuer (syn. Prairie Fire)	Purpurkrone *Monarda fistulosa*	Schneewittchen

Part of the difference in plant responses can be attributed to rainfall and humidity since high humidity but a lack of free water on a leaf surface favors the development of powdery mildew when temperatures are between 59 and 86°F. Temperatures rarely exceed 86°F in summer in the mountains of North Carolina while summer temperatures above 86°F are common near Chicago.

Winter temperatures are also a major factor in both survival and vigor of monarda. Cultivars that performed well under the severe mildew pressure of North Carolina which did not perform well in Chicago all sustained winter injury in Chicago, whereas, 'Marshall's Delight', which displayed excellent mildew resistance in both locations did not show winter injury.

CONCLUSIONS

On the rare occasion when similar research can be compared on different sites, pay close attention to what is being measured. The Chicago study shows a multi-year summary while the North Carolina data is from 1 year with tables showing response at different times during the growing season.

When research is similar enough, always refer to the research done where growing conditions are most similar to local conditions when choosing which cultivars to grow.

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Nonchemical Alternatives for Container Weed Control

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INTRODUCTION

Container production has been increasing rapidly and represents about 30% of Canadian-grown nursery stock. While U.S. nurseries effectively control weeds in containers with a spectrum of licenced herbicides, Canadian nurseries have traditionally resorted to different means — primarily hand weeding, in conjunction with weed discs, and a limited number of herbicides (recently registered) for container use (OMAFRA, 1997).

The typical weed control disc is round and has a slit so that it can be fitted around the stem of the plant. It should be easy to apply; should fit snugly on top of the container mix; should not easily be dislodged or wind-blown; should allow penetration of water to the mix; should not support weed germination and growth on its surface; and should be durable and cost effective (i.e., perhaps costing less than 5 or 10¢ for a 2-gal container).

In the early 1980s, Connon Nurseries (AVK, Rockton, Ontario) introduced the Weed Guard in Ontario. This disc is made of semi-rigid plastic similar to a 45 rpm record. Small holes allow water to penetrate — but also the escape of weeds. Two discs in off-set positions provide better weed control than a single disc.

Chong et al. (1989) reported an 85% reduction of container weeds using Mori-Guard discs made from geotextile fabric (1⁄16 inch thick, introduced by Mori Nurseries, Niagara-On-The-Lake, Ontario) or from foam (1⁄8 inch thick, similar in consistency to polyfoam used for winter storage protection and packaging). The foam disc tended to curl upward at the edges, partially exposing the surface of the container mix. Since then, several types of weed discs have "come and gone" because they did not meet one or more of the criteria listed above. It is noteworthy that, during the past 12 years, the Ornamental Nursery Program at the Horticultural Research Institute of Ontario has annually reused the same fabric discs obtained originally from Mori Nurseries. Unfortunately these discs are unavailable, most likely, due to the high unit cost.

There seems to be a renewed interest in weed discs (Mervosh, 1999), due in part to limited choice and experience with container herbicide use, and also to their potential negative impact on both plant and environment.

Since 1998, we have been evaluating several "new-generation" weed discs fabricated from materials such as pressed peatmoss, cardboard, fabric, and plastic (Table 1), and comparing them to mulches of pine sawdust and paper mill waste, to various herbicides, to selected "old-generation" weed discs, and to the Mori "Weed Bag". This patented method of weed control was introduced by Mori Nurseries in the early 1990s. Black polyethylene sleeves with pre-punched holes are placed onto the containers in the same fashion that florist plants are prepared for market.

Although our trial is still in progress, we believe it interesting and worthy to draw further attention at this time to "nonchemical ways" of container weed control.

Table 1. Description of various "new-generation" weed control discs.

Disc	Material	Comments
Tex-R Geodisc	Polyester and viscose fabric	Easy to apply; fits well but easily wind-blown; made with or without copper coating for preventing surface germination of weeds.
Biodisc	Pressed peatmoss	Easy to apply; fits well; starts to degrade within days after application.
Corrudisc	Corrugated cardboard	Awkward to apply due to rigidity of the material; initially fits well but degrades starting after the first irrigation; it loses shape, separates into layers and progressively deteriorates within days.
Enviro LID	Moulded plastic	Snaps into place; growing medium needs to be at least 3.8 cm (1.5 inches) below top of container or the lid does not fit properly and may dislodge; expensive.

Previously, we made and used weed discs fashioned from commonly used synthetic weed fabrics. We suspect that there may be other materials that are inexpensive and potentially worthy of similar use. There is a good market for the right product.

Nonchemical alternatives will remain important as long as herbicide use is restricted, and may become even more so should there be similar restrictions in other jurisdictions.

Acknowledgements. This project was supported jointly by Willowbrook Nurseries, Fenwick, Ontario and The National Research Council of Canada, Industrial Research Assistance Program (IRAP).

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Forcing Environment Affects Epicormic Sprout Production from Branch Segments for Vegetative Propagation of Adult Hardwoods

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Successful rooting of cuttings of adult hardwoods often requires that propagules be removed from the more juvenile parts of trees. Latent or dormant axillary buds found in the bark of a tree usually possess some juvenile characteristics because these buds developed when the stem or branches were first formed. In this study we evaluated the effect of different forcing environments on production of epicormic sprouts from latent buds on branch segments taken from adult trees of four hard-to-root hardwoods. In addition, we evaluated whether these sprouts were suitable as softwood or semi-woody cuttings for vegetative propagation.

In the spring of 1997 and 1998, one to four lower branches were removed from each of three phenotypically superior trees of black walnut (*Juglans nigra*), white ash (*Fraxinus americana*), white oak (*Quercus alba*), and northern red oak (*Q. rubra*). Branches were cut into 24 cm long segments ranging from 2.0 to 8.0 cm in diameter. Branch segments were place horizontally in plastic 1040 trays filled with moist perlite and set in one of seven greenhouse forcing environments. Forcing environ-

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In the spring of 1997 and 1998, one to four lower branches were removed from each of three phenotypically superior trees of black walnut (*Juglans nigra*), white ash (*Fraxinus americana*), white oak (*Quercus alba*), and northern red oak (*Q. rubra*). Branches were cut into 24 cm long segments ranging from 2.0 to 8.0 cm in diameter. Branch segments were place horizontally in plastic 1040 trays filled with moist perlite and set in one of seven greenhouse forcing environments. Forcing environments include: (1) water daily with 5 cm of water and allow to drain, (2) water daily with 5 cm of water and keep flooded 1 cm deep, (3) mist daily with 10 cm of water in 45 minutes and allow to drain, (4) mist daily with 10 cm of water in 45 minutes and keep flooded 1 cm deep, (5) place inside a humidity tent and water every other day with 5 cm of water, (6) cover trays with humidity domes and water every other day with 5 cm of water, and (7) place on shaded mist bench and mist for 6 seconds every 8 minutes during daylight hours. Due to limited greenhouse space, the forcing experiment had to be replicated over time.

Large differences were found in the number of epicormic sprouts produced per segment among trees within each species even when branch segments were taken from trees of the same age. Overall, white ash, black walnut, white oak, and northen red oak produced 5, 7, 12, and 15 sprouts per m of branch segment, respectively. The most frequently discussed forcing environment in the scientific literature, the water daily treatment, was one of the better treatments for forcing epicormic sprouts on all four hardwood species. Previous studies showed that if the epicormic sprouts were kept dry while watering the perlite, these sprouts could be surface disinfested and used as explants for in vitro culture. Branch segments under the intermittent mist treatment started producing epicormic sprouts later and produced more sprouts over a longer period of time than branch segments within any of the other six forcing environments. Shoots from the intermittent mist treatment made excellent leafy softwood and semi-woody cuttings; however, they may be unsuitable for use as explants for in vitro culture.

Branch segments in the humidity dome treatment also produced more sprouts than the branch segments in the water daily treatment. Because epicormic sprouts of white and northern red oak showed episodic growth, the sprouts inside the humidity dome had to be harvested as softwood cuttings during rapid stem elongation with immature leaves. Branch segments in the humidity tent treatment produced only half as many epicormic sprouts as branch segments in the humidity dome treatment. Presumably, the condensation inside the humidity domes reduced light penetration and kept air temperatures lower than in the humidity tent. Branch segments in the water daily with flooding and mist daily with flooding treatments produced the lowest number of epicormic sprouts. The perlite layer in these two flooded treatments retained high levels of bacteria which may have depleted the amount of oxygen, nitrogen, and carbohydrates available for epicormic sprout growth. An exploratory study with walnut and white oak showed that segments cut from the basal portion of the lower branches produced as many sprouts as segments from along the central stem.

Softwood cuttings from epicormic sprouts 4.0 cm or longer of black walnut and white oak treated with 0.1% to 4.5% IBA in talc and placed under intermittent mist failed to root. Subsequently softwood cuttings of all four species were dipped for 10 to 50 minutes in various dilutions of Dip 'n Grow (1% indole-3-butyric acid and 0.5% napthaleneacetic acid). Over 80% of semi-woody epicormic sprouts from white ash dipped in a 1 : 24 or 1 : 99 dilution of Dip'n Grow rooted and could be transplanted to rootrainers for subsequent field planting. None of the softwood cuttings of black walnut or white oak rooted. Of the few northern red oak cuttings that rooted, all rooting occurred on semi-woody sprouts with full leaf expansion that had not been killed by fungi growing in the vermiculite-perlite rooting medium.

In conclusion, epicormic sprouts can be successfully forced on branch segments cut from adult trees either by periodically watering the perlite medium or by using intermittent mist to maintain a high humidity micro-environment. Epicormic sprouts tended to root best if taken as semi-woody leafy cuttings.

Bara Minerals

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The primary aim of Bara Mineraler is to develop and introduce inorganic products for plant production and landscape gardening. The company has its own production of clay granulate based on the specific clay occurring in the Bara region. Addition of clay granulate to horticultural peat means a considerable increase in its value. Most plant species grow better and get an improved quality in growth substrates with clay granulate from Bara Mineraler AB. There are, however, several mineral products other than clay which are of value for plant production. Within Bara Mineraler we are doing our utmost to provide Scandinavian growers with the most suitable qualities of pumice, perlite, and vermiculite. Furthermore, knowledge and equipment make it possible to develop a series of products for use in public environments as well as in home gardens. These include ornamental pebbles and other stone products for paths and plantations, anti-skid lightweight gravel ("Strävis"), and clay for waterproofing of ponds.

INTRODUCTION

Bara Mineraler produces clay granulate. The primary use is for mixing with peat for the production of plant growth substrates. There are also other applications, for example, as part of an additive to feedstuffs, as means for reduction of algal growth in lakes and ponds, for improvement of the water-retention capacity of sandy soils, and for waterproofing of ponds.

The clay is extracted from pits in the Bara Region, of Sweden. It is a geologically special plateau clay with a favourable mixture of clay minerals. Before extraction starts the topsoil layer is carefully removed and after the clay deposit has been exploited, the topsoil is brought back as a cover. The uncovered clay is loosened, air-dried, and transported to a storage area. During processing it is ground into small pieces, heated to a minimum of 80°C, and dried. The heating kills nematodes, viruses, and weed seeds. This heating procedure together with the favourable qualities of the clay has resulted in the approval of the product by RHP (Regeling Handelspotgronden, The Netherlands). After drying the clay the granules are sifted and sorted into two fractions: 0.1 to 2.0 mm and 2 to 6 mm; both fractions can be mixed and are mixed with peat. After mixing with peat even the smallest fractions remain in the pots and are never washed out of the containers on to the tables or to watering systems.

Tests with equal amounts per volume of the two dry clay fractions have shown that the fine fraction becomes moist faster than mixtures with coarser clay fractions.

The Bara Mineraler clay granulates contain silica (silicon). Cucumbers and roses grow better in substrates with 0.6 or 0.75 mmol silica liter^{-1}. Tests have shown that access to silica gives plants improved resistance against attacks by plant pathogens and vermin.

ARGUMENTS FOR ADDING CLAY TO PEAT

- Pot plants, both big and small, have a lower centre of gravity, which means better stability; they do not overturn so easily, an important fact during production as well as sales.
- Plants grown in peat mixed with clay have a better quality with respect to colour, shape, and keeping qualities.
- Watering is easier. The clay absorbs water and transfers it to peat and roots. After drying the clay immediately absorbs added water. Without clay it takes longer to get dry peat resaturated with water.
- The wilting point is not as distinct as in pure peat. During desiccation a plant's water absorption from a clay-peat mixture starts to slow earlier than from the pure peat. This results in a more gradual transition to wilting.
- The addition of clay gives more compact plants. The reduced access to water is a safe method to produce compact plants. Pure peat is not suited for this type of plant shape adjustment because the limit between access to and shortage of water is very sharp. Addition of clay makes it possible to govern the retardation in a much safer way.
- The clay slows the release of nutrients. Thanks to the ion-exchange capacity of clay colloids, added cations (positive ions) will be adsorbed to the clay granulates. This reduces the risk of leaching as well as root killing caused by high nutrient levels. It is, therefore, to some extent possible to raise the total concentration of nutrients which, in its turn, makes it easier to get compact plants.
- The clay content of a peat mixture stabilises the pH, which is favourable for a more balanced uptake of nutrients.

HOW MUCH CLAY IS NEEDED?

There is no simple answer to this question. It depends on the kind of plant (Table 1), on the cultivation method applied, and on the aim of the cultivation. Experiences collected from practical growing show that the following additions of the clay granulate fraction 2 to 6 mm results in advantages and quality improvements, which correspond to the expectations of the grower.

WHICH IS THE BEST GRANULATE FRACTION?

Both fractions have the same effect. The distances between the granules and the surface of the roots are of importance for the uptake of water and nutrients. The shorter the distance, the bigger the effect. When adding the same amount of clay, the smaller fraction is more effective which has also been confirmed in Dutch tests.

Table 1. Amount of clay granulate fraction 2 to 6 mm added per cubic meter of peat showing quality improvements in plant growth.

Kind of plant	Clay granulate (kg)
Begonia	50
Campanula	70
Poinsettia (*Euphorbia pulcherrima*)	50
Pot mums (*Dendranthemum*)	70
Pot roses (*Rosa*)	70
Pelargonium	100
Perennials	70
Pansy (*Viola* hybrids)	50
Nursery plants	70
Primula	100

SILICA

It is a common opinion among substrate researchers that silica improves a plant's defense against pathogens and, furthermore, results in a more stable growth. Bara Mineraler clay granulate when mixed with peat increases the accessible silica content 15 to 20 times (Table 2).

Table 2. Availability of silica after mixing Bara Mineraler clay with peat.

Growth substrate	Silica (mmol $liter^{-1}$)	pH
100% peat	0.03	3.8
90% peat +10% Bara Mineraler clay granulate	0.50	5.0
90% peat +10% Bara clay granulate, after 3 weeks	0.58	4.9
90% peat + lime+ 10% Bara clay granules, after 3 weeks	0.42	6.0

Grodan — Properties and Use

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INTRODUCTION

Current trends in the pot plant industry still indicate that production methods should aim at uniformity and high quality ("A" products) if nurseries are to survive the intensified competition of the future. In the future, quality will be determined not only by the nursery but also by customers, for whom decorative value and long life are important quality parameters. The production processes must also use fewer growth-retarding chemicals. To meet these demands a wide range of cultivation parameters must be carefully controlled; the most important of these are connected with the development of robust, compact plants which have plenty of lateral shoots and flower buds. In other words, cultivation practices should aim at high plant activity to ensure optimum water and nutrition uptake leading to a high transpiration rate which will result in robust and compact plants.

The environment in which plants grow influences their rate of transpiration. High humidity conditions will reduce transpiration and thereby reduce the transport of water and nutrients from the root zone. But the root zone environment is probably the most important factor with regard to plant activation, and this is where non-absorbing Grodan granulate proves its great worth in modern pot-plant production. Grodan granulate works like an air pump, thus providing roots with the oxygen they need to keep plants constantly active and growing optimally. Grodan granulate also makes sure that plants have a better root-top ratio. This air pump effect of Grodan granulate is a result of the following product properties:

- Maintains good peat structure, and thus structural stability.
- High air : water ratio.
- Faster draining.
- Works like an air pump in connection with watering.
- Forms a natural part of the pot substrate.
- Makes saturation easier after pot substrate has dried out.

Grodan granulate is particularly valuable when:

- Cultures are produced under conditions where it is difficult to maintain high transpiration rate.
- Plants are grown under natural short-day conditions.
- Plants have a poor root system.
- Culture period is long.
- Cultures are produced partially or wholly in the open air.
- Cultures are irrigated with ebb-and-flood systems.

GRODAN GRANULATE IS VERY EASY TO HANDLE AND USE

To achieve the full effect of Grodan, experience shows that 20% to 30% Grodan granulate should be added to the peat. If less is added, the effect of Grodan granulate is reduced considerably. The amount of Grodan granulate to be added should be calculated based on the volume of the peat.

Grodan granulate can be added to the final mix by your peat supplier, or you can mix it in yourself. If you choose to mix it in yourself, make sure that the mixing time is as short as possible to keep the structure of the peat and granulate.

Grodan granulate is made from a mineral wool fibre which has been shown not to be harmful to health. However, since January 1999 it is has been labelled "locally irritating" due to a well known and temporary mechanical irritation of the skin on direct contact with the fibres. When working with Grodan granulate, you should minimise the dust level (e.g., by spraying with water or by dust extraction). We also recommend the use of suitable working gloves. More detailed recommendations about working with Grodan are available from Grodania.

Fertilisation after addition of 25% Grodan granulate is the same as normal, but the amount of lime must be reduced by 25% when the peat is treated with lime. The same irrigation system can also be used, although you should expect irrigation to be necessary slightly more frequently than normal. This is a clear advantage, since it provides the basis for an increased activity in the root zone.

Cocopor® a Cocofiber- and Peat-Based Soil Additive

Rainer Thomsen
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Cocopor® is a special, low-salt containing coconut-fiber additive consisting of 80% nut fibers and 20% sphagnum peat. This product is used for all types of containerized plants and is particularly advantageous in connection with automatic irrigation systems for ornamental plants including perennials. Cocopor® is part of almost all standard substrates made by Stender. For improvement of the structure of substrates mixed by growers 15% to 30% of Cocopor® is added.

Besides improving the optimum air to water ratio, Cocopor® clearly increases the capillarity and water-transport properties in the substrate. The rewetability of the substrate and the important drainage of excess water is clearly improved. Compared to other coconut-based additives on the market Cocopor® has a particularly low salt content, does not affect the pH of the substrate, and is very suitable for automatic pot filling due to its well defined fiber length. An important characteristic compared with other structure-improving additives is the slow decomposition of the fibers, which is expressed by a very low biological activity. This improves the stability of the substrate, making it suitable for long production periods.

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Toresa®

Ralf Schilling
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INTRODUCTION

Systematic development of wood fibre products for horticultural purposes was initiated in France at the end of the 1980s by Elf Aquitaine (Horti-Fibre). A critical part in these developments was played by the two Swiss, Gerhard Baumann and Prof. Penningsfeld. Prof. Penningsfeld was at that time head of the Institute of Soil Science and Plant Nutrition at the University for Applied Science, in Weihenstephan. A fundamental problem encountered during early development was the substantial nitrogen fixation that occurred with wood fibres which could not be solved using the technology available to Horti-Fibre at that time. But Baumann and Penningsfeld refused to give up and continued to develop new ideas. These ideas have been further developed and improved, and still form the basis of the Toresa® product today.

By 1990 these developments had reached the stage of the product being patented and the first production site for Toresa® being established in Switzerland.

Experience was accumulated and the products were further developed. Important help in the early years was the strong involvement of the Migros-Genossenschaftsbund, a retailing chain with a dominant position in the market in Switzerland, which has placed its power very heavily behind ecological products. This company does not stock potting composts and substrates containing peat at its stores and prefers to have plants cultivated with reduced or no peat in its garden centres and flower shops. There have also been similar developments in Germany for some years, where leading retail chains, such as the DIY chain, OBI, offer a completely peat-free range in addition to its conventional compost range.

At present there are four Toresa® locations in Switzerland, Austria, The Netherlands, and Germany which operate as separate companies independently of each other. About 200,000 m^3 of Toresa® wood fibre will be produced and distributed at these four sites in 1999, about 80,000 m^3 of which is produced in Germany alone. After the first production site in Switzerland already mentioned, Toresa Netherlands came into being near Amsterdam in 1992. Then in 1995, TD was set up by the Vereinigte Kreidewerke Dammann KG, a well known lime producer in Germany. At the same time the building of a production site on the property of the shareholder, Vereinigte Kreidewerke in Lagerdorf, about 130 km south of Flensburg, was being tackled. It was easy to incorporate Toresa® production in the existing operational infrastructure at the Vereinigte Kreidewerke site in Lagerdorf. In the Pinneberg district one of the major German tree nursery areas is located on the doorstep and major German peat and substrate companies are also close to this area.

MANUFACTURING AND QUALITATIVE ASPECTS

Toresa® is manufactured from untreated sawn wood residue, mainly from conifers (spruce/pine). Large quantities of these woods accumulate during the production of sawn timber in sawmills. Toresa Deutschland receives the wood, already fractionated, in the form of so-called wood chippings from North German sawmills. The quality of the products is affected strongly by the quality of the woods used.

Therefore, Toresa Deutschland understandably pays a great deal of attention to the quality of the raw materials and monitors them thoroughly. All incoming raw materials are analysed, as are all outgoing products and documented as part of the quality-assurance system. A fundamental quality feature of Toresa®, which also forms part of the patented production process, is compensating for the microbial nitrogen fixation in the wood by means of a precisely adjusted nutrient supply, which has been adapted to the requirements of the microoganisms in the course of lengthy tests.

Microbiological activity is greatly improved in loose, open-structured wood substrates. During the decomposition of the organic substance (carbon), these microorganisms need nitrogen to build up their protein components. Therefore, the so-called nutrient impregnation constitutes the nutrients for the microorganisms present in the wood and not for the cultivated plants. The Toresa® know-how consists in fertiliser formulation adapted to the microorganisms, and it is protected by patent.

The wood chippings are mechanically ground together with an accurately specified quantity of nutrient compounds in so-called retruders (similar to a meat-mincing machine), and the fertiliser components are pressed into the wood's cell structure. The amount of fertiliser can be kept very low as a result of this very homogeneous and intensive mixing. The nutrients are forced into the wood fibres by high pressure created during production. Toresa® adds a minimal quantity of brown coal to give the finished product a dark, soil-like colour. These colorants are of a purely cosmetic nature and do not have any significant effect on the product's properties.

Among the outstanding features of Toresa® are its good structural stability, high air capacity, and low bulk density. Because of a high air capacity, Toresa® improves the drainage and aeration of the substrate which encourages root growth and keeps the roots healthy.

There is considerably less risk of root diseases than with conventional peat substrates. This is particularly evident in systems with ebb-and-flood irrigation. Because of its good structural properties, Toresa® can be used to improve all types of substrates, especially fairly fine and heavy substrates containing compost or clay.

Improved aeration and drainage result in a lower water-retention level than with peat. However, the re-wettability of Toresa®, or substrates containing Toresa®, is considerably better. Experiments show that because the pot's surface dries faster, the growth of moss and weeds is also noticeably lower in substrates containing Toresa® compared to peat.

The decisive factor with Toresa® is that the nitrogen fixing generally seen with wood fibre products does not occur due to the impregnation already mentioned. Therefore, you can maintain your standard method of cultivation and fertilisation. It is only with higher Toresa® proportions, from about 40% to 50%, that slight adjustments to the watering intervals will be necessary, but no change in fertilisation.

ADVANTAGES OF TORESA®

The following may be mentioned as the primary advantages of Toresa®:

- Highly dependable cultivation as a result of constant delivered quality.
- Neutral nutrient behaviour.
- Permanently good structural properties.
- Good wettability.
- Absolute freedom from weed seeds and pests.

Furthermore, Toresa® is manufactured from renewable indigenous raw materials and consequently is an ecologically sound material.

Toresa® can be used for substrates for containerized plants in proportions up to 70%. Quantities of 20% to 40% are usually mixed into commercially available substrates. Substrates containing Toresa® can be processed without problems in potting machines, but if possible, potting pressure should be somewhat firmer when the proportion is higher than 50%. If the pot size is less than 8 cm, it should be tested whether mechanical filling of the pots works without problems. Fertilisation is also done in the usual way, because Toresa® only contains the amount of nutrients that it consumes itself during microbial activity.

Toresa®'s pH value is 5 to 6 and it is here that the only fundamental difference, compared to conventional potting substrates, exists. Since Toresa® itself does not buffer the pH, the Toresa® substrate mixtures do not have to be limed in order to adjust the pH value. Therefore, a peat substrate consisting of peat and Toresa® (3 : 2, v/v) only has 60% of the usual quantity of lime added.

Germany, a country which used to have extensive and good reserves of peat, is now following the trend in Denmark and other European countries, and is importing large quantities of raw materials from the Baltic, for example, because its own raw materials are, to a certain extent, no longer adequate for horticultural requirements. Approximately 80,000 m^3 of pure Toresa® will be used in Germany this year. If it is assumed that on average a 30% proportion of Toresa® will be used in substrate mixtures, this means a total substrate quantity of about 240,000 m^3.

Toresa® is manufactured from indigenous fast-growing conifer timber. When combined with indigenous peat, even finer qualities may result, and there are technically perfect, excellently structured and effective substrates available for Toresa®.

There is a gradual trend in Austria, Switzerland, and Germany for horticulturists to include substrates containing Toresa® in their sales range and to exploit this ecological aspect in their marketing. The Danish firms, such as Nygaards Planteskole and Gartneriet Allan Magelund, are also using Toresa®.

Growth Medium With Composted Cow Manure

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INTRODUCTION

Approximately 5000 years ago the people in Scandinavia started to grow crops. When crops are harvested it implies that the soil is robbed of its vegetation which would turn into mold and nutrients for the crops to come. This makes it necessary to replace the removed organic matter with other organic matter, and if this is not done we shall disturb the ecological balance of nature.

Back in the nineteenth century nearly all organic matter was brought back to the soil in the form of cattle manure. In the twentieth century industrialization began and fertilizers made their entry in agriculture and later on also in gardens. The humus content of the top soil, however, does not last forever. Fortunately, many have started to realize this and think it is a good idea to use nature's own biological reserves to maintain the humus content.

For a long time sphagnum has been the backbone of growth media because it is available in relatively large quantities in Scandinavia and the Baltic area. Luckily weed seeds and pathogenic organisms are rare in sphagnum. To a great extent sphagnum suppliers are producing the mixtures according to the growers' wishes and the special requirements of the cultures, whether it is about admixture of manure or granulated clay, leca, grodan, perlite, etc. The important thing is that the plants are healthy and get a good start. Therefore, the microbiological activity of the growth medium is of utmost importance to the plant. A large content of antagonists is necessary for the suppression of root pathogens. In nature there are a great many possibilities to maintain the natural balance of microbiological organisms in the topsoil by admixture of organic matter, e.g., cattle manure and other forms of compost.

THE HISTORY OF SIMONSTORP'S COMPOSTED COW MANURE

It all started approximately 30 years ago on the experimental farm Simonstorp in Blendtarp, Sweden. On the farm, owned by the Rausing brothers, there were a large number of cows who received litter in the form of sphagnum instead of straw to stand on. Overtime a large compost heap was built up which, after some years, was used with good results in the beds on the farm; this made the Rausing brothers think about its potential. The company, Tetra Pak, assigned a research worker, Lennart Ohlsson, to develop the product for commercial use. The knowledge behind Simonstorp's composted cow manure is not knew, it is the result of our development work that we are marketing today under the name of Simonstorp's composted cow manure which is a pure natural product.

Production takes 3 years to produce, and the first step is the procurement of a proper liquid manure from stocks subjected to veterinary inspection, where cows are removed from the cowsheds if they become ill. In this way no medicine residues will get into the liquid manure which would negatively influence the development of bacteria during the composting process. For the same reason no cleaning chemicals are used in the cow sheds. In the production process 60% liquid manure and 40%

pure unsorted harrow peat are forcibly mixed and stack composted for 3 years. The compost is turned over several times a year in order to be aerated and oxidized according to requirement. This oxidation process means that the microlife is vigorously stimulated, and the ammonium nitrogen is converted into nitrate. This oxidation process is essential to make the compost odourless. During the composting the temperature must never exceed 45°C, as the microbial life will then die from lack of oxygen. The microorganisms expend a great deal of oxygen in order to reproduce, and at the same time oxygen is necessary to decompose and mineralize the compost.

THE SIMONSTORP GROWTH MEDIUM HAS A HIGH MICROBIAL ACTIVITY

After 2 years in the open air the compost is placed in an open shed where it stays for a whole year before it is finally ready for use. Then the compost is completely odourless and has a high natural content of *Trichoderma harzianum* and other useful microorganisms as well as naturally produced organic nutrients in large quantities. The number of useful microorganisms can easily reach 8 to 13 billion per gram of compost.

The pure composted cow manure is a microbiologically active medium which means that we get an opportunity to exploit its natural biological abatement of pathogenic microorganism, and also the nutrients from dead microbes are released to the plants. The nutrients are long-acting and do not get washed out but stay in the pots/beds until the plants assimilate it.

Incidentally, Simonstorp's products are approved for ecological plant production.

AVOID PLANT PATHOGENIC FUNGUS ATTACKS

The best growth results are obtained where sphagnum mixtures with a good structure are enriched with 20% by volume of composted cow manure and 60 kg Bara RHP approved lime-deficient granulated clay m^{-3} in the fraction 0.2 to 2.0 mm. Bara granulated clay has a very high content of silicon. Silicon is accumulated in the cell wall and in this way it slightly delays the growth of the plants. The granulated clay increases the water-holding capacity of the growth medium and this elimates the sharp wilting point. Because of the ion exchange capacity of the clay colloids, cations (positive ions) will be absorbed to the clay granulates. The granulated clay is also a good habitat for microorganisms due to its porous surface.

Naturally, any substrate must in the future be adapted to modern greenhouse production and be consumer orientated. The high microbial activity of the composted cow manure favours the decomposition and the setting free of nutrients and gives the growth medium a high content of naturally occurring *T. harzianum*. According to analyses made by the Danish Growers Associations' laboratory *T. harzianum* propagates vigorously, and this means that root pathogens will find it more difficult to establish.

When using composted cow manure in the soil mixtures it is necessary to alter the irrigation. You have to irrigate somewhat less as the growth medium has a better absorption capacity and thus becomes more hydrous, which means that the soil has a more uniform drying before irrigation.

Peat and Substrate Production: An Overview

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INTRODUCTION

As a substrate producer one is often asked whether there will we be peat enough for the next century or not. The answer is a clear yes, but we will see a bigger part of the peat coming from the eastern parts of Europe.

The area covered by peat bogs or mires worldwide is estimated to approximately 400 million ha of which about 80,000 ha are harvested as horticultural peat. Main peat reserves are in Russia (150 million ha) and Canada (111 million ha). Europe produces ca. 70% of the worlds horticultural peat, while 25% is produced in Canada.

Some years back, environmental discussions focused on the local exploitation of mires in Germany and Great Britain which have lead to a search for alternatives to peat, e.g., bark compost, wood fibres, etc. The search for alternatives will continue in the coming years. I do, however, not expect that alternative substrates without peat can provide satisfactory media for the greater part of the I.P.P.S. member's productions. At least not in the near future.

Peat bogs have their origin in wetlands or lakes. Over the centuries the peat mosses have grown more and more widely, eventually covering all of the now former lakes. The growth of peat moss is approximately 1 mm per year. When opening new areas/bogs for peat harvesting it typically takes a couple of years before the bog actually is in production. The bogs have to be drained, the vegetation has to be removed, and the surface planed before production starts. Hundreds of different mosses are found in mires and the quality of the peat for horticultural usage depends widely on the type, the variation, and homogeneity of the peat mosses which are actually found in a mire. Besides, a great difference between the top and bottom layers is seen. The bottom layer is older and hence more decomposed and generally has less structure.

Horticultural peat is generally harvested by vertically digging of peat blocks or horizontally harrowing or milling. Block peat, where blocks are cut in a layer of 80 to 120 cm per cut and stacked, generally gives the best opportunities for production of high-quality peat substrates. By harvesting and transporting in blocks the amount of small fibres or dust is minimised. Production of block peat is more laborious than milled peat, hence block peat is more expensive.

Milled peat is produced by milling/harrowing the surface of the bog. When loosened, the peat is left to dry and at a certain humidity it is collected and stored in stock piles waiting to be transported to the peat/substrate factory nearby or thousands of kilometres away. The collection of milled peat is often done with big "vacuum cleaners" (vacuum peat).

Peat has been used intensively during the last 30 to 40 years in the horticultural business. Why is peat actually used? Peat is a natural raw material which is abundantly available at a reasonable price. It has good structural stability and other characteristics which makes it superb for growing plants. The perfect relation between air and water capacity also contributes to a safer plant growth.

Peat mosses live in conditions with low nutrient/salt contents and low pH. Therefore, decomposed peat mosses constitute an ideal basis for production of horticultural substrates. You simply add what is needed of fertilisers and lime, until the appropriate level for growth of the actual plant. At the substrate-producers factory the peat is screened in various fractions, depending on what the substrate has to be used for. Often, and to a greater extend than earlier, peat from different bogs and different types of peat are mixed in the substrate, e.g., dark and white peat. After screening and mixing of the peat various other materials can be added. The amount depends on the requirements of the growers:

- Lime: Limestone and/or dolomitic lime, for adjusting the pH.
- Fertilisers: Full macro- and microelements, with immediate or slow release.
- Clay: Powder or granulate form to increase the buffer capacity and changing the wilting limit.
- Structure-keeping additives as perlite, rockwool granulates, coir, etc. The purpose is to change the air/water relations in short and/ or long term.
- Wetting agents: To improve the initial water uptake of the substrate.
- Biological or chemical plant-protecting agents, e.g., against sciarid flies.

When deciding upon what type of substrate one has to use for a specific purpose many important factors must be considered: type of plant (pH, nutritional needs, healthiness of top and roots); irrigation techniques and practices; type of potting machine; pot size; and the growth period. Often it is necessary to compromise in one or more of these factors to be able to have a successful day-to-day operation.

Peat and substrates are sensitive to mechanical handling. At the factories producers are doing their best to handle the peat/substrate carefully to prevent excessive amounts of particles in the substrate. This is also very important in the nurseries. The growers have to handle their substrates carefully:

- Potting machines: Let the conveyors run as slowly as possible. If not the substrate will be milled.
- In dry substrates: Add some water to make the peat expand in the potting machines and not in the pots. Too much water will make the substrate collapse.
- Potting techniques: Press lightly when potting, to prevent compacting of the substrate.
- Transport of filled pots: If too many pots are placed on top of each other the substrate will compact.
- Initial irrigation: Lower the pressure when using overhead irrigation and give small amounts several times.

Unfortunately it is not unusual to see the structure of substrates ruined in the nurseries. Modern growing techniques are industrial and often with monoculture. Modern irrigation systems like ebb and flood often result in poor root air conditions. The reduced usage of fungicides today makes the crop more sensible to diseases. These and other factors provide a demand for higher quality growing media, which ensure a safe growth. This will be followed by the needs for better product specifications and documentation, and last but not least, a closer relationship between the substrate producers on one side and the users of substrates on the other.

Only by joint forces are we able to improve. Much of the research in the past has focused on physical aspects of the substrates. I believe that more focus will be put into the biological aspects of the growing media of which peat will still constitute a big part, since we still do have enough peat, and because the amount and knowledge of other alternatives is still very limited.

Peat Control in Nurseries and Peat Declaration

Torfinn Hodnebrog
Agder College, Dømmesmoen, N-4885 Grimstad, Norway

When nurseries receive peat products for use as growing media, these should be controlled and tested to ensure quality. By doing so the nurseries can avoid any problems with low quality before they use it in plant production. Special assays and a form made for this purpose can be of great help (Hodnebrog and Selmer-Olsen, 1998). The companies who produce and sell growing media are responsible for their products and still have to control and test their own products.

ORDERING AND RECEIVING GROWING MEDIA

Always write down what you have ordered, the quantity, from whom you ordered, juncture of delivery, etc. Control the confirmation note of your order and keep it. The same person who ordered the growing media should control and do the tests when it is delivered in the nursery. That person should ask if this is what was ordered. That person should look for damaged bags and especially for dirt outside the packs, asking whether the weight is normal. Each delivery of peat should have an identification number, which follows the peat during the whole growing period. In case of reclamation this would be of great help.

QUALITY CONTROL

Take samples of the peat; the smell must be fresh. If this is not the case there can be biological activity leading to loss of nitrogen or toxic elements like sulphite and nitrite. Under special circumstances such conditions also can arise when peat is stored in the nursery. A clever nurseryman can look and feel if the peat has a light, good colour, the right fibre size, and the degree of humidification expected compared to his order and to labelling. If the peat has problems with absorbing water and holding it, it may indicate that the peat has gone through a self-heating cycle caused by microbiological activity (Timenes and Hodnebrog, 1998). Such peat has to be returned and should not be used as growing medium.

CONTROL OF CONDUCTIVITY, PH, AND NITRATE

The nurseryman can easily test conductivity, pH, and nitrate content (with nitrate sticks) in the peat before use. One extract can be used for all these tests. The water content in the peat has a great influence on conductivity, so a standardised procedure has to be used every time.

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Take samples of the peat; the smell must be fresh. If this is not the case there can be biological activity leading to loss of nitrogen or toxic elements like sulphite and nitrite. Under special circumstances such conditions also can arise when peat is stored in the nursery. A clever nurseryman can look and feel if the peat has a light, good colour, the right fibre size, and the degree of humidification expected compared to his order and to labelling. If the peat has problems with absorbing water and holding it, it may indicate that the peat has gone through a self-heating cycle caused by microbiological activity (Timenes and Hodnebrog, 1998). Such peat has to be returned and should not be used as growing medium.

CONTROL OF CONDUCTIVITY, PH, AND NITRATE

The nurseryman can easily test conductivity, pH, and nitrate content (with nitrate sticks) in the peat before use. One extract can be used for all these tests. The water content in the peat has a great influence on conductivity, so a standardised procedure has to be used every time.

To get a more exact picture of the amounts of nutrient elements, which are available to the plants, it is necessary to send samples to a laboratory for analysis by the Spurway/Lakanen method (Selmer-Olsen, 1987).

CRESS GERMINATION TEST

A cress (*Lepidium sativum* L.) germination test can give us an indication of the quality in relation to growing trials. Cress tests probably should be more widely used.

AIR CAPACITY

A test of air capacity will tell us the volume filled with air after free drainage from a pot that previously has had all pores filled with water (water capacity). Air capacity tells us about quality and structure of the medium. Do we have to be careful about how much water we give the plants or do we have to mix it with other products to obtain better aeration conditions in the peat? When the pots are filled with peat, pot size and pressure have an effect on air capacity too. Because of this the method has to be a standardised procedure, and it is best if the same person does the tests every time. Measuring air capacity can easily be done in nurseries.

By performing the above mentioned control and tests, the nurseryman can make up his mind if the peat received is a good growing medium for plants or if the peat should be returned.

GROWTH CONTROL

If an identification number is given to each peat delivery, the nurseryman is able to follow the plant growth in this particular batch. Such observations will be helpful if it turns out that reclamation later on is necessary.

PRODUCT LABELING

The Committee for Standardization in the European Union is working on a standard for labeling of growing media (Hauken 1999, pers. comm.). I am only presenting a few aspects that are of great importance for the nurseryman:

1) **The Constituents of Growing Media.** In the Committee report it is proposed that only the major ingredients (above 10%) have to be labelled. From a growers point of view all ingredients should be labelled.
2) **All Additives and Their Purpose are Proposed as Optional Labelling.** These should also be obligatorily labelled.
3) **Methods of Analysis for Nutrient Content.** Three standard methods will be used to control the amount of nutrient elements in growing media (Daldorff, 1999). Three extraction solutions will be used.
   - Aqua Regia, to control total amount of nutrient elements.
   - CAT ($CaCl_2$/DTPA) method, to control amount of nutrient elements available to plants.
   - Distilled water, to control amount of nutrient elements available to plants.

ADVISORY SERVICE — THE SAME METHODS?

Today the advisory service uses different methods to evaluate the amount of nutrient elements in growing media. Spurway/Lakanen, CAT, distilled water, and Al-extract (Daldorff, 1999) are different methods used in Scandinavia. A change to new methods of analysis can cause problems because we don't have enough experience and normative references to new values. We should use common methods in the advisory service. Nutrient elements given in the literature as a norm for relevant amount in growing medium are worthless unless the method of analysis is given. Reference values must be given for every method. Do we still want different methods of advice and the labeling of growing media?

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Self-Heating in Peat

Sissel Brit Ranneklev and Hans Ragnar Gislerød

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INTRODUCTION

Favourable physical and chemical properties as well as a low content of weeds and pathogens make peat an ideal growing medium for plants. From harvesting till processing the peat is stockpiled. During this storage period self-heating may occur. Self-heating causes not only substantial losses of peat (Gärdenäs and Thörnqvist, 1984), but also results in a peat product that may inhibit seed germination and plant growth (Wever and Hertogh-Pon, 1993).

MATERIALS AND METHODS

Peat samples were collected from different mires in Norway being exploited for horticultural use. Seeds of lettuce (*Lactuca sativa* L. 'Rubett') were grown in these peat samples exposed to different levels of self-heating. Chemical analyses of the peat samples were performed by traditional methods (Ranneklev et al., 2000). Total organic carbon (TOC) and chemical-oxygen demand (COD) were measured in the water extract from the pH measurements. Total organic carbon indicates the content of organic matter, while COD indicates a combination of content and type of easily oxidised organic matter.

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RESULTS

Self-heating caused changes in the water extract from the peat (Table 1). Total organic carbon and COD increased after self-heating, while the content of NO_3-N decreased. A reduction in pH could also be observed after self-heating, although this reduction was not statistically significant.

Self-heating of peat reduced the germination percentage of lettuce seeds. Severe effects were obtained when peat samples were exposed to temperatures above 45°C, which is in accordance with observations made by Wever and Hertogh-Pon (1993). Germination percentages lower than 87±6% (standard deviation) should not be accepted. Germination percentages and temperatures measured in the peat at sampling were not well correlated ($r^2 = 0.08$). This indicates that the production of toxic compounds is not only dependent on temperature. Factors like peat quality and exposure time to the elevated temperature may be of importance. In addition, the activity of toxic compounds may be dependent on pH and ionic strength. Correlations between different chemical parameters are given in Table 2. Chemical-oxygen demand and TOC were highly negatively correlated to the germination percentage of lettuce, and as indicated in Table 1, self-heated peat had considerably higher COD values.

CONCLUSION

- Toxic compounds were produced in peat exposed to temperatures above 45°C.
- Reduced pH was observed in peat exposed to self-heating, which may require an additional supplement of lime.
- Losses of nitrate were observed after self-heating. In another study by Ranneklev et al. (2000) self-heated peat was more susceptible towards losses of nitrate during storage.
- A COD value higher than 25,000 and a germination percentage below 87±6% indicate that the peat sample had been self-heated.

Table 1. Chemical properties of peat. Total organic carbon, chemical-oxygen demand, and NO_3-N are given in mg kg^{-1} dry matter.

	Self-heated	Not self-heated^X
pH	3.55	3.70
NO_3-N	7.1*	13.5
TOC^Y	9726*	4415
COD	25,838*	11,861

^{X} peat exposed to temperatures above 35°C.
^{Y}Abbreviations: TOC = total organic carbon, COD = chemical-oxygen demand.
* significant difference at $p< 0.05$.

Table 2. Correlation between different parameters.

	pH	COD[X]	TOC	NO_3-N	Ger (%)[Y]
pH	1.00				
COD	-0.65	1.00			
TOC	-0.65	1.00	1.00		
NO_3-N	0.68	-0.11	-0.11	1.00	
Ger (%)	0.42	-0.67	-0.68	-0.13	1.00

[X]Abbreviations: TOC = total organic carbon, COD = chemical-oxygen demand, GER = germination.
[Y] germination percent of lettuce seeds.

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Experience With Steam-Treated Peat

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MICROORGANISMS IN PEAT

Traditionally peat has been considered to be an almost sterile medium. However, it still contains microbiological activity and the conditions in the raised bog influences the composition of the microflora. Fungi thrive in the acid environment where primarily *Penicillium* dominates. Furthermore, genera such as *Aspergillus, Trichoderma, Pullularia, Alcurisma, Cladosporium, Cephalosporium,* and mycorrhiza-forming fungi are present. Bacteria demand more adaption and are dominated by *Bacillus* and *Pseudomonas*, but *Micrococcus, Arthrobacter, Achromobacter, Chromobacter,* and *Mycobacterium* are also present. Although the microbiological growth in the raised bogs is small and very slow it should not be neglected (Küster, 1990).

PLANT PATHOLOGICAL ANALYSES

Occurrence of root pathogens is of course of special interest in plant production. Samples sent to the Danish Grower's Association laboratory for analysis during recent years show that the traditional pathogens, such as *Pythium, Phytophthora,* and *Fusarium* do not constitute a problem in peat. On the contrary, *Trichoderma* is found in more than half of the samples fluctuating between weak growth and very strong growth.

WHY APPLY STEAM TREATMENT?

Pindstrup Mosebrug A/S started steam treatment of peat in the production of a niche product, Fibremin Mikro, to prevent diarrhoea in young pigs. During heat treatment of this product *Mycobacterium* is removed which may cause mycobacterioses in slaughter hogs. Because the method is at our disposal we have also tested the effect of steam treatment on growth media for plants. Can, e.g., the problem with sciarid flies be solved by heat treatment? The answer is no, the nurseries themselves are contributing to the problem and during testing we could not see any difference between steam-treated and untreated peat. The problem has to be solved by other means.

The propagation of seed potatoes demands a high degree of security in order to prevent the material from being reinfected with viruses. So now the Danish Plant Directorate demands that after meristem propagation only steam-treated growth medium is used.

Recently, increasing problems with root-rot fungi resulting from a reduction in the use of effective pesticides have led to use of steam treatment as part of a possible solution.

HOW DO WE STEAM TREAT?

Steam treatment is carried out by means of high-pressure steam — a steam type with a very high energy content and high efficiency. In addition, high-pressure steam contains very little water and this means that the water content only rises 5 to10 kg m^{-3}. During steam treatment all the peat is heated to a temperature of 100°C for a minimum period of 30 min. After treatment the peat is not sterile, but a large part of the natural microorganisms is removed. Steam-treated peat can either be delivered as it is, or *Trichoderma* may be added when the peat has cooled down. Fertilizers and limestone can be added as required before or after the steam treatment.

RESULTS

After steam treatment we have observed that native *Trichoderma* and *Penicillium* fungi strongly multiply and become dominate in the medium. The reason is probably that carbohydrates released during the heat treatment are digested by these microorganisms and that the competition from other microorganisms is very limited. In order to control the microbiological activity as much as possible you can add commercially available *Trichoderma* strains with a more aggressive behaviour to root pathogens.

The steam-treated products have primarily been tested in connection with propagation of plants and the results fall into two categories:

1) Appreciably healthier young plants resulting in a reduced use of chemicals.
2) No difference in comparison with normal practice. At present no problems with root fungi.

PEAT CHANGES AFTER STEAM TREATMENT

When using steam treated peat the following changes may be noted:

- Steam treatment will lower the pH value by 0.5. Therefore, extra limestone has to be added to get the pH value of normal practice.
- There may be a very high reproduction rate of added *Trichoderma* strains. So strong that *Trichoderma* may use all available nitrogen during peat storage. Therefore, extra nitrogen must be added.
- The increased microbiological activity in steam-treated peat will cause the peat to decompose faster, so steam-treated peat is only suitable for short growth periods, e.g. for propagation.

CONCLUSION

Steam-treated peat can be used together with biological agents for propagation of plants. In this way the application of chemical agents may be reduced considerably.

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Miscanthus Straw Compost as Growth Medium for Pot Plants

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INTRODUCTION

Peat is the dominant growth medium used in ornamental potted plant production. However, in many areas of the world, including Denmark (Aaby, 1996), exploitation of peat bogs is restricted. Composts made from household or garden wastes may be attractive alternatives to peat. Such composts are, however, not uniform from time to time and may contain undesirable levels of salts, nutrients, and heavy metals (Grantzau, 1997). Therefore, commercial growers of pot plants are reluctant to use compost based on municipal waste or biowaste as growth medium.

In order to obtain a uniform, stable, and well defined final compost, *Miscanthus* straw was used as raw material in combination with different nitrogen sources. The purpose of this composting was to obtain defined products. These products were subsequently compared to peat-based growth media for potted plant production.

COMPOSTING OF *MISCANTHUS* STRAW

Shredded straw of *Miscanthus* ×*ogiformis* Honda 'Giganteus' was composted with ammonium sulphate, urea, or pig slurry as nitrogen source or tap water as control. The ratio between carbon and nitrogen, C/N (w/w) was 27 with ammonium sulphate, 27 with urea, 19 with pig slurry, and 96 with tap water. The C/N ratios range of 19 to 27 used in this experiment were close to the optimum, 30, for poplar wood plus urea (Rao et al., 1995) and 22 for urban refuse plus urea (Nakasaki et al., 1992).

Within 2 days of composting peak temperatures rose to 65°C for pig slurry and within 3 days to 59°C for ammonium sulphate, 41°C for urea, and 59°C for tap water. These heat developments are similar to results obtained in a pile of cattle manure (Cáceres et al., 1998). The higher temperature increase and faster heat development in compost based on pig slurry compared to other N sources are probably due to the higher content of both nutrients and microorganisms in pig slurry.

At the end of the composting period volumetric water content, at a suction of 10-cm water, was 60% and 32% for composts with pig slurry and ammonium sulphate, respectively, compared to 80% for the fully fertilized peat. Pig slurry resulted in high electrical conductivity and high concentrations of K, P, Mn, Na, Cl, Cu, and Zn. In composted *Miscanthus,* Grantzau (1999) found high pH values and high nutrient contents, especially of potassium. This corresponds well with results of the present experiment.

PLANT GROWTH EXPERIMENTS

After 5 months the four *Miscanthus* composts were compared with unfertilized or fertilized peat as growth media for *Hedera helix* 'Mein Hertz' and *Fatsia japonica*. Unrooted cuttings of *Hedera* and seedlings of *Fatsia* were grown in 9-cm pots according to a standard growing program using ebb-and-flood fertigation under greenhouse conditions.

After 12 weeks, shoot lengths of *Hedera* were similar in fully fertilized peat and *Miscanthus* composts with urea or pig slurry (13.5 to 16.0 cm). Shoots were shorter from unfertilized peat and *Miscanthus* compost with water (8.3 to 8.5 cm) and from *Miscanthus* compost with ammonium sulphate (5.5 cm). Plant dry weight of *Hedera* was highest for fully fertilized peat (1.4 g), lower for composts with urea or pig slurry (0.9 to 1.0 g), and still lower for unfertilized peat and composts with ammonium sulphate or water (0.5 to 0.6 g). In *Fatsia* the dry weight was highest for fertilized peat (1.8 g). Unfertilized peat and ammonium sulphate or urea composts gave similar results (1.2 g), while pig slurry and water composts resulted in the lowest dry weights (0.8 g and 0.5 g).

The two plant species responded differently with respect to plant growth in different composts. *Hedera* dry matter production was higher in composts with urea or pig slurry than with ammonium sulphate or water-based composts. *Fatsia* dry matter production was higher in ammonium sulphate or urea-based composts than in composts based on pig slurry or water. The different response of the two plant species may be due to a greater susceptibility of *Fatsia* to excess levels of nutrients especially in compost based on pig slurry. The fact that *Fatsia* had roots at transplanting enabling a quicker root establishment in the growth medium than the unrooted cuttings of *Hedera* might also have influenced plant growth. This may have been advantageous for *Fatsia*, especially in ammonium-sulphate compost with low volumetric water retention.

CONCLUSION

Our results demonstrate that shredded straw of *Miscanthus* plus a N source giving a C/N ratio of 20 to 30 comprises a well defined starting material for composting. By testing the growth of *H. helix* and *F. japonica* it was shown that *Miscanthus* compost is a suitable substitute for peat as growth medium for pot plants. Pig slurry as the N source may be better than the other N sources tested due to a better water retention in the 5-months-old compost. Problems caused by supraoptimal concentrations of nutrients when using pig slurry, as in this experiment, are easily solved by dilution with water. Future experiments will define the degree of dilution giving the best results with respect to plant growth.

Acknowledgement. This study was financed by a grant from the Danish Research Councils.

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Addition of Beneficial Microorganisms to Growth Media: An Overview

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Addition of beneficial microbiological products, also called "biopesticides", and other beneficials to growth media has become increasingly explored during the last 10 to 15 years. This is due, in part, to increasing pest and pathogen resistance to chemical products and due to banning of many environmentally harmful pesticides.

INTRODUCTION

Until 1995 there were no legal prohibitions in European Union (EU) against adding microbiological products against pests and pathogens to growth media. In 1995 registration rules for microbiological products where established in EU. Products that had been sold prior to 1993 where allowed to continue if they could pass national registration rules but new microbiological products introduced after 1993 have to pass new tough EU rules. This meant that many "new" products used between 1993 and 1995, especially against pests, suddenly had to be taken off the market in Denmark.

The microbiological product Supresivit (*Trichoderma harzianum*) is one of the products that was in use before 1993. Borregaard BioPlant registered this product nationally in 1995 and in accordance with the new rules (new products with similar active organisms do not need to be registered) this has opened up the market for many other *Trichoderma*-based products on the Danish market.

The tendency in plant production for many years has been to develop as sterile a growth medium as possible. A negative consequence of this has been the difficulty controlling pest and pathogen outbreaks. The natural microbiological balance that exists in nonsterile media almost always helps to suppress such outbreaks to a certain degree. So because of these factors it is highly relevant to consider active incorporation of beneficial organisms in to growth media. For this purpose there are products consisting of: (A) beneficial arthropods, nematodes, etc.; (B) beneficial bacteria; and (C) beneficial fungi. Against pathogens there are commercial products available from the two last groups and against insect pests there exists products from all three groups.

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PRODUCTS AGAINST PESTS

Amongst the different species of *Diptera* (flies) associated with peat, only sciarids (*Bradysia* spp.) may be present in the peat when delivered to the grower. During 1995 to 1998 Borregaard BioPlant made 78 sciarid hatching trials on new peat from different producers delivered to different growers. As shown in Figure 1, hatching of the adult sciarids occurs approximately 3 to 6 weeks after irrigation of the peat. Considering the life cycle of sciarids this indicates that it is the eggs of sciarids, and not larvae or pupae, that are present in the peat when delivered to the grower. When planning a sciarid-control programme it is important to consider the above mentioned facts.

Beneficial Nematodes. Persistence trials made by Borregaard BioPlant with *Steinernema* nematodes in peat have shown live nematodes for more than 2 months after application (peat stored under natural conditions outdoors below 30°C in 200-liter plastic bags). The *Heterorhabditis* species (against vine weevils, etc.) generally have a lower persistence in peat. Incorporation of nematodes to the peat is a good idea because the nematodes will persist long enough to infect larval stages hatching from the eggs present in the peat (and larvae hatching from eggs laid on the peat at the grower as well).

Beneficial Bacteria. The use of available commercial *Bacillus thuringiensis* products (Vectobac and Bactimos) is only relevant after the commencement of plant production in the growth media because the bacteria will not persist long enough to have effect when sciarid eggs hatch.

Beneficial Fungi. Worldwide there exist many beneficial fungi products available for incorporation into growth media. Unfortunately these products are not yet allowed for sale in Denmark. Only products based on *Verticillium lecanii* (Mycotal and Vertalec) are available commercially. The registration of *Paecilomyces*

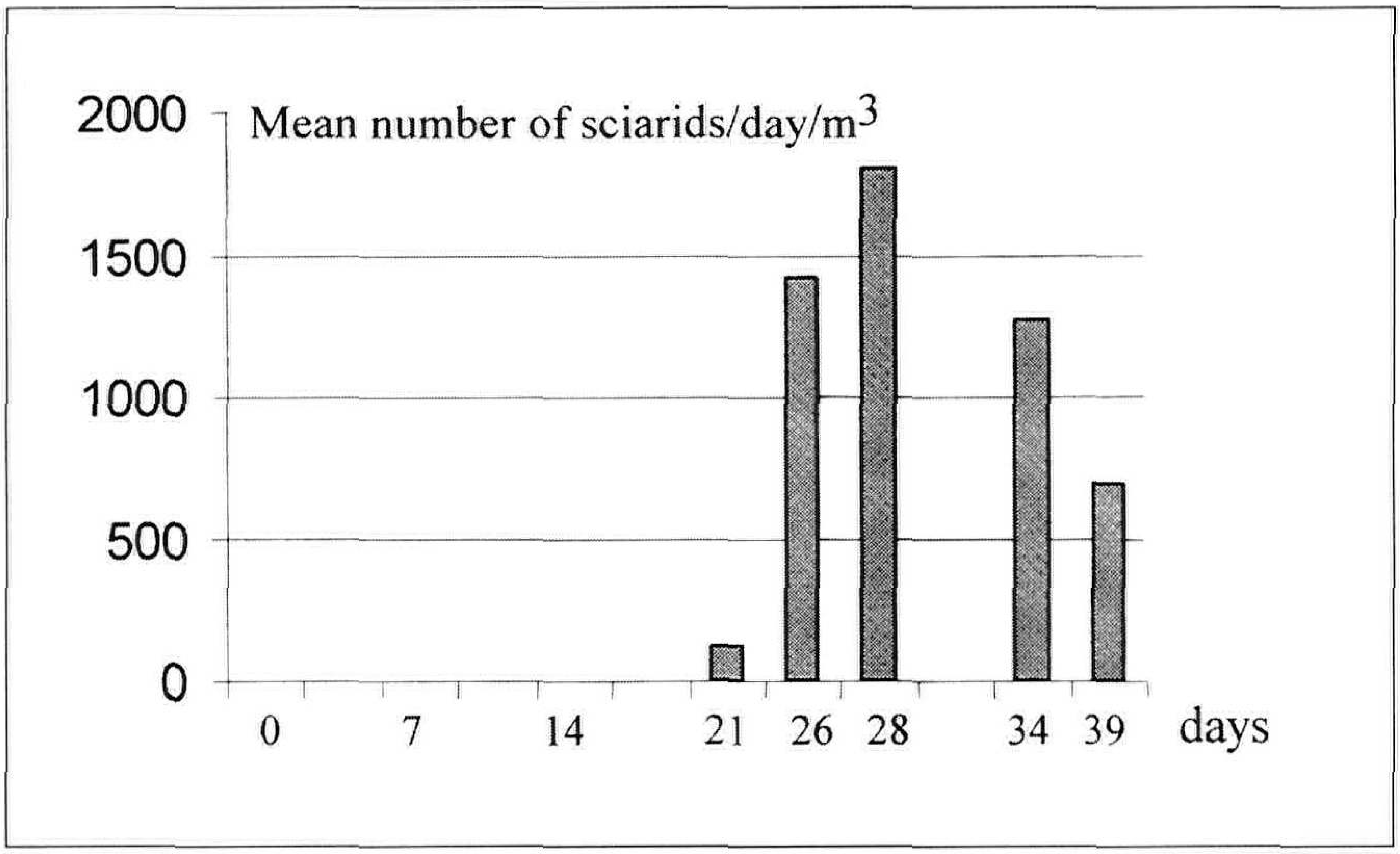

Figure 1. Hatching of sciarids from peat samples.

fumosoroseus (PreFeRal) is due shortly and for other relevant fungi like *Beauveria* spp. (*B. bassiana*: "Boverol", *B. brongniarti*, etc.) and *Metarhizium anisopliae*. It is Borregaard BioPlant's goal to register them in the near future.

Verticillium primarily works on the above-ground parts of the plant whereas *Paecilomyces* and *Beauveria* work above-ground as well as in the growth media. *Metarhizium* primarily has its effect only in the growth media. The three last mentioned fungi are likely candidates for incorporation into growth media in the future.

It is important to demonstrate the beneficial effect and a high demand for these products to make them economically possible to register them in EU and Denmark.

In conclusion, nematodes (against sciarids, beetle larvae, etc.) are the only group of macrobiological beneficials relevant for incorporation in growth media. Products containing beneficial bacteria (*Bacillus thuringiensis* and others) are not at the present time suitable for incorporation into growth media before production starts due to low persistence. In the group of beneficial fungi against pests there exists many products that would be relevant to apply, but these products are very difficult to register for sale in Denmark.

PRODUCTS AGAINST PATHOGENS

Suppliers of growth media normally have a good idea of the potential pest problems at their customers and, therefore, also have the possibility of adding beneficial organisms targeted against these pests. With regard to pathogenic fungi, that is another matter and more complex. To prevent development of pathogens, incorporation of beneficial organisms (antagonists) will be of more prophylactic nature and the organisms will have to protect against a relatively wide range of pathogens. There is also the possibility of incorporating "soil improvers" like mycorrhiza forming fungi which will help the plants in stressful situations by improving the uptake of nutrients (especially phosphorus).

Typical biological plant protection products against pathogens can be grouped in three categories: (1) beneficial bacteria, (2) mixed organisms, and (3) beneficial fungi. From these groups there is registered one bacteria product and several fungi products.

Beneficial Bacteria. Mycostop (*Streptomyces griseoviridis*) is presently the only bacteria containing product registered for use in Denmark. Several other products consisting of, for example, *Bacillus subtilis* and *Pseudomonas* spp., would be interesting to use in the future.

Mixed Products. Effective microorganisms were widely used in Denmark as a "soil improver" but should have been registered as a plant protection product according to the official registration rules from the Danish Environmental Ministry.

Beneficial Fungi. Among the countless beneficial fungi relevant for incorporation in growth media, only *Trichoderma*-based products are legal in Denmark. *Pythium* spp., *Fusarium* spp., *Gliocladium* spp., *Tilletiopsis* spp., etc. are amongst the beneficial fungi that probably will be registered in the future.

Coniothyrium minitans (Contans) against *Sclerotinia* spp. is expected to be registered by Borregaard BioPlant in the near future, but because Contans works against sclerotia it makes more sense to apply it to growth media with a registered attack. The beneficial fungi, *Trichoderma, Gliocladium,* etc., are generalists suppressing a wide range of pathogens. The primary effect of these products is based on the establishment of the beneficial fungi in the growth media before the pathogen can develop into a problem. Therefore, the growth medium has to be treated as early as possible.

Supresivit is an example of a registered product containing the beneficial fungi *Trichoderma harzianum*. Supresivit contains 1.4×10^{10} spores per gram. This high concentration of spores makes it possible to distribute the product very evenly in, for instance, peat. The high concentration together with a broad spectrum effect makes Supresivit a very suitable product for incorporation into growth media.

Cabbage Seedlings Grown Organically in Plugs — Substrate Liming and Fertilizer Supply

Jens Willumsen
Danish Institute of Agricultural Sciences, Department of Fruit, Vegetable and Food Science, Kirstinebjergvej 10, DK-5792 Årslev, Denmark

INTRODUCTION

Organic vegetable production in Denmark has increased rapidly during the last decade. In 1997, the acreage of organic horticultural crops — mainly vegetables — had increased to 769 ha. Accordingly, there is a demand for development of propagation methods with special emphasis on organic farming.

In Danish propagation nurseries, it is common practice to raise seedlings of cabbage in plug trays filled with sphagnum peat. In organic farming, sphagnum peat is usually mixed with limestone and an organic fertilizer. Besides the ability to increase pH of the peat, limestone is an important calcium source. If dolomitic limestone is chosen, a large quantity of magnesium is added at the same time as dolomitic limestone contains about 10% magnesium.

The main purpose of the present study was to assess optimum quantities of dolomitic limestone and fertilizers as additives to sphagnum peat used as a propagation substrate for seedlings of white cabbage raised organically in plug trays. Due to the small volume of plugs it may be necessary to supply extra fertilizer to the plug plants during the propagation period. In the present study, it was investigated whether it is feasible to use diluted recirculated or nonrecirculated liquid cattle manure as a supplementary fertilizer.

EXPERIMENTS WITH SEEDLINGS OF WHITE CABBAGE

Two experiments with organically grown seedlings of white cabbage (*Brassica oleracea* L. Capitata Group 'Bartolo') were carried out to investigate the possibilities for improved fertilization during germination and subsequent growth in plug trays under glasshouse conditions. Each plug tray (60 cm × 40 cm, VEFI A/S), with 54 conical plug cells, each 90 cm^3 and 6.5 cm high, constituted one plot. The seeds were sown on 10 Aug. 1995 (Experiment 1) and 18 April 1996 (Experiment 2) and the experiments were terminated 27 or 25 days after sowing, respectively. The treatments were replicated twice in Experiment 1 and three times in Experiment 2 pressing a wide range of pathogens The primary effect of these products is based on the establishment of the beneficial fungi in the growth media before the pathogen can develop into a problem Therefore, the growth medium has to be treated as early as possible

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In Experiment 1, comparisons were made between different quantities of dolomitic limestone (2, 4, 6 or 8 kg m^{-3}) and composted poultry manure (10, 30, or 50 liters m^{-3}) incorporated into the plug substrate which basically consisted of sphagnum peat (75% light and 25% dark sphagnum peat, particle size up to 10 mm, pH 4.1, Pindstrup Mosebrug A/S). The manure had been composted for 1 to 2 years and thereafter dried and finely screened (manufactured by Farmergødning ApS).

In Experiment 2, one of the best mixes from Experiment 1, with a content of 6 kg dolomitic limestone and 10 liters manure m^{-3}, was compared with Bina-muld, a commercial standard mix manufactured in Denmark by Binadan A/S. Bina-muld consists of light sphagnum peat (particle size up to 30 mm) mixed with dried, noncomposted poultry manure, calcium carbonate, dolomitic limestone, and glacial clay (19, 2.5, 0.9, and 32 kg m^{-3} peat, respectively).

All treatments were irrigated on ebb-and-flood benches with a solution of dilute cattle manure, and there was one separate solution for each plot. In Experiment 1, the solutions were applied from 14 days after sowing and all of the solutions were recirculated. In Experiment 2, they were applied from 7 days after sowing and comparisons were made with plants irrigated with a similar solution that was not recirculated. Recirculated as well as nonrecirculated nutrient solutions were diluted with rain water (pH 6.8) to initial concentrations of 7 mmol $liters^{-1}$ N (100 ppm, the half of it as ammonium N, the other half as organic N) and 3 mmol $liters^{-1}$ K (120 ppm). Further details of the experimental procedures are described by Willumsen (1999).

LIME AND FERTILIZER RATES

In Experiment 1, maximum plant growth was achieved in a substrate mix with 10 liters of composted poultry manure and 4 to 8 kg dolomitic limestone m^{-3} peat (Table 1). Higher quantities of manure and a lower quantity of dolomitic limestone reduced plant growth.

The electrical conductivity in the substrate, as a measure of the total concentration of available major nutrients, was highest, as expected, at the highest fertilizer level (Table 1). Very little nitrate was found in the substrate mixes after 27 days of propagation (Table 1). Almost all accessible N was present as ammonium. Apparently, the nitrification process in the substrates was too inefficient to increase the nitrate concentration. It is suggested that depressed growth occurred as a result of high ammonium and very low nitrate concentrations in the substrate promoting ammonium toxicity in the plant as found in earlier studies (Ikeda and Yamada, 1984; Pill and Lambeth, 1977).

Increased application of dolomitic limestone prior to sowing did only slightly increase the pH of the substrate as shown in Table 1, which also shows that pH increased during the experiment. However, the increases during the propagation period were moderate taking into consideration that pH of all recirculated nutrient solutions of liquid manure simultaneously increased from about 7.3 to 8.2. It appears likely that the buffering capacity of the peat mixes in the plug cells, despite their small volume, together with the supply of liquid manure, forcing plants and microorganisms to take up nitrogen almost exclusively as ammonium with release of protons as a result, were able to keep pH of the plug mixes between 5 and 7.

Table 1. Experiment 1 at the end of the propagation period (27 days from sowing): pH, electrical conductivity (EC), and concentrations of ammonium N and nitrate N in the plug substrates. In addition, fresh and dry matter of aerial plant parts and root density alongside the pot (rated 0 to 5) as affected by the amount of poultry manure and dolomitic limestone mixed into the plug substrate. pH at sowing (Day 0) is also shown.

Treatments:	pH		EC	NH_4-N	NO_3-N	FM[X]	DM[Y]	Root density
	day 0	day 27	mS cm^{-1}	(mmol l^{-1})		(g $plant^{-1}$)		(0-5)
Manure (liters m^{-3})								
10	5.4	6.4	1.4	1	0.1	4.3	0.32	5.0
30	5.5	6.4	1.9	8	0.5	4.0	0.25	4.1
50	5.5	6.4	2.8	24	0.6	2.7	0.15	2.5
$LSD_{.05}$	-	-	0.5	6	-	0.4	0.03	0.4
Limestone (kg m^{-3})								
2	5.1	6.0	2.2	15	0.1	2.8	0.17	3.7
4	5.4	6.4	2.0	11	0.2	3.9	0.26	4.0
6	5.6	6.5	1.8	9	0.5	3.9	0.26	3.8
8	5.7	6.7	2.2	9	0.7	4.1	0.28	4.0
$LSD_{.05}$	0.2	0.3	-	-	-	0.5	0.03	-
Significance:								
Manure	ns[Z]	ns	***	***	ns	***	***	***
Limestone	**	**	ns	ns	ns	***	***	ns
Man. × limestone not estimable (pooled samples)				ns	ns	ns		

[X] FM = fresh matter.
[Y] DM = dry matter.
[Z] ns, **, ***: nonsignificant and significant at $p < 0.01$ and < 0.001, respectively.

Table 2. Experiment 2. The effect of plug substrate and recirculation of the supplementary solution of dilute liquid cattle manure on pH, electrical conductivity (EC), and concentrations of ammonium N and nitrate N in the substrate and in the supplementary solutions at the start (Day 0, in substrate only) and end (Day 25) of the propagation period, and on fresh and dry matter of aerial plant parts.

Substrate	Recirculation	pH	EC ($mS\ cm^{-1}$)	NH_4-N (mmol $liter^{-1}$)	NO_3-N	FM^X (g $plant^{-1}$)	DM^Y
Day 0:							
Bina-muld		6.2	1.5	7.6	0		
Selected mix		5.8	1.5	6.5	1.4		
Day 25:							
Suppl. solution	without	8.0	1.5	5.8	0		
(mean of substrates)	with	7.8	1.4	5.7	0		
Bina-muld	without	6.9	1.1	0.6	0	3.4	0.25
	with	6.8	1.2	0.6	0	3.6	0.28
Selected mix	without	6.7	1.1	0.7	0.4	4.4	0.36
	with	6.6	1.3	0.9	0.4	3.7	0.32
Significance on Day 25:							
Substrate		ns^Z	ns	ns	**	**	***
Recirculation		ns	*	ns	ns	ns	ns
Substrate × recirculation		ns	ns	ns	ns	*	*

X FM = fresh matter.

Y DM = dry matter.

Z ns, **, ***: nonsignificant and significant at $p < 0.01$ and < 0.001, respectively.

RECIRCULATION AND COMPARISON WITH A COMMERCIAL SUBSTRATE

In Experiment 2, Bina-muld and a selected mix from Experiment 1 were compared. It was further tested whether recirculation of the supplementary nutrient solution had any impact on plant growth compared with free drainage from the bench.

Table 2 shows that pH, EC, and the concentration of ammonium N were almost similar in the two mixes, whereas nitrate N was present in the selected mix, but absent in Bina-muld due to the content of noncomposted poultry manure in Bina-muld. The absence of nitrate may explain the differences in fresh and dry matter of plants grown in the two substrates. However, the differences were only significant when the supplementary nutrient solution was nonrecirculated. It appears likely that the recirculation promotes an aeration of the nutrient solution or a balance of microorganisms that counteracts the risk of possible phytotoxic short-chain fatty acids, primarily acetic acid, that may develop when noncomposted manure is applied (Shiralipour et al., 1997). No differences in root growth were visible.

CONCLUSIONS

- Ten liters of dried, composted poultry manure m^{-3} sphagnum substrate gives a higher root density and bigger plants than 30 or 50 liters m^{-3}.
- The optimum rate of dolomitic limestone is 4 kg or more m^{-3} sphagnum substrate.
- Supplementary additions of nitrogen may be necessary because of a low nutrient capacity in the small plugs. Irrigation with dilute liquid manure from cattle is an acceptable possibility. Supplementary additions seem to be a better solution than the addition of a high quantity of an organic fertilizer to the propagation substrate prior to sowing.
- Irrigation with a recirculated nutrient solution may be as good and sometimes better than irrigation with a nonrecirculated solution.

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Pot-in-Pot: From Concept to Reality — I

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INTRODUCTION

Midwest Groundcovers is a large wholesale container nursery located in the Midwest. We have a fully developed 160 acres in St. Charles, Illinois, and a partially developed 300 acres in Glenn, Michigan. We think of ourselves as leaders and trend setters in the American nursery market. We strive to stay one step ahead of the industry. This requires us to sometimes think outside the box. If we always do what we've done, we will always get what we've always gotten. With Midwest Groundcovers participating in such groups as the I.P.P.S., it truly helps us to seek and share information. By visiting other nurseries we are able to see systems in use that we presently don't use. On one visit to Lancaster Nursery we saw a system called pot-in-pot. This system is a hybrid between field nurseries and container nurseries. This is one concept that Midwest Groundcovers decided to explore. We took that information we saw and evaluated it to see: (1) Can and will it work in our system? (2) How can we adapt it to our system? (3) What are the costs of development? (4) What other considerations need to be looked at?

Once we decided to explore this pot-in-pot system the wheels started turning. We brought the information back and reviewed it determining how it could fit into the future of Midwest Groundcovers? There were numerous formal and informal meetings to gather input on the system. In the spring of 1998, we gave the green light to go ahead and build two trial pot-in-pot areas. We wanted to look at them to see what was the best way to construct and grow plants in these areas.

PREPARING AN AREA FOR THE POT-IN-POT SYSTEM

The construction process for Midwest starts a long time before the first trench is dug. During the winter the following preparations were made: (1) quotations for all supplies needed, (2) pre-ordered supplies that needed extra time to get, (3) determined what subcontractors were needed, (4) determined if existing structures needed to be moved, and (5) determined how many people were needed for the project and set-up deadlines for the project.

The beginning of the pot-in-pot project started with the removal of existing *Ajuga* stockbeds and 30-ft-tall *Juniperus* windbreaks. This was completed by a subcontractor using a Case track backhoe and a 20-yd Mack dump truck. Once all plant material was gone, the area had to be pitched for drainage. One problem encountered was that all four sides were bound by fixed grades. We had an overall width of 180 ft north to south and 500 ft east to west. The project had an existing stockbed on the east side, a forest on the south side, an existing road and drainage ditch on the north side and a property line on the west side. The trick was to grade it so it sloped from south to north and from east to west. This was accomplished with a John Deere grader, cutting and shaping the project in two cross directions. The reason why sloping the project was so important was because we had to use a drain tile under each pot in the project. The places we had seen pot-in-pot used elsewhere all had the advantage of very sandy soils, where drainage wasn't a problem. In our application, we had soils ranging from brown clay to lose loamy soil. Our soils hold water and we must get rid of it.

×Pardancanda norrisii **'Sangria'** is an 18-inch plant with heavier, slightly twisted foliage and increased flower count and size. The flower color is an interesting blend of purples with a tough of gold in the sepals.

×Pardancanda **Dazzler Series** is a seedling strain very similar to 'Sangria' in plant and flowering habit It grows 12 to 20 inches in height, with colors ranging from pinks with yellow margins, to darkest purples and near reds, very few with spotting. Another even smaller seedling strain is in the works.

Veronica **'Goodness Grows'** is a release from Goodness Grows Nursery. Spikes of violet-blue flowers, 1 to 1½ ft tall, have an extended bloom season May through frost.

Stokesia laevis **'Mary Gregory'** is a 2-ft plant loaded with 2-inch creamy-yellow flowers in mid summer. It is a Niche Gardens introduction.

Rudbeckia missouriensis **(Missouri black-eyed susan)** has 12-inch mounds of fuzzy foliage topped by bouquets of bright yellow flowers. Zone 6

Sambucus is a shrub that fits well into the perennial garden. The height can be reduced by cutting back the old canes in the early spring. Zone 4

Sambucus nigra **'Pulverulenta'** has green foliage splashed with white specks, starting out nearly white in the spring.

Sambucus nigra **'Madonna'** has bold golden margins, slightly shorter than typical *S. nigra*

Sambucus racemosa **'Plumosa Aurea'** has finely cut leaflets that mature from bright yellow in the spring to lime green in the summer to yellow with a touch of bronze in the fall along with bright red berries.

Ipomoea batatas. There has been an increasing demand for tender perennials, especially the ornamental sweet potato, *I. batatas* They make fast growing ground covers, and prefer the heat of summer to grow. Zone 10

'Blacky' has dark cut foliage to 10 inches tall 'Marguarita' has chartreuse foliage, and 'Pink Frost' has white and green foliage with a violet-pink blush

Lysimachia punctata **'Alexanders' PP#10598** is a Plant Haven, England introduction. The 3-ft plants have cream-green variegated leaves that develop a pink blush during the cooler months of fall and spring. It has golden-yellow, star-shaped flowers in the leaf axils. Zone 5

Oenothera macrocarpa selection (possibly subsp *oklahomensis*). This plant was found in central Oklahoma, it is vigorous and adaptable, and was found growing on an extremely poor site under drought conditions, but it was completely covered by large bright yellow flowers Under normal garden soil conditions, it's a little more open in habit allowing its unusual red stems to be even more obvious. Zone 4

Callirhoe alcaeoides **'Logan Calhoun'** is 8 to 12 inches tall and up to 4 ft in diameter. This native plant is covered by sparkling white flowers throughout most of the summer, and is named in honor of the discoverer, the late Logan Calhoun. Zone 4

Due to the increasing interest in miniatures for troughs and rock gardens we are always looking for new "little jewels". To determine the actual hardiness is very difficult since more are lost during the damp cool weather of fall and spring

***Lewisia* 'George Henley'** is a typical alpine plant forming a 6-inch rosette of fleshy leaves with magenta-red flowers in midsummer It is listed as a Zone 6 plant, but it has been persistent in my Zone 4b garden

Drosanthemum hispidum is a close relative to the *Delosperma*, this miniature forms a dense clump of fleshy leaves covered nearly all summer long with purple-red flowers

New and Usual Conifer Cultivars

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The term "new" is a relative one when dwarf or garden conifers are involved When I use the term "new" it will mean popular or newly acquired by the trade, since collectors usually have this material long before it ever makes it into commercial production Conifers for the garden can come from many sources They can start from a graft of a witches broom, seed from a broom, a chance seedling, or a sport on a plant. The main thing to keep in mind when talking about dwarf conifers is the length of time something can be referred to as new. We all know of the work that Dr. Sidney Waxman has done at the University of Connecticut on broom seedlings. He has introduced many very nice landscape conifers to the industry. This takes quite a long time evaluating each plant to make sure it has a differing characteristic form the next one and then many more years to distribute to the trade, in some cases it can take 20 years or more. Many of these plants are first evaluated by collectors and shared or traded Sometimes a selection can be around for many, many years before it is commercially accepted. So the word "new" is also being used as "collector new" and "industry new"

Which then brings up the classification of sizes The American Conifer Society has established a guide to help eliminate the confusion around the term dwarf conifer They actually prefer to use "garden conifer"

- **MINIATURE**. Grows less than 3 inches a year or will reach around 2 to 3 ft in 10 years Example is *Chamaecyparis obtusa* 'Nana'.
- **DWARF.** Grows around 3 to 6 inches a year or will reach about 3 to 6 ft in 10 years. Example is *Pinus strobus* 'Blue Shag'
- **INTERMEDIATE**. Will grow about 6 to 12 inches a year or will be about 6 to 15 ft in 10 years. Example is *Chamaecyparis pisifera* 'Gold Thread'
- **LARGE.** Grows more than 12 inches a year and will be around 15 ft in 10 years. Example is *Cedrus atlantica* 'Glauca'.

Miniatures are perfect for the trough or patio garden since they will almost never outgrow the space allotted for them. Dwarfs are great in shallow borders or lower level foundation plantings. Intermediates will tend to outgrow the space if not used properly Large should be used only as specimens or where plenty of room is given

One thing to keep in mind when landscaping with conifers is to keep the growth rate in perspective By using the proper plant in the correct location many years of enjoyment can be had

Pot in Pot: From Concept to Reality — II

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INTRODUCTION

I'll begin by telling you who we are. Midwest Groundcovers is a Wholesale Container Nursery started in 1969 by Peter and Irma Orum. We are propagators and growers of: groundcovers, perennials, roses, vines, and shrubs, and we service landscapers and garden centers in the Chicago area and Midwestern states.

I think we have all heard some version of the old saying: "The customer is always right." Although we may get a little tense about this sometimes, I think we all agree, we need to listen to what the customer has to say if we are to remain competitive in the marketplace. My presentation explains one way our company has tried to respond to customer demand in the market.

In our industry there is an increasing demand for larger sized landscape plants. We can sell half of our 5-gal deciduous crop in the same season it is produced. Spring is when we make 60% to 70% of our annual sales. This would suggest we are missing out on 30% to 40% of the potential spring sales of this crop. The easy answer is, "Make more!" right? There are two things preventing this: (1) Our current growing facilities are filled; (2) Capital for new production facilities is limited.

The options we considered in responce to this need are: developing land we currently owned or developing leased or rented land. Using our own land sounds good, but finances and timing are limiting. Rented or leased land seems more feasible. We know the costs of building our own production systems, and the costs of our quonset houses and the plastic to cover them. We have heard of something called a pot-in-pot production system. As a matter of fact, a fellow plant propagator, Charlie Parkerson of Lancaster Farms, is using this system. So we took a trip to see Charlie on a fact-finding mission.

Our hosts are gracious and really practice the slogan of I.P.P.S.: "To Seek and to Share". The system as they use it, certainly appears successful! The key points of the system are: Empty containers are "planted" in a field, much like a field production system. Plants potted in containers are nested into these "socket" pots. The pot (root system) in the ground should be less susceptible to the heat of the summer as the sun does not strike it and the surrounding soil cools it. The pot (root system) in the ground is also insulated by the soil from winter cold and rapid temperature fluctuations.

Some considerations we found pertinent to our situation were:

- Container types and sizes;
- Irrigation system, pressure, and filtration;
- Fertilization method;
- Plant spacing;
- Installation methods;
- Problems unique to the system;
- Pests;
- Costs.

Back at home, our challenges are to research costs, determine installation methods, and design trials. For my part, I will concentrate on our trials.

THE POTS

Beginning with the easier decisions, the container size would be 5 gal as this is our product line. The in-ground, or socket pot, was not a difficult match since our pot supplier makes a more sturdy pot which fits this use perfectly. It turned out that our 5-gal containers worked fine in this system. However, larger containers might encourage plants to grow larger, with a better balance of root system to top growth. Looking to the future, in our 2nd year of trials, we will try some 7-gal containers as well.

PLANT SELECTION

As we thought about plant selection, we considered several factors. The installation equipment would impact the spacing between rows in the field, the tendency being toward wider spacing. To be efficient in land use, plants requiring wider spacing should be used. Using a similar argument, plants on tighter spacing fit more plants per square foot. If the price is near the same regardless of spacing, it is more cost efficient to grow tighter spaced plants in existing production areas.

To ensure timely turnover of crops, plants were chosen for their popularity. In the 1st year, 15 taxa were chosen based on space requirement and popularity. These taxa: *Cornus* 'Isanti'; *Cotoneaster acutifolius*; *C. apiculatus*; *Hydrangea arborescens* 'Annabelle'; *Juniperus sargentii*; *J.* ×*pfitzeriana* 'Mint Julep' (syn. *J. chinensis* 'Sea Green'); *J. horizontalis* 'Blue Chip'; *Potentilla fruticosa* 'Jackman's Variety'; *Ribes alpinum* 'Europa'; *Spiraea japonica* 'Little Princess'; *S. nipponica*; *Syringa meyeri* 'Palibin' (syn. *S. palabin*); *Thuja occidentalis* 'Brabant'; *Viburnum dentatum* Autumn Jazz™ arrowwood; *V. lantana* 'Mohican'. Of these, six seemed suited to pot in pot after the first season: *C.* 'Isanti'; *H.* 'Annebelle'; *S. nipponica*; *T. occidentalis* 'Brabant'; *V. dentatum* 'Autumn Jazz', and *V. lantana* 'Mohican'.

The remainder of the taxa were stunted or grew with less vigor than above-ground plants. Of the plants that appeared healthy in pot-in-pot production, most grew larger than the above-ground controls in the normal production system. This season, though we can't explain why, we've found many of the plants that did poorly in last season's trials are performing well this year.

IRRIGATION AND FERTILIZATION

Plans began to get more complicated as we considered irrigation and fertilization. Our friends in Virginia use both liquid and slow-release fertilizers in their program. A slow-release program can be very efficient in fertilizer dispersal and, with proper irrigation practices, runoff can be minimized. Slow-release fertilizers rely on water contact to carry, and in many cases activate the product. Charlie Parkerson of Lancaster Farms uses a spray stake attached to a drip tube. It delivers 7 gal h^{-1} (gph) in a 180° or 360° pattern.

We are a liquid-feed operation. We are not experts in the use of slow-release fertilizers. We use overhead sprinklers on our smaller materials and in-line drip irrigation in our 5-gal growing areas. If future expansion takes the rented/leased farmland route, it would be our desire to minimize run-off. Our drip system would not be effectively used in combination with slow-release fertilizers. Nor would it work well during the harvesting of pot-in-pot crops.

As far as irrigation systems go, we tested three brands of spray stakes of varying throw patterns and delivery rates, as well as our own in-line drip. Spray patterns included 90°, 160°, 180°, and 360°. Delivery rates were 3, 4.2, 5, 6.6, or 7 gph. Spray patterns seem unimportant but placement of the stake was critical to keep the water within the pot. While 3 gph produced good quality plants, the largest plants were produced using delivery rates greater than 3 gph. The highest rates appear to be overkill for this size container, 4 or 5 gph are sufficient for our needs.

Fertilization trials were carried out in two growing areas. Our own liquid feed in one area, and two slow-release fertilizer products in an area in which we had the ability to irrigate with unfertilized water. For reference we included some plants that would not receive liquid feed or slow-release fertilizer. Slow-release products containing high percentages of nitrogen were chosen since our soil mix contains good amounts of phosphorus and potassium. They were products with 5 to 6 months release time and applied in April since we wanted the plants to run out of fertilizer in the fall.

As I mentioned, we are not slow-release experts. The soil of the plants in both slow-release trials showed very high salt levels in July with nitrogen levels 2 to 8 times optimum. By September nitrogen levels had dropped dramatically to ⅓ to ½ optimum. Despite the high salts, the plants we felt benefitted from pot-in-pot culture and put on good growth. *Hydrangea* in particular showed extreme symptoms of nutrient stress. For the 1999 season we delayed the slow-release application to June 1st and tried using 3- to 4-month products. So far the results are more favorable, though less dramatic, with all plants having similar healthy shades of green (Fig. 1).

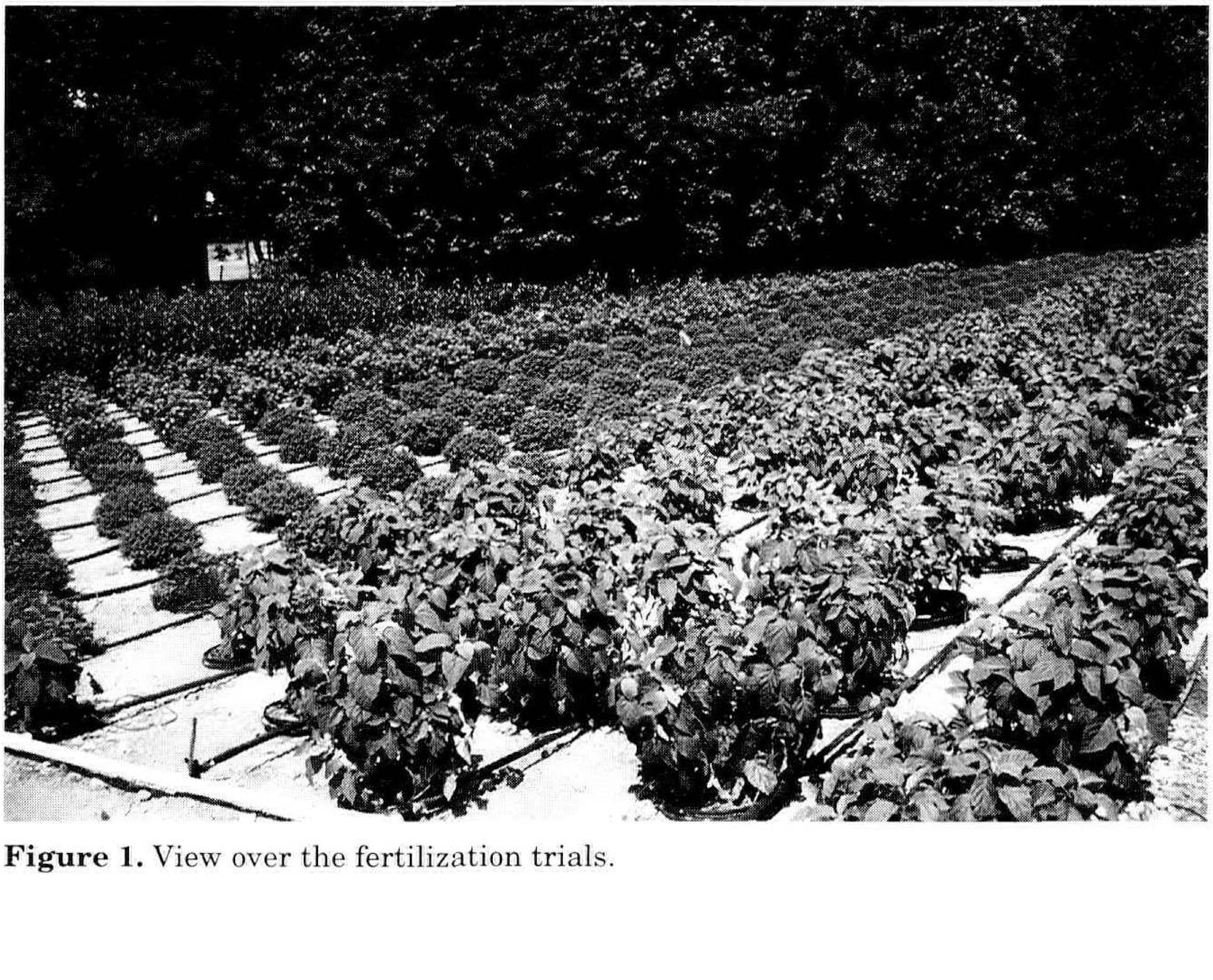

Figure 1. View over the fertilization trials.

SPACING

The first season we put all plants on 36-inch centers for ease of installation. The first season it appeared that plants we normally space closest performed the most poorly. This season (our second season of trials) many of these "poor performers" are growing considerably better, though the reasons are unclear. We've found that detailed measurements, not visual observations, will be necessary to determine whether more space or a larger pot will improve plant quality.

The second season of trials we have begun looking at spacing slow-growing types closer within rows. The idea being it might be economical to produce smaller types in this manner in the future. This would be an easier adjustment and more likely an option than pushing rows tighter together. We also spaced some taxa wider, and put them in larger pots to see if a plant might grow bigger in this system if allowed more space and rooting area to grow.

ROOT ESCAPE

Due to the small relative size of the plants we grow, we did anticipate little problem with roots escaping the two pots and growing into the surrounding soil. We did, however, develop trials to explore the potential of the problem. A root-control product currently popular in the market is a copper compound painted on the inside of growing containers. The compound inhibits root growth on contact, but loses its inhibiting effect once the plant is removed from the container. Another product involves a cloth with capsules impregnated with herbicide, used to control weeds in landscape beds, etc. A piece of the cloth is placed in the socket pot, the cloth and herbicide get wet, and the herbicide volatilizes. The vapors produced should inhibit root growth in the space between the two containers. Our trials included plants with one or the other product, both products, and neither of these two products.

We learned, from the control portion of the trial, that we must take this factor seriously. Some taxa in which we anticipated root escape, like *C.* 'Isanti', were not a problem. Others, like *T.* 'Brabant', seemed to ignore the control measure.

COVER CROPS

As we thought about harvesting the plants, we considered weather conditions at these times. In the summer there should be no problem, but in the spring there can be extended rainy, wet periods. For this reason we seeded grass between some of the rows to provide a stable surface to walk on throughout the year. This caused an impossible situation to maintain. Beside the problem of trying to cut the grass and not the drip tubes, the grass out-grew the plants. Eventually, we sprayed herbicide on the grass before the plants got too big. This would provide a short-term solution. This season we came upon an unexpected source of hardwood mulch which we spread between the socket pots prior to "planting". This appears to be a strong option if economically feasible.

OVERWINTERING

An important part of the trial was winter hardiness. While the root systems are protected more than sitting outside above ground, would this be enough? What varmints might feast on them? Would the plants be smashed by snow/ice?

We certainly had cold temperatures, near record-breaking at -25°F. Unfortunately for the trial, we also had 24 inches of snow on the ground at that time. In our area, snow cover is very unreliable as a form of winter protection. All plants that were alive in the fall made it through the winter. We will repeat this portion of the trial this coming winter.

PESTS

Surprisingly, rabbits and mice have not been a problem to this point, although deer damage has been evident.

CONCLUSIONS

We certainly have learned a lot throughout the investigation of this production process. We are still scratching our heads about some things. Many taxa show great promise in the system while others do not. Our own method of fertilization appears to work best within our version of pot-in-pot production. Spray stakes are an effective method of irrigation in this system. Each plant type must be tested as to the benefits of: root control measures, spacing, overwintering, and overall success within the system. There are many factors to consider, but we think our work will pay off in the long run.

Acknowledgments. I would like to thank Peter Orum for encouraging and sponsoring me in this presentation, Gary Knosher for allowing me the time to work on the project, Charlie Parkerson and the staff at Lancaster Farms for sharing their knowledge and hospitality, Robert Adolph for installing a "new" system and making it work, Mike Rizzi for your assistance throughout the project, the Midwest Groundcovers staff for your patience and cooperation, and my wife, Denise, for letting me go to Denmark to present this paper.

Destiny of Tree Seeds During Germination Under Stress

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INTRODUCTION

When testing germination capacity of seeds in soil or growth substrates the emergence of the shoot is normally recorded. Germination events in the soil are not observed. It would, however, be very beneficial to know more about what happens to the seed in the soil. When studying vigour in tree seeds, it is well known that high- and low-vigour seed lots display different emergence capacity. But what happens to the fraction of the seeds that do not emerge? These may die, stay alive without germination, or may develop a small root or shoot without being able to penetrate to the surface of the soil and, therefore, not establish themselves as seedlings. The fraction of seeds that will not be able to penetrate the surface is larger when environmental stresses increase, but it is not well known how different stress factors affect the destiny of seeds during germination. Increasing our knowledge of the different germination events in a population will enable us to better understand seed vigour and develop more reliable laboratory tests for testing field germination capacity.

METHODS

Seeds of *Abies nordmanniana* (nordmann fir) were prechilled under moist conditions at 4°C for 6 weeks to release dormancy, and sown in boxes with sand. These boxes were developed specifically to test the effect of different temperatures, soil moisture, and sowing depths. A specific type of washed sand was used as growth substrate. The sand was moistened before being placed into the boxes and moistened again in the boxes to water saturation. Afterwards, water was drained off to different levels of standing water in the boxes establishing distances of 4 (V8), 8 (V4), and 12 (V0) cm from the seed position to the water level. These three moisture regimes represent very high, semi-high, and close to optimal moisture contents of the sand. The oxygen concentration is expected to be inversely related to the sand moisture content. Surplus drained sand from each box was used to cover the seeds after sowing. No irrigation was done during the test period.

Exact sowing depths were obtained by using sand-scraping devices to establish a precise sowing surface and surface of the covering sand. The distance from sowing surface to cover surface was 1 (S1), 2 (S2) or 3 (S3) cm, providing increased mechanical stress to the seeds. Controlled temperatures of 5 (T5), 15 (T15) or 25°C (T25) were obtained by placing the sand boxes in growth rooms at 12 h artificial light.

One hundred seeds were sown in each box with three replicate boxes per treatment. Emergence was recorded after a 30-day test period and all non-emerged seeds were retrieved from the sand and classified into empty seeds, dead ungerminated seeds, viable ungerminated seeds, and seeds that germinated in the sand but did not emerge. The final average germination percentage (radicle protrusion of 3 mm) of 4 replicates of 100 seeds on top of moist filter paper at constant 5°C (T5) in the dark was used as control.

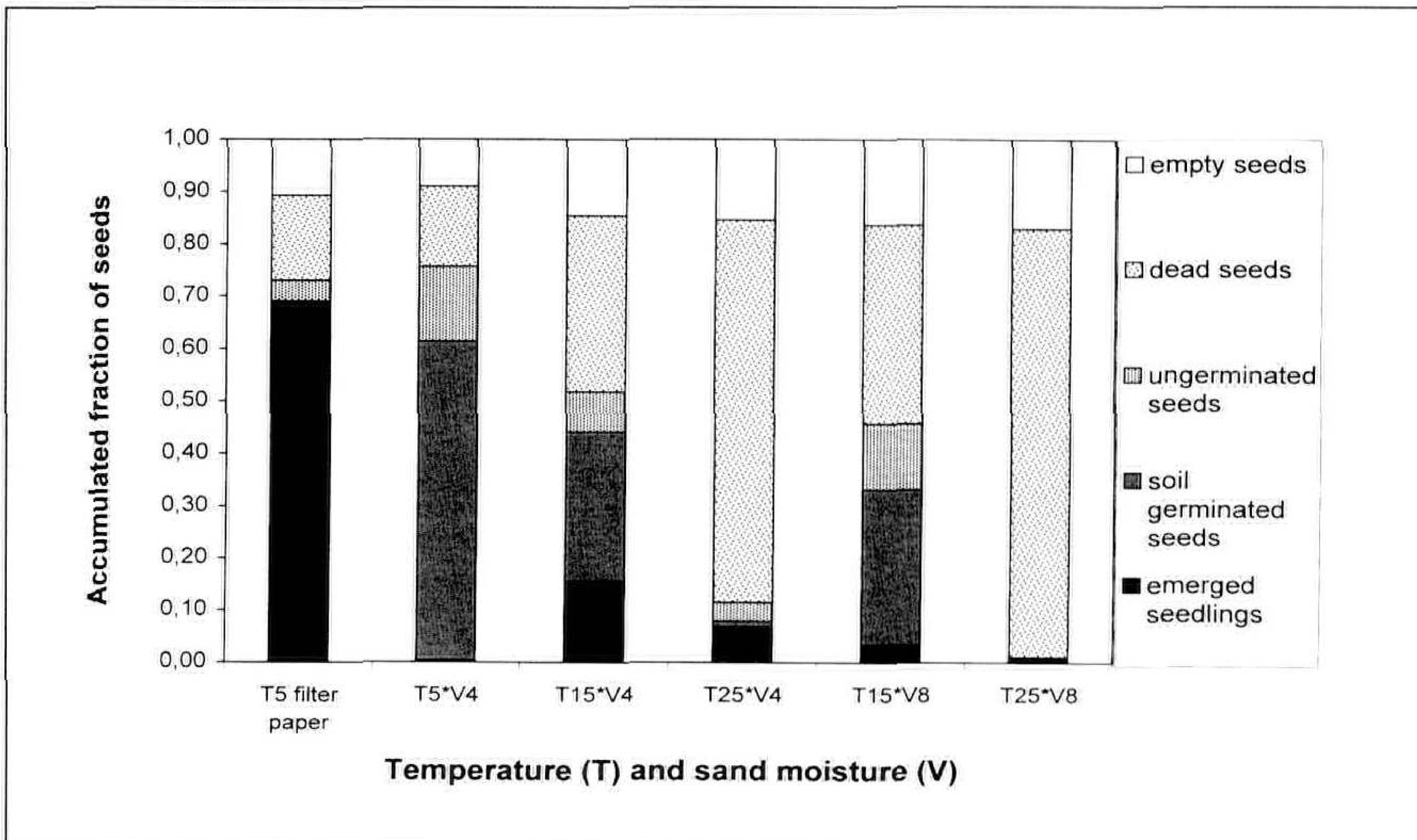

Figure 1. Destiny distribution of *Abies nordmanniana* seeds after a 30-day germination test in sand at different temperatures (T) and sand moisture contents (V). Sowing depth was 1 cm.

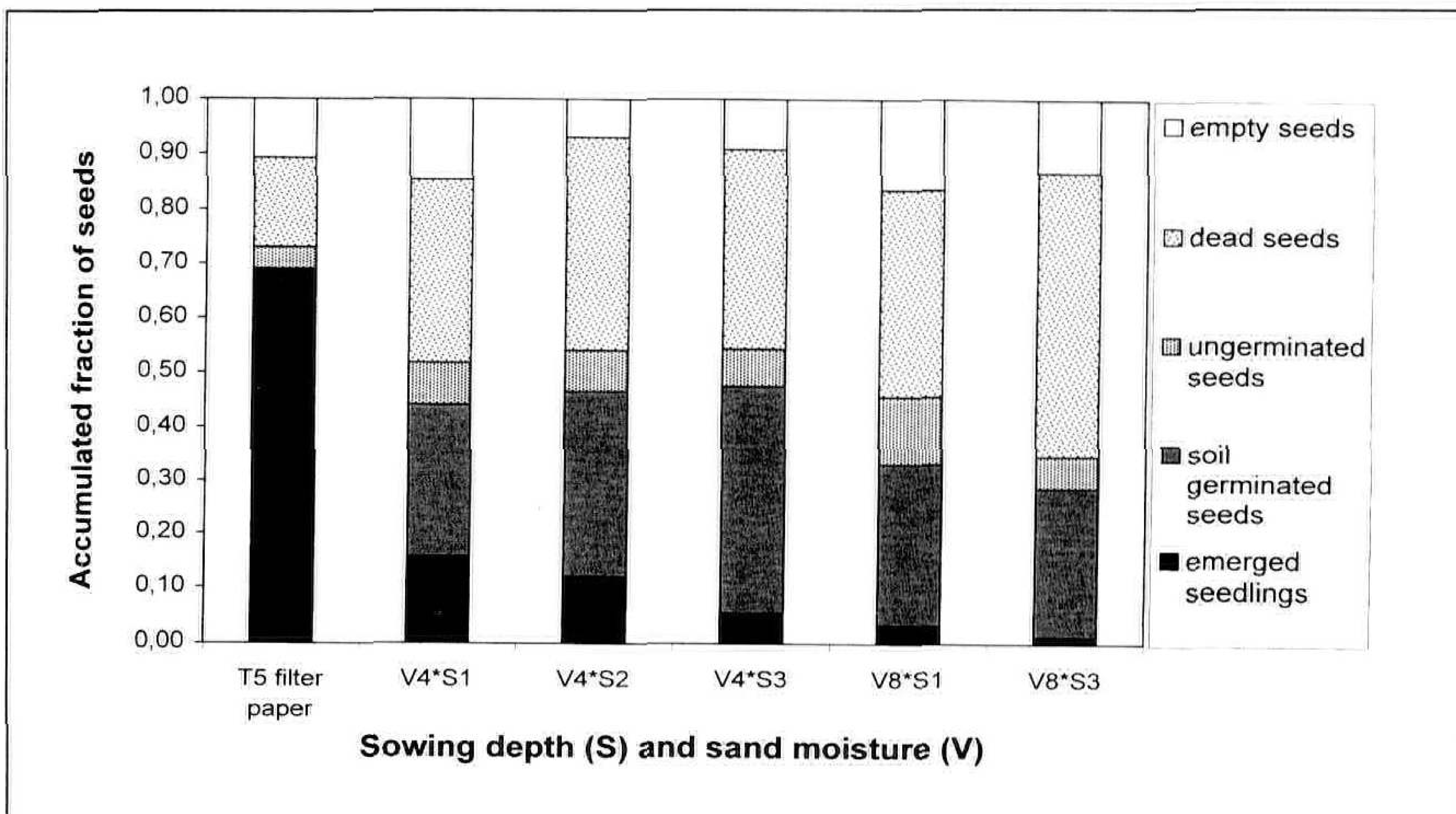

Figure 2. Destiny distribution of seeds after a 30-day germination test in sand with different moisture contents (V) and sowing depths (S). Temperature was 5°C in the filter-paper test or 15°C in sand.

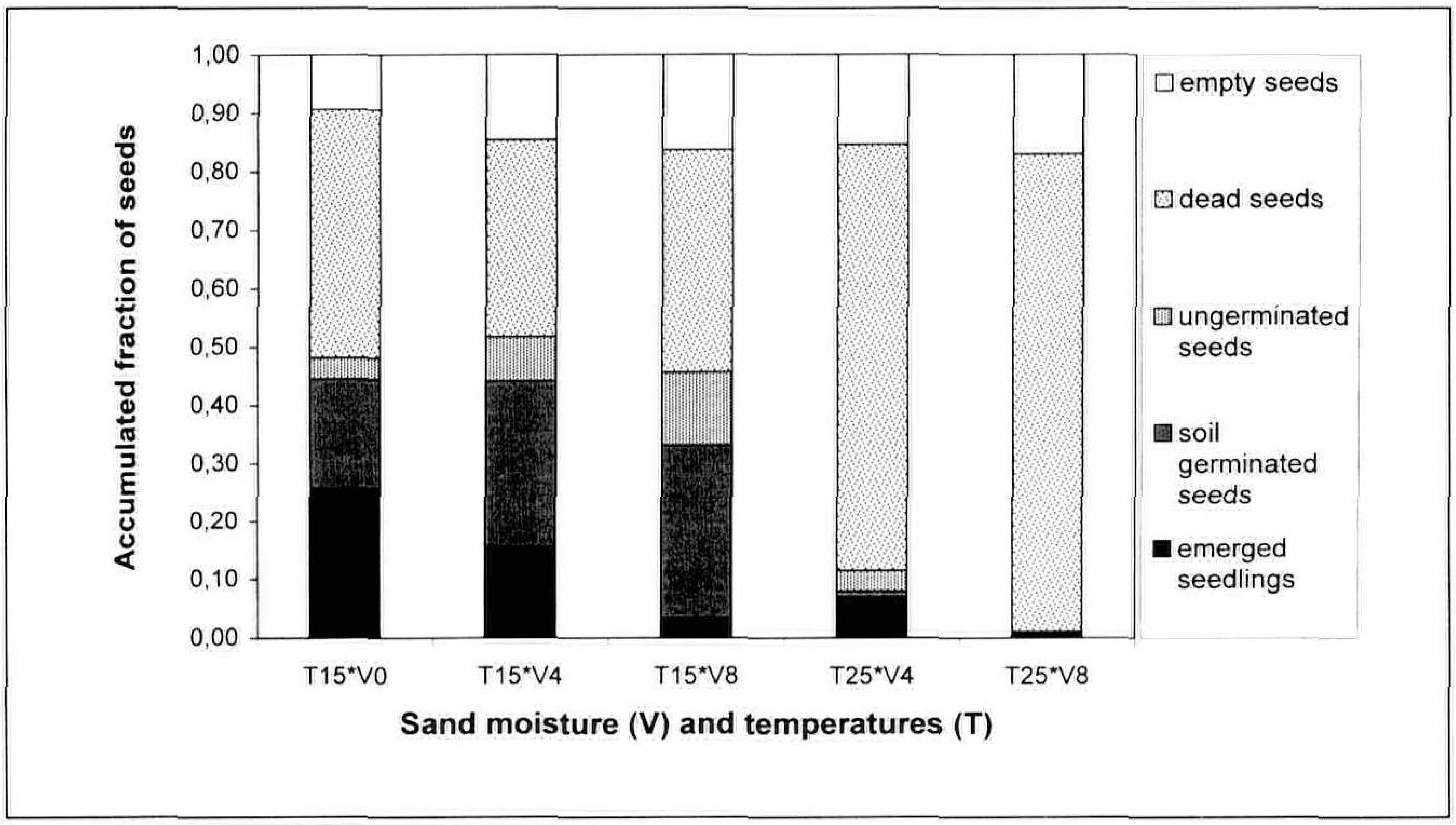

Figure 3. Destiny distribution of seeds after a 30-day germination test in sand at different temperatures (T) and sand moisture contents (V). Sowing depths was 1 cm.

RESULTS

Effect of Temperature. At 5°C and semi-high moisture content (T5V4) seeds germinated almost as well in sand as on filter paper (Fig. 1). However, none of the seeds emerged from the sand. At 15°C some seeds emerged but the fraction of dead seeds at the same time increased significantly. At 25°C a very large proportion of the seeds died before they could initiate germination. In sand with very high moisture content (V8) this was even worse, almost all seeds were killed at 25°C. The combination of high temperature and sand with very high moisture content is found to be detrimental to germination in this seed lot. This tendency is believed to be general to seeds of *A. nordmanniana*.

Effect of Sowing Depth. At 15°C even 1 cm of sand cover reduced the summed fraction of emerged and soil-germinated seeds compared to the germination capacity on filter paper at 5°C (T5, Fig. 2). At increased sowing depths the percentage of emerged seedlings decreased whereas the percentage of sand-germinated seeds increased correspondingly. Thus, the seeds were able to germinate but could not overcome the increasing mechanical resistance of the covering substrate to emerge. The combination of deep sowing and high moisture content of the sand seems to affect emergence capacity negatively.

Effect of Substrate Moisture Content. At 15°C the percentage of emerged seedlings decreased significantly at increasing moisture content from V0 to V8 while the total percentage of emerged, germinated, and viable seeds only changed little (Fig. 3). At 25°C emergence and soil germination was almost completely eliminated when substrate moisture was raised from V4 to V8.

DISCUSSION

This study clearly shows that not all seeds that will germinate under optimal conditions on moist filter paper at 5°C are able to germinate and emerge when sown in a substrate. This partly implies that the seed lot was of medium or low vigour and partly that germination in a substrate impose increased environmental stress on the seeds. Increased stress generally leads to reduced emergence. Seed germination in *A. nordmanniana* seems to be particularly sensitive to high temperatures, high moisture contents, and deep sowing — combinations of these factors giving detrimental results.

The results suggest that oxygen availability is critical. It is shown that it is possible to establish reproducible germination tests with defined stress. Such a test can be used as a vigour test for separating low- and high-vigour seed lots but may also be used to test and predict field emergence, when test conditions are chosen to simulate field stress. An applied vigour test for predicting field emergence based on the sand box system is currently being developed in our laboratory.

ADDITIONAL READING

Jensen, M. and **L. Westergaard.** 1999. Test af frøspiring under stress. Gartnertidende 115 (19)18-19.

Native and Naturalized Plants of North America Worthy of Garden Merit

Howard W. Barnes
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INTRODUCTION

The North American portion of the United States is vast with 9,375,000 km^2, 10 climatic zones, over 8000 native species of plants, and 1600 naturalized plant species (Flora of North America, 1993). The climates range from near tropical with rain forest, swamps to deserts, to high plains steppes, and high altitude mountains with arctic conditions at the summits.

Over all summers are hot, usually 25°C or higher, at times near 38°C, highly humid on the East Coast and much drier and less humid west of the Mississippi River. Winters are often cold in the northern portions with wide temperature ranges and snow.

More southernly reaches don't experience severe cold but this is relative with respect to plant populations. These vast climatic differences account for the great potential for natural plant development since many species occur over several climatic and geographic ranges. Plants of the same species found in New York will often be different from those in South Georgia or Texas.

Another factor influencing native plant development is the occurrence of glaciers during the several ice ages. The latest about 13,000 years ago pushed many cold-hardy species into the more southernly reaches of the continent where they have

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Another factor influencing native plant development is the occurrence of glaciers during the several ice ages. The latest about 13,000 years ago pushed many cold-hardy species into the more southernly reaches of the continent where they have remained, now being in a more temperate climate. However, genetically they have retained much of their ancestors' genetic potential and have proven remarkably adaptable to new homes in much colder climates. These conditions have allowed observant horticulturists and nurserymen to bring many new and exciting things to the gardening world.

PLANT SELECTIONS

***Juniperus virginiana* 'Blue Sentinal'.** *Juniperus virginiana* has a wide range from near New England to Florida and westward towards the Mississippi River, with a disjunct population in the high plains. The potential for new cultivars is large. 'Blue Sentinal', a Lorax Farms introduction is propagated by grafting during winter.

***Hamamelis vernalis* cultivars.** *Hamamelis vernalis* is native to the Ozark Mountains of Missouri and Arkansas and is winter hardy to at least -28°C, (-20°F). 'Autumn Embers' and 'Sandra' are Roy Khlem (Bear Creek Nurseries) introductions with magnificent fall colors. Flower colors are orange and yellow, respectively. The cultivar Carnea is a red-flowered selection. All can be propagated by budding or rooting cuttings.

***Clethra alnifolia* 'Ruby Spice' and 'Hummingbird'.** *Clethra alnifolia*, a common wetland shrub along the Atlantic Coast of the U.S.A. It is easily propagated from softwood cuttings. It is hardy to our Zone 6, which is -23°C (-10°F). The cultivar 'Ruby Spice' is a bright pink to red and 'Hummingbird' is a dwarf form with white flowers.

***Halesia diptera* var. *magniflora*.** There are two species of *Halesia* (Styracaceae) native to the U.S.A. This variety is a selection chosen for superior flowering. It can be rooted from soft tip cuttings in limited numbers, but budding onto the species or *H. carolina* is preferable. Hardy to -23°C (-10°F).

***Callirhoe alcaeoides* white-flowered form and *C. involucrata*.** The *Callirhoe* (Malvaceae) are from the mid western to far western reaches of the U.S.A. They are cold hardy to -34°C (-30°F) and quite adaptable to a wide range of conditions if given drainage. Propagation is from seed that has been cold stratified.

***Clematis texensis* and *C. fremontii*.** North America is blessed with many overlooked *Clematis* species. *Clematis texensis* is a red-flowered vine native to the more southernly portion of the U.S.A., while *C. fremontii* is a shrubby form found in the high plains of the Western States. Both plants are propagated from seed that has been cold stratified. Hardiness is Zone 5, -28°C (-20°F) and Zone 4, -34°C (-30°F), respectively.

***Veronicastrum virginicum* 'Alboroseum' (Scrophulariaceae).** An eastern U.S.A. native. *Veronicastrum* is equally at home in the high plains. It is easily propagated from seed that has been stratified, by division, or by tip cuttings taken early in the season. Hardy to Zone 3, -40°C (-40°F).

***Eupatorium rugosum* 'Chocolate', syn. *Ageratina altissima* 'Chocolate'.** Native to the North East U.S.A. *E. rugosum* 'Chocolate' is a purple-leaved selection. The species is commonly found on disturbed sites and is quite tough. Propagation is by tip cuttings early in the year. Hardy to Zone 6, -23°C (-10°F).

***Spiranthes cernua* f. *odorata*.** An orchid species native to wetlands. *Spiranthes cernua* var. *odorata* is commonly produced via tissue culture, but can be propagated via division and in some cases by cuttings from bloom shoots. Hardy to Zone 3, -40°C (-40°F). It is native from Canada to Florida.

***Morus alba* 'Green Wave'.** *Morus alba* is a naturalized species from China. 'Green Wave' is a weeping selection that can be rooted from softwood cuttings or top grafted. It is hardy to Zone 5, -28°C (-20°F).

***Aesculus parviflora* and *A. pavia*.** Both of these species are from the south-central part of the U.S.A. *Aesculus parviflora* is stoloniferus, forming large tickets and is white flowered. *Aesculus pavia* is a small tree with pink to red flowers. It is one of the parents of *A.* ×*briotti*. *Aesculus parviflora* can be propagated by division, root cuttings, seed, or stem cuttings (Bir and Barnes, 1994). *Aesculus pavia* is propagated solely by seed. Both are hardy, Zone 5, - 28°C (-20°F).

***Ulmus alata* 'Lace Parasol'.** The species *U. alatus* is native to the northern and southeastern portions of the U.S.A. 'Lace Parasol' was discovered in North Carolina about 35 years ago and given its name by J.C. Raulston of North Carolina State University. It is propagated by grafting. Cold hardy to Zone 4, -34°C (-30°F).

***Rudbeckia fulgida* 'Pot of Gold'.** The species is native to the southeastern portion of the U.S.A. 'Pot of Gold' is a more compact and dwarf selection being about ⅔ the size of *R. fulgida* 'Goldstrum'. It is propagated via division or early season off shoots. Cold hardy to Zone 4, -34°C (-30°F).

***Hydrangea quercifolia* 'Snow Queen'.** *Hydrangea quercifolia* is native to southeastern U.S.A. It is quite hardy to Zone 5, -28°C (-20°F). It is easily propagated by seed for the species, whereas the cultivars are grown from softwood cuttings. 'Snow Queen' is an especially floriferous form discovered at Princeton Nurseries, Princeton, New Jersey.

***Thuja* 'Green Giant'.** 'Green Giant' was bred in Denmark and brought to the worlds' attention by the U.S. National Arboretum. It is a hybrid of an North American species, *T. plicata*, and a Japanese species, *T. standishii*. Having hybrid vigor it is a fast grower and has earned quite a reputation for being deer resistant. It is quite hardy to Zone 5, -28°C (-20°F) , and is easily propagated via hardwood cuttings in fall or winter.

***Coreopsis major*.** This plant is native to the Appalachian Mountains and sadly is not used much by the American nursery industry. It is quite floriferous in late summer and is easily propagated via spring cuttings, seed, or division. It is hardy to Zone 6, -23°C (-10°F).

***Cotinus obovatus*.** This a small tree grown principally for magnificent fall color. While native to the Southern U.S.A. it is hardy to Zone 5, -28°C (-20°F). It is propagated via seed that has been stratified and via extremely soft cuttings taken early in the season (Dirr, 1998).

***Salvia lyrata*, lyre-leaf form and red form.** An especially wide spread plant as it ranches from Maine to Florida. The name "lyrata" refers to the central red blotch in an otherwise green leaf. The red leaf form has a darker blotch with a dark leaf. It has blue flowers. It is easily raised from seed or division. Hardy to Zone 3, -40°C (-40°F).

Hibiscus coccineus. *Hibiscus coccineus* is a wetland species found in the swamps of the Mid-Atlantic States. It is easily propagated from seed and from soft tip cuttings. Hardy to Zone 7 and possibly 6 with protection, -17°C (0°F).

***Iris virginica* selected form.** This selection of southern blue flag is native to the eastern portion of the U.S.A. It blooms in midsummer with an especially large blue flower. It is hardy to Zone 6, -23°C (-10°F). Propagation by division.

***Zenobia pulverulenta* 'Woodlander's Blue' (Ericaceae).** A selection by Woodlanders Nursery, Aiken, South Carolina. 'Woodlander's Blue' has especially blue-grey leaves that make the plant quite different than the species and a superior selection. Easily raised from cuttings. The species can be produced via seed. Hardy to Zone 5, -28°C (-20°F).

***Stokesia laevis* 'Purple Parasol' and *Stokesia laevis* 'Mary Gregory'.** Native to the lower Southern U.S.A. These two selection are outstanding. 'Purple Parasol' is self descriptive and 'Mary Gregory' is a soft yellow. Propagation is via root cuttings or by shoot offsets early on. Hardy to Zone 6, -23°C (-10°F).

***Schizachyrium scorparium* 'The Blues'.** A dry-land grass from Eastern North America. 'The Blues' is unique in having intensely blue foliage. It is easily propagated via division. Hardy to Zone 4, -34°C (-30°F).

***Wisteria frutescens* 'Amethyst Falls'.** Two *Wisteria* are native to the U.S.A. *Wisteria frutescens* normally has white flowers but this blue-flowered selection was brought to the trade by HEADLEE Nursery in Seneca, South Carolina. Propagated via cuttings in early summer. Hardy to Zone 5, -28°C (-20°F).

Aster carolinianus. *Aster carolinianus* is an enigma in that it is the only climbing form of *Aster* known. It can be a strong vine, climbing with support to 3 m. It has light blue flowers in late summer or early fall. Hardy to Zone 7 and possibly 6 with protection, -17°C (0°F).

***Acer pensylvanicum* 'Erythrocladum'.** The snake bark maples are exceptionally popular in the U.S.A. and *A. pensylvanicum* 'Erythrocladium' is especially desirable in that the bark is red with white stripes as opposed to the normal green/white stripe combination. As with all snake barks these plants require shade for good development. Hardy to Zone 3, -40°C (-40°F). It can be propagated via budding or grafting onto other snake barks and a more recent report suggests *A. rubrum* as an understock.

Magnolia ashei. Coming from North Florida in the Southern U.S.A., *M. asheii* challenges convention. It is a strong robust tree with huge (30 cm to 40 cm) white, highly fragrant flowers that have a sweet smell of vanilla and lemon. It is hardy to Zone 6, and possibly colder, -23°C (-10°F). Propagation is by seed.

***Betula nigra* 'Tecumse Compact'.** There are few cultivars of *Betula nigra*. Studebaker Nurseries of Carlise, Ohio, have come up with this dwarf form. It is approximately ⅓ the size of the species. 'Tecumse Compact' is easily propagated by cuttings in early summer and by budding. It is hardy to Zone 4 -34°C (-30°F).

***Cercis canadensis* 'Covey'.** Found in New York State and developed by Brotzman Nursery, East Madison, Ohio, 'Covey' has a strong weeping form. Flowering is a bright pink, making for a spectacular effect. It is hardy to Zone 5, -28°C (-20°F). Propagation is via budding onto the species.

***Monarda fistulosa* 'Carmen Miranda'.** 'Carmen Miranda', developed by Lorax Farms, has stunning purple-fuchsia flowers and has not shown signs of powdery mildew in tests. It is easily propagated via soft tip cuttings. Hardy to Zone 4, -34°C (-30°F).

***Gillenia trifoliata* 'Pink Profusion' (syn. *Porteranthus trifoliatus* 'Pink Profusion') (Rosaceae).** 'Pink Profusion' is a variation of the normally white-flowered form. It is easily propagated via soft tip cuttings in early spring. The jury is still out when it comes to seed propagation. Perhaps there is hope that it will come true via seed. Hardy to Zone 6. An introduction of the Mt. Cuba Center for the Study of Piedmont Flora, Greenville, Delaware.

Lithospermum caroliniense. A shrubby type perennial native to the high plains of Central North America, *L. caroliniense* (Boraginaceae) is stunning with an explosive burst of yellow flowers. However, attempts at propagation have defied even the best of propagators so this plant has not made it into cultivation. Seed would seem to be the logical choice but its specific requirements have not to date been met. A Holy Grail that deserves pursuit. Hardy to Zone 5, - 28°C (-20°F).

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Plant Hunting for the 21st Century

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The Southern landscape is a landscape dominated by exotic woody species, mainly in the small tree, shrub, and vine category. Plants from Asia, Mexico, the Old World, and other distant lands create the character of our urban landscapes. Opportunities for the introduction of new plants still exist. Many exciting species, forms, and varieties have yet to find a spot in the mix of landscape plant materials used in Southern U.S. landscapes.

INTRODUCTION

Can you imagine a Southern U.S. landscape without exotic plants? First, eliminate all the old-time harbingers of spring: shrubby flowering quinces, forsythias, bridal wreaths, and flowering almonds. They all trace their ancestry back to Asia. They are durable, showy, long-lived landscape plants that continue to make their mark simply because people plant them and like them. In the evergreen category, the ligustrums remain as Robinson originally described, "the meanest of all mean shrubs." Waxleafs and privets have easily escaped landscapes and found their way to the fence rows and back corners of every nook and cranny of the southern forest. Can you think of a world without the Japanese honeysuckle, *Lonicera japonica*? What about nandinas? They are as tough as they come and are prospering on their own in many a sunlit woodland pocket, self-seeding and spreading quietly and slowly, without much fanfare or applause.

The rose of Sharon, *Hibiscus syriacus*, is really not from Syria as Linnaeus believed, but evolved instead in China and India. *Euonymus* may get a bad word or two from horticulturists "in-the-know", but it's still an Asian species that won't go away — one that remains a mainstay in the trade in spite of pest problems and overuse. The Japanese and Chinese wisterias have left the urban landscapes to become a part of our natural forest, more common in fact than the better behaved native wisterias of the Southern U.S. Asian abelias, particularly the *Abelia* ×*grandiflora* cultivars, remain one of the most common shrubs in the south and finds a sunny spot to its liking almost anywhere from Texas to the U.S. East Coast. The indica and kurume azalea world can be seen on every main or side street in every urban landscape of the Southern U.S. — millions of plants if a count were to be made. There are many, many other Asian woody species that take their place in the woody plant inventory of small trees, shrubs, vines, and ground covers of the South.

Why so many exotics and so few natives in Southern landscapes? One might think that the root cause of the dominance of exotic plants might simply be snobbery. After all, the history of settlement in North America involved an unwillingness to give up the landscapes of the "Old World". In fact, in the 1850s, Downing wrote of Americans unwilling to appreciate or plant the local flora, instead going to great lengths to secure the plants of the Old World, many somewhat temperamental, for their new home in America. The plant explorations in the 18th and 19th centuries retrieved many choice plants from China, with a surge around the turn of this century, and these were quickly brought into the landscape trade. While the trendy tendency to "exotic" plantings may play a part in the mix of natives vs. exotic species utilized, most of the reason for Asian plant domination can be attributed to the landscape merits of the plants involved. Toughness of character, bloom show, habit, and form, and ease of propagation, care, and culture are the major factors that have led to the dominance of Asian plants in the landscapes of the Southern U.S.

Are all the glory days of plant hunting over? Have all the landscape-worthy species been found, collected, and planted in the New World? The answer is simply no. While some might argue that all the great collections are behind us, there are still species to be introduced and tested and, most important, there are still varieties, selections, and forms to be evaluated and crosses to be tried. Hunting plants is a lifestyle. Strengthening the argument for more woody plant evaluation in the South, one must note that many if not most of the early Asian introductions were made into the prestigious botanical gardens and arboretums of the North. Many species perhaps more adapted to southern climes were lost. The encouraging news is that the evaluation of species, forms, and varieties in the arboreta, botanical gardens, and private gardens of the South is escalating with all kinds of promising landscape candidates emerging.

HUNTING PLANTS IN FOREIGN LANDS

Plant hunting in foreign lands requires planning depending on the country involved. Besides the usual passport/visa details, there are plant importation procedures to be followed for the successful introduction of horticultural germplasm into the U.S. (White and Waterworth, 1996).There are all kinds of private/academic programs that are successfully introducing nonrestricted plants into the U.S. Strategies to retrieve the special plants and provenances of the flora of distant lands are certainly going to intensify as economic and societal dictums allow.

In a trip to China in 1997, the author took these notes at the Yunnan Academy of Forestry Sciences (contact person: Jiaqing Yin, VP Senior Engineer, Heilongtan, Kunming, China 650204 – please note: spelling as per Yin's unpublished notes and plant labels): "Incredible collection of magnolias and conifers and others. So many other species I wish I could get my hands on but they are under lock and key. However, I retrieved a species list (unpublished manuscript) and contacts for the future. Standout specimens included a strange weeping *Sophora* spp., *Michelia chinensis*, *M. platypetala,* and a recently discovered yet-to-be-named species of *Michelia*; *Mangletiastrum* spp.; *Parakmeria yunnanensis*; *Keteleeria evelyniana*, *K. davidiana* (syn. *K. calcarea*), *K. fortunei*, and *Keteleeria* unknown species; *Abies delavayi*, *A. smithii*, and *A. georgei*; *Pseudotsuga sinensis*, *P. forrestii*; *Tsuga dumosa*; *Picea crassifolia*, *P. likiangensis*; *Larix principis-rupprechtii*; *Pseudolarix amabilis* (syn. *P. kaempferi*); *Pinus yunnanensis*; *Taiwania cryptomerioides* (syn. *T. flousiana*); *Cryptomeria japonica* var. *sinensis* (syn. *C. fortunei*); *Thuja orientalis* (syn. *Playtycladus orientalis*); *Calocedrus macrolepis*; *Juniperus formosana* and *J. monosperma*; *Nageia wallichiana* (syn. *Podocarpus wallichiana*); *Cephalotaxus sinensis*, *C. oliveri*; *Taxus yunnanensis*, *T. chinensis*, *T. mairei*; *Amentotaxus yunnanensis* and *A. argotaenia*. The Magnoliaceae is at its finest here; in the Manglietias, I found *M. grandis*, *M. yunnanensis*, *M. hookeri*, *M. crassipes*, *M. megaphylla*, *M. moto*, *M. forrestii*, *M. insignis*, *M. glauca*, *Manglietia* spp. (to be named), *M. tenuipes*, *M. duclouxii*, and finally *M. fordiana*. I still remain dazzled by the diversity, yet unsure of whether we are looking at synonymy or stretched taxonomic gymnastics. In the magnolia world, I found plants listed as *Magnolia maudiana*, *Parakmeria yunnanensis* (syn. *M. yunanensis*), *M. odoratissima*, *M. megaphylla*, *M. henryi*, *M. delavayi* (and a red-flowering form; saw a photograph; plant was not in bloom), *M. officinalis*, *M. sicholaiik*, *M. amoena*, and *M. liliiflora*. Others of interest: 13 species of *Cinnamomum*, *Phoebe sheareri*, and *P. zhennan;* five species of *Mahonia*, *Holboellia fargesii*, and *H. latifolia*, and five species of *Pittosporum*.

At the Kunming Botanical Garden we received the grand tour via Guan Kaiyun (Director, Senior Research Fellow, Kunming Botanical Garden, the Chinese Academy of Sciences, Heilongran,Kunming, Yunnan 650204, China) and Shi-qiong Wang (Kunming Institute of Botany, Heilongtan, Kunming 650204, Yunnan, P.R. China). At the Kunming Botanical Garden, the magnolia family collection is in a walled garden and included a cornucopia of species and forms that I have not seen reported. The genus *Magnolia* was represented by very healthy specimens of *M. amoena*, *M. campbellii*, *M. coco*, *M. cylindrica*, *M. delavayi*, *M. denudata*, *M. grandiflora* (U.S.), *M. kobus*, *M. lilliflora*, *M. officinalis*, *M. officinalis* var. *biloba*, *M. rostrata*, *M. sargentiana*, *M. shangpaenis*, *M. sieboldii*, *M.* ×*soulangiana*, *M. sprengeri*, *M. tripetala*, *M. wilsonii*, and *M. zenii*. *Manglietia chingii*, *M. crassipes*, *M. duclouxii*, *M. fordiana*, *M. glauca*, *M. grandis*, *M. insignis*, *M. wangii* round out the manglietias — all strong candidates for our area of the South. *Manglietiastrum sinicum* was new to me and looked exciting. *Michelia*, the banana shrub, typified in our area by *M. figo* and *M.* ×*foggii* is another favorite in the SFA Mast Arboretum; *Michelia* species represented at the Kunming Botanical Garden included *M. champaca*, *M. chapensis*, *M. chingii*, *M. doltsopa*, *M. fallax*, *M. figo*, *M. floribunda*, *M. foveolata*, *M. hedyosperma*, *M. macclurei*, *M. martinii*, *M. maudiae*, *M. platypetala*, *M. skinneriana*, *M. sphaerantha*, *M. velutina*, *M. siensis* (syn. *M. wilsonii*), and *M. yunnanensis*. A *Paramichelia baillonii* was reported to be a new species find in the Yunnan. *Parakmeria lotungensis*, *P. nitida*, and *P. yunnanensis* should have fine potential in the South — with only the first being tested in the U.S. to my knowledge. *Tsoongiodendron odorum* rounds out the last of the Magnoliacea that impressed me.

In the Illiciaceae, I came across eight species that made my heart race, including *Illicium simonsii* (note: now in the U.S.) and *I. verum*. Readers wishing the entire expedition diary should contact the author. There are many other exciting opportunities for plant introductions and plant improvements. The following are a few:

Abelia. A common, durable generally pest-free landscape plant with many attributes of bloom, foliage, and form. Clarke Abel gets the credit for the first abelia out of China in 1817: the deciduous, somewhat open shrub *Abelia chinensis*. The species languished and was underutilized until Robert Fortune reintroduced living plants, and a new species, *A. uniflora*, in 1844. About the same time, *A. floribunda* was introduced out of Mexico, a tender species sporting spectacular red flowers. Crosses of *A. chinensis* and *A. uniflora*, the product of which is *A.* ×*grandiflora* are not mentioned in the literature until the early 1900s. There are nine other species of *Abelia* listed in the Royal Horticultural Society Dictionary of Gardening, most of which are rarely seen. Other sources list six more. Open-pollinated *A. chinensis* (somewhat irregular form, deciduous with outstanding fragrant bloom show), most likely crosses with taxa in the

A. ×*grandiflora* group (good form, evergreen with a less-than-striking blooms), are in the evaluation stage as the result of work by Michael Dirr in Georgia. The first year of evaluation at the SFA Mast Arboretum indicates some excellent plants in the offing. Future work should consider crosses of *A. floribunda* with *A. chinensis* or *A.* ×*grandiflora* cultivars; the combination might create some exciting results.

Illicium. The anise trees of American and Asian origin offer all kinds of exciting possibilities with several species just now reaching the United States. We have long been enamored with the anise shrubs/trees in the SFA Mast Arboretum. In our opinion, *I. floridanum* (the Florida Anise) and *I. parviflorum* (small anise tree) have been underutilized in our stretch of the South for years. The culitvar picture is improving (Michael Dirr lists seven cultivar but more exist in the underworld of *Illicium* afficionados). More recently, the Asian species are just now finding their spot in the gardens of the South. Three or four cultivar of *I. anisatum*, the star anise, exist and a relatively new species, *I. henryi*, the Chinese anise tree, was introduced by Bob McCartney from a source in England in 1971. The latter is proving to be an outstanding species for the South, a durable evergreen large shrub, dense in foliage with showy pinkish-white flowers.

We are currently testing *I. henryi* in "full sun" and the results are promising, if careful attention is paid to moisture in the establishment years. *Illicium mexicanum* has received some fanfare in the trade, but the SFA Mast Arboretum has had poor results, except with one plant that has done well in a partly shaded location. The most exciting part of the *Illicium* picture is that many species (in China) remain uncollected, or are just now entering the trade. Zhang et. al. (1999) list 10 species still unknown in the U.S. *Illicium simsonii* is a recent entrant into the U.S. (to a botanical garden on the U.S. West Coast). It is reported to sport large, yellowish flowers; this is an anise tree with outstanding potential in the South. *Illicium verum* is described by the Royal Horticulture Society as a small tree to 7.5 m (25 ft) with yellowish flowers. There are many others that have not yet been tested in the South.

Loropetalum. Few Chinese woody plants have surged to the head of the pack as quickly as the Chinese fringe flower, *L. chinense*. The advent of sizzling hot pink blooms and burgundy foliage forms in the early 1990s (red-flowered forms) has an interesting history but has nonetheless resulted in a plethora of cultivars and forms. Michael Dirr lists 19 cultivars and the list continues to expand. 'Burgundy' remains a winner; 'Zhuzhou Fuchsia' appears to be more upright; 'Ruby' is performing well in the SFA Mast Arboretum, but it's too early to know if this is a true dwarf. The Arboretum will be planting 23 clones in Fall 1999. With care and culture characteristics similar to the witch hazels, the Chinese fringe flower is destined to expand its home all across the Southern U.S.

Styrax. The styraxes or snowbells of Asia remain under exploited in our section of the Southern U.S. and there are all kinds of opportunities to expand the cultivar picture. Three species and their cultivars dominate the trade: *S. americanus* (our native with no major cultivars – two forms), *S. japonicus* (many cultivars), and *S. obassia*. There are over 100 species of *Styrax* in the world and the opportunities for selection are enormous. In the *S. japonicus* world, there are white-flowering forms, weeping forms, and pink-flowering forms. Most promising are the pink weepers, which are not in our collection but which we want to obtain. J.C. Raulston's most significant introduction, *S. japonicus* 'Sohuksan' (currently sold as 'Emerald Pagoda'), is a step apart from others of the same species and sports bigger leaves and flowers. It's proving to be an outstanding small tree in our garden; however, questions about chilling requirement remain (late foliation, blind buds, tufted appearance early in the season after mild winters). We have six other species and several taxa in the Arboretum in early stages of evaluation. Again, opportunities for selection abound.

Closely related, *Sinojackia rehderiana* is proving to be a winner. While it needs a common name a little more appealing than "jack tree", it's proving to be an easily propagated, fast growing snowbell-like tree for the South. Introduced into the U.S. in 1930, it has yet to achieve the notoriety it deserves. Less vigorous, the smaller-leaved *S. xylocarpa* appears less adapted to our region.

Others With Promise for Improvement. There remain opportunities everywhere for improving the nature and quality of "our" Asian landscape plants. For instance, *Campsis grandiflora*, the Chinese trumpet creeper offers a very showy, large bloom. The cross with the native *C. radicans* results in a robust hybrid with dark orange blooms, often referred to as a "Madame Galen" type, which is actually a specific cultivar of the cross. Because *C. grandiflora* has self-fertility problems, the transfusion of other *C. grandiflora* clones into the mix might allow greater diversity in flower color and flower size. That is already happening with recent introductions into the trade. *Cephalotaxus harringtonia*, the Japanese plum yew, and other *Taxus* species, offer opportunities for exploration. The maples of China, Japan, and Korea all deserve more intense evaluation in the south. There are many obtuse recent introductions that deserve attention:

- *Celtis sinensis* 'Emerald Cascade' — a one-of-a-kind geotropically challenged weeping Chinese hackberry;
- *Euscaphis japonica* — the Korean sweetheart tree with a brilliant red fruit display in the fall;
- *Persea thunbergii* (syn. *Machilus thunbergii*) — a broad-leaved evergreen tree with flowers that never distract;
- *Cinnamomum chekiangenses* — a hardy 9 m (30 ft) camphor tree in our arboretum;
- *Phoebe chekiangensis* — a broadleaved evergreen now at 6 m (20 ft) in our arboretum and still growing;
- *Emmenopterys henryi* — flowering "for-the-first-time" events in the U.S. now;
- *Daphniphyllum himalense* var. *macropodum* — the ultimate "I-need-a-common-name" round, green meatball with bold glossy foliage.

The list could go on.

CONCLUSIONS

Plant hunting and the transfusion of plants into the Western world have a relatively recent history — three centuries for the bulk of the introductions. While the great plant introductions have left us with an undeniable exotic influence, there remains much to be done. The long-term nature of woody plant evaluation makes the point that arboretums, botanical gardens, public gardens, and plant enthusiasts in the Southern U.S. can drive the landscape picture of the future!

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Plant Breeding Efforts in *Stokesia, Cercis,* and *Buddleja* at North Carolina State University

Dennis J. Werner

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INTRODUCTION

Breeding and genetic studies of various herbaceous perennial and woody ornamentals have been initiated by the author at North Carolina State University. These efforts, in conjunction with ongoing efforts by Dr. T. Ranney in the development of pest-resistant ornamental taxa, and the continuing commitment to new plant acquisition and testing by the J.C. Raulston Arboretum (JCRA), under the direction of Dr. Robert Lyons, reflect the department's commitment to the development of new cultivars for the nursery industry.

The author has initiated breeding efforts in various ornamental taxa based on available genetic resources currently available in the JCRA, and based on discussions with colleagues and nurserymen. In this report I will discuss the current efforts in *Stokesia, Cercis,* and *Buddleja* breeding. In addition to development of new ornamental cultivars, the research program will also focus on other related objectives including studies of reproductive biology, genetic diversity, propagation, and inheritance of important traits in these genera.

Stokesia. *Stokesia laevis* (Hill) E. Greene (Stokes aster) is a herbaceous perennial native to the Southeastern U.S. Its range is quite restricted, with scattered populations found primarily in Mississippi, Alabama, Florida, Louisiana, and Georgia. Historically, Stokes aster has enjoyed moderate popularity in the perennials industry. Renewed interest in this plant has been fueled by the discovery in central Georgia of a population of Stokes aster demonstrating unique architecture. This population, now lost due to agricultural use of the site, was discovered in Colquitt County, GA, near the town of Omega by Ron Dieterman of the Atlanta Botanical Garden. Plants in this population showed tall, upright flowering scape architecture, unlike the shorter, non-upright scapes typical of the species. Selections from this population have given rise to the cultivar 'Omega Skyrocket'. 'Omega Skyrocket' has lavender-blue flower color typical of the species.

Our initial breeding objectives have focused on incorporating the novel upright scape architecture into a broader range of flower colors. Accordingly, we have hybridized 'Omega Skyrocket' with cultivars 'Alba', 'Mary Gregory', and 'Purple

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Parasols', demonstrating white, yellow, and deep violet flower color, respectively. Preliminary hybridization experiments suggested that Stokes aster is sexually self-incompatible, simplifying the hybridization process and eliminating the need for emasculation (removal of male sexual flower parts on the intended female parent). First generation hybrid plants (F_1 progeny) in all crosses demonstrate both violet-blue flower color and upright growth architecture characteristic of 'Omega Skyrocket', suggesting genetic dominance of these characters. Selected progeny within each of these three F_1 families have been intercrossed, and F_2 seed have been obtained. F_2 populations, which will show genetic segregation for the various traits of interest, will be field planted in the summer of 2000. Individuals showing the desired combinations of traits will be selected and further tested in comparative performance trials.

Cercis. The late J.C. Raulston accumulated a large collection of species of *Cercis* and cultivars of *C. canadensis* L., now established at the J.C.R.A. The high number of interesting genetic variants in *C. canadensis* offers a number of breeding opportunities. Traits of interest include red leaf color ('Forest Pansy'), leaf variegation ('Silver Cloud'), double flowers ('Flame'), white flowers ('Alba'), pink flowers ('Wither's Pink Charm'), violet-red flowers ('Appalachian Red'), weeping growth habit ('Traveller' and 'Covey'), purple fruit color (some accessions of *C. canadensis* var. *texensis* [syn. *var. mexicana*]), and glossy foliage (*C. canadensis* var. *texensis*). We have made hybridizations in numerous combinations between all of these taxa. Initial hybridization attempts suggest that controlled crosses in *Cercis* are difficult, as fruit set was poor.

Because the pollination biology of *Cercis* is unknown, we resorted to emasculation when making crosses, which may result in flower injury and a decrease in fruit set. However, we were successful in obtaining F_1 seed from 15 different parental combinations in 1999. 'Traveller', a weeping cultivar of considerable breeding interest, is particularly difficult to use in hybridization. Two years of effort suggest that it is highly female sterile, and will produce little or no fruit. Additionally, 'Traveller' appears to produce little to no viable pollen, and also performs poorly as a male parent in hybridizations. Fertility of this cultivar will be studied further.

We have grown out open-pollinated progeny (seed collected from a specific cultivar, hence the female parent is known, but with no knowledge of the male parent) of various cultivars. Of particular interest are the progeny grown from seed collected from the variegated 'Silver Cloud'. Of 520 daughter plants, only two individuals showed the variegated character of 'Silver Cloud'. This demonstration of sexual transmission of the variegated trait from 'Silver Cloud' to its offspring suggests that the variegated character present in this clone is not caused by chimerism. Because of our lack of knowledge of the pollination biology of *Cercis*, and consequently our inability to infer whether these offspring are a result of self or cross pollination, no conclusions can be made regarding the inheritance of this trait at this time.

Buddleja. The high amount of genetic variability present in *Buddleja* affords considerable opportunity to develop new and novel taxa through controlled breeding. Initial efforts in our *Buddleja* breeding have focused on compactness, silver-gray leaf color, flower color, and the development of sterile cultivars. Considerable effort has been made hybridizing the yellow-flowered *Buddleja* 'Honeycomb' with various cultivars with the objective of developing yellow-flowered taxa demonstrating more compact growth, greater flower production, and silver-gray foliage color. The potential for interspecific hybridization in *Buddleja* appears great. Numerous clones already in the commercial trade represent interspecific hybrids, and our initial breeding efforts suggest that controlled hybridization of *B. davidii* Franch. with *B. lindleyana* Fortune, *B. globosa* Hope, *B. fallowiana* Balf., and *B. salviifolia* (L.) Lam. are possible. Other interspecific combinations are currently being explored.

Because *Buddleja* has the potential to spread from cultivation, we are exploring the possibility of developing sterile cultivars. The approach we are using is to develop triploid (plants with three sets of chromosomes) cultivars by hybridizing normal diploid cultivars with a tetraploid clone (four chromosome sets) developed by Dr. Tom Ranney. These hybridizations appear successful. Progeny will be field tested in summer of 2000.

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Ranney, T. 1999. North Carolina State University, Horticulture Sciences Department, Mountain Horticulture Crops Research and Extension Center, Fletcher, North Carolina 28732.

New Color Plants for the South

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INTRODUCTION

My lifelong goal is to trial, discover, and develop low maintenance ornamental plants uniquely adapted to the South. Most of the plants I work with are tropical in origin and produced by cuttings. Others are old-fashioned heirlooms and I have a particular interest in perennial bulbs and reseeding annuals. This presentation includes a sampling of my recent projects.

***Lupinus texensis* 'Texas Maroon' (maroon bluebonnet).** An aggie maroon strain of the Texas State flower. This took years of selection from original blue tinges on pink flowers in a production field of pink bluebonnets. This was a joint introduction between Dr. Jerry Parsons and myself of Texas A&M University (TAMU). The selection was introduced by Wildseed of Fredericksburg, Texas, and is a 2000 TAMU CEMAP (The Coordinated Education and Marketing Assistance Program) promotion. This program is an industry - university cooperative program in which Texas A&M University and industry leaders partner in the identification of superior landscape plants for Texas and their subsequent promotion in the market place.

***Consolida ajacis* (syn. *C. ambigua*) (bunny bloom larkspur).** This is a selection of old-fashioned single larkspur by Dr. Jerry Parsons of TAMU. It blooms at Easter and has a rabbit in every flower!

***Petunia integrifolia* (syn. *P. violacea*) 'VIP' (VIP petunia).** 'VIP' is a vigorous, heat-tolerant, cultivar from South America. I made a selection from seed collected in a German garden. It has darker flowers and is more floriferous than the common compact growth, greater flower production, and silver-gray foliage color. The potential for interspecific hybridization in *Buddleja* appears great. Numerous clones already in the commercial trade represent interspecific hybrids, and our initial breeding efforts suggest that controlled hybridization of *B. davidii* Franch. with *B. lindleyana* Fortune, *B. globosa* Hope, *B. fallowiana* Balf., and *B. salviifolia* (L.) Lam. are possible. Other interspecific combinations are currently being explored.

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***Consolida ajacis* (syn. *C. ambigua*) (bunny bloom larkspur).** This is a selection of old-fashioned single larkspur by Dr. Jerry Parsons of TAMU. It blooms at Easter and has a rabbit in every flower!

***Petunia integrifolia* (syn. *P. violacea*) 'VIP' (VIP petunia).** 'VIP' is a vigorous, heat-tolerant, cultivar from South America. I made a selection from seed collected in a German garden. It has darker flowers and is more floriferous than the common form. 'VIP' is propagated from cuttings, but I am working on a seed strain in several colors. It is a 1999 TAMU CEMAP promotion.

***Petunia* 'Laura Bush' (Laura Bush petunia).** A seed-propagated, heat-tolerant, strongly reseeding petunia that occurred as a cross between *P. violacea* and an old-fashioned petunia (*P.×hybrida*). 'Laura Bush' was introduced by Peterson Brothers of San Antonio, Texas. It is a joint introduction with Dr. Jerry Parsons and a 2002 TAMU CEMAP promotion.

***Verbena* 'Blue Princess' (blue princess verbena).** A prolific, heat-tolerant, perennial verbena that I obtained from the Royal Horticultural Society's nursery at Wisley, England, on a trip with J.C. Raulston. Tops in Texas A&M verbena trials. It was introduced by Lone Star Growers (ColorSpot), and is a 1998 TAMU CEMAP promotion.

***Verbena* 'Pinwheel Princess' (pinwheel princess verbena).** A lavender and white pinwheel striped sport of 'Blue Princess' I found at the Stephen F. Austin (SFA) Mast Arboretum. 'Pinwheel Princess' has the same super strong 'Blue Princess' vigor. It appears to be an identical sport found by former SFA graduate and friend Matt Welch in North Carolina.

***Verbena* 'Rose King' (rose king verbena).** Perhaps the most vigorous of any perennial verbena I have grown. It has gaudy, magenta-pink flowers. The all-pink version of 'Tiger Rose'. It may occasionally revert to purple striped flowers. 'Rose King' was collected from an old landscape in East Texas, and introduced by Aubrey King at King's Nursery in Tenaha, Texas.

***Ruellia brittoniana* - dwarf cultivars (dwarf Mexican petunia).** Besides the popular dwarf purple ('Katie'), a dwarf pink and dwarf white are now on the market. In addition to developing the dwarf pink, by crossing 'Katie' and 'Chi Chi', I hope to develop others as well.

***Hibiscus* 'Flare' (flare rose mallow hibiscus).** A fantastic development from Sam McFadden of Somerville, Tennessee. 'Flare' has glowing hot pink flowers on a nice compact plant, and is sterile with no seed set. It was introduced by Dr. Jerry Parsons and Lone Star Growers (ColorSpot) of San Antonio. It is a 2000 TAMU CEMAP promotion.

***Hibiscus* 'Moy Grande' (Texas giant hibiscus).** An introduction from Ying Doon Moy of the San Antonio Botanic Garden. This is the largest flowering hibiscus on earth! It is a cross between *H. grandiflorus* and *H. moscheutos,* and has big pink flowers on a huge plant. It is a 2000 TAMU CEMAP promotion.

***Ipomoea battatas* 'Black Beauty' (black beauty sweet potato).** It is a heart-shaped sport of 'Blackie' from Dan Lineberger at Texas A&M. Black Beauty' is a nice companion to 'Margarita'.

***Tecoma stans* 'Gold Star' (gold star esperanza).** It is precocious and has prolific flowering "yellow bells"; I selected it in San Antonio. 'Gold Star' was introduced by Lone Star Growers (ColorSpot), and is a 1999 TAMU CEMAP promotion.

***Lycoris incarnata* (peppermint spider lily).** A pink and white striped *Lycoris* from China. It was obtained from Cleo Barnwell of Shreveport who got it from Sam

Caldwell of Tennessee. Peppermint spider lily was introduced by Plant Delights Nursery. Many others species and hybrids are appearing on the market.

***Rhodophiala bifida* (oxblood lily).** Adapted to all parts of the South. It is a spectacular miniature fall-blooming amaryllid from Argentina. It is a German-Texas heirloom, and is also known as schoolhouse lily. Oxblood lily has an August bloom, winter foliage, and goes through summer dormancy.

Selecting and Marketing New Plants

Rick Crowder
Hawksridge Farms, Inc., Hickory, North Carolina 28603 U.S.A.

INTRODUCTION

Hawksridge Farms, Inc. is a production nursery in the western foothills of North Carolina. Although we are a fairly large nursery and produce a lot of the more common plants in the nursery trade, our interest really lies in new or seldom-used plants. We bring in, on the average, around 40 to 50 new varieties per year. Our acquisitions of new material vary from arboretums to mail-order sources. We also acquire many plants from out of the country through our import license. We have made some excellent contacts with various nurseries outside the United States and hope to expand this more in the future.

We immediately begin to propagate these plants once acquired. As soon as possible we try to plant a sample in our test gardens to evaluate its adaptability to our growing conditions. We are located in Zone 7a.

The following is a list of plants that we are currently evaluating. Some of these plants are being sold now and the rest we hope to have in the market in the near future. Only about 10% of the plants evaluated will become production items.

NEW PLANTS UNDER EVALUATION

***Aesculus* ×*carnea* 'Fort McNair'.** Rounded-crown tree with dark pink upright panicles that are 15 to 20 cm (6 to 8 inches) long. The leaves are more heat tolerant than other cultivars. Reaches a height of 12 to 15 m (40 to 50 ft) and has a 9 m (30 ft) diameter. A Zone 3 plant.

***Berberis* ×*frikartii* 'Telstar'.** An evergreen shrub that has a flat top when mature and a height of 0.9 m (3 ft) and a 1.2 to 1.5 m (4 to 5 ft) diameter. A Zone 6 to 9 plant.

***Berberis* ×*interposita* 'Wallich's Purple'.** An evergreen with mid-green leaves that are bronze-purple when young. It has a height of 0.9 m (3 ft) and a diameter of 1.2 m (4 ft). A Zone 6 to 9 plant.

***Berberis julianae* 'Spring Glory'.** Leaves and stems are tinted red to bronze-red with brilliant coloration to the new shoot growth. Has a height of 1.8 to 2.4 m (6 to 8 ft). A Zone 5 to 8 plant.

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***Berberis* ×*ottawensis* 'Red Rocket'**. Columnar growing with red-purple leaves. Has a height of 1.2 to 1.4 m (4 to 4.5 ft). A Zone 5 to 9 plant.

***Berberis* 'Red Jewel'**. Compact, semievergreen with dark to mid-green leaves that are dark red when young. Has a height of 1.2 m (4 ft) and a diameter of 1.8 m (6 ft) spread. A Zone 6 to 9 plant.

***Berberis* 'Red Tears'**. Leaves color well in spring and fall. Has red berries in many long grape-like bunches. Grows to a height of 1.8 m (6 ft). A Zone 6 plant.

***Berberis thunbergii* 'Concorde'**. A dwarf form that is more compact and more dense with darker purple foliage than *B. thunbergii* 'Crimson Pygmy'. Grows to a height of 0.3 to 0.5 m (1 to 1.5 ft) with a diameter of 0.6 to 0.8 m (2 to 2.5 ft). A Zone 4 to 8 plant.

***Berberis thunbergii* 'Royal Cloak'**. A shrub with a large arching form and deep reddish-purple leaves. Reaches a height of 1.8 m (6 ft). A Zone 4 to 8 plant.

Berberis wilsoniae* var. *stapfiana. Semievergreen with blue-green leaves. Has a taller growth habit than is typically found in the species. Forms yellow flowers that become coral-red berries. Has a height of 0.9 m (3 ft) and a diameter of 1.5 m (5 ft).

***Buddleja davidii* 'White Ball'**. Has a dense and compact habit with white flowers. Its height and diameter are around 0.9 to 1.2 m (3 to 4 ft). A Zone 5 plant.

***Calocedrus decurrens* - incense cedar**. Has a columnar form with deep green foliage that remains glossy green throughout the winter. Attains a height of 9.1 to 15.2 m (30 to 50 ft) and a diameter of 2.4 to 3.0 m (8 to 10 ft). A Zone 5 to 8 plant.

***Camellia japonica* 'White Mermaid'**. Leaves are fan shaped. Has single white flowers with a large yellow center. Zone 6 to 7 plant.

***Camellia japonica* 'Unryu'**. The stems twist at each leaf giving it a zigzag effect. Has single flowers that are single, small and deep pink.

***Castanopsis cuspidata* 'Variegata'**. A large evergreen shrub with green leaves that have bright yellow edges. The flowers are small, erect, white catkins 5.1 to 7.6 cm (2 to 3 inches) long and produce acorn-like fruit. It requires a sheltered area. It will reach a height and diameter of 7.6 m (25 ft). A Zone 8 plant.

***Chamaecyparis obtusa* 'Verdon'**. It has yellow tear-shaped foliage that tolerates the hot summers at Hickory, North Carolina, without any visible leaf scorching. It has an upright growth habit. A Zone 4 plant.

***Cotoneaster salicifolius* 'Gnom'**. A compact-growing form of willowleaf cotoneaster. A Zone 4 plant.

***Cryptomeria japonica* 'Araucarioides'**. This cryptomeria usually starts out as a single stem of cord-like light green foliage that completely covers the stem. New growth is in the form of clusters of foliage on each branch tip. Will reach a height and diameter of 1.8 m (6 ft). A Zone 5 plant.

***Cupressus arizonica* var. *glabra* 'Sulphurea'**. Has a creamy-yellow foliage that tolerates heat. Will reach a height of 4.6 m (15 ft) and a diameter of 1.8 to 2.4 m (6 to 8 ft). A Zone 6 plant.

***Elaeagnus pungens* 'Variegata'**. Has evergreen, dark-green leaves with a narrow, creamy-yellow edge. Will reach a height and diameter of 3.0 to 4.6 m (10 to 15 ft).

***Euonymus* 'Wolong Ghost'**. Has evergreen, narrow, black-green leaves with white variegation along the central and side veins. It is a ground cover that reaches 15 cm (6 inches) and has a diameter of 0.9 m (3 ft). A Zone 6 plant.

***Hydrangea luteovenosa* 'Aureovariegata'**. Has glossy green foliage blotched with yellow, and lacy white flowers. Will reach a height of 1.5 m (5 ft). A Zone 6 plant.

***Hydrangea macrophylla* 'Adria'**. Has a compact, dwarf growth habit, and forms dark blue hortensia-type flowers. Its height and diameter will reach 0.9 m (3 ft).

***Hydrangea macrophylla* 'Hörnli'**. Has a dwarf growth habit with a spreading tendency. Its crimson-red hortensia-type flowers turn grayish-pink in fall. Has a height of 31 to 32 cm (12 to 15 inches) and a diameter of 0.6 to 0.8 m (24 to 30 inches).

***Hydrangea macrophylla* 'Rotdrossel'**. A dark crimson-red lacecap which has the darkest red in the Teller collection.

***Hydrangea macrophylla* 'Tovelit'**. Has a compact, dwarf growth habit. Its flowers are hortensia-type, with pink and mauve depending on soil pH. Reaches a height and diameter of 0.4 to 0.6 m (1.5 to 2 ft).

***Hydrangea macrophylla* 'Wave Hill'**. Has green leaves variegated with white and yellow. Its lacecap-type inflorescence has inner fertile flowers which are shades of salmon and rosy-red surrounded by pale pink and white sterile flowers.

***Hydrangea paniculata* 'Floribunda'**. Has numerous white sterile flowers that become pink-tinged with age. Reaches a height of 2.4 to 3.0 m (8 to 10 ft) and a diameter of 2.4 m (8 ft). A Zone 4 to 8 plant.

***Hydrangea quercifolia* 'Sikes Dwarf'**. A compact, dwarf-growing oakleaf hydrangea. Will reach a height of 0.6 to 0.8 m (2 to 2.5 ft) and a diameter of 1.2 m (4 ft). A Zone 4 to 9 plant.

***Hydrangea serrata* 'Kiyosumi'**. Has small lacecap-type flower heads with pinkish-white fertile flowers and white sterile florets with rose-red margins.

***Hydrangea serrata* 'Shichidanka'**. Has lacecap-type flowers with double-deep lavender sterile florets.

***Hydrangea serrata* 'Shirofugi'**. Forms small lacecap-type flower heads of white fertile florets surrounded by pure white, fully double sterile florets.

***Ilex crenata* 'Elfin'**. Has a very dense, dwarf growth habit. Reaches a height and diameter of 0.6 m (2 ft).

***Ilex sugerokii* 'Nakahari'**. Has a dense upright growth habit with dark green, evergreen foliage. Forms red fruit in the leaf axils.

***Ilex* 'Rock Garden'**. A true dwarf selection made by Dr. Elwin Orton. It is very slow growing and may reach a height and diameter of 31 cm (1 ft) after 10 years.

***Juniperus chinensis* 'Mac's Golden'**. Has a dense, upright, pyramidal growth habit with soft yellow foliage. Will reach a height of 1.8 to 4.6 m. A Zone 4 plant.

***Juniperus conferta* 'Blue Lagoon'**. This National Arboretum release has a more compact growth habit and slightly deeper blue foliage than *J. conferta* 'Blue Pacific'. It will reach a height of 1.8 m (6 ft) and a diameter of 2.4 m (8 ft). A Zone 5 plant.

***Juniperus* ×*pfitzeriana* 'Daub's Frosted'**. Has blue-green foliage on the underside and golden-frosted on top. The growth habit is wide spreading with pendulous tips. Will reach a height of 31 to 38 cm (1 to 1.5 ft) and has a diameter of 1.2 to 1.5 m (4 to 5 ft).

***Juniperus squamata* 'Blue Alps'**. The bright silver-blue needles resemble *J. squamata* 'Blue Star', but the branching on 'Blue Alps' is upright with arching slightly nodding tips. Will reach a height of 1.5 to 1.8 m (5 to 6 ft) and a diameter of 0.9 to 1.2 m (3 to 4 ft). A Zone 4 to 7 plant.

***Ligustrum japonicum* 'Green Meatball'**. The foliage is smaller with a finer texture and it is dependably evergreen. Forms a dense globe without shearing, and reaches a height and diameter of 0.9 m (3 ft). A Zone 6 to 10 plant.

***Ligustrum sinensis* 'Wimbei'**. Has an upright growth habit with tiny leaves that are packed along the stems. It can reach a height of 2.4 m (8 ft), but with pruning can be kept smaller. A Zone 7 to 10 plant.

***Mahonia* ×*media* 'Underway'**. Relatively compact growing with glossy green leaves. Has yellow flowers in the fall. Will reach a height of 2.4 to 3.0 m (8 to 10 ft). A Zone 7 plant.

Microcachrys tetragona. A spreading, coniferous shrub with dark-green leaves. The female cones become fleshy and red resembling red mulberries. Reaches a height of 51cm (20 inches) and a diameter of 0.9 m (3 ft). A Zone 6 plant.

***Osmanthus heterophyllus* 'Fastigiata'**. A dense, upright form with glossy holly-like sharply toothed leaves. Reaches a height of 1.2 to 1.5 m (4 to 5 ft) and a diameter of 0.9 m (3 ft).

***Osmanthus heterophyllus* 'Sasaba'**. Has jagged, evergreen leaves with three triangular overlapping lobes. Very slow growing, but will reach a height of 0.9 m (3 ft). A Zone 6 plant.

***Philadelphus* 'Innocence'**. Slower-growing cultivar of the species with variegated white and gray-green leaves. Upright growth habit with arching branches and white fragrant flowers. Will reach a height of 3 m (10 ft) and a diameter of 1.8 m (6 ft). A Zone 5 to 8 plant.

***Pieris japonica* 'Flaming Silver'**. Has light red new growth which changes to very dark green leaves with white margins. It flowers a couple of weeks later than *P. japonica* 'Mountain Fire' and has a more prominent leaf color than *P. japonica* 'Variegata'. Will reach a height and diameter of 1.2 m (4 ft). A Zone 5 plant.

Pieris phillyreifolia. Also called "climbing pieris" which often climbs on another plant. Has short, leathery, evergreen, foliage with white flower clusters. A Zone 6 plant.

***Poncirus trifoliata* 'Flying Dragon'**. Stems start out as thorns which become twisted. Has green leaves change to yellow in the fall, white flowers become yellowish-green; has lemon-like fruit. Reaches a height of 1.8 to 2.4 m (6 to 8 ft) and a diameter of 1.2 to 1.5 m (4 to 5 ft). A Zone 6 to 9 plant.

Syringa josikaea **- Hungarian lilac**. A late-blooming lilac with very fragrant, lilac-pink flowers. Reaches a height of 30 cm (12 inches) height. A Zone 4 plant.

Thuja koraiensis **'Glauca Prostrata'**. Low growing with silver-blue foliage. Reaches a height of 0.6 m (2 ft) and a diameter of 1.5 m (5 ft). A Zone 5 plant.

Thuja occidentalis **'Spiralis'**. A narrow pyramidal grower with short branches of dark green, fern-leaf-shaped sprays. Reaches a height of 9.1 to 13.7 m (30 to 45 ft). A Zone 2 to 7(8) plant.

Viburnum ×globosum **'Jermyns Globe'**. Has evergreen, dark-green, leathery leaves with reddish petioles. Its form is a dense, rounded habit, and in late spring has white flowers in flat-topped clusters.

Viburnum tinus **'Gwenllian'**. Has profuse flowers that start out as rich pink buds opening to a plush pink in late winter to spring, forming dark blue-black fruit. 'Gwenllian' has green, evergreen leaves. Reaches a height of 1.5 to 1.8 m (5 to 6 ft). A Zone 7 plant.

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Propagation of *Anemone* ×*hybrida* by Root Cuttings

Jean-Jacques B. Dubois, Frank A. Blazich, and Stuart L. Warren
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Stock plants of *Anemone* ×*hybrida* Paxton 'Honorine Jobert' and 'Richard Ahrends' were grown in 3.8-liter (#1) containers beginning April 1998, and fertilized daily with a nutrient solution providing 10, 40, 80, or 150 mg liter^{-1} (ppm) nitrogen (N). After 30 weeks (November), root cuttings were harvested from the stock plants and treated with K-IBA at 0, 100, 500, or 1000 mg liter^{-1} (ppm), then placed in cell packs, one cutting per cell. The containers were arranged under intermittent mist in a heated greenhouse. Overall, 91% of the cuttings regenerated a new plant. There were cultivar differences in percent regeneration, and the highest K-IBA concentration was inhibitory to 'Honorine Jobert', but not to 'Richard Ahrends'. Time to emergence of a shoot was reduced by higher rates of N applied to the stock plants, and increased at the highest concentration of K-IBA in 'Honorine Jobert'. Dry weight of the regenerated plants increased with increasing weight of the cuttings from which they originated, and was linearily related to rate of N applied to the stock plants in 'Honorine Jobert', and quadratically in 'Richard Ahrends', with maximum plantlet weight predicted at 114 mg liter^{-1} (ppm) N. At the observed optimal rate of N applied to the stock plants, maximum plantlet weight is predicted at 459 mg liter^{-1} (ppm) K-IBA in 'Honorine Jobert', and at 425 mg liter^{-1} (ppm) in 'Richard Ahrends'.

INTRODUCTION

Fall-flowering anemones are highly sought after perennials whose widespread acceptance in the landscape has been hampered by propagation difficulties. Growing in partial shade, they are robust, adaptable plants within the limits of U.S.D.A. cold hardiness Zones 5 to 8. Once established, they spread, sometimes aggressively, by means of shoots developing in great numbers along the entire length of the roots (Huxley, 1992; McKendrick, 1990). In a survey of perennial propagation firms across the United States conducted by the authors, fall-flowering anemones were the plants most often cited as needing improvement in propagation.

Currently, propagation is accomplished by division or root cuttings, with very low multiplication rates in either case. Published information regarding this topic is limited to general recommendations on handling of root cuttings (Fisher, 1961; Hartmann et al. 1997; Kessel, 1986; McKendrick, 1990), and based on scant research involving woody species (Del Tredici, 1995; Peterson, 1975).

In *Chondrilla juncea* L. (skeleton weed) and *Euphorbia esula* L. (leafy spurge), several studies have shown a positive correlation between high N levels in the growing substrate of stock plants, and both the number of shoot buds produced on their roots and the ability to regenerate whole plants from root segments (Kefford and Caso, 1972; McIntyre, 1972). In stem cuttings, however, adventitious root formation has been shown to be affected negatively by high N nutrition of stock plants (Blazich, 1988). Therefore, the following investigation was undertaken with two cultivars of fall-flowering anemone to (1) determine the effect of N nutrition of stock plants on propagation by root cuttings, (2) study the influence of K-IBA treatment of root cuttings on plantlet development, and (3) provide the basis for a practicable system for production of plantlets of anemone in small cell containers with a high success rate.

MATERIALS AND METHODS

Sixty four #1 field divisions each of cultivars 'Honorine Jobert' and 'Richard Arhens' anemone were grown for 30 weeks, beginning April 1998, in 3.8-liter (#1) containers filled with a substrate of composted pine bark and sand (8:1, v/v), amended with 2.4 kg m^{-3} (4 lb yd^{-3}) dolomitic limestone and 0.9 kg m^{-3} (1.5 lb yd^{-3}) MicroMax (The Scotts Co., Marysville, Ohio). Plants were fertigated daily via pressure-compensated spray stakes with a nutrient solution providing 10, 40, 80, or 150 mg $liter^{-1}$ (ppm) N in a constant ratio of 1 ammonium : 2 nitrate, in addition to P, K, Ca, Mg, and S at constant concentrations.

After 30 weeks (November), root cuttings 4 cm (1.6 inch) in length were harvested from the stock plants, weighed individually, and dipped for 5 sec in K-IBA at 0, 100, 500, or 1000 mg $liter^{-1}$ (ppm), then placed in bedding plant containers (9 × 4 cells, No.1020 flat) containing a pine-bark-based substrate, one cutting per cell [cell vol. = 160 cm^3 (9.8 $inches^3$)], and covered with 1.5 cm (0.6 inches) substrate. Containers were placed under intermittent mist in a heated greenhouse under natural photoperiod and irradiance with mean day/night temperatures of 24 ± 1.7°C (75 ± 3°F) and 20 ± 1°C (68 ± 2°F), respectively. Mist was applied via a gantry-mounted traveling spray boom (ITS, McConkey Co., Sumner, Wash.) with continuous regulation of frequency as a function of relative humidity, and traveling speed adjusted to 15 m min^{-1} (50 ft min^{-1}). This setting resulted in the medium surface just reaching dryness before being misted again. The experiment was a randomized complete block design with a factorial arrangement of treatments: two cultivars, four rates of N applied to the stock plants, and four rates of K-IBA applied to the root cuttings. There were six replications with six cuttings per replication. After 8 weeks, misting was discontinued, and plantlets were irrigated overhead every 3 days. After 12 weeks, roots of the resulting plantlets were washed free of substrate, and separated from the shoots. Roots and shoots were dried 96 h at 70°C (160°F), and weighed. Data were subjected to analysis of variance and regression analysis where appropriate. Effects of cutting weight were analyzed by analysis of covariance, with cutting weight as the covariate.

RESULTS AND DISCUSSION

Percent Regeneration. Percent regeneration across cultivars and treatments, as measured by the proportion of root cuttings that resulted in a complete, viable plantlet, was 91%. There was a significant difference between the two cultivars, with 'Honorine Jobert' averaging 84% across all treatments, and 'Richard Ahrends', 98%. Weight of the root cutting and rate of N applied to the stock plant did not affect percent regeneration in either cultivar, while response to K-IBA was quadratic in 'Honorine Jobert', with a maximum of 90% regeneration predicted at 240 mg $liter^{-1}$ (ppm) K-IBA (Fig. 1). Percent regeneration was unaffected by K-IBA in 'Richard Ahrends'.

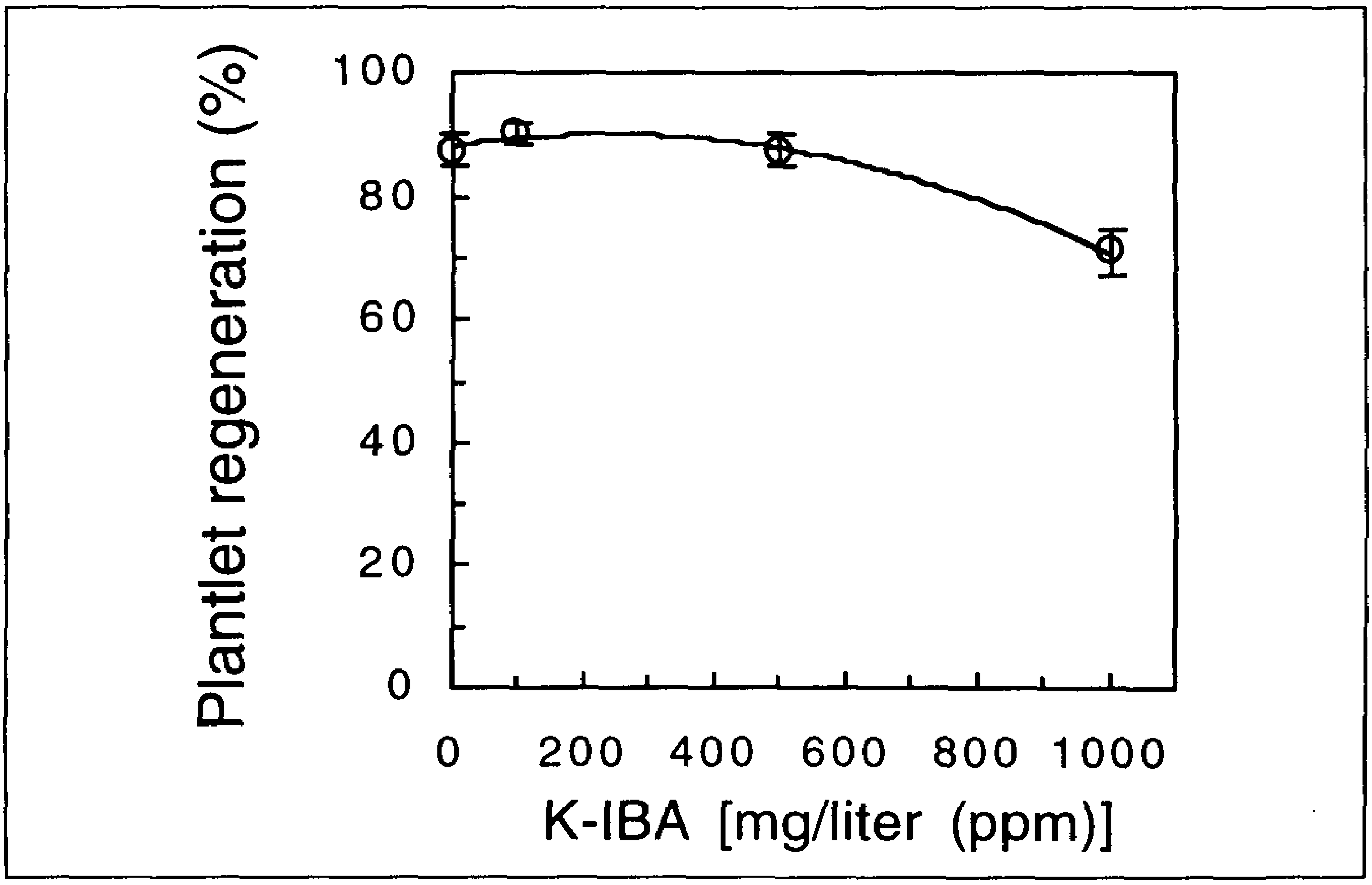

Figure 1. Effect of K-IBA treatment on percent regeneration of 'Honorine Jobert' anemone from root cuttings. Each point represents the mean of 24 observations. Vertical bars are the standard error of the mean. r^2=0.9947.

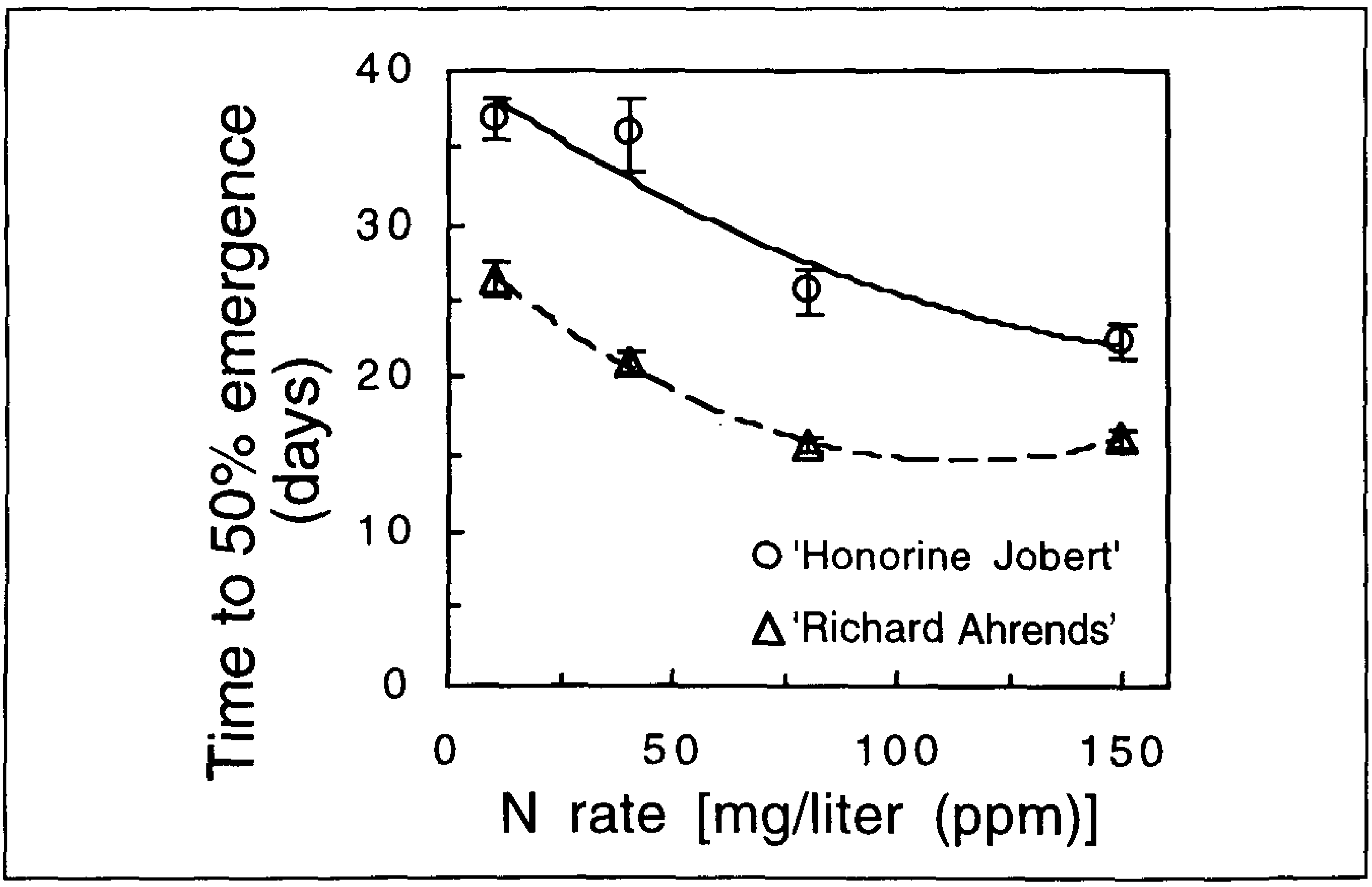

Figure 2. Effect of rate of nitrogen applied to the stock plants on time to 50% shoot emergence from root cuttings. Each point is the mean of 24 observations. Vertical bars are the standard error of the mean. 'Honorine Jobert' r^2= 0.8897. 'Richard Ahrends' r^2 = 0.9983.

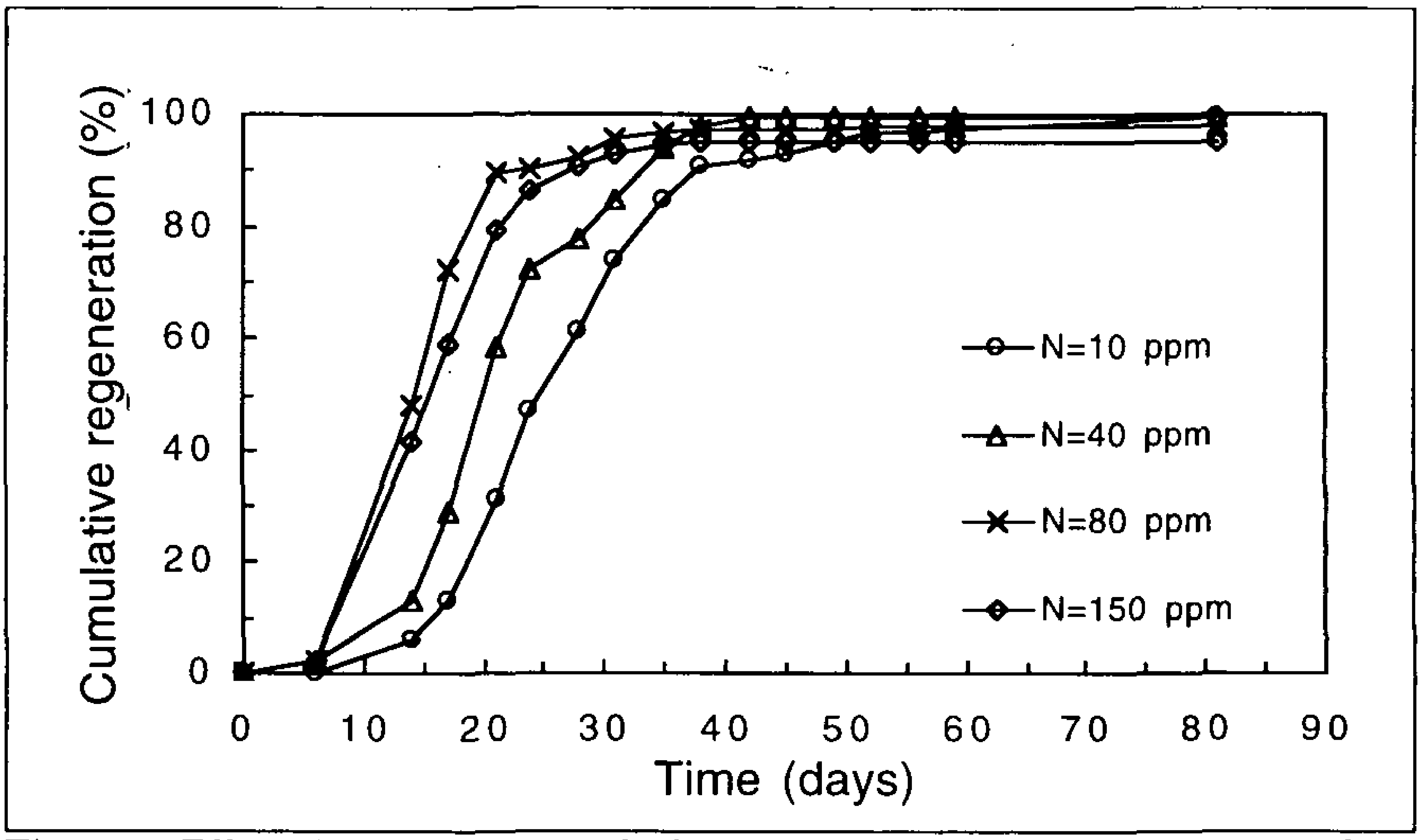

Figure 3. Effect of nitrogen rate applied to stock plants on cumulative percent shoot emergence over time in root cuttings of 'Richard Ahrends'. Each point represents the mean of 24 observations.

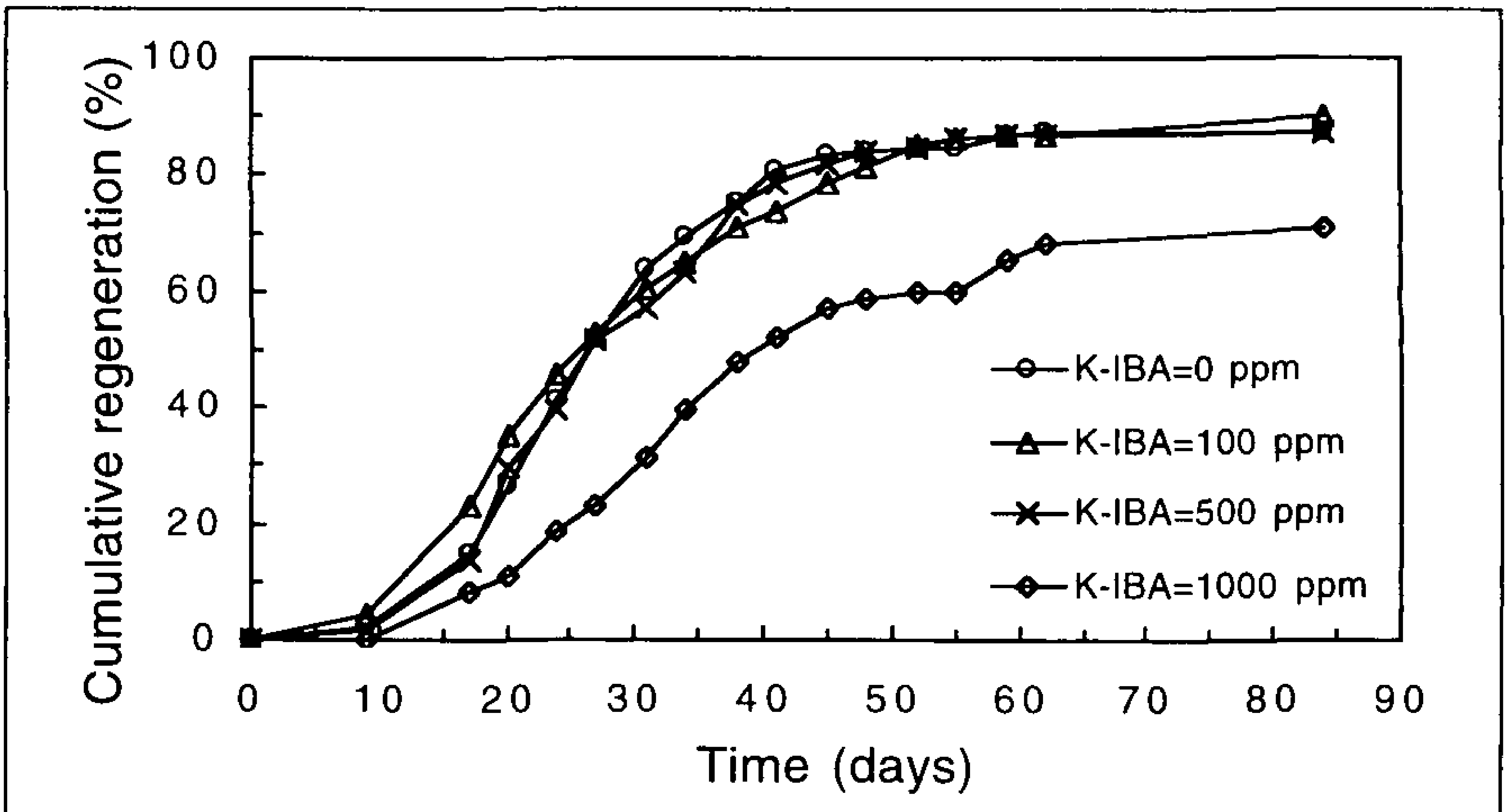

Figure 4. Effect of K-IBA on cumulative percent shoot emergence over time in root cuttings of 'Honorine Jobert' . Each point represents the mean of 24 observations.

Time to Emergence. 'Honorine Jobert' reached 50% emergence in 30 days, and 'Richard Ahrends' in 20 days. Cutting weight did not affect time to 50% emergence. The relationship between time to 50% emergence and rate of N was linear in 'Honorine Jobert' and quadratic in 'Richard Ahrends' (Fig. 2). Increasing rate of N applied to the stock plant shortened time to emergence in both cultivars. For 'Richard Ahrends' the fastest emergence (15 days) is predicted to occur at 114 mg liter^{-1} (ppm) N (Fig. 3).

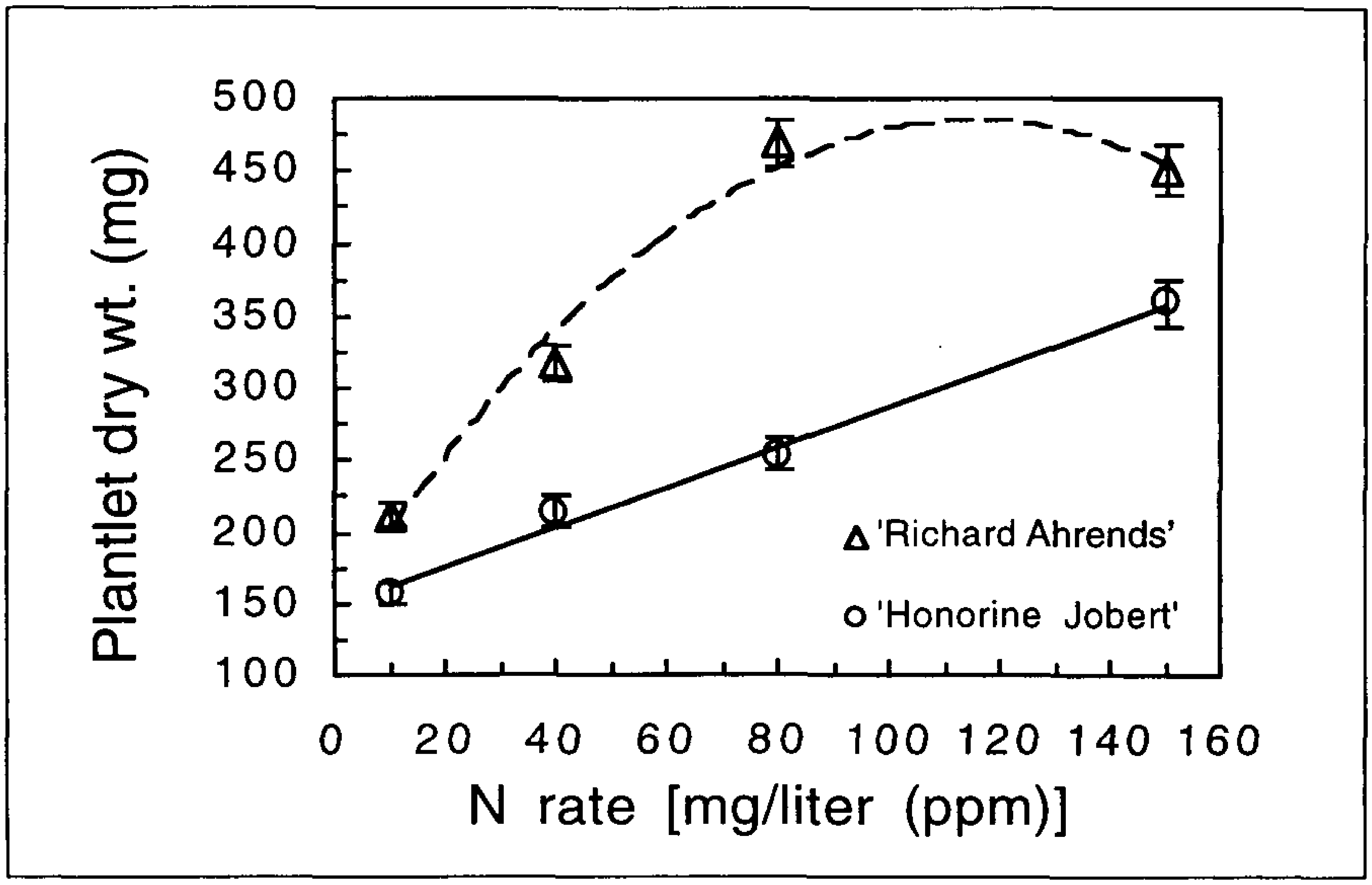

Figure 5. Effect of nitrogen rate applied to stock plants on dry weight of plantlets regenerated from root cuttings. Each point represents the mean of 114 to 133 observations for 'Honorine Jobert', and 136 to 143 observations for 'Richard Ahrends'. Vertical bars are the standard error of the mean. 'Honorine Jobert' r^2= 0.9922. 'Richard Ahrens' r^2= 0.9788.

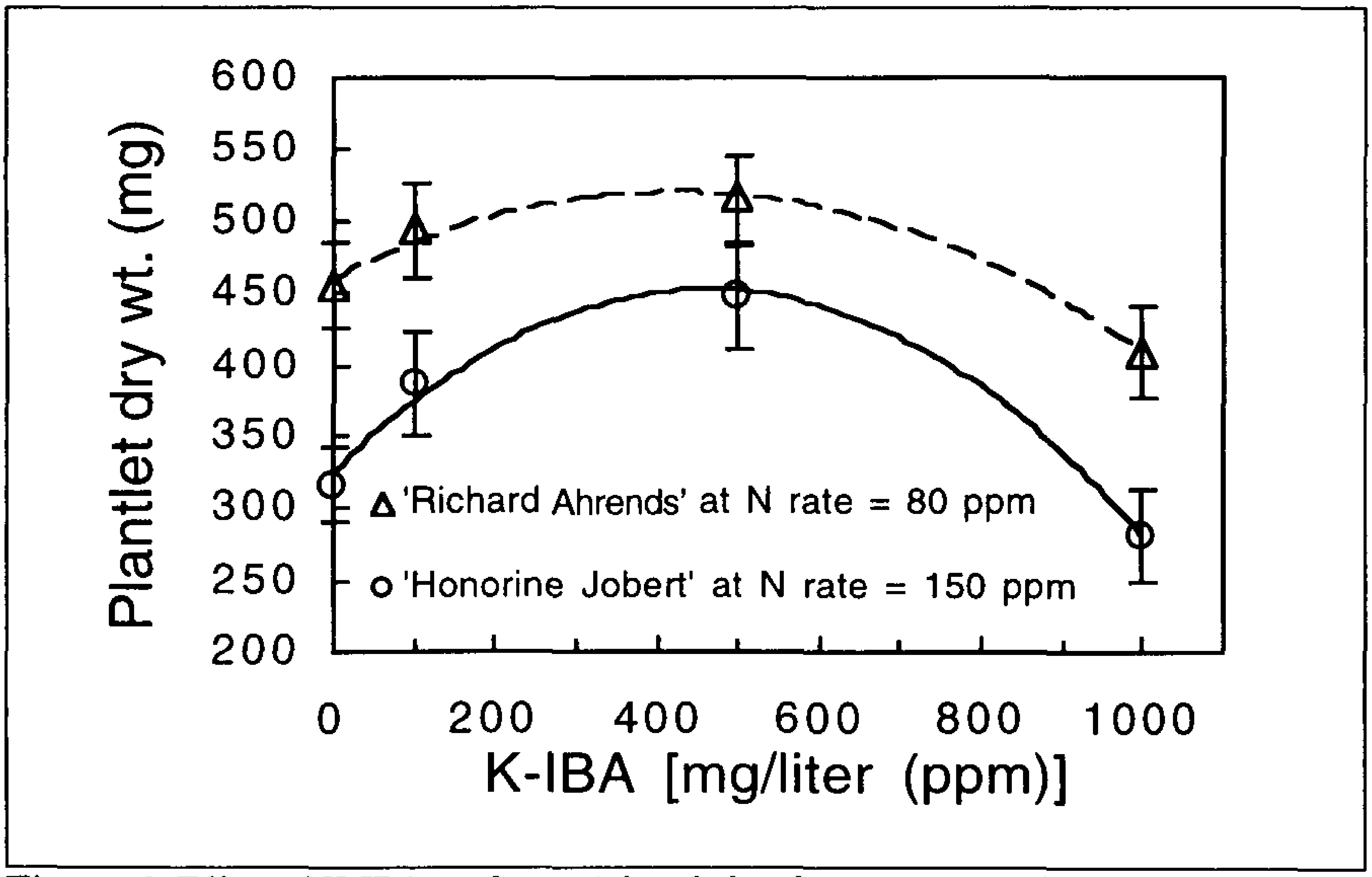

Figure 6. Effect of K-IBA on dry weight of plantlets regenerated from root cuttings. Each point represents the mean of five observations, one observation is six cuttings. Vertical bars are the standard error of the mean. 'Honorine Jobert', at rate of nitrogen applied to the stock plant = 150 mg liter^{-1} (ppm). r^2= 0.9839. 'Richard Ahrends', at rate of nitrogen applied to the stock plant = 80 mg liter^{-1} (ppm). r^2= 0.9836.

Time to emergence was unaffected by K-IBA in 'Richard Ahrends', whereas increasing K-IBA concentration delayed emergence in 'Honorine Jobert' (Fig. 4). The latter cultivar exhibited a quadratic increase in time to 50% emergence with increasing K-IBA concentration, with an observed maximum mean time to 50% emergence of 38 ± 2 days at 1000 mg liter^{-1} (ppm) K-IBA.

Plantlet Dry Weight. Overall mean plantlet dry weight was 245.6 mg (0.009 oz) for 'Honorine Jobert', and 362.2 mg (0.013 oz) for 'Richard Ahrends'. Cutting fresh weight had a strong positive influence on dry weight of the resulting plantlet. The slope of the covariance adjustment was 0.92 ± 0.10 for 'Honorine Jobert', and 1.14 ± 0.09 for 'Richard Ahrends'. From this, we concluded that within the range used in this experiment, each unit increase in cutting fresh weight will result in approximately one unit increase in the dry weight of the plantlet produced from that cutting.

Plantlet dry weight increased linearly with increasing N in 'Honorine Jobert', and responded quadratically in 'Richard Ahrends', with maximum plantlet weight predicted at 115 mg liter^{-1}(ppm) N in this cultivar (Fig. 5). The largest mean dry weight by rate of N was 358 mg for 'Honorine Jobert', observed at 150 mg liter^{-1} (ppm) N, and 469 for 'Richard Ahrends', at 80 mg liter^{-1} (ppm) N.

At those respective rates of N, plantlet dry weight responded to K-IBA in a quadratic manner in both cultivars. However, there was no overall interaction between rate of N and K-IBA. Maximum response is predicted to occur at 459 mg liter^{-1} (ppm) K-IBA in 'Honorine Jobert', and at 425 mg liter^{-1} (ppm) in 'Richard Ahrends' (Fig. 6). At these concentrations, a 37% increase in plantlet dry weight would be expected in 'Honorine Jobert', as compared to not using any K-IBA. In 'Richard Ahrends', the increase would be expected to reach 13%. At those concentrations, K-IBA would not affect percent regeneration or rate of shoot emergence.

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Plant Growth Regulator Effects on Canna Lily

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A study in 1998 determined the effects of several rates of B-Nine, Bonzi, Cutless, and Pistill on vegetative growth and flowering in *Canna xgeneralis* 'Florence Vaughn'. Canna lily is often difficult to manage during production due to their top-heavy growth pattern and rapid growth. Controlling the plant's height could potentially lower shipping costs to market and reduce maintenance during the production and retail stages. Vegetative height 30 and 60 days after treatment (DAT), vegetative and inflorescence heights and scape length at first flower, and vegetative height at 30 days after planting (DAP) in the landscape were reduced by increasing rates of Cutless, while days to flower increased 1 to 6 days. With increased rates of Bonzi, vegetative height at 30 DAT, and vegetative and inflorescence heights at first flower were suppressed, but to a lesser degree than with Cutless. B-Nine and Pistill did not significantly affect the plant characteristics measured, with the exception B-Nine delayed flowering 3 to 8 days.

INTRODUCTION

Species and cultivars of canna lily are characterized by heights of up to 1.5 m (5 ft) and 0.6 m (2 ft) long leaves up to 15 cm (6 inches) in width (Still, 1994). Canna lilies bloom in early to mid-summer and continue through frost (Still, 1994). Canna lilies may become difficult to manage during container production due to their rapid and top-heavy growth habit. These characteristics lead to frequent blow-over during production and later at retail facilities, and increased shipping costs, especially when plants are racked during shipment.

Plant growth regulators (PGRs), such as B-Nine, Bonzi, Cutless, and Pistill, are effective in suppressing height in numerous species (Barrett, 1982; Pisarezyk and Splittstoesser, 1979) and may offer benefits in the production, shipping, and marketing of canna lilies. B-Nine, Bonzi, and Pistill are labeled for use in greenhouse and nursery environments, whereas Cutless is labeled for use on turfgrass only. While these PGRs have been effective on numerous horticultural crops, none are labeled for use on canna lily during nursery production. PGRs used in production occasionally have residual effects which carry over into the landscape (Keever and Cox, 1989).Suppressed growth in the landscape may reduce the intended visual effect of treated plants, as well as customer satisfaction. The objective of this study was to determine the effects of several rates of four PGRs on height and flowering of canna lily during container production and in the landscape.

MATERIALS AND METHODS

On 3 April 1998, 3.8-liter (4 qt) containers of gladiolus-flowered canna lilies (*Canna* 'Florence Vaughn') were divided into quarters and repotted into 3.8-liter (4 qt) containers while dormant. The substrate consisted of a 7:1 (v/v) pine bark to sand medium amended with 10.7 kg m^{-3} (18 lb yd^{-3}) Polyon 22-4-14, 0.9 kg m^{-3} (1.5 lb yd^{-3})

Micromax, and 3.0 kg m^{-3} (5 lb yd^{-3}) dolomitic limestone. Plants were placed in full sun under overhead irrigation. On 6 May 1998 plants were blocked by height, initial height measurements taken, and the following PGRs applied as foliar sprays in a volume of 0.2 liters per m^{-2} (2 qt 100 ft^{-2}).

- B-Nine at 2500, 5000, and 7500 parts per million (ppm);
- Bonzi at 33, 66, and 99 ppm;
- Cutless at 50, 100, and 150 ppm;
- Pistill at 125, 250, 500, 750, and 1000 ppm;
- Control.

Ambient temperature and relative humidity at treatment ranged from 30 to 39°C (86 to 102°F) and 71% to 53%, respectively. Treatments were arranged in a completely randomized design with ten single-plant replications.

Data collected included time to first flower, inflorescence height, scape length at first flower, and vegetative heights (from the substrate to the top of the uppermost leaf) at first flower and 30 and 60 days after treatments (DAT). On 20 July 1998, five plants each from the control treatment and all Bonzi and Cutless treatments were planted in the landscape and blocked by replication. Vegetative heights were measured at 30, 60, and 90 DAP. Plants from the B-Nine and Pistill treatments were not transplanted because treatments did not affect inflorescence height at first bloom or vegetative heights 30 or 60 DAT during container production.

RESULTS

The results of our study show that canna lily height can be controlled during production using certain PGRs at the rates tested (Table 1). For example, plants treated with increasing rates of Cutless were shorter compared to untreated plants by 42% to 50% at 30 DAT and 37% to 47% at 60 DAT. Cutless-treatments delayed flowering in canna lilies 1 to 6 days. Though statistically significant, the delay of flowering of 1 to 6 days would not be a major detriment to the commercial grower. The inflorescence height and scape length at first flower were 50% to 68% and 25% to 57% shorter, respectively, for Cutless-treated plants compared to untreated plants. The average inflorescence height of Cutless treated plants was less than that of the foliage. This suppression was least pronounced at the lowest rate applied (50 ppm) with foliage on average 5 cm (2 inches) taller than the inflorescence. A major concern of growers with the use of PGRs is the impact on the plants after purchase by the consumer. With Cutless-treated plants, the vegetative height was reduced 5 to 14% compared to untreated plants at 30 DAP in the landscape (approximately 100 days after PGR treatment), indicating a slight residual effect. However, by 60 DAP vegetative heights were similar among Cutless and control treatments.

With increasing rates of Bonzi, vegetative height of treated plants at 30 DAT was 16% to 29% shorter compared to untreated plants. Days to first flower for Bonzi-treated plants were similar to untreated plants. Vegetative and inflorescence height at first flower were reduced for Bonzi-treated plants by 12% to 26% and up to 20%, respectively. Scape length was not affected by Bonzi treatments. Bonzi-treated plants were similar in height to untreated plants at 60 DAT and 30 and 60 DAP. However, at 90 DAP, Bonzi-treated plants were approximately 12% taller than untreated. B-Nine and Pistill had no effect on any characteristic measured during the study, with the exception B-Nine delayed flowering 3 to 8 days compared to control plants.

Table 1. Vegetative and inflorescence heights, scape lengths, and days to first flower for *Canna* 'Florence Vaughn' treated with Bonzi or Cutless.

Plant growth regulator	Rate (ppm)	Days to flower	First flower: Vegetative Height (cm)	First flower: Inflorescence height (cm)	First flower: Scape length (cm)	Vegetative height (cm): Container production 30 DAT[z]	Vegetative height (cm): Container production 60 DAT	Vegetative height (cm): Landscape 30 DAP[y]	Vegetative height (cm): Landscape 60 DAP
Control	0	42	86.0	93.2	32.4	85.7	86.5	94.6	110.4
Cutless	50	41	52.9	47.3	24.5	50.2	55.1	90.2	109.8
Cutless	100	43	49.1	43.7	21.8	45.9	49.0	78.4	108.8
Cutless	150	48	36.6	30.4	14.0	43.6	46.1	81.2	108.2
Dose response[x]		L*	Q*	Q**	L**	Q***	Q***	L*	NS
Bonzi	33	43	76.5	94.1	35.0	72.8	92.5	99.4	113.2
Bonzi	66	46	78.2	92.3	37.6	68.2	90.5	93.8	117.0
Bonzi	99	43	64.6	74.8	36.3	61.5	83.4	98.0	124.2
Dose response		NS	L**	L*	NS	L***	NS	NSL*	

[x] Nonsignificant (NS), linear (L), or quadratic (Q) response at the 5% (*), 1% (**), or 0.1% (***) level, control included in regression analysis.
[y] Days after planting.
[z] Days to flower.

DISCUSSION

In container production of canna lily, growers can apply Cutless at the rates tested and have a significant suppression in vegetative height for around 60 days. However, average inflorescence height for Cutless-treated plants was less than that of foliage at first flower. In previous research, Cutless decreased inflorescence length and width of *Buddleja davidii* (Keever and Gilliam, 1994). For canna lilies, the inflorescence heigth reduction detracted from the floral display of treated plants which could be detrimental to plant marketability. Following transplanting inflorescence heights among treated and untreated plants appeared similar by 30 DAP. Bonzi applied at the rates tested should suppress vegetative height for 30 days during container production. Shorter plants will reduce blow-over, making shipping easier, and improve the overall plant appearance in the retail market. The noted delay in flowering (1 to 6 days overall) is minor considering the overall production cycle and the lengthened window of marketability. Furthermore, once planted in the landscape, plants treated with Bonzi outgrew control plants. This increase in growth observed with Bonzi treatments is not uncommon (Blanco, 1988; Keever and Gilliam 1994) and relates to how Bonzi controls height. Bonzi suppresses plant height by retarding internode elongation. However, plants continue to produce plant cells following the PGR treatment. After cessation of treatment effects, the plant cells previously produced will rapidly elongate to their normal size. This enhanced post production performance will benefit the consumer and should improve consumer satisfaction. The results presented above represent data collected from one growing season. The test will be repeated in 1999 to obtain additional data from a second growing season.

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Propagation of *Clematis* by Cuttings

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INTRODUCTION

Happy Hollow is a very small nursery, located in the southwestern corner of British Columbia. We have about 1.2 ha (3 acres) of production and specialize in growing some of the harder-to-grow plants — in as economical manner as possible. We are located near the U.S. border and about 64 k (40 mi.) inland from the Pacific Coast. Our climate is typically mild and wet — a West Coast rain forest. Our winter is mostly gray skies and cold rain, interrupted by possibly 2 weeks of freezing weather with or without snow. We can occasionally expect temperatures to drop as low as -18°C (0°F) for several days to several weeks. These cold spells can happen more than once, and can happen anytime from early November until late February. Spring and fall often have extended periods of sunshine (2 weeks), interrupted by several days or so of rain. Our summers can get hot — up to 32°C (90°F) for several weeks at a time. If we go for 3 weeks without rain, we are having a drought! Annual rainfall is about 2032 mm (80 inches) per year. In the U.S. Hardiness Map, we are rated Zone 7.

Clematis are among the most beautiful vines in the world, but are known also to be some of the most difficult plants to propagate and grow. *Clematis* is not a plant for beginners to propagate. There are literally hundreds of species and cultivars of *Clematis* available for the gardening public. At Happy Hollow Nursery we propagate only 30 or so cultivars such as 'Jackmanii', 'Nelly Moser', 'The President', 'Lord Nevill', and 'Rouge Cardinal', as well as some small flowered species: *tangutica*, *montana*, *macropetala* culitvars, and *armandii* — the most sought after evergreen *Clematis*.

PROPAGATION

Stock Plants and Cutting Wood. Cuttings are taken from vigorous container-grown plants, not from a stock block. When we can avoid it, we do not use stock blocks. We prefer to take cuttings from vigorously growing 1-gal plants, ready for the retail trade. Good clean cutting wood is probably the single most important contributor to successful propagation. We do not use any fungicide or pesticide treatment of cuttings at sticking. Hence, it is very important that our container-grown plants are kept clean at all times. Cutting wood is taken in small batches, early in the day, preferably on cool days, and moved immediately to our cutting bench in the greenhouse, where the cuttings are made. We do small batches at a time, so that unstuck cuttings are not allowed to wilt.

We like semihardwood growth, not too soft, with a green or purple color, but not brown or with flower buds. So long as the wood is in the right stage, we take cuttings from February until frost in October. However, the early cuttings always seem to do the best.

Cuttings. The cuttings are made from long pieces of vine cut from the 3.8-liter (1-gal) plants. Using very sharp pruners, the cuttings are trimmed into 5-cm (2-inch) long internodal cuttings. On varieties with large leaves we remove one leaf. We also use up to 10,000 ppm liquid IBA. We stick directly into 73-plug trays with a peat, perlite, bark, and sawdust propagation mix. The cuttings are well watered in and placed on the floor of a hot water, bottom-heated, plastic house. A high-pressure [5516 kPa (800 psi)] fog system is used to keep the humidity above 90%. We use a wet bulb/dry bulb humidisat to control the fogging intervals, rather than a time clock. Weather can change rapidly and often, making it important for the humidistat to automatically alter the fogging intervals with the weather. At one time we had time clocks and mist lines and could not root any of the hard-to-root summer cuttings with any reliability. We would either desiccate the cuttings when the sun suddenly appeared, or we would drown them on a rainy day. The humidistat has changed our life, particularly on weekends — and definitely enhanced our success rate.

Care During Rooting. Care of the rooted cuttings is the second most significant factor in successfully producing *Clematis*. Slugs, botrytis, and mites are our major pest problems in containers. We use Ornalin alternated wth Benlate throughout rooting. During the peak of summer mites can become a problem, and it is with mites that the gallon plants must be kept clean. Slugs can be a major problem in newly breaking growth in spring, as can mice which love to visit us from the cold during winter. Mice enjoy the bottom heat. We use a lot of liquid slug and snail killer containing metaldehyde throughout the year. In Canada Measurol® is not available. For mice we use peanut butter set in traps — it sticks to the roof of their mouths! If they prove not to be the "peanut butter type", then on occasion we resort to poison. We prefer not to use poison, since it can also kill the cats which are an important control of the mice population.

It takes from 4 to 8 weeks to produce a well rooted plug liner, depending on the weather and variety stuck. Our rooting percentages vary from 50% to almost 100%, again depending on type and weather during rooting. *Clematis* like to have cool cloudy days during the first period of rooting, then sunshine to break buds after rooting. Some cultivars are definitely easier to root than others.

Growing On. Once rooting has taken place we use a liquid fertilizer such as 10N-20P-20K to encourage root proliferation and bud break. When growth has begun and the roots fill the plugs, the plants are either sold as a liner to other growers or potted directly to gallon pots for our own production for sale to garden centres. We grow all our *Clematis* in a soilless media using fir bark as the substrate and Osmocote as the slow-release fertilizer source. We like to stake thevines with cedar stakes and staple them from the outside of the pot. The stakes remain firm if they are stapled. Our *Clematis* are all grown inside a plastic-covered unheated greenhouse. The plastic houses are double skinned inflated houses. Pruning, tying, and taping vines are very labour-intensive activities. We probably go through all the individual plants once every 2 weeks to retie the tips to the stakes, and make sure they are climbing their OWN stake not their neighbors. We try to have at least two stems to the top of the 3-ft stake before selling the plants.

In summary, *Clematis* is not the easiest of plants to propagate and grow. They take a lot of "tender loving care" to produce a clean, healthy, and thriving plant ready for the "real world" in the garden.

Let's Think Out of the Pot

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INTRODUCTION

Environmental issues are always on the front burner when dealing with the production of ornamental crops. Issues such as water quality, runoff water, fertilizer leaching, pesticide movement, and others are paramount at production facilities. As nursery producers, we need to think out of the pot – instead of thinking about making plants grow 95 miles an hour — think about what is taking place out of the pot with leachate and runoff from production beds.

In the last few years, there has been a lot of research concerning container leachate, how to maximize controlled-release fertilizers, and utilization of cyclic irrigation for reducing runoff from production pads to minimize production practices that affect the environment. Many of you have been operating with Best Management Practices (BMPs) for many years or have implemented BMPs in the past few years to decrease or eliminate irrigation runoff from production facilities.

CLEAN WATER ACTS OF 1972, 1977, AND 1987

Regulatory agencies have been reevaluating the Clean Water Acts of 1972, 1977, and 1987. These acts were designed to protect surface and ground waters. Section 303(d) of the Clean Water Act provides for: 1) identification of water for which technology-based effluent limitations are not stringent enough to implement water quality standards, 2) a priority ranking for water quality segments, and 3) establishment of total maximum daily loads (TMDL) for pollutants.

Many of the watersheds in each state have been monitored for the impact of agriculture and other pollutant sources. Each watershed has an identification number, the impacted water body, the pollutant cause, the pollutant source, the magnitude of the impact, and finally whether a TMDL has been assessed. A TMDL is the total maximum daily load that is approved for a particular water body. TMDL is defined as the sum of nonpoint sources plus the sum of point sources plus a margin of safety. Nonpoint source is defined as any source of pollutant that enters a water body from no particular point. For example, flow from a pasture or runoff from paved areas is considered nonpoint source pollution. A point source is described as a discrete discharge through a pipe or similar conveyance. The margin of safety accounts for uncertainty in the loading calculation that water can receive without violating water quality standards. TMDLs for watersheds in your state are available on the U.S. EPA web site (www.epa.gov).

The U.S. EPA is using a term "impairment" as a collective term for pollutants in the water that reduce water quality, such as nutrients. A specific nutrient, phosphorus, would be an example of a pollutant. In Tennessee, there are 35 different types of impairments. Some examples include siltation, pathogens, nutrients, pesticides, and oil and grease. The top 5 sources of impairments are agriculture 15%, channelization 11%, urban runoff 11%, land development 7%, and contaminated sediment 5%.

A priority level, low or high, is recommended for developing TMDLs in each watershed. The priority level is dependent on the amount and type of impairment. In many watersheds, sediment caused by soil erosion is the primary impairment. Soil erosion can be a severe problem from moving soil particles, but also in that nutrients and pesticides can adhere to the moving soil particles. In some areas, nutrients were listed as a primary impairment, in which agriculture is listed as the cause of the nonpoint source pollutant.

NITROGEN AND PHOSPHORUS

Two nutrients of concern to nursery producers are nitrogen and phosphorus. Nitrogen, in the form of nitrate, has been a health concern in potable water for over 50 years. The maximum contaminate level of nitrate-N is set at 10 ppm, or nitrate levels at 44 ppm. As a BMP, we have recommended sampling irrigation waters, irrigation runoff, and holding ponds to document nitrate-N levels at different times during the production cycle. Another approach is to develop a nutrient management plan (NMP). This includes not only nitrogen, but also phosphorus and potassium. It will be important to maintain records for levels of nitrate-N in runoff water, and documentation of how many pounds of nitrogen and phosphorus are used per unit area. Currently, as producers we are familiar with pounds of fertilizer per cubic yard, not pounds of fertilizer per greenhouse or surface growing area [m^2 (yd^2)]. This information helps to determine the potential for nutrient loading of surface and ground water.

Phosphorus, in the form of phosphate, is targeted for environmental concerns due to the phosphorus activity in water. Phosphorus is the most limiting element in water, while nitrogen is the most limiting element in plant growth. Phosphates can enter bodies of water in runoff water, soil particles, and plant debris. High levels of phosphates cause algae blooms and are a health concern for fish and other aquatic life. This in turn can cause irrigation pump damage or clogging of irrigation emitters. Phosphorus at 1 ppm or phosphates at 3 ppm are considered high levels, but the maximum contaminant level for drinking water is not defined.

IMPLEMENT BEST MANAGEMENT PRACTICES

A nutrient management plan (NMP) for your production facility is a BMP to implement and meet environmental concerns. A nutrient management plan can be defined as irrigation management plus fertilizer application. The first step in developing a plan is to get an overview of the production facility. Your county U.S.D.A. Farm Services Agency (the old ASCS) should have aerial photographs of your land. Some of the photos are out dated and a new aerial photograph may be needed. Identify the growing area, the location of stored chemicals and fertilizers, and potential runoff sites. Locate streams, creeks, lakes, wetlands, and sinkholes in relation to your property. Mark and identify any areas where irrigation effluent enters lakes, streams, or any other body of water. Evaluate runoff potential from the production facility. If all the runoff is contained on site, then you will have fewer problems developing a NMP.

One of the ways to prevent irrigation waters from leaving production nurseries is to build ponds, also known as retention basins or abatement structures. This is one of the best BMPs to prevent irrigation water from leaving a nursery. The Natural Resources and Conservation Service (NRCS) has field representatives that can help you determine the best location for ponds and waterways. They provide a valuable service in this area. Older nurseries may not be able to build ponds on existing properties, so other BMPs to reduce irrigation effluent are paramount.

Plant vegetative filter strips in drainage ditches between the production facility and waterways whether these waterways lead to holding ponds or funnel effluent into a public water source. The plants in the vegetative filter strip use some of the nutrients carried in the runoff water, prevent soil erosion, and play a role in degradation of pesticides. After a heavy storm, check the nursery to see if there is soil erosion or sediment movement from your property. NRSC can advise you on plants recommended for riparian areas.

Evaluate Your Irrigation System. Document irrigation volumes at different times during the growing season. Apply only the amount of water needed to grow the plants. Set rain gauges or cups in a block of plants to check the amount of water applied and the irrigation distribution during an irrigation event. If an irrigation sprinkler is not operating correctly, fix or replace it. Do not overwater the rest of the block of plants to compensate for a faulty sprinkler. Consider cyclic irrigation. It has proven to be a technique that requires less irrigation water, reduces leachate potential, and lowers nitrate-N levels in container leachate.

Develop a Fertilizer Budget. Make a computer spread sheet or worksheet to document the method of application and the schedule of application to plants. Keep accurate records of fertilizer use (and pesticide use) by blocks of plants, production houses, or specific nursery crops. Evaluate your use of fertilizers, such as controlled release and liquid, for the best plant growth and environmental concerns.

Calculate the Total Pounds of Fertilizer You Apply to the Production Facility Annually. How may pounds per acre of nitrogen and phosphorus are needed to produce quality nursery stock? Most of us do not think in terms of nitrogen per acre for container production. We are conditioned to think about pounds of controlled-release fertilizer per cubic yard or ppm of nitrogen for liquid feed. Future regulation on fertilizer use will require documentation of the total amount of a particular nutrient applied in a known area.

The U.S. EPA will allow individual states to manage water quality issues if states can show they are capable of preventing these contaminants from adversely affecting human health and the environment. So the interpretation of the regulations may differ from state to state. In Tennessee, a three-step program is proposed. The first step is to monitor to assess the water quality of streams and lakes and to document problem areas. The second step is to implement BMPs to reduce the impact of the problem. The third step is to educate producers as to the production techniques that cause the problem and solutions to minimize the environmental impact. As a last resort, if the impairment problem is not corrected, then regulatory agencies can suspend the use of that practice or chemical until the problem is corrected.

CONCLUSION

Finally, maintain a positive proactive approach – educate yourself and learn the lingo of the environmental issues. Most of the states are underfunded to support the policing of all the water quality concerns and regulatory action will be done on a complaint basis. Using recommended BMPs, irrigation effluent from container nurseries should not adulterate water quality standards.

How to Computerize Production Scheduling

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INTRODUCTION

Before you can begin to write or use any scheduling program, you will need to compile data for the program. You will need relevant information on your company that covers labor and supply expenses, soil mix volumes, and container volumes. After you start to compile all of this information, you may realize that you are not totally prepared to computerize your scheduling. In order to use any computer program to assist with scheduling, a complete understanding of the materials, steps in production, expenses, and timelines for your crops is needed.

My program was first created to schedule annual flower production for greenhouse space and availability for sale. The first step towards the program was creating a list of plants I wanted to track and what basic information I wanted from the program. The basic information I wanted included the following:

- Dates of flower plug arrival and the average date the planted flowers would be saleable.
- Numbers of flats per variety and total number of flats per week.
- Greenhouse space needed per week and monthly total space needed.
- Supplies needed per week and month and even year.

MAIN TABLES TO BE ENTERED TO BUILD DATABASE

Table 1: Labor Expenses. This table will require the greatest modification among different companies, since every firm has differences in methods of potting plants, piecework (labor incentive) rates, as well as different crops. Some of the fields of data that are required in the table are covered below. This table has several calculations of data that can give you a large "what if"scenario for labor expenses.

EXPLANATION OF TABLE 1.

- **Job description** - list of different jobs involved in propagation.
- **Number of workers** - number of people usually used for the job.
- **Average dollars per hour** - average wage of the crew for the job.
- **Number of hours** - time required for the job.
- **Minimum pots per day** - quota set by management for the crew.
- **Dollars per minimum** - calculation of (*# of people * avg. $ per h * # of h*).
- **Bonus dollars per pot** - bonus set by management for every plant over quota.
- **Average pots per day** - average pots planted per day. This number is updated regularly.
- **Bonus pots** - calculation of (*average pots per day - minimum pots per day*).
- **Bonus expense** - calculation of (*bonus $ per pot * bonus pots*).
- **Average expense per day** - calculation of (*$ per minimum + bonus expense*).

Table 1. Labor expenses.

Job Description	No. of workers	Avg $ per hour	No. of hours	Min. pots per day	$ per min	Bonus $ per pot	Avg pots per day	Bonus pots	Bonus $	Avg exp per day	Avg exp per pot
Mixing perlite	1	$7.00	1					0	$0.00	$0.00	
Mixing direct stick soil	1	$6.00	2					0	$0.00	$0.00	
Mixing pot soil	1	$6.00	4					0	$0.00	$0.00	
Mix and fill flower tray	4	$6.00	3		$72.00			0	$0.00	$72.00	
Canning 4-inch flat	1	$6.00	8	200	$0.00	$0.50	200	0	$0.00	$0.00	$0.00
Canning 4-inch pots each	1	$6.00	8	200	$0.00	$0.03	200	0	$0.00	$0.00	$0.00
Canning 1 gal	4	$6.00	8	2500	$192.00	$0.03	4000	1500	$45.00	$237.00	$0.06
Canning 3 gal	4	$6.00	8	1600	$192.00	$0.10	2000	400	$40.00	$232.00	$0.12
Canning 5 gal	4	$6.00	8	1600	$192.00	$0.10	2000	400	$40.00	$232.00	$0.12
Canning 7 gal	4	$6.00	8	600	$192.00	$0.15	1000	400	$60.00	$252.00	$0.25
Canning 10 gal	4	$6.00	8	400	$192.00	$0.20	600	200	$40.00	$232.00	$0.39
Canning 20 gal	4	$5.70	8	400	$182.40	$0.20	600	200	$40.00	$222.40	$0.37
Planting flower plug	1	$5.70	8	200	$45.60	$0.00	200	0	$0.00	$45.60	$0.23
Planting 4-inch stock plants											
Run and load flowers											
Unload flowers											

Table 2. Soil expenses.

Soil ingredients	Volume	Units	Cost	Cost per unit	Unit	Rate/yd	Unit	Cost/yd
Agrosoke	55	lbs	$278.00	$5.05	lbs	2.50	yd	$12.64
Aquagro 2000	120	lbs	$291.00	$2.43	lbs	5.00	oz	$12.13
Banrot 8G	40	lbs	$271.00	$6.78	lbs	1.00	lbs	$6.78
Excell 21-5-20	50	lbs	$17.00	$0.34	lbs	0.60	lbs	$0.20
High N 24-4-7	50	lbs	$33.78	$0.68	lbs	9.00	lbs	$6.08
Lawn and garden	40	lbs	$5.45	$0.14	lbs		yd	$0.00
Merit-broadcast rate	40	lbs	$638.80	$15.97	lbs	85.30	grams	$1,362.24
Merit	30	lbs	$54.30	$1.81	lbs	6.00	lbs	$10.86
Micromax	50	lbs	$47.33	$0.95	lbs	1.00	yd	$0.95
Nutricote	50	lbs	$40.00	$0.80	lbs	15.00	lbs	$12.00
Osmocote 14-14-14	50	lbs	$39.00	$0.78	lbs	6.00	lbs	$4.68
Osmocte 18-6-12	50	lbs	$39.56	$0.79	lbs	9.00	lbs	$7.12
Peat moss-7.6 ft^3	7.6	cu. ft.=.28 yds.	$6.00	$0.39	ft	1.00	yd	$10.66
Peat moss-large bale	110	cu. ft.=4 yds.	$93.65	$0.43	ft	1.00	yd	$11.49
Perlite	4	cu. ft.=.15 yds.	$7.47	$1.87	ft	1.00	yd	$50.42
Red bark	90	yds	$1,065.00	$11.83	yds	1.00	yd	$11.83
Red sand	13	yds	$134.07	$10.31	yds	1.00	yd	$10.31
Regrind	65	yds	$1,065.00	$16.38	yds	1.00	yd	$16.38
Soil conditioner	65	yds	$1,065.00	$16.38	yds	1.00	yd	$16.38
Sprint	5	lbs	$26.32	$5.26	lbs		yd	$0.00
Step	50	lbs	$26.14	$0.52	lbs	1.84	lbs	$0.96
Sunshine Mix #1	4	ft^3=.15 yds.	$15.53	$3.88	ft	1.00	yd	$104.83
Superbloom	20	lbs	$23.05	$1.15	lbs	0.60	lbs	$0.69
White fill sand	23	yds	$720.00	$31.30	yds	1.00	yd	$31.30

- **Average expense per pot** - calculation of (average expense per day / average pots per day).

Table 2: Soil Expenses. The soil expenses database is a basic list of all ingredients used in our soil mixes. Extra ingredients can be added at any time to the bottom of the list. If you choose to use this program, it is best to add items to the bottom of the list and to not delete any old items. If you delete any items, this may affect the calculations for other tables. All information is listed in the size it is purchased in, and then broken down into smaller units. There are several calculations of the inputted data on this table. Calculations are italicized and in parenthesis.

EXPLANATION OF TABLE 2.

- **Soil ingredients** - list of ingredients.
- **Volume** - volume of ingredients.
- **Units** - units used for volume of ingredients as purchased.
- **Cost** - cost for ingredients as packaged.
- **Cost per unit** - this is two columns. The first is a calculation of (*cost / volume*). The unit part is inputted.
- **Rate/yd** - amount inputted by management and changed as needed.
- **Unit** - entered as needed to calculate rates. This is different from other units column.
- **Cost/yd** - calculation of (*cost per unit * rate / yd*).

Table 3: Can Volume. The can volume database is the easiest database to create. The majority of containers that we use are Lerio, so I chose Lerio as the standard container sizes to use. Lerio supplied a price list that included container volume and number of containers per yard. The only calculation needed was discounted price. The price and discount will change with every company. The prices used here are 1997/1998 prices. Calculations will be italicized and in parenthesis.

EXPLANATION OF TABLE 3.

- **Container type** - taken from Lerio price list.
- **Can code** - taken from price list.
- **List cost** - taken from price list.
- **Discount cost** - calculation of (*inputted discount * list price*).
- **Net cost** - calculation of (*list cost – discount cost*).
- **Volume in yards** - taken from price list.
- **Number of pots per yard** - taken from price list.
- **$ per yard** - calculation of (*# of pots per yard * $ per yard*).

Table 4: Soil Mixes. As with labor expenses, this table will vary widely between companies.The soil mixes used in this program are our basic mixes and do not reflect the most current mixes in use. The mixes here can be modified in any way and the program will still work as long as the space from total volume to cost per yard is not modified for each mix. As with the other table explanations, calculations are italicized and in parenthesis.

EXPLANATION OF TABLE 4.

- **Ingredients** - this is a list of all ingredients used in the soil mix.
- **Quantity** - quantity of the ingredients needed. This is the actual quantity, not unit quantity.

Table 3. Can volume.

Container type	Can code	List $	Discount	Net $	Volume-yds	No. pots/yd	$ pots/yd
2¼-inch Lerio	SR225	$0.01	$0.00	$0.01	0.000249	4016	$29.72
Lerio flats for 2¼ inch		$1.85	$0.48	$1.37	N/A	63	$86.25
3-inch Lerio pots	SR300	$0.05	$0.01	$0.04	0.000433	2310	$85.47
Lerio flats for 3 inch		$0.66	$0.17	$0.49	N/A	64	$31.26
4-inch Lerio pots	VSR4	$0.06	$0.02	$0.04	0.000713	1402	$62.25
Lerio tray for 4-inch pots	SST418	$0.61	$0.16	$0.45	N/A	78	$35.21
4-inch flower pots-18/sheet		$0.02	$0.01	$0.01	0.000556	1170	$17.32
Trays for 4-inch flowers		$0.40	$0.10	$0.30	N/A	65	$19.24
1 gal	C650	$0.21	$0.05	$0.16	0.003518	284.25	$44.17
5-gal egg can	C1150	$0.95	$0.25	$0.70	0.007979	125.33	$88.11
5-gal pecan	TC1020	$3.24	$0.84	$2.40	0.019487	51.32	$123.04
10-gal blow mold	B10	$2.07	$0.54	$1.53	0.050855	19.66	$30.12
10-gal injected	C1700H	$3.30	$0.86	$2.44	0.052176	19.17	$46.81
15-gal blow mold	B15	$2.52	$0.66	$1.86	0.051166	19.54	$36.44
15-gal injected	C1900	$3.69	$0.96	$2.73	0.065701	19.22	$52.48
20-gal blow mold	B20	$4.90	$1.27	$3.63	0.098159	10.19	$36.95
20-gal injected	C2150	$6.62	$1.72	$4.90	0.099055	10.1	$49.48
25-gal blow mold	B25	$5.20	$1.35	$3.85	0.124541	8.03	$30.90
30-gal vacumn formed		$19.00	$4.94	$14.06	0.154278	6.48	$91.11
45-gal blow mold	B45	$11.47	$2.98	$8.49	0.229253	4.36	$37.01
45-gal vacumn formed		$21.00	$5.46	$15.54	0.211871	4.72	$73.35
90-gal-32-inch-tree box		$44.00	$11.44	$32.56	0.439632	2.27	

- **Unit** - the unit measurement of the ingredients needed.
- **Volume in yards** - the amount of volume the ingredients equal.
- **Cost per mix** - calculation of (*quantity * cost per unit*). This data is taken from the soil expenses (Table B).
- **Total volume** - calculation of the volume of all ingredients used.
- **Total cost** - calculation of all costs for the mix.
- **Cost per yard** - calculation of (*total cost / total volume*)
- **Cost per flat** - this is only shown where the soil is used for flats. It is a calculation of (*cost per yard / 85 flats*).

THE SCHEDULING PROGRAM

A. Table 5: Plug Arrival-booking Example. This is where I input the actual plug count of each variety ordered. The table is divided by plant varieties and by weeks in the year. The weeks are used since numbered days change year to year. These numbers of plugs are changed year to year.

B. Table 5: Flats Arrival-booking Example. This table is only a simple calculation. It takes the number of plugs from the prior table and calculates the number of flats that need to be filled for each week. The formula is the plug number divided by 18 for our flat size. This table also calculates the total flats on hand and how many greenhouses are needed. The far right column calculates the number of flats for each variety to aid in ordering tags.

C. Table 5: Calculation of Flats Ready at End of Production. This table is another simple calculation. It takes the number of plugs from the prior table and calculates the number of flats that will be ready on a specific week. It will take Week 5 flats and put this quantity in Week 9.

D. Table 6: Perennial and Groundcover Bookings. This is a list of perennial and groundcover plants booked for each month of the year. All counts are complete trays of 98 plants per tray.

E. Table 7: Supply Schedule for Flowers. This table incorporates all supplies for flowers. All figures on this page are calculations from other tables.

- **Flats and Pot Sheets** - this row calculates the flats and pots sheets needed each month by adding the number of flats of flowers each month from the flats arriving (Table 5).
- **# of Yards of Soil** - this row calculates how much soil is needed by multiplying the number of flats needed each month by the volume of soil needed in each flat. The soil volume is looked up in can volume (Table 3).
- **# Batches of Soil** - this row takes the number of yards of soil needed and divides it by the number of yards per batch of soil listed in the flower soil mix section (Table 4).
- **Peat Moss** - this row includes the number of batches of soil and divides the number of batches by how many bales of peat moss are needed per batch that is needed in the soil mixes (Table 4).
- **Perlite, Soil Conditioner, Nutricote, Banrot, Aquagrow, Agrosoke, and Merit** - use the same calculation method for peat moss (Table 4).

Table 4. Soil mixes.

1998 flower mix

Ingredient	Quantity	Unit	Volume-yds	Cost per mix
Peat moss	7	7.6 cu.ft. bales= cu ft	1.98	$42.00
Perlite	3	4 cu.ft. bags	0.45	$22.69
Propagation mix	2	Scoops=1 cu. yds	2.00	$20.66
Osmocote 14-14-14	15	lbs	0.00	$11.70
Nutricote		lbs(15/yd)	0.00	$0.00
Banrot	3	lbs	0.00	$20.33
Aquagrow	4.5	lbs	0.00	$10.91
Agrosoke	13	lbs	0.00	$65.71
Merit	26.5	lbs	0.00	$47.97
Total volume-yd^3	4.43			
Total cost	$241.96			
Cost per yard	$54.62			
Cost per flat	$0.64			

1998 1 gal mix and larger

Ingredient	Quantity	Unit	Volume-yds	Cost per mix
Regrind	190	yds	190.00	$2,303.75
Peat moss-large bale	30.8	yds(7 bales of 4.4 yds)	30.80	$964.17
Red sand	13	yds	0.00	$79.05
White sand	10	yds	0.00	$0.00
High N 24-5-7		50 lb bags	0.00	$0.00
Nutricote	66	50 lb bags(15 lbs/yd)	0.00	$3,123.78
Step	9	50 lb bags	0.00	$103.44
Osmocote 18-6-12	0	50 lb bags	0.00	$0.00
Osmocote 14-14-14	0	50 lb bags	0.00	$0.00
Total volume-yd^3	220.80	Cut peat to 7 bales for 14%		
Total cost	$6,574.19	Cut peat to 6 bales for 12%		
Cost per yard	$29.77			

1998 propagation mix

Ingredient	Quantity	Unit	Volume-yds	Cost per mix
Soil conditioner	65	yds	65.00	
Peat moss-large bale	5	110 cu ft/4 yds	20.00	$468.25
Perlite	54	cu. ft.=.15 yds.	8.10	$403.38
MicroMax	95	1#/yd. Rate	0.00	$89.93
Total volume-yd^3	93.10			
Total cost	$961.56			
Cost per yard	$10.33			
Cost per flat	$0.16			

1998 jasmine, liriope, lantana, ivy, mix

Ingredient	Quantity	Unit	Volume-yds	Cost per mix
Propagation mix	4	Scoops=1 yd/scoop	4.00	$41.31
Peat moss	2	7.6 cu. ft bags	0.56	$12.00
Nutricote 24-3-7	12	lbs	0.00	$9.60
Total volume-yd^3	4.56			
Total cost	$62.91			
Cost per yard	$13.80			
Cost per flat	$0.02			
Cost per gallon	$0.05			

Direct stick mix

Ingredient	Quantity	Unit	Volume-yds	Cost per mix
3.8 Berger	1	3.8 bale	0.28	
Perlite	1	Bag	0.15	
Vermiculite	1	Bag	0.15	
Cedar flake	1	20g bucket	0.09	
Propagation mix	2	20g buckets	0.18	
Soilgaurd	1	lb		
Total volume-yd^3	0.85			
Total cost	$0.00			

Table 5. Calculation of flats.

Plug arrival booking example

Plant name	Plant cultivar	WK5	WK6	WK7	WK8	WK9	WK10
Begonia	Gin	1400	550	1400	1375	2100	1375
Begonia	Mix	700			825	1750	550
Begonia	Scarletta	700	275	700	825	1050	825
Begonia	Vodka	2800	1100	2800	1625	5600	1650
Begonia	Whiskey	700	275	350	550	700	275

Flat arrival booking example

Plant Name	Plant cultivar	WK5	WK6	WK7	WK8	WK9	WK10	Tags and flats
Begonia	Gin	78	31	78	76	117	76	456
Begonia	Mix	39	0	0	46	97	31	213
Begonia	Scarletta	39	15	39	46	58	46	243
Begonia	Vodka	156	61	156	90	311	92	865
Begonia	Whiskey	39	15	19	31	39	15	158
Flats arriving		350	122	292	289	622	260	
Total flats on hand		350	472	764	1053	1325	1463	
Houses needed		0.3	0.4	0.6	0.9	1.1	1.2	

Flats ready example

Plant name	Plant culitvar	WK9	WK10	WK11	WK12	WK13	WK14
Begonia	Gin	78	31	78	76	117	76
Begonia	Mix	39	0	0	46	97	31
Begonia	Scarletta	39	15	39	46	58	46
Begonia	Vodka	156	61	156	90	311	92
Begonia	Whiskey	39	15	19	31	39	15

Table 6. Perennial and groundcover bookings.

Plant name	Size	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL TRAYS	TOTAL PLANTS
CUP-DWF	1gal	20				10		10						40	4000
CUP-DWF	4 inch	30				20		10						60	6000
IVY-ALG	4 inch			50		25		50		50	50	200		425	42500
IVY-ENG	4 inch			80		35		60		70	70	300		615	61500
JAS-ASI	1gal					150	50		50	50				300	30000
JAS-ASI	4 inch					400	300		300	300	400			1700	2E+05
LAN-GOL	1gal	50				40		20						110	11000
LAN-GOL	4 inch	80		80		80		80		50				370	37000
LAN-PUR	1gal	25				15		10						50	5000
LAN-PUR	4 inch	60		55		55		55						225	22500
LAN-RAD	1gal	5				5								10	100
LAN-RED	1gal	5				5		10						20	2000
LAN-WHI	1gal	10		10		10		10						40	4000
LAN-WHI	4 inch	50				30		30						110	11000
SAL-GPK	1gal	10		10		10		20						50	5000
SAL-GRA	1gal	10		10		10		20						50	5000
SAL-GRD	1gal	30		30		30		30						120	12000
SAL-GWH	1gal	10		5		5		10						30	3000
VIN-MAJ	4 inch	50		50		50				50				200	20000

Table 7. Supply schedule for flowers 1999.

Supplies	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Flats and pot sheets	0	0	0	0	0	0	0	0	0	0	0	0	-
Yards of soil (number)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Batches of soil (number)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Peat moss	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Perlite	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Soil conditioner	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Nutricote	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Banrot	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Aquagrow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Agrosoke	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Merit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Supplies for flowers and other bookings													
Total flats and pot sheets	1494	0	1744	0	3811	1633	1583	1633	2850	2844	2778	0	20372
Total Merit-lbs	0.0	0.0	45.0	0.0	61.7	0.0	58.3	0.0	16.7	0.0	0.0	0.0	182

	Jan	Feb	Mar	Apr	May	Jun
Pot expense	$ 1,058.52	Ø	$ 1,235.59	Ø	$ 2,699.41	$ 1,156.89
Merit	Ø	Ø	Ø	$ 23.30	Ø	$ 31.92
Total	$ 1,058.52	Ø	$ 1,258.89	Ø	$ 2,731.33	$ 1,156.89

	Jul	Aug	Sep	Oct	Nov	Dec	Total
Pot expense	$ 1,121.48	$ 1,156.89	$ 2,018.66	$ 2,014.72	$ 1,967.50	Ø	$ 6,150.41
Merit	Ø	$ 30.20	Ø	$ 8.63	Ø	Ø	$ 55.22
Total	$ 1,151.67	$ 1,156.89	$ 2,027.28	$ 2,014.72	$ 1,967.50	Ø	$ 6,205.62

Table 8. Supplies list for perennials and groundcovers.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
For ivy flats-jasmine mix w/fungicide													
Soilgaurd	0	0	7	0	3	0	6	0	7	7	28	0	58
Flats and pot sheets	0	0	722	0	333	0	611	0	667	667	2778	0	5778
Yards of soil (number)	0	0	11	0	5	0	9	0	10	10	43	0	89
Batches (number)	0	0	3	0	1	0	2	0	2	2	10	0	20
For Marathon flats-jasmine mix w/Marathon lantana, mx heather, vinca													
Merit-ounces	0	0	45	0	62	0	58	0	17	0	0	0	182
Flats and pot sheets	1222	0	750	0	1028	0	972	0	278	0	0	0	4250
Yards of soil (number)	19	0	12	0	16	0	15	0	4	0	0	0	65
Batches (number)	4	0	3	0	4	0	3	0	1	0	0	0	15
Other flats-jasmine mix jasmine													
Flats and pot sheets	272	0	272	0	2450	1633	0	1633	1906	2178	0	0	10344
Yards of soil (number)	4	0	4	0	38	25	0	25	29	34	0	0	159
Batches (number)	1	0	1	0	9	6	0	6	7	8	0	0	36

For Merit gallons-regular mix lantana, mx heather													
Merit-lbs	0	0	0	0	0	0	0	0	0	0	0	0	0
1-gal pots (number)	11270	0	980	0	8330	0	5880	0	0	0	0	0	26460
Yards of soil (number)	0	0	0	0	0	0	0	0	0	0	0	0	0
Batches (number)	0	0	0	0	0	0	0	0	0	0	0	0	0
For other gallons-regular mix jasmine, salvia													
1-gal pots (number)	5880	0	5390	0	20090	4900	7840	4900	4900	0	0	0	53900
Yards of soil (number)	0	0	114	0	424	103	166	103	103	0	0	0	1014
Batches (number)	0	0	18	0	69	17	27	17	17	0	0	0	164
Total pot supplies perennials and groundcovers													
Total gallons pots	17150	0	6370	0	28420	4900	13720	4900	4900	0	0	0	80360
Total 4-inch sheets and trays	1494	0	1744	0	3811	1633	1583	1633	2850	2844	2778	0	20372
Total yards of jasmine flat soil	23	0	27	0	59	25	24	25	44	44	43	0	313
Total batches of jamine flat soil	5	0	6	0	13	6	6	6	10	10	10	0	71
Total Merit	0	0	45	0	62	0	58	0	17	0	0	0	182
Total fungicide-Soilgaurd	0	0	7	0	3	0	6	0	7	7	28	0	58
Peat moss-large bale													0
Peat moss-small bale	10	0	12	0	27	11	11	11	20	20	19	0	141
Nutricote-lbs	62	0	73	0	159	68	66	68	119	119	116	0	849

- **Total Flats and Pots Sheets** - this is a calculation of the flats needed for flowers from the supply schedule for flowers and supplies list for perennials and groundcovers (Table 7).
- **Pot Expense** - calculation of the number of pots and flats needed times the price of each from the can volume sheet (Table 3).
- **Merit $** - this is a calculation of the total Merit needed times the cost of Merit from soil expenses (Table 2).

Table 8: Supplies List for Perennials and Groundcovers. This page works similar to the supplies schedule for flowers (Table 7).

CONCLUSION

Hopefully I have provided some ideas and samples for anyone interested in computerizing their production and scheduling. As with any program, whether you buy a complete program or write your own, there will be a large amount of data to be inputted before you can start using the program. Before you purchase any program, I would recommend looking at any and all types of scheduling programs that you can find. Some good sources of programs are other growers, searching the Internet, or even construction scheduling programs. Keep in mind that price does not reflect performance. You may want to start with a simple and limited program and upgrade later to a more complex or custom written program. We are currently switching our scheduling over to a new custom written scheduling program. The new program allows every crop to have different growing periods such as weeks, months, or quarters and will even separate crops for the purpose of contract growing. A demo of this program can be downloaded from the following website (www.jchdiversified.com).

If you would like to use my program, it can be downloaded from the Internet at the following website (www.mortellaro.com/ipps).

Should you have any questions, my email address is: jim@mortellaro.com

Shipping and Packaging of Perishable Propagation Material

Larry C. Newton
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INTRODUCTION

Since Classic's beginning, the idea of "Sudden Service" has meant there would be an emphasis on customer service. This has led to a program of shipping plants as quickly and efficiently as possible and still having them arrive in good condition.

Classic Groundcovers, Inc. is a 36-year-old nursery that propagates and grows groundcovers in 6-cm (2¼-inch) and 10-cm (4-inch) pots as well as bare-root material. We ship nationwide and do some overseas deliveries. We also propagate over 4,000,000 cuttings per year and can ship 1000 packages per day, averaging 2500 packages per week.

We use waxed chicken boxes from the poultry industry for our shipping. Wax is important because we pull orders daily in all weather and the waxed boxes hold up when wet. Each box holds 24 10-cm (4-inch) pots or 70 6-cm (2¼-inch) pots and is packed with newspaper on the sides and top to prevent shifting. We also sell bare-root material, which is bundled, the roots are dipped in a gel polymer solution. Sphagnum moss is put in the bottom of the boxes, and paper is used to fill any gaps.

SHIPPING AND PACKING

Shipping with UPS and FedEx. Years ago, Greyhound Bus was the most commonly used system of shipping, along with taking packages to the local UPS outlet. We then started preparing packages for shipment at our facility using Pitney Bowes equipment. In 1992, we were shipping enough volume that UPS set up a computer weighing system in our shipping shed, allowing us to totally prepare packages for UPS shipment. About 3½-years ago, we looked into setting up a similar FedEx system alongside our UPS system because they offer 2-day delivery to the Northeast, which is a 3-day delivery zone for UPS. The timing of adding this additional system was very fortunate, because UPS went on strike that summer and we relied totally on FedEx to make our deliveries. Since then we have considered it necessary to have both of these systems on line.

Processing an Order for Shipment. A salesperson will take an order on the phone and type in all pertinent information on the computer. They will then print an acknowledgment, which has three copies and labels to be attached to the boxes. Our office is separated from our shipping facility, so the shipping manager will come to the office several times a day to collect orders. When she returns to the shipping shed, the copies are separated, one for the incoming line that goes on the box to the customer and the other to the computer. All orders are written on a master pull chart. The shipping crews come to the shed, get their orders and enough boxes and paper, then go out to the nursery to assemble the order. Finding the plants in the greenhouse is facilitated by an inventory of plants contained in each greenhouse. This is on a chart attached to each greenhouse door. The items in red are still in production and the items in green list all plants available to be shipped. All but one of the crew members will take their boxes and paper and begin pulling plants for orders. The other crewmember stays with the trailer and makes lids for the boxes. On each box, he will write the plant name, the size 10 cm (4 inch) or 6 cm (2¼ inch) or bare root, and the quantity in each box. When they finish packing the boxes they return to the trailer, put on the appropriate lids and return to the shipping shed. Here they unload the boxes on a roller rack. One for UPS and one for FedEx. As the boxes slide down the roller rack, the shipping crew reads the contents written on the boxes and matches them up with the proper acknowledgment. We have three baskets of acknowledgments, one for orders containing only 6-cm (2¼-inch) pots — one containing orders for 10-cm (4-inch) pots and the middle basket contains orders with mixed sizes. There is a separate station for processing bare-root plants.

Handling Bare-Root Plants. Bare-root plants are bundled in groups of 50 and held together with either rubber bands or twine. They are carried to a dip tank in the shipping shed containing a gel polymer material. Here the roots are dipped in the gel slurry and placed on a wire rack to drain off excess water. They are then packed in the same chicken boxes we use to ship our containerized plants in. The bare-root boxes will have sphagnum moss in the bottom of the box to keep roots moist during shipping.

Orders to California, Washington, Oregon, Arizona, Hawaii, and overseas must be bare-root plants. These locations will not accept our pine-bark soil. All roots must be hand-washed to remove any soil particles and inspected by USDA inspectors before shipment. A phytosanitary certificate as well as all appropriate paperwork from an independent freight forwarder must accompany all orders going overseas. These orders are usually taken to the Atlanta airport for direct airfreight shipment. All others are direct shipped by UPS or FedEx. These boxes are moved to the appropriate roller rack with the correct address label attached to each box.

Processing of Boxes Containing Plants for Shipment. A packing slip with an acknowledgment, a nursery stamp, and a fire-ant-free stamp are put on the last box for each order. The boxes are then lifted to a strapping machine that straps the lids firmly in place. They are then lifted to a roller rack that slides these boxes to a computer station. When they reach the computer station our shipper will read the address label on the lid and find the appropriate acknowledgment in an accordion folder. They move the box to a scale where the box is weighed, then enter the appropriate information, typically phone number and zip code, on the computer screen and then push a button to receive two labels. One is the UPS or FedEx Bar Code box label, the other is a smaller label which is attached to each acknowledgment for each package sent. This label contains freight amounts for adding to COD labels and tracking numbers so each package can be tracked in case of a lost shipment. This is where all specialty stickers will be attached to the box such as CODs, next day air, next day Saturday, 2nd day, etc.

When completed the package is moved to a roller rack which returns the package to the front of the building where we have a large sliding door. UPS parks a trailer in this entrance every morning and we fill it during the day. It will hold about 300 boxes. When it is filled, we stack the remaining packages next to the door and one UPS driver will have to load these in the truck he brings to pull the trailer. UPS comes in the late afternoon and early evening, picks up the trailer, and delivers all the packages to the UPS hub in Athens where they are dispatched overnight. At the end of our shipping day we print the daily records, one is for our office and the driver takes the other. Both UPS and FedEx computers are connected online with a modem so they have constant knowledge of our activity at their central office.

The next morning all acknowledgments from the previous day are taken to accounts receivable where the orders are double-checked for errors or backorders. The total freight bill is also totaled at this time and the invoices are prepared and sent to the customers. We also have software that allows us to track packages. It can tell you where packages were scanned and also proof of delivery.

A Tour of Your National Arboretum and Its Latest Cultivar Releases

Margaret R. Pooler
USDA-ARS-U.S. National Arboretum, 3501 New York Ave., NE, Washington, DC 20002 U.S.A.

THE U.S. NATIONAL ARBORETUM

The U.S. National Arboretum, established by an Act of Congress in 1927, is a research facility and living museum in northeast Washington, DC. Administered by the U.S. Department of Agriculture, the mission of the Arboretum is to conduct research, provide education, and conserve and display trees, shrubs, flowers, and other plants to enhance the environment. The Arboretum is a unique federal institution linked by partnerships to many governmental agencies, the scientific community, other arboreta and botanic gardens, and various private-sector groups. As a national center for public education, the Arboretum welcomes over 600,000 visitors annually to a stimulating and aesthetically pleasing environment.

Located on 185 ha (446 acres), the National Arboretum has plant collections, historic sites, and special attractions that appeal to visitors year-round. These attractions include separate landscaped collections of Asian plants, azaleas, conifers, dogwoods, hollies and magnolias, boxwood, native plants, perennials, and state trees. Other attractions include aquatic plants, the Capitol Columns, Friendship Garden, National Herb Garden, National Bonsai and Penjing Museum, National Herbarium, and the Washington Youth Garden.

Gardens, Education, and Research. The approximately 110 full-time staff and over 200 volunteers at the National Arboretum work primarily in either the Gardens Unit, the Education Unit, or the Research Unit. The Gardens Unit is responsible for maintaining most of the display collections and attractions mentioned above. The Education Unit oversees tours for groups, special exhibits, docent programs, discovery stations, interpretive signs, the Washington Youth Garden, and media presentations. The Research Unit, with labs in Beltsville, MD, Glenn Dale, MD, McMinnville, TN, and Washington, DC, conducts wide-ranging basic and applied research on trees, shrubs, and floral plants in areas as diverse as genetics, pathology, taxonomy, entomology, and physiology. Overall objectives are to develop new technologies for the floral and nursery industries, breed new plants with superior characteristics, and develop new methods of disease detection and control.

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Some of the more recent accomplishments of the research unit include: development of new floral plants including *Ornithogalum*, *Estoma*, *Clematis*, and *Curcuma*; development of improved landscape plants, including red maples, disease-tolerant American elms, and miniature hybrid crapemyrtles; discovery and application of natural plant compounds made from neem oil for insect and disease control; and development of genetically engineered virus-resistant plants.

Cultivars from the National Arboretum. Since it was established 72 years ago, the National Arboretum has released over 650 new plant cultivars, including the Glenn Dale hybrid azaleas, cold-hardy camellias, disease-resistant crapemyrtles, a wide variety of well adapted viburnums, pest-tolerant red maples, Dutch elm disease-tolerant American elms, New Guinea impatiens, and dwarf Easter lilies. Some of these cultivars are the result of years of cross breeding and selection, while others are selections from plants or seeds received from other locations in the U.S. and abroad. Although many of the cultivars released over two decades ago continue to be propagated and sold by the hundreds of thousands today, the purpose of this section is to introduce you to some of the newer cultivars developed at the U.S. National Arboretum. Unless noted, all of these cultivars can be propagated readily from softwood or semihardwood cuttings following standard practices for the genus and species.

***Acer rubrum* 'Brandywine'**. (USDA Zones 4 to 8). Selected for its stunning, long-lasting fall color which turns from red to a brilliant red-purple, 'Brandywine' also has a significant level of tolerance to the potato leafhopper. With a height of 7.6 m (25 ft) and a 3.7 m (12 ft) crown spread after 12 years of growth, 'Brandywine' is an excellent choice for lawn, street, highway, or park plantings, and as a shade tree for residential sites. It is a male selection, so produces no fruit and therefore no nuisance seedlings. Released in 1994, 'Brandywine' is expected to be available in retail nurseries after 2001.

***Acer rubrum* 'New World'.** (USDA Zones 4 to 8). Selected from a group of seedlings grown from seed collected in Maine, 'New World' has a unique and desirable crown structure, with lower branches upright, and higher branches flaring outward, creating a shape similar to a small American elm. The foliage is highly tolerant to the potato leafhopper, and turns an attractive orange-red in the fall. Like 'Brandywine', 'New World' is a male selection and is ideal for city street or landscape planting. It was released in 1997 and liners will be distributed to propagating wholesale nurseries this fall for expected retail availability after 2003.

***Acer rubrum* 'Red Rocket'.** (USDA Zones 3 to 8). A male selection from a group of seedlings grown from seed collected in Minnesota, 'Red Rocket' is an extremely cold-hardy selection with superior tolerance to the potato leafhopper. Growth rate is slower in warmer zones, but results in a strongly columnar crown filled with a dense canopy of large leaves that show spectacular red autumn color. Such a habit makes it effective as a windbreak or as a living screen, as well as a specimen tree. 'Red Rocket' was released in 1997, and is currently being propagated by wholesale nurseries for expected availability after 2002.

***Hemerocallis* 'Chesapeake Sunset'**. (To USDA Zone 5). Noteworthy for its striking scarlet red flower color, this daylily cultivar combines a short, 20 cm (8 inch) stem with masses of 20 or more buds per plant. Single flowers, approximately 6 cm (2.5 inches) in diameter, open in masses to create a stunning display throughout early to mid summer. 'Chesapeake Sunset' daylily was registered with the American Hemerocallis Society in 1996, and is being produced by vegetative propagation of fans or by tissue culture under a licensing agreement with commercial nurseries. Finished plants will be available through retail nurseries in spring 2001.

***Lagerstroemia fauriei* 'Kiowa'.** (To USDA Zone 7). Received in the 1960s in a shipment of cuttings from Japan, 'Kiowa' was selected for its brilliant exfoliating cinnamon-brown bark, large white-flowered inflorecences, high tolerance to powdery mildew, and overall vigor. Deciduous, dark green elliptical leaves turn yellow in the fall. When planted in full sun in a heavy loam soil, this multi-stemmed tree will reached a height of 7.6 m (25 ft) or more, making it well suited as a specimen tree or for planting in wide expanses of parks, streets, or highways. Although 'Kiowa' was released in 1994, it has a reputation of being difficult to propagate, and is therefore available from relatively few wholesale and retail nurseries.

***Lagerstroemia* 'Chickasaw'.** (USDA Zone 7b). The first in a series of miniature hybrid crapemyrtles released from the U.S. National Arboretum, 'Chickasaw' reaches a height of only 0.5 m (20 inches) and a width of 0.7 m (26 inches) after 7 years in container culture. The habit is a densely branched, compact mound with fine-textured, glossy dark green deciduous foliage that is highly tolerant to powdery mildew. Pink-lavender flowers emerge in mid to late summer and persist until frost. 'Chickasaw' is adaptable to the same cultural conditions as other crapemyrtle cultivars, and thrives in full sun in a heavy loam soil. Because of its unique habit, it is well-suited as a small foundation or border plant, mass plantings in beds in parks or public areas, as a specimen plant in rock gardens or terraces, or as a patio container plant. Released in 1997, 'Chickasaw' is currently available through wholesale and a limited number of retail nurseries.

***Lagerstroemia* 'Pocomoke'.** (USDA Zone 7b). The second miniature hybrid crapemyrtle from the U.S. National Arboretum, 'Pocomoke' is similar in habit to 'Chickasaw', but slightly faster growing and larger at maturity. Flowers are deep rose pink. The small glossy foliage emerges maroon, matures to a deep dark green, and ends the season with a bronze-red fall color. As with 'Chickasaw', the foliage, ornamental flower buds, and flowers are highly tolerant of powdery mildew. Released in 1998, 'Pocomoke' will be available through wholesale and retail nurseries in 2000-2001.

***Ornithogalum* 'Chesapeake Blaze', 'Chesapeake Sunburst', and 'Chesapeake Sunset'.** (USDA Zone 9; indoor pot plant). Unlike the popular cut flower star-of-Bethlehem, these three new hybrid cultivars were developed for container culture. Dense clusters of bright orange ('Chesapeake Blaze'), bright yellow ('Chesapeake Sunburst'), or deep orange ('Chesapeake Sunset') flowers are displayed on short 25 to 30 cm (10 to 12 inch) thick flower stems and last for months. Bulbs produce 2 to 3 flower stems in succession, with individual flower stems blooming for 3 to 4 weeks. These *Ornithogalums* were released in 1998, and are being produced by vegetative propagation of bulbs or by tissue culture under a licensing agreement with commercial nurseries. Finished plants will be available through retail nurseries in spring 2000.

***Prunus* 'Dream Catcher'.** (USDA Zones 6-8). Released in 1999, 'Dream Catcher' is an initial release from the flowering cherry genetic improvement program at the U.S. National Arboretum. It is well suited to nursery production and offers year round ornamental features, high insect and disease tolerance, combined with ease of propagation. Large, medium pink single flowers emerge in late March, approximately 1 week after the parent, *Prunus* 'Okame', blooms. With a height and spread of 7.6 m (25 ft) by 4.6 m (15 ft) and an upright vase-shaped habit, 'Dream Catcher' may be used as a specimen plant, in group plantings, or as a street tree. Limited quantities of finished trees are currently available from wholesale distributors.

***Thuja* 'Green Giant' (*T. standishii* × *T. plicata*).** (USDA Zones 5 to 7). This large evergreen arborvitae has been acclaimed by nursery professionals for its tolerance to significant disease and pest problems, as well as its adaptability to a wide range of soil and hardiness zones. Received in 1967 from Denmark at the U.S. National Arboretum, 'Green Giant' was selected for its vigorous, pyramidal evergreen growth which holds its green color in winter, dense rich green scale-like foliage in flattened sprays, and overall adaptability. It is suitable as an evergreen screen or specimen plant, and is an excellent substitute for Leyland cypress. Plants are readily available from many wholesale and some retail nurseries.

***Ulmus americana* 'Valley Forge' and 'New Harmony'.** (USDA Zones 5 to 7). Selected after 20 years of research, both 'Valley Forge' and 'New Harmony' combine good levels of tolerance to Dutch elm disease with the classic American elm shape and the adaptability to poor soil conditions typical of the species. Both have a height and crown spread of approximately 21 m (70 ft) at maturity, and grow rapidly once established. 'Valley Forge' has an upright, arching, broadly vase-shaped habit with a full, dense leaf canopy. 'New Harmony' has a broadly V-shaped crown with limbs terminating in numerous slender, often drooping branches. Because of their tolerance to deicing salts, drought, poor soil conditions, air pollution, and a range of soil pH, these two cultivars are perfectly suited to urban and suburban settings. Released in 1995, both cultivars should be available to retail nurseries by 2003.

***Viburnum* ×*burkwoodii* 'Conoy'.** (USDA Zones 5b to 8). Recognized as one of the late Don Egolf's best viburnums, 'Conoy' is a compact plant with fine-textured dark green foliage, fragrant white flowers, long-lasting red fruits, and evergreen leaves to Zone 7. At maturity it reaches 1.2 to 1.5 m (4 to 5 ft) tall and 2.1 to 2.4 m (7 to 8 ft) wide, but is amenable to pruning. An excellent choice for a specimen plant, as a low to medium natural or sheared hedge, or as a foundation plant, it is easily cultivated under diverse climatic and soil conditions, including drier soils, and prefers full sun to partial shade. Released in 1988, 'Conoy' is readily available from mail-order firms, retail, and wholesale nurseries.

***Viburnum rhytidophyllum* 'Cree'.** (USDA Zone 5 to 8). A seedling selection from open-pollinated seed collected in China, 'Cree' is a leatherleaf viburnum that was selected for its superior dark evergreen foliage, excellent cold hardiness, and good flowering and fruiting. A spreading, densely branching habit makes this plant suitable as a specimen plant, as a background in the annual or perennial garden, or as a low screen. 'Cree' is adaptable to the same cultural conditions as other *V. rhytidophyllum* plants, and suffers from no serious disease or pest problems. Released in 1994, 'Cree' is available from mail-order firms, retail, and wholesale nurseries.

For more information on the U.S. National Arboretum, its research and education programs, and its cultivar releases, please visit the web site (www.ars-grin.gov/na).

Propagation of Camellia Species and Cultivars in Australia

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INTRODUCTION

My brother and I own and operate a wholesale Nursery in the Lower Blue Mountains on the east coast of Australia. This nursery is approximately 80 km (50 mi) west of Sydney. We are very proud to be one of only six nurseries to earn Quality Assurance: AS/NZS ISO 9002. This was achieved in February 1997.

The climate is ideal for *Camellia* species. We have an altitude of 500 m (1640 ft) and there is little frost. Minimum temperature in early mornings in winter rarely drops below –1°C (30°F). We have only seen snow in this area twice in our lifetime. In the 1950s when we had 5 cm (2 inches) 1 year, and 1.3 cm (0.5 inches) 2 years later.

PROPAGATION

Propagation commences mid-December (early summer) and continues until we have stuck approximately 200,000 cuttings. We have a small crew doing this each year working 5 days a week. All propagation must be completed by the end of January. All cuttings are grown in Hiko tube trays of 40 cells for *C. japonica* cultivars and 67 cells for *C. sasanqua* cultivars because of the small leaves and shortage of bench space. If we had more space we would use the 40-cell trays for all cuttings.

Pretreatment of tube trays is required if they are to be used more than once. This is best done before the commencement of propagation by dipping in a strong disinfectant or by putting through a pot washing machine designed to wash trays.

All benches in the glasshouse and preparation room and all areas where cuttings are likely to contact disease are also treated with strong disinfectant prior to cuttings being placed in the glasshouse. The propagation growing mix consists of Canadian peat and course perlite (from an Australian source) (1:2, v/v), 3 kg m^{-3} Osmocote, 400 g m^{-3} superphosphate, and 240 g m^{-3} Micormax. The substrate components are mixed in a tumble mixer and water is added during mixing until the substrate is damp but not wet. The trays are filled direct from the mixer, and watered to fill air spaces in the mix. They are then transported to the propagation room for planting.

Cutting Preparation. All cuttings are cut from large trees (mother plants) planted in the field or large tubs (large containers) kept within the shade area, these plants are all kept for this purpose. Cuttings are about 10 to 15 cm (4 to 6 inches) in length, and are kept cool in the shade and transported to the preparation area as soon as possible. They are sprayed with water and stored in a cool area. All cuttings are semihardwood with a light brown area extending 20 mm from the base. The cuttings are prepared by removing only enough leaves to allow them to stand in the propagation mix alone; the base of the cutting are slightly wounded on one side about 20 mm long. The cuttings are then dipped in Rite–Gro rooting powder No. 3 (12,000 ppm IBA), stuck in the propagation mix, and moved to the glasshouse as quickly as possible.

Propagation House Conditions. The glasshouse is set out with benches heated by electrical cables in a bed of sand. Temperature is maintained at 25°C (77°F) — utilizing thermostats on each bench. Temperature can be increased at greater cost. One year we had a thermostat break down and this was not observed until the temperature reached 32°C (90°F) with no ill effects, and a faster growth rate of roots. The electrical cables are turned on immediately after cuttings are placed in the glasshouse, regardless of the ambient outside temperature.

Above the benches is a mist irrigation line, which is activated by a time clock system. The mist spray is adjusted to suit the weather each day. On very hot days the mist will activate every 6 min for 10 sec, but if the temperature and light drops, the mist is adjusted to 8 to 10 min, or longer during long periods of inclement weather. The mist is maintained during daylight hours until the plants are rooted and removed for potting.

Callus is usually observed within 14 days and rooting occurs within 30 days. We commence potting into 10- or 14-cm pots in about 10 weeks. The potting time can vary depending on light fluctuation caused by variation in weather. Because of the fertilizer in the cutting mix, plants can be left in the tubes for up to 6 months without ill effects.

Camellia Cultivars and Potting-up. We grow about 450 cultivars of camellias, consisting of 320 cultivars of *C. japonica*, 60 cultivars of *C. sasanqua*, and the rest are hybrids including about 10 other species. We can have some variation in rooting time and rate of rooting. We have about a 90% rooting success, but cuttings can deteriorate if left in the tubes longer than necessary.

The irrigation supply is from a dam on the nursery, and all run–off is drained back for re-cycling. All water is treated with chlorine and a liquid disinfectant is added to the water for the mist system to control algae growth on the misting heads.

All plants are potted into 10- or 14-cm pots. From the following November (spring) we sell plants in 10-cm pots to other nurseries throughout Australia for further growing on in their area, as transport of larger sizes to other regions in Australia is costly. The following year we sell plants in 10-cm pots and other sizes to major chain stores. We grow all sizes up to 25-cm pots. Any plants grown above this pot size are grown by other nurseries.

Rooted Cuttings for Southern Pines

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INTRODUCTION

Producing planting stock for reforestation using rooted stem cuttings is becoming an increasingly widespread practice around the world (Ritchie 1994, Zobel 1992). Vegetative propagation can deliver planting stock of higher genetic quality compared to the system of bare-root seedlings derived from wind-pollinated seed that is currently being used in the southeastern United States.

Producing rooted-cutting planting stock for forestry presents some unique challenges as compared with vegetative propagation for horticultural applications. The foremost difference is acceptable cost. Reforestation stock is a high-volume, low-cost product. Over 1.2 billion seedlings of loblolly pine (*Pinus taeda* L.) and slash pine (*P. elliottii* Engelm.) are produced in the U.S. each year at a cost of only a few cents per seedling. Most horticultural crops are worth much more per plant and fewer plants are needed to meet market demand.

Another difference is the genetic make-up of the plants to be propagated. Most vegetatively propagated horticultural crops are produced as cultivars. A superior genotype is identified and then multiplied. This is a more difficult process for forest trees. One reason is that fairly extensive field-testing is required to identify the best clones. Another is that for most coniferous species, including the southern pines, donor plant maturation begins early and reduces propagation (rooting) efficiency of the identified clones.

This "Catch-22" has led to two scenarios for pine rooted-cutting propagation and deployment. In both scenarios, donor plants arise from controlled-pollinated crosses between genetically proven superior parents (a full-sib family). The first scenario involves mass propagation of the entire family. This has the advantage of eliminating the field-testing requirement, because the genetic values of the parents are already known from previous tests. It also minimizes the donor plant maturation problem, because donor plants can be used for a short time and then new seeds can be germinated to replace them. This full-sib multiplication scenario, however, has the disadvantage that the genetic quality of the reforestation stock is only moderately improved relative to open-pollinated seedlings and falls far short of the quality that can be obtained with the second scenario, clonal forestry.

Clonal forestry is analogous to the cultivar system with clones in horticulture. The donor plant maturation problem can be approached in several ways. First, seedlings are rigorously pruned to produce "hedges" or "stool plants" that produce large numbers of cuttings and remain juvenile, at least for a few years. Hedging alone, however, may not be sufficient to retain juvenility for an adequate period of time. Two techniques are currently being evaluated that, hopefully, will maintain the juvenile, easy-to-root, phase of the hedge plants: (1) continuous hedging and serial rooting where the most vigorous rooted cuttings in a clonal line replace the older donor hedges and (2) serial micropropagation accompanied by cold storage of tissue cultures (Aitken-Christie and Singh, 1987).

DONOR PLANT DEVELOPMENT

The development of clonal lines can begin with the identification of a small number of unrelated families that have a proven genetic superiority for particular traits (e.g., fast growth rate, pest resistance, wood quality) and the establishment of 100 to 200 seedlings from each family. Initially, the seedlings are hedged to provide the cutting material for an initial screening trial. Early field data can be used to select the top lines in each elite family. These top lines can then be re-evaluated in a series of advanced clonal trials that are replicated in several locations. This second round of tests can be used to select the top few lines in each family for operational deployment. This strategy has the potential to produce genetically superior individuals that will be 30% to 50% better than the improved material that is currently being produced in wind-pollinated seed orchards.

PRODUCTION SYSTEMS

A typical cutting is 8 to 10 cm (3 to 4 inches) long (from the terminal bud to base) and has a basal diameter of 3 mm. It may be from a dormant or actively growing shoot. In the latter case, collection of the cutting may be delayed to allow some lignification of the shoot that makes the cuttings more able to withstand rooting environments that are less then fully protected. Once the cutting is set, callus formation is evident in 2 to 3 weeks and the emergence of adventitious roots from the basal region of the stem occurs within 5 to 6 weeks.

Pine cuttings can be rooted in a field nursery, shadehouse, or greenhouse. Rooting directly in a field nursery bed has the advantages of reducing propagation costs (less labor-intensive handling of the rooted cuttings) and requiring no specialized structures for rooting. However, extreme variation in outdoor environmental conditions can result in a variable end-product and, in some cases, even loss of an entire crop. While a shadehouse does provide a more consistent rooting environment, in many climates, one is prevented from utilizing the dormant winter cuttings, because of low ambient temperatures. The rooting environment inside a greenhouse is the most controlled and has the additional advantage that two or three crops could be produced each year. But, the cost of the more specialized structure does increase production costs. In addition, containers and rooting substrate must be purchased for both the shadehouse and greenhouse rooting systems and the added cost of handling containerized planting stock during tree planting needs to be considered.

One possible solution is a transplant production system where the cuttings are rooted in small plugs inside a greenhouse and then transplanted to a conventional forest tree seedling nursery. The greenhouse provides optimal and uniform rooting conditions, and allows one to expand the time of year cuttings are set. Small plugs allow the grower to maximize expensive greenhouse space. Certain types of small plugs might be amenable to transplanting to a bare-root nursery to allow the rooted cutting to finish growing like a bare-root seedling. The rooted cutting can then be handled like its seedling counterpart and the costly logistics of handling millions of containerized plants in large-scale reforestation operations could be avoided.

Cost-efficient rooted cutting production systems will be critical to the success of clonal forestry, because if it does not make economic sense, clonal propagules will never be planted on a large scale. Current costs of producing rooted cutting planting stock at a research scale are very high relative to the current system of bare-root seedlings. Future improvements in efficiency and economies of scale will be needed to make this technology more price competitive.

One such improvement could come in the form of automating the more labor-intensive steps involved in producing rooted cuttings. Forest products companies cannot afford to pay for the high-cost of labor necessary to collect, set, or transplant cuttings, because of the relatively low-value of pine propagules compared to high-value, horticultural, container crops. Mechanization of any one of these labor-intensive propagation steps will help reduce unit costs. This will require forest tree propagation specialists to be creative in modifying existing equipment (e.g.,transplanters) and designing new equipment (e.g., cutting harvesters and stickers) to handle the special needs of pine cuttings.

Nevertheless, it is reasonable to expect that rooted cuttings will never be as inexpensive as bare-root seedlings. The higher cost of rooted cuttings can be counter balanced by deploying them on high quality lands where high-input silviculture can be practiced (e.g., site preparation, weed control, fertilization, and pest control) in competitive markets (Stelzer and Goldfarb, 1997). In these locations, the greater return on investment should make the increased initial cost economically feasible

ROOTED CUTTINGS AND FUTURE TECHNOLOGIES

There are several emerging technologies that could be easily coordinated with an operational rooted cutting program. Controlled mass pollination is a process whereby pollen collected en masse from one parent is used to pollinate isolated female flowers of another parent. This would provide seed that could be raised as seedlings in existing bare-root nurseries, would be the equivalent genetic value as the full-sib multiplication (but not clonal forestry) option with rooted cuttings, and, probably, will be less expensive than rooted cuttings. However, in some situations, the large number of seed necessary for meaningful levels of reforestation could be difficult to produce. In these cases, the resulting elite family could be vegetatively propagated using rooted cuttings (full-sib multiplication).

Somatic embryogenesis (SE) and the cryopreservation of SE germplasm could mitigate the problems of hedge maturation and rapid clonal scale-up in the clonal multiplication strategy. Somatic embryos could also serve as a suitable vehicle for inserting genetically engineered genes into elite pedigrees. While SE is a clonal multiplication system in its own right, rooted cuttings are currently cheaper, primarily due to the high costs involved in establishing and operating a tissue culture lab, and because of some current biological barriers in the SE process for loblolly and slash pines. An ideal system could entail: (1) initiation of clonal lines using SE, (2) cryopreservation of SE lines for juvenility maintenance, (3) establishment of clonal trials using a limited number of SE plants, (4) rapid multiplication of selected clonal lines using SE to produce sufficient plants for hedge populations, and (5) production of reforestation stock using rooted cuttings.

CONCLUSIONS

With 1.2 billion pine seedlings produced annually in the southern U.S., rooted cuttings will probably never completely replace open-pollinated bare-root seedlings. Rooted cuttings are, however, increasingly becoming a viable option for increasing the genetic quality of forest planting stock in high wood cost areas and on the most productive sites. Despite the progress made in rooting pine cuttings, more research is needed on efficient production systems, maintaining hedge juvenility, selecting the best clones, evaluating the growth and yield of those clones, and the ecological consequences of clonal forestry.

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Timing and Auxin Concentration Affects *Cotinus coggygria* 'Royal Purple' Rooting

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Softwood cuttings of *Cotinus coggygria* 'Royal Purple' had 92% rooting when taken on 25 May and treated with a 10,000 ppm IBA + 5,000 ppm NAA quick dip. With the exception of the 2,500 ppm IBA treatment, a higher percentage of rooted cuttings resulted when cuttings were taken on 25 May. Cuttings harvested on 25 May were from actively growing shoots with 13 to 19 cm (5 to 7.5 inches) of growth. Cuttings treated with 20,000 ppm IBA and cut on 25 May produced the highest number of roots per cutting (59).

INTRODUCTION

Cotinus coggygria, commonly known as smoketree or smokebush, is an upright multi-stemmed shrub or small tree reaching 3 to 7 m (10 to 20 ft) in height. Best known for their flower panicles that create a smoke effect, several green-leafed and purple-leafed cultivars are currently sold. Smoketree is easily propagated from seed, however this produces variable seedlings with a large percentage having green leaves. Hancock (1957) reported successfully mound layering *C. coggygria* in Canada. However, propagation from cuttings is the preferred propagation procedure because of seedling variability, preference for selling named cultivars, and impracticality of mound layering in commercial nurseries.

Rooting of *C. coggygria* 'Royal Purple' is variable based on time of cutting, wood selection, and auxin concentration. John Sjulin (1958) reported propagating softwood cuttings of *C. coggygria* 'Royal Purple' in outdoor mist beds in Iowa. Using softwood cuttings, treating them with Hormodin #2, he reported a 60% stand going into winter. Kelly and Foret (1977) reported softwood cuttings taken in Iowa rooted as high as 90% when taken 11 June and decreased to 33% by 24 July. Macdonald (1986) reported *C. coggygria* 'Royal Purple' is difficult to root due to the waxy nature of the cuticle causing excess water to accumulate on leaves, encouraging damping off. Additionally, stems "bleed" when severed.

Auxin applications have been shown to increase rooting in hard-to-root species. The most widely used root promoting chemicals today are IBA and NAA. Although IBA is the most commonly used auxin to induce rooting, NAA is superior for some species (Dirr, 1986; Morini and Isoleri, 1986). The purpose of this study was to determine the most advantageous cutting time for Royal Purple smoketree and optimum auxin treatment for cuttings at that time.

MATERIALS AND METHODS

On 15 May and 25 May, 1996 softwood terminal cuttings 10 to 13 cm (4 to 5 inches) long were taken from plants in 19-liter (5 gal) containers located in full sun at Greenleaf Nursery in Park Hill, OK. On 15 May shoot length from bud to the end of the terminal shoot was 10 to 13 cm (4 to 5 inches). The cuttings were very soft and pliable. Shoots were in active growth with immature leaves at the terminal end of the shoot. Cuttings had no visible lenticels and had a "rubbery" appearance. On 25 May shoots were 13 to 19 cm (5 to 7.5 inches) and actively growing with leaves still expanding, and lenticels beginning to show. Cuttings were taken to a building, recut to 10 cm (4 inch) length and lower leaves were stripped. The basal 1 cm was dipped 5 sec in one of the following auxin treatments:

- tap water,
- 70% isopropyl alcohol,
- 2500 ppm IBA,
- 5000 ppm IBA,
- 10,000 ppm IBA,
- 20,000 ppm IBA,
- 1250 ppm NAA,
- 2500 ppm NAA,
- 5000 ppm NAA,
- 10,000 ppm NAA,
- 2500 ppm IBA + 1250 ppm NAA,
- 5000 ppm IBA + 2500 ppm NAA,
- 10,000 ppm IBA + 5000 ppm NAA,
- 20,000 ppm IBA + 10,000 ppm NAA.

Cuttings were placed in 12 cm (4.5 inch) wide × 36 cm (14 inch) long × 6 cm (2.4 inch) deep plastic flats filled with peatmoss and perlite (1 : 1, v/v) and placed in a quonset greenhouse on black groundcloth under 73% shade. DGT Mist Nozzels 2 LPM were placed 52 cm (20.5 inches) above the flats and spaced at 0.9 m (35.6 inch) intervals. Mist cycles were adjusted daily for changing environmental conditions, but averaged 6 sec duration every 60 min between 8:00 and 11:00, and then 8 sec every 30 min between 11:00 and 18:00 hours.

A randomized complete block design was used with 10 replications of 5 subsamples for each auxin treatment at each cutting date. Cuttings were evaluated 9 weeks after collection for primary root number and mean primary root length of the three longest roots.

RESULTS

Cuttings taken on 15 May had consistently lower rooting percentages that those cut on 25 May (Table 1). There was little rooting percentage difference between 20,000 ppm IBA (32%), 2500 ppm IBA (31%), and 5000 ppm IBA + 2500 ppm NAA (29%) treatments when cuttings were harvested 15 May.

Cuttings taken on 25 May and treated with 10,000 ppm IBA + 5000 ppm NAA produced the largest number of rooted cuttings (92%). Average number of roots per rooted cutting was higher on 25 May cuttings regardless of treatment. Treatments resulting in the highest number of roots per cutting included 20,000 ppm IBA (59.3), 10,000 ppm IBA + 5000 ppm NAA (51.5), and 10,000 ppm IBA (47.8). For all treatments, the longest mean primary root length of the three longest roots was measured on cuttings harvested on 25 May. Longest mean root length (15.9 cm) was produced by the 5000 ppm IBA + 2500 ppm NAA treatment. NAA treatments produced less rooted cuttings, less roots per cutting, and less root length than IBA or IBA + NAA treatments, regardless of cutting time.

Table 1. Effect of two cutting dates and IBA and/or NAA on *Cotinus coggygria* 'Royal Purple' rooting percentage, root number, and average length of the three longest roots.

IBA (ppm)	NAA (ppm)	Rooted (%)		No. of roots per cutting		Avg. length three longest roots (cm)	
		15 May	25 May	15 May	25 May	15 May	25 May
2500	0	62	40	11.5	19.1	4.9	11.6
5000	0	34	72	11.6	30.8	6.5	11.8
10,000	0	56	86	15.0	47.8	8.3	13.8
20,000	0	64	64	27.0	59.3	8.5	13.7
0	1250	2	54	1.0	13.1	3.2	8.9
0	2500	4	62	3.5	22.0	2.6	11.9
0	5000	14	26	11.4	19.3	4.3	12.4
0	10,000	10	32	2.0	24.4	3.4	11.8
2500	1250	44	82	13.4	32.9	5.5	12.6
5000	2500	58	86	8.0	34.3	8.4	15.9
10,000	5000	54	92	16.5	51.5	8.4	13.9
20,000	10,000	44	56	23.3	25.9	9.1	13.2

DISCUSSION

Many varieties of trees and shrubs have a short (4 to 6 weeks) window of rootability. Stoutmeyer (1942) found difficult- to-root *Chionanthus retusus* Lindl. and Paxt.will root in high percentages if obtained during a 1-week period in May. A very narrow window of rootability was also shown in native *Rhododendron* (Nienhuys, 1980), *Syringa* (Wedge, 1977; Mezitt, 1978), and *Pistacia chinensis* (Dunn et at., 1996). Kelly and Foret (1977) found cuttings taken from *C. coggygria* 'Royal Purple' on 11 June produced the highest rooting percentage with rooting percentage dropping as wood matured. After evaluating three types of cutting wood (immature/green), intermediate, and mature at each cutting date they found immature wood resulted in the highest rooting percentages on all four cutting dates with the exception of 11 June when intermediate cuttings rooted better. The results of this experiment are consistent with Kelly and Foret's findings with slightly more mature cuttings taken on 25 May rooting in greater percentages than immature cuttings taken on 15 May. Control treatments showed a substantial increase in rooting from 15 May to 25 May indicating the importance of cutting time regardless of auxin treatment.

Beakbane (1961) proposed a correlation between the degree of sclerification of the primary phloem and rooting capacity suggesting that rooting of difficult subjects might be facilitated by using very young shoots taken before the cells of the primary phloem lose their living protoplasts. She suggested it may be possible to forecast rooting capacity from the structure of the stems. Our study shows that rooting capacity for *C. cotinus* 'Royal Purple' is greater when cuttings are taken from soft actively growing shoots with 13 to 19 cm (5 to 7.5 inches) of new growth and immature leaves at the terminals. While softwood cuttings of *C. coggygria* 'Royal Purple' are necessary for rooting success, immature cuttings collected too early in spring had reduced rooting success. Softwood cuttings harvested on 25 May and treated with 10,000 ppm IBA, 2500 ppm IBA + 1250 ppm NAA, 5000 ppm IBA + 2500 ppm NAA, and 10,000 ppm IBA + 5000 ppm NAA produced the largest number of rooted cuttings. Cuttings treated with 20,000 ppm IBA + 10,000 ppm NAA had a decrease in rooting, indicating the negative effects of high auxin concentration. Cuttings harvested 25 May and treated with 2500 ppm IBA + 1250 ppm NAA produced the longest roots, but that may have been influenced by the lower number of roots per cutting when compared to the 10,000 ppm IBA + 5000 ppm NAA treatment. In conclusion, cuttings harvested on 25 May and treated with 10,000 ppm IBA + 5000 NAA produced the best overall results. It was visually noted that all IBA + NAA combinations produced more secondary roots than IBA or NAA alone. While 10,000 ppm IBA produced similar results to 10,000 ppm IBA + 5000 ppm NAA, the minimal difference in cost of auxin treatments makes addition of NAA more cost effective.

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Cutting-Grown *Quercus:* The Future

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INTRODUCTION

Quercus species are commonly produced from seed. Seedlings are variable in growth rate, foliage qualities, and adaptability to soil, light, and space restrictions. Seedlings are also variable in their tolerance to insect and disease problems. Selections of *Quercus* species are usually vegetatively propagated by grafting or budding. This method of propagation has had mixed results due to incompatibility with seedling rootstocks or the limited supply of seedling rootstocks for grafting or budding. Growing cultivars of *Quercus* species from stem cuttings would overcome the scion to rootstock incompatibility problem.

Scion to Rootstock Incompatibility. Incompatibility of the scion to rootstock has been the greatest limiting factor in the successful propagation of cultivars of *Quercus* species for the nursery industry. Hybridization between oak groups (white oak, red oak, and black oak) has been suggested as a factor for some of the incompatibility of scion to rootstock. Dirr (1990) reported that *Q. palustris* 'Sovereign' was incompatible when grafted to seedlings produced from acorns of the original 'Sovereign' tree. If 'Sovereign' pin oak could have been produced from stem cuttings, it would be an industry standard today, due to its excellent ornamental qualities.

Successful Stem-Cutting-Grown *Quercus*. Some cultivars of *Quercus* species have been successfully propagated by stem cuttings. The late J.C. Raulston distributed a stem-cutting-grown cultivar of Q. *phillyreoides* 'Emerald Sentinel'. Tree Introductions, Inc. has a patented *Q. virginiana* 'QVTIA' PPAF Highrise® that is cutting grown. Ray Bracken Nursery, Inc. is introducing a hybrid *Q. palustris* × *Q. phellos* that can be grown from stem cuttings.

Cultivar Selection. Cultivar selection is the first step in developing the future of cutting-grown *Quercus*. Selection of cultivars of *Quercus* species for aesthetic qualities, insect and disease resistance, cold and heat tolerance, and adaptability to environmental stresses are characteristics that are used to evaluate all ornamental plant selections. However, when selecting cultivars of *Quercus* species for own-root production, the potential for good rooting is very critical. A necessary consideration is the selection of vigorously growing cultivars, which produce quality liners that will adapt and survive transplanting. Abundant development of mycorrhizae in and on the roots and root zone is also important to successful plant growth.

Mycorrhizal Importance to Plant Growth. Mycorrhizal fungi are very important for a plant's survival and adaptability to poor soil conditions. Mycorrhizal development on the roots of cutting-grown cultivars of *Quercus* species has varied between species and cultivars of species.The growth rate between cultivars lacking mycorrhizae and those with mycorrhizae development on their roots has shown some differences. The ability to survive environmental stresses may be enhanced by mycorrhizae. Those cultivars that quickly develop mycorrhizae in their root zone may better adapt to environmental stresses and have greater survival at all stages of plant production.

Mycorrhizal fungi have been reported to enhance rooting and growth in ericaceous plants and should be further studied in *Quercus* cultivars.

***Quercus* Cultivars That can be Rooted.** *Quercus* species cultivars rooted to date are: *Q. acuta, Q. georgiana, Q. germanea, Q. glauca* (2 cultivars), *Q. laurifolia* (2 cultivars), *Q. marilandica, Q. nuttallii, Q. palustris, Q. palustris* 'Sovereign', *Q. phellos* (4 cultivars), *Q. phillyreoides* 'Emerald Sentinel', *Q. virginiana* (6 cultivars). Hybrid oaks such as *Q. palustris* × *Q. imbricaria, Q. palustris* × *Q. phellos, Q. laurifolia* × *Q. virginiana,* and *Q. marilandica* × *Q. nigra* have also been successfully rooted. These *Quercus* species and cultivars have varied in their ease of rooting. Younger trees rooted in higher percentages than very old trees. Evergreen types of *Quercus* have rooted better than deciduous types. Those cultivars having active development of mycorrhizae have rooted and grown faster than those with poor mycorrhizae development. There are many exceptions to the above statements and each *Quercus* cultivar must be evaluated for rootability, growth after rooting, production of lining-out stock, and production of finished landscape-sized plants. There seems to be no direct link between tree characteristics and rootability, so choosing several cultivars of a *Quercus* species with desirable characteristics and then testing to evaluate rootability and other desirable traits will have to be done. It will require years of evaluation to develop *Quercus* cultivars which will be able to be grown from stem cuttings for lining-out stock and then to finished landscape-grade trees.

Tips For Successful Rooting. A *Quercus* hybrid, *Q. palustris* × *Q. phellos*, was used for the rooting study, due to its ease of rooting. Stem cuttings were taken in July using 10- to 15-cm (4- to 6-inch) segments of new growth where the terminal buds had matured and leaves were matured and well formed. Cuttings do not have to be tip cuttings. The condition of the wood in relation to starch and auxin build-up has the most to do with how well the cutting roots, survives, breaks bud, and grows. Cuttings should have three or more leaves. Large leaves may need to be reduced to allow sufficient air and light penetration around each cutting. Rooting media can be any material that drains well. Peat, perlite, and pine bark (1:1:1, by volume) or any combination of these materials will work. A rooting media of one part perlite and two parts ground pine bark was placed in rooting containers for the study. The containers were 606 deep cell packs. There were 36 cells, 5.7 cm (2.3 inches) wide and 7.6 cm (3 inches) deep. The cuttings should not be stuck any deeper than 50% of the container height.

Environmental Conditions for Rooting *Quercus*. Cuttings in propagation structures should be under 50% to 70% shade. The geographical region, time of year, and frequency of irrigation dictates the need and degree of shade necessary for success. Irrigation should be frequent enough to keep the foliage moist during daylight hours. Irrigation intervals will vary, but 60 sec every 15 min will be adequate. Temperatures of the rooting media will be close to air temperatures during summer propagation periods, however in cold weather, the minimum temperature of the rooting media should be 16°C or 60°F.

Auxins. Auxins are needed to root *Quercus* species and cultivars. Concentrations vary from 3000 to 20,000 ppm depending on the cultivar, age of stock plant, cutting location on the stem, time of year, and stage of growth that the plant is in. Generally a 10,000 ppm potassium salt formulation of IBA has the best rooting response. Auxins stimulate the initiation of roots and result in higher rooting percentages. Rooting time varies from 2 weeks to 3 months and is dependent on several factors. *Quercus* cultivar traits, age of stock plants, stage of cutting growth, stored carbohydrates, plant nutrition, and rooting co-factors of the cutting under environmental conditions determine the success of the cutting's survival.

Rooting of *Quercus palustris* × *Q. phellos* Hybrid Oak. Cuttings taken in July began rooting in 2 weeks and all rooted within 6 weeks. Thirty-six cuttings in varying stages of growth and positions on the stem were cut 10 to 15 cm (4 to 6 inch) long. Cuttings were quick dipped for 5 sec in a water solution of 10,000 ppm of KIBA. Propagation media is ground pine bark and perlite (2 : 1,v/v), respectively. Deep 606 cell packs were filled with rooting media and watered to settle the media in the cell packs. Treated cuttings were stuck one to each cell. Intermittent mist was set at 60-sec intervals every 15 min from 9:00 to 19:00. After 6 weeks, 34 of the cuttings were viable and 31 showed rooting by the tug method. Of the rooted cuttings, half were in stages of new growth.

CONCLUSION

- Rooting of *Quercus* species and cultivars is possible if cultivars are selected for rootability as well as desired ornamental characteristics.
- Experimentation by propagators allows the development of successful rooting techniques of *Quercus* species and cultivars.
- Each *Quercus* cultivar may need different conditions for successful rooting. Also, different conditions may be needed in producing quality liners for lining-out stock in the production of landscape-size trees.
- Several cultivars of *Quercus* are currently being produced from stem cuttings and the future own-rooted *Quercus* should become more common.

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Propagation of Ornamental Grasses

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INTRODUCTION

Propagation of ornamental grasses is dependent on several criteria including, but not limited to, the time of year, the age of the stock plant, and the method by which the grass is propagated. To complicate matters, all of these criteria are often interdependent on each other. Methods by which ornamental grasses may be propagated are by seed, cuttings, and division. In this paper, the factors influencing successful propagation of ornamental grasses are discussed.

TYPES OF GRASSES

Most grasses can be categorized as cool- or warm-season grasses. Cool-season grasses can be propagated in the spring or fall when they are actively growing. Most cool-season grasses actually stop growing and may even "brown out" due to the heat of the summer. Examples of cool-season grasses include *Festuca glauca* 'Elijah Blue' (blue sheep's fescue), *Helictotrichon sempervirens* (blue oat grass), and *Calamagrostis ×acutiflora* 'Karl Foerster' (feather reed grass). The warm-season grasses should be propagated in spring and summer when they are actively growing. Examples of warm-season grasses are *Pennisetum* (fountain grass), *Miscanthus*, and *Arundo donax* (giant reed).

PROPAGATON OF GRASSES BY SEED

Propagation by seed of ornamental and native grasses can be the least expensive way to produce grasses in large quantities. This is especially useful in the landscape when the landscaper wants to direct seed grasses into large masses or meadow plantings. In the nursery setting, it is useful for propagating grasses that are not named cultivars, when the preservation of specific traits of a particular plant are not necessary. Although growing the grasses from seed requires extra attention and may take longer than from a division, it still can be helpful for producing grasses.

Grasses can be sown most of the year if they are given the right growing conditions. Seeds are available commercially and can be collected from available stock plants. Usually, seed from commercial sources does not need to be cleaned. Seed collected from available stock plants is manually taken from stems and outer coverings are removed. The seed is stored at roomtemperature in labeled paper bags to prevent moisture build up and subsequent rotting. Germination rates of the grass seed can vary from days to weeks to even months. Many of the grasses benefit from cold stratification. To cold stratify, cleaned seed is put into a plastic bag with peat at a ratio of seed to peat of 1 : 1 (v/v). This mix is lightly moistened and shaken to thoroughly combine and spread the moisture throughout the bag. The labeled bag is then refrigerated for 2 to 4 weeks depending on the variety. The bags are checked frequently to make sure there is no unwanted mold, etc. Cold stratification can help to decrease the days until germination and increase the yield of seedlings that can be potted.

The grass seed is evenly sowed in trays (usually 288s or 144s) filled with pre-moistened Metro Mix 220 or Southern States Tobacco and Vegetable Seed Starter. It is then covered with media to a depth of no more than one and a half times the width of the seed (note that some seed is not covered since it needs light to germinate). Some fluffy seed may need to be wetted before covering to keep it in place. The trays should be misted regularly and the media should be kept moist to the touch. Each tray is labeled with name, date sown, and seed source. Germination rates vary with the different seed and with the different seed sources. Improved germination rates and decreased germination periods have been achieved using bottom heat that keeps the seed at 70°F. Germination periods can be 1 to 21 days or longer. The best germination rates and decreased germination periods are obtained in the spring and early summer. Adequate rates and germination periods during other parts of the year can be achieved with the combined use of cold stratification and bottom heat.

PROPAGATION OF GRASSES BY CUTTINGS

Several grasses can be propagated by cuttings. Annual grasses such as *Pennisetum setaceum* 'Rubrum', *P.* 'Burgundy Giant', and *Saccharum officinarum* 'Pele's Smoke' can be propagated by cuttings. Perennial grasses such as *A. donax* and several *Panicum* varieties can be propagated by cuttings. Cutting methods vary with the plant selected for propagation. One grass, *A. donax* (giant reed), can be propagated by cuttings. *Arundo donax* cuttings are usually collected in the late summer or early fall. For best results, stems are selected from stock plants with medium growth. The smaller or larger stems do not seem to produce as many rooted cuttings per stem. The stems are then cut into 1- to 2-ft sections and all of the leaves are removed. The top 30 to 46 cm (12 to 18 inches) of stem are discarded since they rarely root well. The 1 to 2-ft stems are laid in water in small pools for 3 to 5 weeks. During that time, some of the nodes produce shoots and then roots. The stems around the rooted nodes are cut into 3-inch pieces and then potted into 3½-inch pots. Because of the variability in weather from year to year, sizes of stems, location of nodes on the stem, etc., it is very difficult to develop criteria to determine percentage of actual takes for a particular node and to determine which nodes would come closest to 100% take.

Most of the other grasses that are propagated by cuttings are stem cuttings taken from vigorously growing stock plants or container plants. These cuttings, taken from the "woody" part of the plant, are usually 8 to 10 cm (3 to 4 inches) long with the node about 1 inch from the bottom of the cutting. All leaves are cut back to about 1 to 2 inches to reduce transpiration. The cuttings are soaked in Dip-'N-Gro for about 1 to 5 min. The cuttings are stuck in a soilless potting mix such as sand or a bark and perlite mix and watered in well. The cuttings stay under intermittent mist for 1 to 3 weeks until the roots come out of the bottom of the plug trays. Overall, this system works well especially during the warm part of the year. Some, but not all, rooting can be done in the cooler months in a hot house kept at 13°C (55°F) if the cuttings are placed on bottom heat set at 21°C (70°F).

The propagation by cuttings of other perennial and annual grasses is accomplished using similar techniques with only slight variations in soil mix and when and how to select the cuttings. Overall, propagation of grasses by cuttings is not always the best way to produce plants on a large scale; however, it is helpful to building stock on certain grasses.

VEGETATIVE PROPAGATION OF GRASSES BY DIVISION

By far, vegetative propagation by division is the most viable, usually the quickest, and easiest method to produce grasses on a large scale. In addition, this is usually the only way that clonal cultivars can be propagated unless cuttings can be taken. As with the propagation by seed and by cuttings, the success of the vegetative propagation is influenced by a combination of factors including stock material, time of year, and size of the division.

As with any plant, the stock plant is the most important part of the propagation process. The best stock plants undeniably produce the fastest growing, fastest rooting, and most showy final product. The age of the stock plant must be considered for a variety of reasons. Usually an older stock plant will result in less new plants produced and reduced quality of new plants. This is because the centers of older grasses in the landscape become weak in the middle resulting in useless stock material. It is important to use the new outer growth for propagation since it is the strongest part of the plant. Older container plants may also be problematic as stock plants for propagation since they may be lacking in the proper nutrients. After living in the soilless mixture for an extended period of time, the stock plant can be weaker than one grown in a field or landscape situation. All stock plants, field grown and container grown, should be inspected for any pests that weaken the plants and cause a reduction in viable divisions.

Because vegetative propagation is usually on a grander scale, it is very important to consider the time of year that the propagation is being done. The cool season grasses should be split in the early spring or early fall. Splitting at this time of year should be more successful for these types of plants since they are actively growing. The warm season grasses should be split in the spring through the late summer. This is the time when the air temperatures during the day and night are highest and will encourage fast root and top growth. Many of the grasses do not split well after they have started flowering. Most perennial grasses, especially natives and *Miscanthus*, need to go dormant before they can be divided successfully.

There are several things that must be considered during the splitting process including care of the stock plant before division, the size of the division, and care of the division until it is planted into a container. It is best to keep the stock plant in the ground until it is needed for division to reduce the shock to the plant and to shorten the recovery time for the new divisions. If the clump needs to be dug early, watering well before digging can be especially helpful on hot days. If the grower can afford to make the divisions larger, the success rate will increase tremendously. Extreme heat or cold can also hurt the divisions and, again, the smaller divisions seem more vulnerable to any type of stress. It is beneficial to keep the divisions moist until they are planted into the container (i.e., covered in wet burlap in a laundry basket can work). Care after the division is planted into the pot is also a crucial part of keeping a new division alive. One of the biggest mistakes is allowing a new division to dry out, even momentarily.

SUMMARY

Sowing seed, making cuttings, and dividing from stock plants are all viable methods to propagate grasses. Sowing grass seed is especially appropriate for propagating large quantities of native or ornamental grasses. Cuttings are a great way to build stock on some grasses and still maintain the desirable traits of a particular variety. Vegetative division is the best method for producing many grasses on a large scale. Critical factors that contribute to the successful propagation of grasses include: time of year, type of grass it is, and the condition of the stock plants.

Micropropagation of *Farfugium japonicum*

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INTRODUCTION

Farfugium japonicum Kitam., a perennial plant in the Asteraceae Family, is grown for food or as an ornamental plants in the forest area of the south-west coast of Japan. The plant is propagated usually from seed or by division. The technique of micropropagation, however, is considered to be more effective for obtaining a large number of elite clones of the plant. We studied the effect of hormones on the propagation of plantlets by in vitro division and on the formation of adventitious buds from petiole explant.

MICROPROPAGATION PROCEDURES

Donor plants derived from the meristems were cultured on Murashige and Skoog (MS) medium supplemented with 0.1 mg liter^{-1} benzyladenine (BA) and 0.1 mg liter^{-1} naphthaleneacetic acid (NAA). When the plants reached about 5 cm (2 inches) in height, all the leaves and roots were cut off from these basal parts. The stumps were divided into three parts which were approximately 3 mm in diameter. The divided stumps were cultured as explants on the MS medium supplemented with thidiazuron (TDZ) or BA.

RESULTS

The formation of adventitious buds from the explants was greatly enhanced by 1 mg liter^{-1} TDZ. The in vitro division was carried out at monthly intervals. The majority of plantlets divided had four leaves. After 2 months of culture, the cultures were transferred to the medium without hormones to obtain normal plantlets by division. BA (1 and 2 mg liter^{-1}) had little effect on the propagation by in vitro division. In the medium with 1 mg liter^{-1} TDZ, the number of plantlets obtained by division, increased exponentially with the time of culture. From this, the equation $Y=A^x$ was derived experimentally, where Y is the number of plantlets, ^{x} is the culture time (month), and A is the rate of propagation. From the data in this experiment, the value of A was estimated to be 5.6. This suggests that the plantlets could be multiplied constantly 5.6 times per month by in vitro division using TDZ. The plantlets obtained rooted easily in the MS medium without hormones.

The combination of TDZ (1 mg liter^{-1}) and NAA (0.1 m liter^{-1}) gave the best result for the formation of adventitious buds from the petiole explants. The successive effect was observed in the medium with 1 mg liter^{-1} BA and 0.1 mg liter^{-1} NAA. In the medium supplemented with the cytokinin but without NAA, the formation of adventitious buds was rarely observed. The results show that the combination of cytokinin (TDZ or BA) and auxin (NAA) is necessary for the formation of adventitious buds from the petiole explants. After acclimatization, the plants obtained by the methods grew normally in a greenhouse.

The Dogwood Improvement Program at the University of Tennessee

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INTRODUCTION

Flowering dogwood, *Cornus florida*, comprises about 16% of all woody ornamental plant production in Tennessee. Annual sales of this species accounts for $50 million. Flowering dogwood is an important and widespread component of eastern woodlands. In recent years, two destructive diseases have severely impacted native stands of flowering dogwood, and to a lesser degree have caused problems in nursery and landscape situations. Dogwood anthracnose (*Discula destructiva*) was first observed 20 years ago in Connecticut and has since spread rapidly through native stands in the Appalachian mountains and highlands. In the last 5 years, flowering dogwoods have been under an epiphytotic attack throughout the eastern U.S. by powdery mildew (*Microsphaera pulchra*). While generally not life-threatening in the woods, powdery mildew severely reduces growth of nonsprayed seedlings in nurseries, thus impacting budding operations. The University of Tennessee Institute of Agriculture (UTIA) formed a multidisciplinary team of scientists to research solutions for these disease problems.

Dogwood Anthracnose. This disease was first reported in eastern and western regions of the U. S. about 20 years ago. It was discovered in Tennessee in 1988, and pathologists set up survey plots to track the spread and severity of the disease throughout the southeastern states. Concerned researchers, regulatory personnel, and U.S. Forest Service staff, primarily from southeastern states, convened a series of dogwood Anthracnose Workshops to exchange information, plan research, and track the spread of the disease. *Discula* is sensitive to heat [above 30°C (86°F)] and dry weather — thus it was worst for plants at high elevations, on northern slopes, situated near foggy sites or water, and on shady sites as opposed to trees located in open sites. Thus, the fungus was initially difficult to inoculate in the greenhouse and laboratory. This problem was overcome and progress swiftly mounted on epidemiology, means of dispersion, and control measures. We now know that spores can over winter in active cankers, dead leaves, and berry tissue and that sporulation begins in cool moist weather in mid-spring. Spores can spread via windblown rain and mist as well in the gut and on the skin of a variety of insects. Secondary infections continue as long as weather conditions are favorable.

Definitive verification of disease presence depends on the distinctive appearance of the spores. Dogwoods grown at lower elevations in open nursery fields, as is usually the case, are generally at little risk. Since this is a quarantinable disease, growers must protect their stock with fungicide sprays. Banner MAXX, Daconil 2787, Dithane F, Systhane 2EC or 40WP are labeled and give excellent protection when applied at 10 to 14 day intervals in the spring until hot weather occurs consistently. A more economical solution would be to use resistant cultivars. At a dogwood anthracnose workshop, Keith Langdon of the National Park Service reported finding two trees that survived the epiphytotic which had killed nearly all the flowering dogwood at the top of Catoctin Mountain in Maryland. In a subsequent search by Mark Windham (UTIA) five Catoctin Mountain survivors were discovered and he obtained permission to take cuttings. Cuttings were harvested in early July 1991 and propagated under intermittent mist, using Hormodin #2 and peat and perlite medium. Rooted plants were placed under a long-day photoperiod, fertilized with 200 ppm N Peters 20N-10P-20K to induce a growth flush, and overwintered in a minimum heat greenhouse. Plants were transplanted into larger containers and then challenged for dogwood anthracnose resistance at Ozone, Tennessee in 1992 and in a double blind test at Bent Creek Forest near Asheville, North Carolina in 1996. Most of the rescued clones showed some resistance when compared to the controls, but only one clone exhibited strong resistance. When that clone bloomed, we were pleased that bract size, quantity, and quality was as good as many named cultivars. We continued to root cuttings whenever cutting wood was available. Two of the original cuttings were planted in our field nursery and are now 2.4 m (8 ft) tall with a diameter of 2.1 m (7 ft), and a trunk caliper exceeding 6 cm (2.5 inches). Despite removal of wood for cuttings and budsticks, a normal growth habit and horizontal branching is developing. Leaf color is apple green with lighter venation and no hint of anthocyanin reddening. Leaf size is strikingly large (25% longer and wider than 'Cherokee Brave'). DNA fingerprinting was conducted and five distinctive markers were identified. Principle Coordinate Analyses showed that our resistant clone was located outside the cluster of five other dogwood cultivars commonly used in the industry.

Release of 'Appalachian Spring'. The UTIA plant release committee has approved the name 'Appalachian Spring' and the release has been published (Windham et al., 1998). Since the original tree was found in the wild, it cannot be patented. However, the cultivar is being closely controlled. The word 'Appalachian' is being considered as a trademark name for the series of dogwoods that we intend to release. Buildup of foundation stock and marketing is controlled by the Tennessee Crop Improvement Association (TCIA), Tennessee Foundation Seed, Inc. (TFS), and Tennessee Advanced Genetics (TAG) — all located at 2640-C Nolensville Road, Nashville, TN [615.242.0467, FAX 615.248.3461]. Foundation stock is being multiplied by a few growers in Franklin County, Tennessee. We appear to be 1 or 2 years away from the next step, which is the formation of a marketing group by TAG.

Powdery Mildew. Powdery mildew on flowering dogwood is caused by two organisms, *Microsphaera pulchra* and *Phyllactinia guttata*. The former appears to be the most prevalent problem today. This disease was never significant until 5 years ago when an epiphytotic suddenly exploded throughout the eastern U.S. While having only moderate impact in forest sites, powdery mildew causes major growth reduction of flowering dogwood in nurseries, especially on seedlings, young plants, and variegated cultivars. Understock fails to sufficiently develop to meet growth standards required for budding. Mildew appears later in the season than dogwood anthracnose, but can progress rapidly unless fungicides are applied. The same fungicides that are effective for dogwood anthracnose prevent powdery mildew with the exception of Daconil 2787. In addition, growers can apply Rubigan

AS, Bayleton 25WP, Cleary's 3336F, or Zyban 75WP. Cover sprays should be applied every 7 to 10 days when two conditions are met: (1) night temperatures do not drop below 21°C (70°F) and (2) nighttime relative humidity is 85% or more. Best control and minimum phytotoxicity is obtained when fungicides are rotated in a spray program.

Powdery-Mildew-Resistant Plants. We screened 22,000 dogwood seedlings in nursery fields in 1994 and 1995. Eighty seedlings were flagged as being free of signs and symptoms of powdery mildew. In the fall, these were dug and taken to the UTIA research nursery, where they were containerized and overwintered. Seedlings were again challenged for disease resistance in a shaded greenhouse, which was maintained at high humidity, and included an abundance of inoculum from potted dogwood trees with mildew. While none of the seedlings were immune, 20 remained almost free of mildew under the artificially high disease pressure. In contrast, the moderately resistant 'Cherokee Brave' cultivar developed mildew. Resistant seedlings were propagated by rooted cuttings. Six trees bloomed in Spring 1998. Two consumer preference surveys have been conducted and we currently plan to name and release the three best clones. Since these trees were found in cultivation, they are patentable and UTIA is proceeding with plant patent applications for this group of the Appalachian™ series of dogwoods. We are currently rescuing and testing additional flowering dogwoods that appear to be disease resistant in nursery fields. This is not as easy as in the beginning because almost all nurseries are using fungicides and we can no longer simply walk rows and pick out good plants.

Breeding Efforts. Our breeding work has been only with *C. florida*. Initial efforts began in 1993, mainly via manual emasculation and pollination on containerized trees of a number of cultivars. Flowering dogwood is an obligate out-crosser and will not set seed when self-pollinated. To verify the hypothesis that insects naturally played the major role in dogwood pollination, five trees each of 'Cloud Nine' and 'Cherokee Brave' were placed in a large double screened cage which excluded all insects. Since the trees bloomed normally but no berries were set, we conclude insect pollinators are necessary. We attempted to trick honeybees into pollinating dogwood flowers, something they do not ordinarily do. We built screened cages around our two largest 'Appalachian Spring' trees, synchronized the bloom of containerized 'Cherokee Brave', and introduced them into the cages along with nuclear colonies of honeybees. About twice a day during warm weather, a droplet of sugar solution containing queen mandibular pheromone (9-oxydecenoic acid) was placed on the base of a bract of each inflorescence with open flowers, being careful not to get the material on the true flowers or on leaves. Significant bee feeding was induced and we observed bees moving between trees. By the time bracts fell, berry set had occurred and we removed the bees and opened the cages. As berries ripened in the fall, they were harvested, labeled, cleaned, and stratified. Seedlings were germinated in the greenhouse and when three pair of leaves had formed, one developing leaf was harvested for DNA analysis. Profiles confirm hybrid origin, thus reducing the need to rely on morphological characteristics. Hybrid seedlings are grown on, cuttings propagated to build up a small stock of a clone, and the clones will be challenged for resistance to both dogwood anthracnose and powdery mildew. So far we have several hundred seeds and plants progressing through this process. We have also raised open pollinated seedlings from the six powdery-mildew-resistant clones that have bloomed, and hundreds of open-pollinated seedlings of 'Cherokee Brave'. Of these, few have shown significant resistance to powdery mildew, so inheritance is not simple, and it may not be the same in all resistant trees. We think more than one gene is involved and that recombination of resistance genes in the F_2 generation may be needed. If this hypothesis proves correct, it suggests we are six or more years away from producing F_2 seed, plus additional time for growing and testing hybrid seedlings in the hope of finding one or more flowering dogwood trees resistant to both diseases.

Chinese Dogwood Selections. About 10 years ago, Polly Hill of Vineyard Haven, Massachusetts, reported the occurrence of dogwood anthracnose on some *C. kousa* selections. We requested seed from diseased trees and also disease-free trees. She graciously complied, and in 1990, we cleaned, stratified, and germinated the seed. Each seedling was labeled with a code that identified the parent tree. We challenged these seedlings for dogwood anthracnose resistance in the Great Smoky Mountains National Park and found no correlation between disease ratings and the parent, indicating that inheritance is not simple. Five hundred of the best seedlings were planted in a non-irrigated field at the UT Arboretum in Oak Ridge. The largest trees bloomed in 1998. We flagged five trees that had prolific bloom and good bract size and shape. A drought occurred later that year and we flagged trees that were free of leaf scorch and leaf curl, and had dark green color and horizontal presentation of foliage. In late Summer 1999, east Tennessee experienced the worst drought in 100 years. We re-examined for drought tolerance and flagged 10 trees, pleased that most were repeats from the previous year. These trees were equal or better in quality of foliage during the drought than 'Blue Shadow', 'Temple Jewel', and 'Trinity Star', which performed best during the drought in our replicated cultivar trial. Next year we will propagate cuttings from our selections. We plan to conduct replicated trials in a deep-South location, as well as at a northern site to test for cold hardiness. Eventually, we hope to name and release one or more cultivars of heat- and drought-tolerant Chinese dogwood.

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Garden Worthy Commercial Plants from England — Plus Some New Georgia Woody "Goodies"

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SABBATICAL LEAVE AT SIR HAROLD HILLIER GARDENS AND ARBORETA

For the past 6 months I was on sabbatical leave at the Sir Harold Hillier Gardens and Arboreta, in England. They have possibly the largest collection of woody plants in the temperate world. I have been studying, photographing, collecting, traveling, and visiting kindred spirits. This has resulted in more than 5000 photographs, 400 pages of field notes, 112 gardens and nurseries visited, eight major articles written for *NMPRO* magazine, and over 100 new plants for evaluation in the span of 6 months. I have made terrific contacts that ensure the flow of new plant material. The English are as interested in U.S. plants and our breeding activities, as we are in their material. I met fanatical plants people from the greatest plant collector (Roy Lancaster) of my generation, to a former butcher (Richard Duke) who has the passion and collector's eye seldom seen in the most ardent professional. All shared information, plants sources, and their gardens.

Interestingly, a significant number of our Georgia nursery producers visited England during my 6 months sabbatical. All were embraced enthusiastically by the people we visited and myself. All believed that significant opportunities are available for plant and information trading. In May 1999, four nurserymen purchased 84 plants of which 70 made it through customs.

John Woodhead, Manager, Nursery Operations at Hillier told me that new products (plants) are the absolute key to his company's future. The word EXCLUSIVITY was a recurring tenet of his conversations. New perennials are a dime a dozen, trees and conifers have no market appeal (no space), whereas new flowering shrubs are the major focus, but in abbreviated supply. Hillier's hired a Ph.D. to conduct in-house research and conduct plant breeding. Something that was absolutely unheard of in English nursery circles until now. John provided numerous examples to me and stateside visitors about the ECONOMIC essentiality of new plants. Hillier's strives for at least a 5% net profit on each plant type with overall net profit approaching 15%. On great new products like *Cotinus coggygria* Golden Spirit™ smoke tree, released this summer, the net return is 60%. All 15,000 plants were sold immediately at £6.85 ($11.30 U.S.) per 3.8-liter (1-gal) container. Average price for everyday 3.8-liter common denominator plants is £2 to £3 ($3.30 to $4.95 U.S.).

I sense the feeling among the Hillier staff that any nursery can grow a plant, but not to their quantity and quality specifications and uniqueness. In fact, many specialty growers I visited had nothing approaching the quality of Hillier's. To be sure, lists of 200 salvia, or 150 magnolias, or 90 hydrangeas are exciting to the collector. However, the "stick in the bucket" approach will doubtfully work at the better garden centers and mass market venues.

I believe my sabbatical will yield fruits for our Georgia and southeastern nursery profession well into the next century.

POTENTIAL NEW PLANTS FOR CONSIDERATION

Abelia chinensis, A. floribunda, A. mosaenensis, A. schumannii, A. spathulata — A unique mix of germplasm for developing commercial cultivars.

***Aucuba japonica* 'Crotonifolia', 'Marmorita', 'Hillieri', 'Pink Champagne'** — New hybrids with ' Rozannie' × 'Crotonifolia'.

***Buddleja davidii* 'Dartmoor' × *B.* ' Lochinch' seedling** — A chance seedling with blue-purple flowers, gray foliage.

***Cephalanthus occidentalis* var. *angustifolia* (Hillier) and *Cephalanthus occidentalis* 'Statesboro White'** — Questing after a compact form.

Cotinus coggygria* Golden Spirit™ smoke tree, *C. szechuanensis — Unique species with wavy leaves already hybridized with *Cotinus* 'Grace'. The first named clone is 'Dusky Maiden'.

***Daphne* ×*burkwoodii* 'Pam's Gold'** — Wow, an excellent plant!

Euonymus alatus* f. *microphyllus — A beautiful compact, fine-textured leaf type with red fall color. Would compete favorably with 'Compactus'.

***Hydrangea arborescens* 'Bounty'** — An impressive sterile-flowered form. May prove a substitute for 'Annabelle'.

Hydrangea macrophylla — Chasing a perpetual flowering clone and/or series. A devastating freeze in England provided the opportunity to survey rebloomers and cold hardy types. Of 150 taxa observed, only 5 have significant rebloom potential.

***Hypericum* species** — The late J.C. Raulston got me excited about *Hypericum galioides* 'Brodie'. This sabbatical has opened my eyes to its breeding potential.

Indigofera decora* 'Rosea', *I. heterantha, I. himalayensis, I. kirilowii, I. pendula, I. potaninii — An opportunity for great range of flowering shrubs. They flower on new growth.

***Magnolia* 'Summer Solstice'** — A magnificent hybrid between *Magnolia globosa* (hardy form) × *M. hypoleuca*.

***Parrotia persica* ' Lamplighter', 'Pendula', 'Spinners'** — Has more variation that I ever imagined.

Sarcococca hookeriana — Two unique clones with willow-like leaves. *Sarcococca orientalis, S. ruscifolia* 'Dragon Gate'.

***Spiraea formosana, S. chamaedryfolia* var. *ulmifolia, S. japonica* 'Red Princess', 'White Gold', 'Snowball'.**

***Thuja occidentalis* 'Malonyana'** — Has a telephone-pole-like habit.

***Trachelospermum jasminoides* 'Variegatum'** — Has a beautiful cream-margined leaf form with increased hardiness.

Viburnum* ×*burkwoodii — Cultivars such as 'Anne Russell', 'Chenaultii', 'Park Farm Hybrid' are tremendously confused. The latter is the superior cultivar.

Viburnum utile — A great source of quality genes. The late Don Egolf knew this and produced 'Eskimo', 'Chesapeake', 'Conoy', 'Mohawk'.

Growing Plants in a Cinder Block

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INTRODUCTION

The main problems of growing tree seedlings in containers is development of the root system and blow-over of the plants. Improving root system quality and preventing wrapping and circling can be achieved with RootMaker™ and other air-root-pruning containers. An assortment of devices have been created to keep larger trees from blowing over. However, most of these techniques are not practical for container-grown trees during the first 1 or 2 years.

Each time a black plastic container blows over and the side is exposed to direct sunlight, roots on the exposed side are killed. In a study to determine these effects, sides of containers were exposed for precise times. The shortest exposure used was 15 min, which was sufficient to kill roots on the exposed side of the container. As a result, I had the idea of growing tree seedlings in the cavity of a cinder block with a liner made of fabric. Seedlings cannot blow over, roots are insulated from heat, and the plants are properly spaced for good top development. I had previously tried growing in cinder blocks without a liner and found growth to be excellent, but removal of the tree seedlings was so difficult that the procedure was dropped.

The Study. Initially, four cinder blocks were used with a cavity liner made of fabric with precise openings for root pruning. The eight oak trees planted in early Aug. 1996 did well. For 1997, nearly 1000 cinder blocks with 2000 cavities 13 × 14 × 20 cm (5 × 5.5 × 8 inches) were set up for a much more extensive study. Half of the blocks were placed on 6-mil poly and half on 6-ounce Typar™ which lets water through, yet prevents root growth into the soil below.

Bags were made of: (a) special knit fabric for root-pruning, (b) 3-ounce Typar, (c) 6-ounce Typar™, and (d) 5-ounce spun-bonded weed barrier fabric. The bags were filled with a soilless mix of pine bark, peat, and sand (3 : 1 : 1, by volume) amended with Osmocote and Micromax micronutrients, and placed in the block cavity.

Tree seedling liners of shumard (*Quercus shumardii*) and bur oak (*Q. macrocarpa*), lacebark elm (*Ulmus parvifolia*), Chinese pistache (*Pistachia chinese*), loblolly pine (*Pinus taeda*), catalpa (*Catalpa bignonioides*), redbud (*Cercis canadensis*), bald cypress (*Taxodium distichum*), and shantung maple (*Acer truncatum*) were grown to a height of 20 to 30 cm (8 to 12 inches) in 6 × 6 × 10 cm (2.5 × 2.5 × 4 inch) deep RootMaker™ propagation containers before being shifted to the block bags in late June 1997. Planting was done using a cone-shaped dibble that fits the RootMaker™ shape. Irrigation was by overhead sprinklers.

Plant Growth. Growth of all species was excellent (Fig. 1). Overall growth, stem diameter, and branching with the knit fabric bags was superior to all previous techniques tried (Fig. 2). Root systems were excellent if grown in the knit fabric (Fig. 3). On the other hand, tree seedlings grown in Typar™ (which restricts roots) circled and were deformed. The 5-ounce spun-bonded fabric had good growth but removal of the fabric was quite difficult.

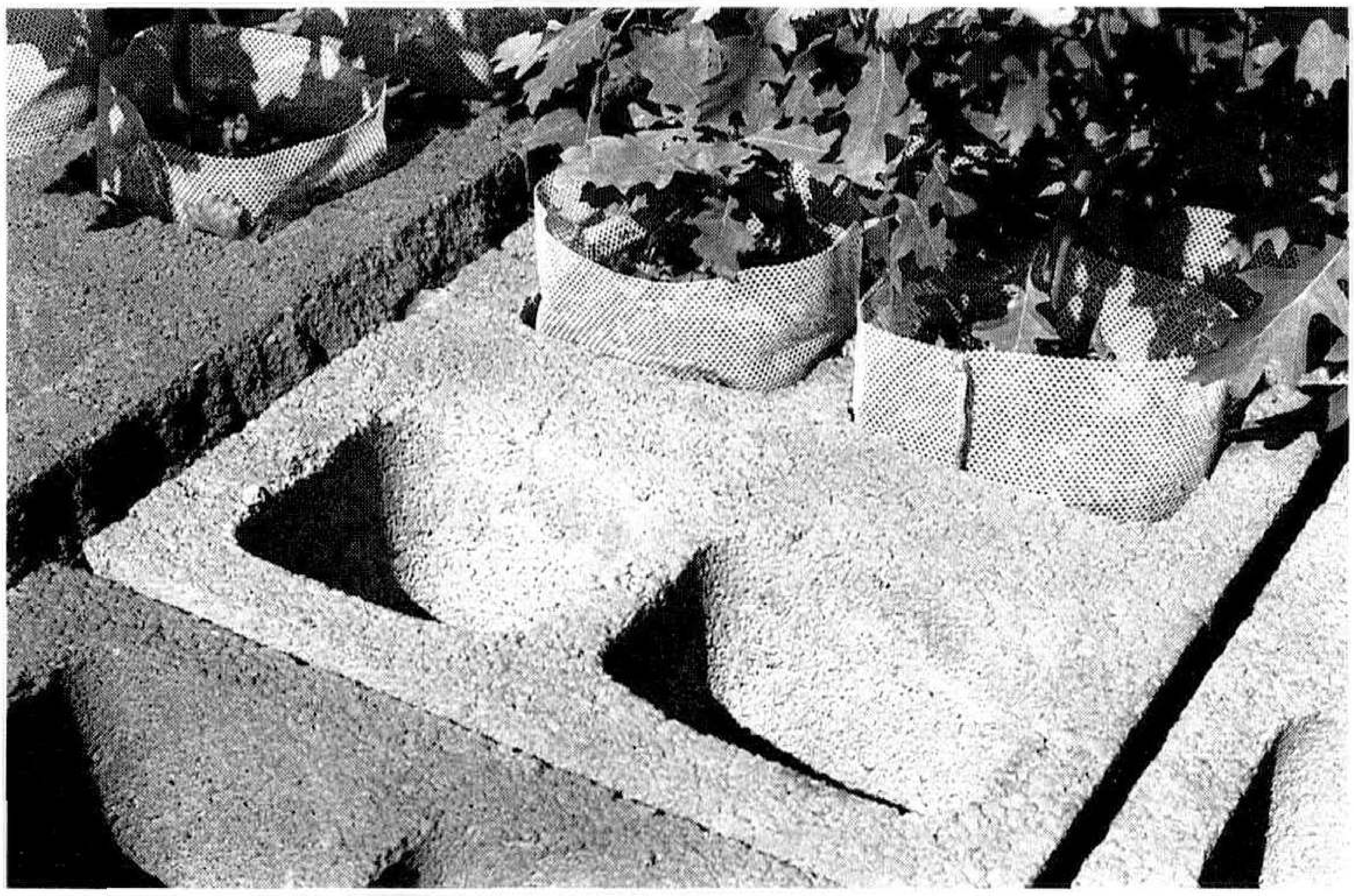

Figure 1. General view of tree seedlings in the cavities of 20 × 20 × 41 cm (8 × 8 × 16 inch) cinder blocks.

One of the surprises of this technique was the improvement of water availability and aeration to the root system. After watering any conventional container there is a saturated zone at the bottom. However, the cinder block is porous and both absorbs and releases water to aid plant growth; thus water availability is improved while also improving aeration.

In most areas grade-two cinder blocks are available at about half price. In my experimental area the set-up cost was about 30 cents per cavity, but longevity is indefinite. The trees planted in late June were 3 to 5 ft tall by mid-Oct. 1997. To transplant into the field for further growth, the trees were pulled from the cinder blocks using the stems, the fabric was removed by pulling off using the two folds at the bottom or by cutting down one side. All trees transplanted grew well in the field. The study was repeated in 1998 with similar results.

Evaluating Winter Root Damage. In Oct. 1998, one third of the trees were removed and planted in the field, while the rest were left in the blocks to evaluate overwintering. For comparison, three blocks and six trees of Shumard oak, Chinese pistache, and loblolly pine were moved to a poly-covered overwintering house. The minimum temperature experienced was -16°C (8°F) on two successive nights in Jan. 1999.

With the arrival of spring, the 18 trees that had overwintered in the blocks inside the poly house were planted into 3-gal containers. Trees of the three species and of similar size were removed from the blocks and also planted into 3-gal containers. Emergence of buds, length of the spring flush of growth, leaf size, and color were similar for both treatments. This indicates that the winter temperatures did not cause significant damage to roots in the cinder blocks.

Transplant Tolerance. Another question to be answered was the sensitivity or tolerance of the tree seedlings to removal and transplanting from the blocks during

Figure 2. Shumard oaks grown from late June to mid-October 1997. Note the stem diameter and natural branching of the seedling in the knit fabric and the absence of any support stake.

Figure 3. Root systems of a bald cypress tree grown in the 13-cm (5-inch) knit bag inside a cinder block for 4 months, then washed for inspection

the growing season. On August 3 and 4 Aug. 1999, when temperatures were consistently 35 to 38°C (95 to 100°F), 12 trees each of Shumard oak, Chinese pistache, and loblolly pine were pulled from the blocks, fabric was removed, and trees were transplanted into 3-gal RootMaker™ containers. All were hand-watered initially then irrigated by overhead sprinklers three times daily.

No leaves were lost nor was leaf damage observed with any of the three species. The Shumard oaks all made a modest flush of growth during the following 3 weeks. Eight of the Chinese pistache made new growth, while the other four simply matured the young tissue and developed a strong terminal bud for next spring. The loblolly pines made no new growth following transplanting. All three species increased stem diameter following transplanting.

No Staking. None of the trees grown in the cinder blocks were ever staked while in the block or after transplanting into larger containers or in the field. This benefit alone translates into substantial savings in time and labor.

Other Species Also Benefitted. Bearded iris, Japanese iris, calla lilies, lantana, plume grass, and oak leaf hydrangea were also grown in cinder blocks compared to conventional containers during the 1999 growing season. All species tested grew well and outperformed plants in conventional containers of similar volume.

SUMMARY

This technique provides several advantages over conventional plastic pots:

- Plants cannot blow over.
- Spacing is 20 cm (8 inches) on centers with standard 20 × 20 × 41 cm (8 × 8 × 16 inch) blocks.
- Roots are insulated from summer's heat.
- Roots are sufficiently insulated from winter's cold in USDA Zones 8 and 9, but may need some additional protection in Zone 7 or northward.
- Changes in moisture levels after irrigation is slowed by the water absorption and release by the block.
- Aeration to the root system is improved.
- Plants are easily removed at any time. Knit fabric is easy to remove and with some species can be reused.
- Set up cost is moderate, but longevity is indefinite. Six-ounce Typar™ worked best beneath the blocks.
- Roots in bags made of knit fabric did not circle.
- Roots in bags made of knit fabric were very fibrous and prime for transplanting by early fall.
- With most species tested, planting into the 13 cm (5 inch) bags in the cinder block during May or June, yielded excellent plants for transplanting into larger containers or planting into the field by early October.
- If tree seedlings are left in the blocks for two growing seasons, every other plant on a staggered arrangement should be removed to avoid over crowding and weak stems.

Effect of Water Quality on Plant Propagation

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INTRODUCTION

Water is an essential component of all life on earth. The application of water to nursery and greenhouse plants is the most universal treatment in greenhouse and nursery culture, the most important treatment for crop success and the most discounted and neglected. It is estimated 80% of crop success is due to proper management of water and light. Water quality has a major influence on nursery and greenhouse plant nutrition, growth, and crop quality. The influence water quality imparts is most significant when dealing with young plants or propagation materials.

In woody plants, water has four important functions. First, water is an essential constituent of the plant protoplasm. The water content of plant cells ranges from 10% of dried seeds to 95% of some fruits and young leaves. Water generally represents 80% to 90% of the fresh weight of actively growing tissue. Second, water is the solvent in which gases, salts, and other solvents move in and out of cells and from organ to organ. Third, water is a major reagent in photosynthesis and in a number of other hydrolytic processes. Fourth, water is essential for the maintenance of turgidity (Kramer and Kozlowski, 1979). In plant water relations, maintenance of a sufficiently high water content and turgor to permit normal functioning of physiological and biochemical processes involved in growth is essential (Kramer and Kozlowski, 1979).

In coastal regions, the three most common problems with water for greenhouse and nursery stock irrigation are high salt content, high pH, and high alkalinity. These three are increasing in severity and becoming of major importance in certain regions. They are of concern to all producers of nursery and greenhouse material; however, for propagators they pose an even greater worry.

WHAT ARE YOU LOOKING FOR?

It is recommended that you have a water test done at least once each year. It may be good to have two water tests done the first time you are investigating your irrigation supply. The two tests should be conducted as follows: (1) in the spring, after all the rains; and, (2) in late summer, before the rains begin. The spring test will give you the best synopsis of your irrigation water and the test in late summer your worst scenario. Water quality testing should also be conducted more than once a season if any of the four following conditions apply. First, there has been an exceptionally dry or wet growing season. Second, there has been a period of abnormally high or low water usage. Third, a drought has occurred. Fourth, the irrigation water comes from various sources, including a city or municipal source.

When reviewing the results of a water analysis it is important to note excess or minimal levels first, before studying the balance of parameters measured. Presented in Table 1 are some ornamental irrigation water quality guidelines. The characteristics in set one should definitely be monitored. They are the minimum set of analyses that should be done on a regular basis. Set two characteristics are desirable but not as essential.

Table 1. Desirable ranges for specific elements in irrigation water.

Characteristic	Upper limit	Optimum range
Set 1:		
pH		5-7
EC general production	1.25 dS/m	Near zero
plugs & seedlings	0.75 dS/m	Near zero
Phosphorus (P)	0.005-5 mg liter^{-1}*	< 1.0 mg liter^{-1}
Calcium (Ca)	120 mg liter^{-1}	40 –120 mg liter^{-1}
Sulfate (SO_4)	240 mg liter^{-1}	24-240 mg liter^{-1}
Alkalinity	200 mg liter^{-1}	0-100 mg liter^{-1}
Sodium (Na)	50 mg liter^{-1}	0-30 mg liter^{-1}
Boron (B)	0.8 mg liter^{-1}	0.2-0.5 mg liter^{-1}
Fluoride (F)	1.0 mg liter^{-1}	0 (especially for sensitive crops, i.e. lilies, freesias
Magnesium (Mg)	24 mg liter^{-1}	6-24 mg liter^{-1}
Chloride (Cl)	140 mg liter^{-1}	0-50 mg liter^{-1}
Bicarbonate equivalent	150 mg liter^{-1} **	30-50 mg liter^{-1}
Set 2:		
Nitrate ($N0_3$)	5 mg liter^{-1}	0-5 mg liter^{-1}
Potassium (K)	10 mg liter^{-1}	0.5-10 mg liter^{-1}
Zinc (Zn)	2.0 mg liter^{-1}	0.1-0.2 mg liter^{-1}
Molybdenum (Mo)	0.07 mg liter^{-1}	0.02-0.05 mg liter^{-1}
Iron (Fe)	5 mg liter^{-1}	1-2 mg liter^{-1}
Copper (Cu)	0.2 mg liter^{-1}	0.08-0.15 mg liter^{-1}
Aluminum (Al)	5.0 mg liter^{-1}	0-5.0 mg liter^{-1}
Sodium absorption ratio (SAR)	4 mg liter^{-1}	0-4 mg liter^{-1}

* 1 mg liter^{-1} = 1 ppm

** Acidification is usually required to correct pH if bicarbonate equivalent is above 50 mg/liter

TOTAL SALTS

If you have compared your water analysis to the guidelines in Table 1 and discovered an electrical conductivity (EC) problem, you should take comfort that you are not alone. High salt content is a relatively common problem.

Salinity is the total quantity of salts dissolved in water and one way to measure it is by EC. A commonly used unit for measuring conductivity is millimhos per centimeter (mmhos cm^{-1}) which is equal to the millisiemen (mS). More recently mmhos cm^{-1} has been renamed decisiemens per meter (dS m^{-1}).

Effects on Plant Growth. The total amount of dissolved salts in a water supply constitutes its salinity. The cells of plant roots absorb water as a result of the differences in osmotic pressure between the cell contents and the surrounding soil water. Whenever salinity of the soil solution is near to or greater than that of the cell contents, plants are unable to take up sufficient water for growth and other processes. Mature plants can tolerate higher salts than young plants. Some common salt sensitive ornamental plants are *Cotoneaster horizontalis, Photinia ×fraseri, Ilex cornuta* 'Burfordii', *Vinca minor, Hibiscus rosa-sinensis* 'Brilliant', *Nandina domestica, Rhododendron* spp. (azalea spp.), *Gardenia* spp., and *Limonium perezii*, to name a few.

When evaluating salinity, it is important to note the dominant anion in the water. For water with bicarbonate as its principal anion, the salinity hazard is much lower than if the principal anion were chloride. The irrigation water constituents of greatest concern to growers of ornamental species are chloride, boron, and sodium. High sodium and bicarbonate are the two I have come across most often, to date.

Sodium. Plant roots can absorb sodium and transport it to leaf tissue where it accumulates. Sodium toxicity symptoms are similar in appearance to those of chloride toxicity, i.e., marginal scorch on older leaves.

Bicarbonate. The principle concern with bicarbonate is not that it is a toxic ion, but that it increases soil pH. Waters that contain sodium and bicarbonate as the major cation and anion can cause serious problems for plants.

Alkalinity and pH. Remember alkalinity and pH are not the same. The characteristic of water that will have a bearing on the change in medium pH is alkalinity, not pH. Alkalinity for all practical purposes, is the "buffering capacity" of the water. A buffer solution is a solution that has the capacity to resist change in pH (usually a decrease). The greater the alkalinity of water, the greater is the buffering capacity of that water and the tougher it is to acidify. Alkalinity is measured in units expressed as mg $liter^{-1}$ of calcium carbonate. As the units imply, the source of alkalinity is usually from bicarbonates (HCO_3^-) and carbonates (CO_3^{-2}). Both of these components will cause growing media to increase in pH if present in sufficient amounts.

As soils dry after having been irrigated with water high in bicarbonate, calcium and magnesium combine with the bicarbonate to form calcium and magnesium carbonates. These are insoluble salts and are not readily leached from the soil. With each irrigation, more calcium and magnesium carbonates are added to the soil. As they accumulate, they ease the soil pH upward, above pH 7. High soil pH levels make zinc, iron and manganese less available to plants. The rate and extent of pH increase will depend upon media formulation, watering practices, and fertilization practices.

Table 2. Acid injection into irrigation water.

Formula: A × B × C = ounces of acid per 1000 gal of water to adjust pH to approximately 6.4.

"A" is a factor determined by water pH.

Water pH	A	Water pH	A
6.7	0.249	7.7	0.475
6.9	0.342	7.9	0.484
7.1	0.400	8.1	0.490
7.3	0.437	8.3	0.494
7.5	0.460	8.5	0.496

"B" = the sum of bicarbonate and carbonate expressed as milliequivalents/liter (meq).

"C" = A factor determined by the type acid used.

Acid Source	C
75% phosphoric	10.60
85% phosphoric	8.74
93% sulfuric	3.72
61.4% nitric acid	15.6

Example: Water pH = 7.5, carbonate + bicarbonate = 3.4 meq

A × B × C = ounces of acid per 1000 gal.

0.460 × 3.4 × 10.6 = **16.5 ounces** of 75% Phosphoric acid per 1000 gal of water.

Source: Vaughan's Seed Company 1993

Table 3. Common antagonisms occurring in plants.

Nutrient in excess	Induced deficiency
N	K
K	N, Ca, Mg
Na	K, Ca, Mg
Ca	Mg
Mg	Ca
Ca	B
Fe	Mn
Mn	Fe
Cu	Fe
P	Cu

The most important point is "high pH does not determine the capacity of irrigation water to increase a potting medium's pH during production – it is the water's alkalinity".

Waters that contain less than 50 mg $liter^{-1}$ of bicarbonate usually do not have a serious effect on soil pH. Water containing concentrations of bicarbonate above 50 mg $liter^{-1}$ cause pH increases in growing media and need to be acidified. Work closely with a consulting laboratory if acid injection is necessary.

If you experience periodic iron or micronutrient deficiencies, total carbonates may be one of the causal factors. If your media pH values constantly run too high, the carbonate and bicarbonate levels in your water may be the cause of this problem. If certain crops that prefer a lower pH turn yellow, evaluate the total carbonates in your water. See Table 2 for additional information on acid injection.

Water quality, of course, is not the only reason you may see nutrient deficiencies. Some nutrients will interfere or promote the uptake of other nutrients. Table 3 contains a list of common antagonists.

Acids also supply plant nutrients and you may have to modify your fertility program after injection. Acid injection may also change the solubility of trace elements in your water. Analyze your water after acid injection and confirm that you have achieved the desired results. Also, one message about phosphoric acid. It is the most commonly used but probably should not be used as widely to correct alkalinity problems as it causes "stretch" in plants. It will have a definite stretching effect on primulas, petunias and impatiens. Citric acid is a much better acid for propagation materials.

SUMMARY

The take home message of this presentation was have a "Water Quality Action Plan". That "Action Plan" should contain these five steps: (1) have your irrigation water laboratory tested at least once each year; (2) compare your test results with the standards; (3) consider whether acid treatment will improve your water quality and which acid is best for your situation; (4) make adjustments to your water and fertilizer practices based on steps one to four; and, (5) always use pH and EC meters to make well-informed decisions, don't guess.

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Sticking the Knife In: Grafted Nursery Stock Production at Yorkshire Plants

Steen Berg
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INTRODUCTION

Yorkshire Plants is a wholesale nursery located in the north of England approximately 200 miles north of London. Temperatures range from -10°C in the winter up to about 30°C in the summer. We have rainfall of about 24 inches per year. This is not totally unfamiliar to the climate of the Northwest; just not as cold nor as warm and not as wet. Winds, gales, and spring frosts are our other main climatic challenges. Our main crops (*Cotoneaster, Euonymus, Larix, Photinia, Prunus, Salix*) are top-worked patio trees on an 80- to 150-cm stem. These trees are convenient for retail sales and not too large (they cannot fit into a small family car) but not so small they can still be considered trees. We have tried to search for unusual hard-to-find trees, but with garden appeal (e.g., variegated, purple foliage, large leaves, cut leaves, or contorted forms). Conifers (*Picea, Pinus, Cedrus, Abies, Taxus*) are grafted plants with high value.

SHRUBS

We grown *Hibiscus, Syringa, Wisteria*, and *Corylus* that are propagated by grafting. The U.K. nursery stock industry has largely left this type of product to be grown by continental growers. There is no great tradition in this type of production in the U.K. Our market is retail garden centers/nurseries in the U.K. and Ireland.

GRAFTED NURSERY STOCK PRODUCTION

Grafting. Our grafting is nearly all done in the winter (December to March) using a simple side or whip graft. Only on *Aesculus* and *Gleditsia* do we use the whip and tongue method to help bind the graft union. Bottom-working of trees and shrubs is mainly done on a hot-callus-pipe system where water is heated by a small domestic

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Top-working. *Cotoneaster, Salix, Photinia, Euonymus, Larix*, and *Prunus* are main subjects for top-working. There has been a fashion for these novelties in the U.K. in recent years. However, now most plant retailers have experienced this material and are demanding high quality plants with a purpose. They are looking for straight thick stems, large even heads and large containers that will carry this top-heavy product. Our response as growers has been to take 3 years to grow the plants instead of 2 years. In some cases we double the final pot size and in nearly all cases put two scions on a single stem.

Top working is done on pot-grown and bare-root stems. *Cotoneaster, Pyracantha, Prunus*, and *Larix* are grafted onto pot-grown stocks, whereas *Euonymus, Robinia,* and *Salix* are grafted on bare-root stocks and potted after grafting. In all cases, apart from the willow stems, we buy in understocks from specialist producers. In the case of willows we produce our own, by sticking hardwood cuttings of *S. viminalis* or 'Boles Hybrid' of about 5 to 6 inches long though a polythene mulch with two lines of tape irrigation under the polythene. The cuttings are stuck in March and by

August have reached about 10 ft high. The maintenance has included high levels of water and several times walking through the crop to make sure each plant has only one growth leader. Out of this crop we get three grades; plants for grafting at 120-cm stems and 80-cm stems, and for bottom-working.

Top-working is done in the case of the pot-grown stocks *in situ* within a double-skin poly tunnel or within a cold house. Bare-root stocks are grafted in our shed then potted and taken to a double-skin tunnel or cold glasshouse. When using two scions we use a whip graft for the top scion and a side graft for the bottom scion, putting the scions at opposite sides of the stem. The grafted union area is then dipped into melted paraffin wax. Tying is done with rubber strips. Cotoneasters are usually the first plants to be top-worked in January with *Robinia* being the last in March. Plants are maintained through spring routinely suckered and heads pruned to shape them. They are then transplanted into their saleable pots in May and June or an intermediate pot should the plant require the extra time to make sale. Due to us putting a lot of work into the plants prior to going into their final container, little more than light pruning is done to the plants. We do have a windy climate in the U.K. and these plants have to be tied to some kind of support when grown outside. All plants are staked and tied, the stake itself is tied to their support. We use drip irrigation for all our trees and patio standards. This is an expensive method of delivering water to the plant, but it does use water efficiently, we pay 80 pence or $1.25 for 1000 liters of water. I have to use mains water as there is no viable underground supply and the capital costs for collecting roof water is, as yet, prohibitive. The storage of this water would take up a large amount of valuable growing space.

Conifers have recently dropped off in popularity in recent years in the U.K. in favor of more fashionable herbaceous, grasses, and bamboo. We do grow some of the more high-value conifers such as *Pinus*, *Cedrus*, *Abies*, and *Taxus*. Our method of propagation is a very traditional side graft onto a pot-grown stock during February to March and placed under a polythene tent within a cold glasshouse. Successful grafts are planted out into the open ground during June and remain there for 2 years, transplanted into containers and sold in or planted out for an additional 2 years.

Stock Plants. We have planted stock plants for all the subjects we are growing; they act as a valuable source of material for grafting and as trial grounds for the plants we are growing.Showing customers semi-mature plants is a great way to educate and to give them confidence to buy. We have planted conifers through woven plastic matting to act as a mulch on our very sandy soil and to suppress weeds so reducing the need for spraying herbicide. Great care is taken over our stock plants with pruning and feeding. During spring they are as important as our saleable crop. Without our stock plants in good condition the whole business will suffer over a period of time.

GENERAL NURSERY OPERATIONS

Our stock is moved around our site with compact tractors. We have an automatic irrigation system using a mixture of drip irrigation and overhead sprinkler system. Generally we have our main program come on about 3 AM and a secondary program will top tip about 5 PM in the early evening. Although when the weather is very hot we find ourselves putting on the drip irrigation three times a day. Working on the theory of a little and often. If we give them just one long blast of water then we find the water just runs out of the bottom of the pot and is wasted. Staff personnel include a mixture of full-time college-educated nursery people, students, part-time labor, and press-ganged family.

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Dunn, N.D. 1995 The use of hot callusing for bench grafting. Comb. Proc. Intl. Plant Prop. Soc. 45:139.

Control of Botrytis During Plant Propagation

Walter Mahaffee
Horticulture Crops Research Laboratory, 3420 NW Orchard Avenue, Corvallis, Oregon 97330

INTRODUCTION

Diseases caused by species of *Botrytis* (Table 1) are probably the most frequent and widely distributed diseases of nursery plants, with *B. cinerea* being the most common. Symptoms of *Botrytis* diseases generally appear as blights or rots of various plant tissues. Under humid conditions the characteristic gray cottony sporulating mycelia appears, thus the common name of gray mold. In addition, symptoms can consist of leaf spots and cankers. Diseases caused by *B. cinerea*. are also some of the most difficult diseases to control due to the pathogen's prolific asexual reproduction, ability to survive as a saprophyte, and the continuos susceptibility of plants to infection.

PATHOGEN BIOLOGY

Botrytis spp. have an extremely complex life cycle (Fig. 1) that involves sexual and asexual reproduction, and the abilities to survive indefinitely as a saprophyte on organic material, to remain latent on infected plants, and sporulate at any point in its life cycle. In addition, *Botrytis* spp. are extremely genetically variable due to multinucleate hyphae and spores, the heterokaryotic (both male and female) nature of some strains, and sexual recombination. However, *Botrytis* spp. tend to be weak pathogens, usually requiring an exogenous nutrient source (e.g., insect frass, senescent tissue, wounds, etc.) or a compromised host for successful infection.

Dispersal is mainly through the dissemination of airborne conidia from sporulating mycelia. Dispersal can also occur through ascospores, dispersion of infected debris, insects, and mechanical transmission. Conidia are released during rapid changes in relative humidity accompanied by air movement or water splashing. Generally, peak spore release is associated with activity in the greenhouse (e.g., watering plants, moving plants, leaf removal, etc.). Once released, conidia land on plant tissues where they can remain dormant or germinate if conditions are favorable. They require RH > 93% or free water and an exogenous nutrient source to germinate. Germination can occur between 32 and 79°F, with an optimum of 68°F for *B. cinerea*. Infection and disease development can occur at 32 to 95°F.

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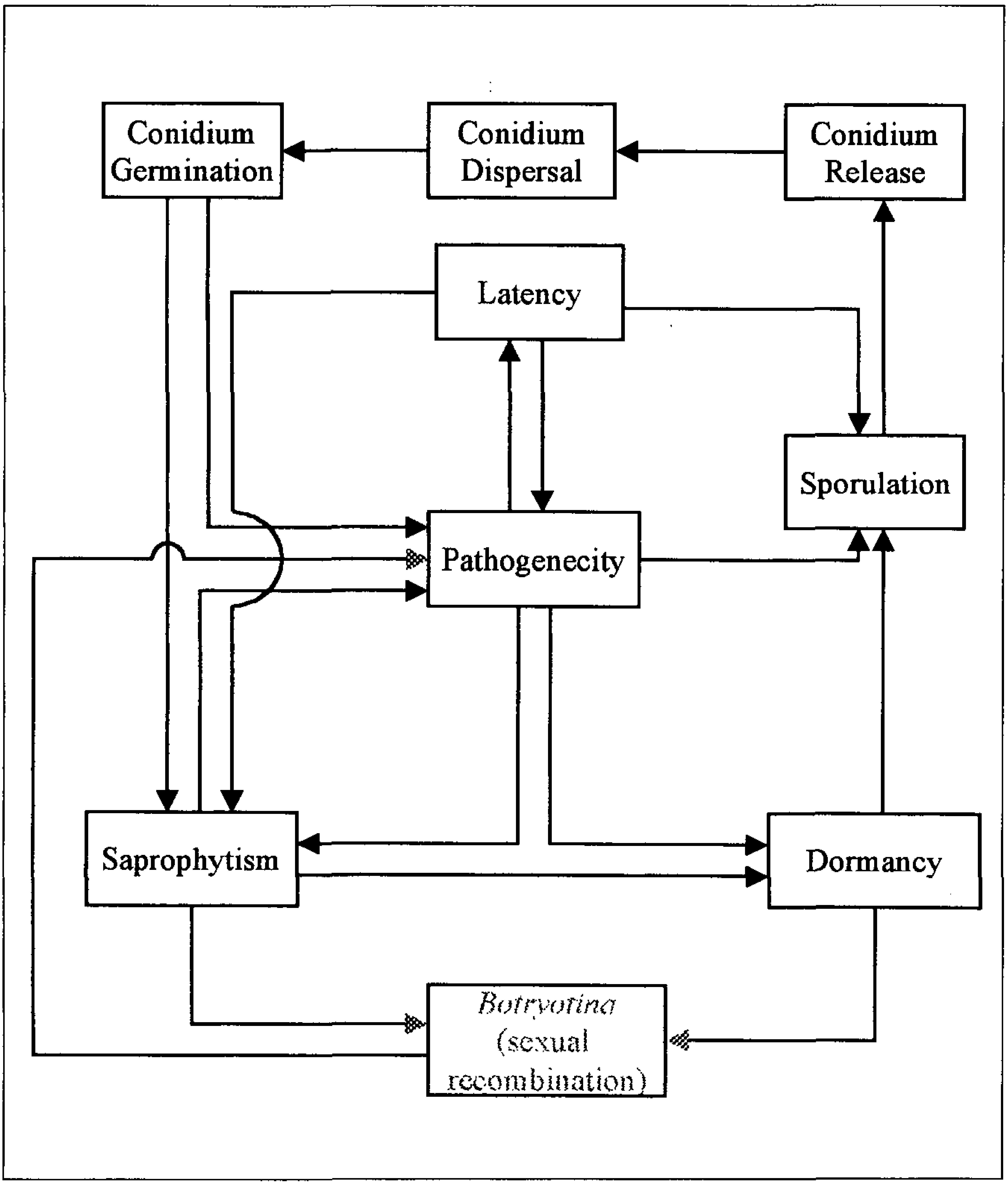

Figure 1. The life cycle of *Botrytis* species. The principle means of *Botrytis* survival and dissemination is in bold. The conidium is an asexual spore. Saprophytism is the growth and survival on dead organic material. Pathogenecity is when *Botrytis* has infected plant tissue but symptoms may or may not be visible. Latency is a state where the pathogen is either no longer actively growing in the infected plant tissue or there no symptoms expressed.

At any time during the infection process *Botrytis* can enter a state of latency where the pathogen no longer grows. The cause of latency is not understood but is thought to be associated with plant susceptibility or changes in environmental conditions.

PREDISPOSITION

Numerous factors can predispose plants to infection by *Botrytis* (Table 2), the most important being senescent tissue and wounds. Nutrients that become available on

Table 1. Species of *Botrytis* and major host plants[1].

Botrytis species	Hosts
B. allii, B. sphaerosperma	*Allium* spp.
B. anthophila, B. spermophila	*Trifolium* (clovers)
B. cinerea	most dicotyledons, many monocotyledons, and some Pteridophyta
B. elliptica	Lily
B. fabae	Leguminosae
B. tulipae	Tulips
B. narcissicola, B. polyblastis	Narcissus
B. paeoniae	Peony
B. gladiolorum	Gladiolus
B. convoluta	Iris

[1]Host range of individual *Botrytis* species is not always exclusive of other taxa.

Table 2. Factors that predispose plants to infection by *Botrytis*.

Plant fertility
Low calcium, phosphorus, or potassium increases susceptibility
Ammonium nitrogen increases susceptibility compared to nitrate nitrogen
Keep fertility in balance so plant sugars stay in balance (<50% total carbohydrates) to dry weight

Nutrients on leaves
Pollen, insect frass, other organic compounds

Fungicide applications
Zineb increases sugar exudation and stimulates mycelial growth

Leaf damage
Insect feeding, mechanical, chemical or salt/fertilizer burn,

Wounds

Water stress (either too much or too little)

Low light

Senescent tissue

Temperature (cold or heat) injury

senescent tissue and wounds stimulate germination of *Botrytis* and serve as an energy reservoir to infect healthy tissue. Thus, measures that reduce the presence of senescent tissue and wounds greatly reduce *Botrytis* infections. Fertility management is another critical factor that can predispose plants to infection by *Botrytis*. Plants need a balanced fertility program such that nutrients are neither in excess or deficient. Nutrients of particular concern are N, P, K, Mg, and Ca.

CONTROL MEASURES

No one control measure is going to give effective control of *Botrytis* diseases during plant propagation. Control will be dependent on the integration of cultural methods, pesticide (biological or chemical agents) applications, and environment control into a holistic management system so that many pathways of the life cycle are disrupted. An example system is presented in Table 3.

Cultural Control. Cultural control of *Botrytis* is mainly through sanitation and the manipulation of environmental parameters. Use of resistance varieties, fertility management, keeping mother plant's architecture open, placing a physical barrier (e.g., a white plastic disk) on the soil surface to prevent leaf contact, are also useful cultural control measures.

Sanitation consists of roguing infected and senescing plant tissue and removing plant debris from on and under benches. Rogued material should be disposed of immediately into covered containers. This material should then be burned or moved off site. Do not have cull piles near air intakes or doors for the greenhouse. The use of clean propagation media and source material are also part of the process.

Preventing latent infections in mother plants and plants placed in cold storage should be a major focus during their production. All of these sanitation practices attempt to reduce the *Botrytis* spore load in the greenhouse, and thus reduce chances for infection.

Environmental parameters can be manipulated in order to reduce the ability of those *Botrytis* spores that do land on susceptible tissue to infect. The relative humidity, temperature, and light can be manipulated to make the greenhouse environment less favorable for *Botrytis* infections.

Relative humidity within the plant canopy should be maintained below 90%. This can be accomplished through plant arrangement (adequate spacing and orient rows parallel to air currents), ventilation, heating of the house at critical times (sunset), avoiding overhead irrigation or irrigating at times when free water on leaves does not dry quickly, and maintaining good air circulation. Air circulation is used to reduce humidity in the canopy and homogenize air temperature within the greenhouse. Care must be taken to ensure that the leaf flutter is minimized so that mechanical damage to leaves does not occur.

Temperature should be adjusted to optimize growth of the plants without respect to what temperature is favorable to *Botrytis*. Temperature fluctuations should be avoided and the night time cooling should be minimized to reduce the probability of dew forming on leaves or increasing humidity. An alternative to raising the temperature at night would be to increase other measures to reduce humidity (i.e., ventilate and heat for a few hours at sunset).

Light intensity and wavelength can be manipulated in order to reduce infection of *Botrytis* either directly or indirectly. Greenhouse covers that block ultraviolet light

Table 3. An example of an integrated *Botrytis* management system for mother plants and cuttings.

Mother Plants
General
Keep humidity below 90% and foliage dry
Force air heating under bench
Drip irrigation
Air circulation
Space between plant
Open plant architecture
Vent and heat house around sunset
Harvesting
Rogue infested material 24 h before harvest
Take cuttings in the morning before house heats up and humidity drops
After Harvesting
Reduce humidity to < 60% for 24 h
Apply a control measure immediately after completed harvesting
Maintain optimum fertility
Plastic shield covering soil in pots
Rogue diseased and senescent tissue
Control insects
Cuttings
Steam clean propagation bench and any area cuttings will be handled
Allow cuttings to dry before placing under mist
If cutting will survive, heat treat by dipping into 122°F water for 20 to 40 sec.
Daily rogue infected cuttings
Treat with control measure immediately after harvesting or sticking.
Keep cuttings from different days or hosts with different susceptibilities separate

enhance the blue/UV ratio that inhibits sporulation by *Botrytis*. While this effect can result in an 80% reduction in sporulation, there is a high degree of variability among *Botrytis* isolates. A more practical approach is the use of long-wave infrared absorbing coverings which help to hold heat inside the greenhouse during the night, thus reducing changes in relative humidity.

Chemical Control. There are numerous fungicides available for application to ornamental and nursery crops, however, resistant *Botrytis* populations have also been developed (Table 4). Chances are that if you have been using a compound for several years without rotation resistance has developed and you should choose a compound from a different fungicide class.

Effective use of chemical pesticides depends on the thorough coverage of plant tissue, particularly within the plant canopy. These tissues are probably more susceptible to infection due to the presence of debris of the leaf surface and senescing tissue. In order to manage resistance development, it is extremely important to use mixtures (preferable) or rotate with different classes of chemicals. Some pesticides on the market are ready mixes of two different fungicide classes (e.g., Benefit, Duosan). Alternating or mixing chemicals when you have a population that is resistant to one of the compounds does little to reduce resistance build-up, since you will be selecting for a population that is resistant to both compounds. Once resistance to a compound is present, there is little utility in continuing to employ that compound in your management program. There are some laboratories that will test *Botrytis* isolates for resistance to pesticides (e.g., Plant Disease Clinic, Oregon State University).

Biological Control. The use of biological control agents in the production of ornamental and nursery crops is gaining strong interest due to improved efficacy and reduced re-entry intervals (usually < 4 h). However, the effective utilization of

Table 4. Fungicides[1] labeled for use against diseases caused by *Botrytis* on ornamental and nursery crops in the United States[2].

Class	Common	Trade Name Examples	Resistance
Aromatic hydrocarbons	DCNA or Dichloran	Botran	No
Chloronitrile	Chlorothalonil	Daconil, Exotherm Termil	No
Benzimidazole	Benomyl, Thiophanate-methyl	Benlate, Cleary's 3336, TopsinM	Yes
Dicarboximide	Iprodione, Vinclozolin	Curalan, Chipco Ornalin, Touche	Yes
EDBC's ethylenebis-dithiocarbamates	Mancozeb Maneb	Dithane, Manzate 200, Maneb	No
EBDC-like	Ferbam, Thiram, Ziram	Ferbam, Thiram, Granuflo	No
Fatty Acids	N-alkyl fatty acids	Physan, Triathlon	No
Hydroxyanilide	Fenhexamid	Decree	Yes
Inorganic compounds	Copper hydroxide	Kocide, Champion,	No
	Copper Sulfate	Phyton	No
	Sulfur	Sulfur, Mylox	No
	Sodium bicarbonate	Armicarb	No
Oils	Petrolium distillate	JMS Stylet Oil	No
Phenylpyrroles	Fudioxonil	Medallion	No
Phthalimides	Captan	Captan	Yes
Other	PCNB	Terraclor, TurfPro	No

[1] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of the products or vendors that may also be suitable.

[2] Legal uses of many pesticide are constantly changing, therefore always obtain and read a current table prior to using a product.

Table 5: Biological control agents for *Botrytis* registered by the U.S. Environmental Protection Agency for application to ornamentals in the United States.

Common Name	Organism and Strain	Target	Use	Company
Mycostop	*Streptomyces griseoviridis* strain K61	*Fusarium* spp., *Alternaria brassicola*, *Phomopsis* spp., *Botrytis* spp., *Pythium* spp., and *Phytophthora* spp.	Can be applied as seed treatment, transplant or cutting dip, and soil spray or drench.	AgBio Development Inc. Westminster, CO Tel: 303-469-9221 Fax: 303-469-9598
Prestop	Gliocladium catenulatum strain J1446	*Alternaria*, *Botrytis*, *Cladosporium*, *Didymella*, *Fusarium*, *Helminthosporium*, *Pencillium*, *Plicaria*. *Pythium*, *Phytophthora*, *Rhizoctonia*, and *Verticillium*.	Can be applied as seed treatment, transplant or cutting dip, and soil spray or drench.	AgBio Development Inc. Westminster, CO Tel: 303-469-9221 Fax: 303-469-9598
TopShield	*Tricoderma harzianum rifai* strain KRL-AG2	*Botrytis*	Foliar spray with a surfactant	BioWorks Geneva, NY Ph: (315) 781-1703 Fax: (315) 781-1793

[1]Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of the products or vendors that may also be suitable.

[2] http://www.bioworksbiocontrol.com

Table 6: Biological control agents for *Botrytis* that should be registered by the U.S. Environmental Protection Agency for application to ornamentals in the near future.

Common Name	Organism and Strain	Target	Use	Company
Serenade[1]	*Bacillus subtilis*	Botrytis, powdery mildews, downy mildews, *Alterneria* spp., Fire blight, *Xanthomonas* spp.	Foliar Spray	AgraQuest Davis, CA Ph: (530) 750-0150 Fax: (530) 750-0153 www.agraquest.com

[1]Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of the products or vendors that may also be suitable.

biological control agents does require special knowledge and a different mind set toward plant production.

Biological control is the suppression of disease through the manipulation or use of one or more organisms other than humans. The basic tenant of biological control is that a balance between the host plant and potential pathogens must be maintained such that the growth of the pathogen is not favored. This balance is dependent on the establishment and maintenance of a stable microbial community. One means of developing a beneficial microbial community is through the introduction of biological control agents. Currently, there are only two commercial products that are EPA-registered to control *Botrytis* on ornamental and nursery crops (Table 5). However, there are a few other products near registration (Table 6) and many more being developed.

Biological controls can control *Botrytis* by secreting antimicrobial compounds that inhibit or kill *Botrytis* mycelia or spores, competing for nutrients to prevent germination or growth, induce plant resistance, or directly parasitize and feed on *Botrytis* mycelia or sclerotia. Therefore, most biological control agents should be applied as protectants before symptom development. Resistance development to most biological control agents is generally not a concern, since most operate by multiple mechanisms. However, resistance might develop to biological control agents that mainly operate by production of antibiotics.

THE FUTURE

The control of plant diseases is entering a new era. We are no longer looking at each production problem as an isolated entity but are realizing that every management decision influences whether disease will develop and impacts which control measures should be implemented. We have begun to look beyond the short-term gains of the amount of marketable-product produced, to long-term sustainability and profitability. In essence, growers are becoming ecosystem managers. When using this approach, we must remain aware of the most basic concept of ecology. A stable ecosystem is a diverse ecosystem, where diversity implies that all components are interacting. Thus, when making disease management decisions, we must think in terms of integrating multiple measures to create a stable control system. This integration will include the implementation of appropriate cultural practices along with judicious use of chemical and biological controls. The effective management of *Botrytis* diseases requires such an approach.

FURTHER READING

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Mahaffee, W.F. Biological Control. (in press) In: R. Jones. and D.M. Benson. (eds.), Diseases of woody ornamentals in nurseries. APS Press, St. Paul.

The Process of Testing and Introducing a New Plant

Kathleen Echols
Midhill Farms, 197 Midhill Rd. Martinez, California 94553

When a new plant makes its entry into the world of retail nurseries, it comes with a fascinating history behind it. For many plants, their beginning started with the hybridization process. Some new plants, however, were chance seedlings that Mother Nature saw fit to bless a grower with, while others were sports that popped up in plants and were noticed and developed by their astute owners.

Hopefully, for most plants that are introduced into the nursery trade, there has been considerable time given to testing and trialing to determine the stability and uniformity of the plant. Failure to do so may lead to unhappy customers and sometimes embarrassment for the grower who developed it.

In the process of developing a new plant for the nursery trade, the hybridizer spends many years and sometimes a lifetime working on specific plants. She or he may make thousands of pollen crosses and save millions of seeds and grow and evaluate unfathomable numbers of plants before one may finally meet his expectations. As the hybridizer evaluates each seedling, she or he is looking for a variety of qualities which might include; color, size, or shape of leaves; flower color, shape, and perhaps fragrance; the habit of the plant, its vigor, and the overall impression that the plant gives. Some of the seedlings may meet most of the standards but fall short in one or more areas. If breeders set their standards high, and have been fair in their evaluations, they will continue to cross those plants until they get their ideal specimen. Once that has occurred, they will set about testing it in various situations.

Many hybridizers work with trialers all over the U.S.A. and Europe who are interested in the same genus. The criteria hybridizers look for are; various geographical areas, growers with various types of greenhouses, and associates with various degrees of nursery skills. It is usual to select trialers for their potential to be future producers. Some growers will use up to 17 various sites for testing. The hybridizer will usually have a formal agreement with the trialer specifying that the plant will not be propagated and that the tester will agree to dispose of the plant should the hybridizer decide that it doesn't warrant further development. Clonal material of the plant is then sent to these associates for them to test.

The new plants are tested in containers as well as in nursery beds. The reason for this is that many plants will show different characteristics when planted out into a variety of soils. One of the main reasons for sending plant material to various locations is to see how the plant will respond to these different soils and climates. Through the growing period, testers log information about the plant. Information such as disease and pest resistance, heat and humidity tolerance, and hardiness are very important to the hybridizers for their evaluations. Plants are tested for a minimum of 1 year and sometimes much longer.

Many seed companies will do their own trialing. They will then send seed they feel has merit to the All-America Selections (AAS) trials which are held at 47 trial grounds in 30 states and provinces in the U.S.A. and Canada. Each site has a judge who evaluates the plant on basis of color, disease resistance, insect and weather stress, prolonged flowering, uniformity, uniqueness, and fragrance. Judges submit their score sheets for tallying and each January the Board of Directors of the All

America Selections meets to determine the next year's winners. The winners are announced the following September.

Tissue culture is another process that is being used by some growers to help in their testing process. Plants that have merit are being sent to laboratories where they can be checked for viruses. It has been shown that viruses can affect the ability of the plant to be propagated as well as its performance in the garden. By cleaning up the plant material, more high-quality plants are becoming available.

Plants that develop as chance seedlings or sports should be treated similarly to hybridized plants and should be tested with as much diligence as possible. Growers sometimes get so excited in the discovery of a new plant that they forget to test for deviations within the new cultivar. With the thrill of having such a unique plant, the grower is often driven more by the desire to make money than the need to trial the plant. Plants thought to be dwarf sometimes end up full size and plants with unique flower color may revert back to their original parent color. Many plants that have been introduced into the trade, after a substantial period of time, are discovered to be rampant weeds. Plants, which run invasively, or reseed so badly that the gardener has trouble controlling them, give the growers a bad name. If they had been trialed adequately, these characteristics could have been discovered before the release of the plant.

With the current trend toward variegated plants, it is important in the testing process that the grower looks at the stability of the variegation. As many of the variegated plants come from sports on all-green plants, those sports will sometimes revert back to their parent type. Adequate time should be allowed to test these plants thoroughly.

Probably the hardest thing to do in the trialing process is to cull and destroy plants that are not quite good enough to be carried on in the propagation line. It is very difficult to throw out beautiful and sometimes great plants even though they don't meet the tough standards set for them. How many plants have become cultivars because the grower was unable to decide on which plant to save and which to cull? How many "cultivars" of one species are too many? With many plants being promiscuous in their reproduction, there are sometimes lots of seeds with which to experiment. It is up to the grower to decide on the very best. It is the grower's responsibility to throw out the mediocre ones and save only those that will best represent the species. The most reputable grower creates new plant introductions that are of high quality and are valuable assets to the garden for the long term.

Discussion Group: Practical Integrated Pest Management

Facilitator: Robin Rosetta
Department of Horticulture, Oregon State University, NWREC 97002

Approximately 65 members were involved in the two discussion sections. Many of the participants stayed through both sections. Topics of interest were solicited from the participants at the beginning of the first section and discussed according to the order below.

TOPICS:

- Mites and "softer"control methods.
- Symphylans.
- Powdery mildew prevention and control.
- General discussion on IPM.
- Leafroller control.
- Fire ant control and quarantine issues.

MITES

Situation: Grower was concerned about mite outbreaks and wanted to know if there were "softer" ways to control mites than some of the harsher chemicals available.

An inquiry was made to the room regarding any successes concerning mite management in greenhouses. Various responses were forthcoming including the use of moisture (spraying plants with water alone), use of predatory mites (several in the room had some experience and success using predatory mites), cutting off affected foliage, use of insecticidal soap (Safer's), keeping air flow and humidity up, scouting weekly to catch early mite populations, and use of abamectin (Avid).

Question: Is there a specific time of year when mites appear?

Response: Depended on geographic location and also amount of protection or heating of plants. Another factor to consider was which species of spider mites was a problem as their life cycles varied.

Question: What is the best way to get rid of mites on plants coming in?

Response: Quarantine and scout daily. Entire cutting is dipped.

Question: Can you use predatory mites to get control in a bedding plant operation (before shipping)?

Response: It was thought that the plant turnover time might be too short to achieve the desired effect. It was stated that it was critical to find out how the problem began and that could be achieved by a good scouting program, allowing for early detection and intervention as needed.

SYMPHYLANS

Situation: In field-grown shrubs, a grower suspected but was not sure if he really had symphylans and wanted some suggestions for control.

Many in the room were unfamiliar with symphylans or "symphs". A brief description of the minute centipede-like animal and discussion of the problem ensued. There was some variation as to whether symphylans were actually a problem, but several growers thought they had an effect and were best controlled. Methods of control discussed ranged from chemical control (fumigation, and drenches), to trap crops and solarization.

Question: What is solarization? Would solarization destroy beneficial microorganisms in the soil?

Response: Solarization was described (using the heat from the sun trapped by use of plastic covering to kill pest organisms, including insects, diseases, weeds, nematodes). Limitations of solarization were discussed: depth and range of organisms controlled, need to fallow, disposal of plastic. It was thought that nontarget organisms would be affected as well, similar to fumigants.

MILDEW

Situation: Grower wondered if anyone had ideas for control of powdery mildew.

Participants were asked to share their successes in mildew management. Responses were that several had success with application of water (water kills spores), increased air movement, baking soda and oil (this prompted a discussion of "homemade" sprays versus EPA-registered materials and compliance with the law), and using narrow-range oils (Sunspray). Only one grower had tried AQ10 (a biological control product that is a mycoparasite of powdery mildew).

Situation: A grower asked about mildew on rhododendrons. He described the symptoms (predominantly that the leaves turned yellow) and felt he'd seen evidence that it was wind blown. There was limited experience of this mildew by others in the room.

Question: Has anyone used oil on sedum?

Response: There was limited experience of this mildew by others in the room.

Question: Are there any people with ideas on soil nutrients affecting mildew?

Response: No direct response to this, but there was a brief discussion of the nature of a parasitic fungus like powdery mildew, the need for a host and how this might affect management of the disease.

GENERAL DISCUSSION ON IPM

Situation: Four or five are using the Internet for info on IPM. Concerns that it is very time consuming to research IPM. One grower expressed his opinion that Mid-Atlantic states have very poor county-based info available. Several growers feel like there is good support from chemical manufacturers in terms of information and support.

Situation: Several people mentioned that customer intolerance for any insects on the plants they purchase make it very difficult for nursery people to implement IPM programs.

Question: Does anyone have good information on IPM of mealybugs and aphids?

Response: Participants described success using IGRs (insect growth regulators) in the winter, at least once a month for aphid and thrips control, and using repellents, especially neem. Again, scouting was brought up due to the propensity of these insects to increase rapidly.

LEAFROLLERS

Question: Are there any good books on identification of leafrollers?

Response: Suggestions to check Idaho Master Gardener information. Check entomology information on the web. Don't be afraid to go internationally. There is a great French website for identification.

FIRE ANTS

Question: Do native ants kill fire ants?

Response: There was limited experience in the room regarding IPM and control of fire ants. It was mentioned that the exotic fire ant did seem to successfully displace the native fire ants.

Discussion Group: Seeds and Seedlings

Facilitator: David Woodske
British Columbia Ministry of Agriculture & Food, 1767 Angus Campbell Road, Abbotsford, BC, Canada, V3G 2M3

During the two discussion groups on seeds and seedlings a diverse range of topics were discussed. The major topics discussed are presented below.

1) How to Control Liverwort, Moss, and Algae in Containers.

The majority of the discussion referred specifically to liverwort. A wide range of methods were suggested, including several cultural approaches, such as applying a thin layer (¼ inch) of pumice or chicken grit (#2 or #8 size) on the surface of the medium, managing irrigation frequency, and copper-infused weed discs. However, the majority of control approaches mentioned were chemical. Chemical methods included 50% vinegar solution applied on a sunny day, liquid iron sulfate (caution: can be phytotoxic, especially with *Erica vagans* 'Mrs. D.F. Maxwell') or granular iron, Zerotol (preventive), Moss Out, Dawn Ultra dishwashing detergent at 1 oz per 32 oz of water when applied on a sunny day and not washed off, constant injection of 3 ppm of copper chelate into the irrigation system inhibits growth, and

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Facilitator: David Woodske
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During the two discussion groups on seeds and seedlings a diverse range of topics were discussed. The major topics discussed are presented below.

1) How to Control Liverwort, Moss, and Algae in Containers.

The majority of the discussion referred specifically to liverwort. A wide range of methods were suggested, including several cultural approaches, such as applying a thin layer (¼ inch) of pumice or chicken grit (#2 or #8 size) on the surface of the medium, managing irrigation frequency, and copper-infused weed discs. However, the majority of control approaches mentioned were chemical. Chemical methods included 50% vinegar solution applied on a sunny day, liquid iron sulfate (caution: can be phytotoxic, especially with *Erica vagans* 'Mrs. D.F. Maxwell') or granular iron, Zerotol (preventive), Moss Out, Dawn Ultra dishwashing detergent at 1 oz per 32 oz of water when applied on a sunny day and not washed off, constant injection of 3 ppm of copper chelate into the irrigation system inhibits growth, and

Cinnamite works well in the summer (e.g., June, July, and August) when applied at a rate of 1.5 to 2.0 oz gal^{-1} but it has a short shelf life once opened. Of all the products discussed, Mogeton was most frequently mentioned as the best eradicant. It provides about 3 weeks of control. Mogeton is a Japanese product that has been used for many years in Europe. It is not registered in North America, but the company is currently evaluating the returns associated with registering the product in North America.

2) Seed Germination.

Stratification Requirements. The location where the seed is collected can give an indication of the stratification treatment required. In general, seed collected at high elevations require a cold stratification treatment, whereas seed from low elevation sites and subtropical areas require warm stratification.

Leaching seeds to remove water soluble germination inhibitors can be performed by placing the seeds in a nylon stocking and hanging it in the toilet tank. This way the seeds are flushed with fresh water every time the toilet is flushed. Seeds are left in the tank for 2 weeks. Seed leaching is used for seed of *Prunus* spp., *Mahonia aquifolium, Elaeagnus* spp., and *Magnolia* spp. to improve the uniformity of seed germination.

***Nandina* spp.** It can take at least 2 years to get a crop to germinate. Cold treatments do not work. Seed quality and maturity is a major reason for growers' poor results.

Romneya coulteri. The biggest problem is poor seed viability. Test viability before treating seeds to encourage germination.

***Eucalyptus* spp.** Seeds are large and have a short life. They are best stored at low temperatures and low RH. They require a cold stratification pretreatment to promote germination.

Mahonia aquifolium. Collect the seed in August when they are purple in color. Clean the seed by mashing in buckets of water, then dry and plant in September. Another way to clean the seed is with a food processor. Use the dough blade or cover the sharp blades with rubber tubing. The pulp and dead seeds will float and therefore can be removed by applying a slow trickle of water to the container. There is an oily film on the seeds that can cause healthy seeds to float, and thereby can be lost when the water is decanted. The cleaned seeds are planted in September.

Legume Seeds. It is important to collect seed from plants in the legume family before they develop a hard seed coat and plant the seed immediately without allowing them to dry. For some seeds with a hard seed coat, such as *Robinia pseudoacacia* and *Cercis* spp., it is best to put the seed in hot water in an insulated container until they expand. Another option is to scarify the seed in sulfuric acid.

3) Seed Storage. Store seed in a humidity and temperature controlled room (e.g., 21°C and 25% RH), which will cause the seed to dry down to 4.5% moisture. Seed can also be dried and stored in silica gel, but they must be sealed in a polyethylene bag to prevent moisture uptake from the air. A grower in southern California stores seed in a house constructed of straw bales that is sealed with plaster and that has no climate control. The structure just moderates the daily temperature fluctuations.

Excessive moisture in this type of facility can lead to seed rot. A final system mentioned was sealing dried seeds in a polyethylene bag and freezing at -3 to -4°C.

4) Mycorrhizal Inoculants. Inoculating seed trays with mycorrhizae can increase the germination and growth of cuttings of native plants. Mycorrhizae show some specificity to the type of plant they will infect. Mycorrhizae can be on seed collected in the wild (e.g., oaks) and thereby naturally inoculate the growing media during the germination period. There is no benefit from using mycorrhizae inoculants on transplants that are going into soil with good biological activity (i.e., not sterilized with methyl bromide). After treatment with methyl bromide, it can be beneficial to treat soil with mycorrhizae. For *Betula papyrifera*, mixing humus collected from underneath a stand of trees into the potting media increased plant growth by 30%. The loss of beneficial microbes from fumigated soils was suggested to be the cause of severe replant losses in some crops. This can be overcome by adding nontreated soil to the site to re-establish the population of soil microbes. Typically, disease-causing organisms are first to re-colonize soil after being fumigated.

5) Mice Control. What control options, other than poison baits, are available to deal with mice problems in the greenhouse? One option is to make the habitat around the greenhouse less attractive to mice. Mice do not like crossing areas where they are exposed, therefore frequent cultivation or mowing and the application of a groundcover apron around the greenhouse can retard mice from entering the structure. Cats and/or live traps were also suggested, although it was noted that small mice can get out of some live traps.

Discussion Group: Budding and Grafting Made Better

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The following is a summary of the questions, answers, and general commentary from the two "Budding and Grafting Made Better" discussion sessions at the I.P.P.S. Western Region meeting on 14 Oct. 1999.

A walnut grower from California reported that the cold spring weather adversely affected their field-grafted walnuts so that graft survival could not be determined until May. This was unacceptable and he asked if anyone in the group had tried using a pipe to provide heat to the graft union in a field setting so that the rootstock could remain in the ground. No one in the group had knowledge of this being done in the field.

Mr. Frank Byles, a grower of Japanese and related maples in Olympia, Washington, described a pipe and shelf system that he developed for hot callusing the graft unions of containerized *Acer palmatum*. Mr. Byles reported observing more than eight hot-callus operations before designing his system. None of the systems he studied were alike, they varied by factors like: (1) provision of heat by different configurations of electrical heating cables or hot water systems; (2) type and size of pipe used; and (3) space utilization of ground and or shelf systems. He found that every hot-pipe-callus system was different and that the designs were

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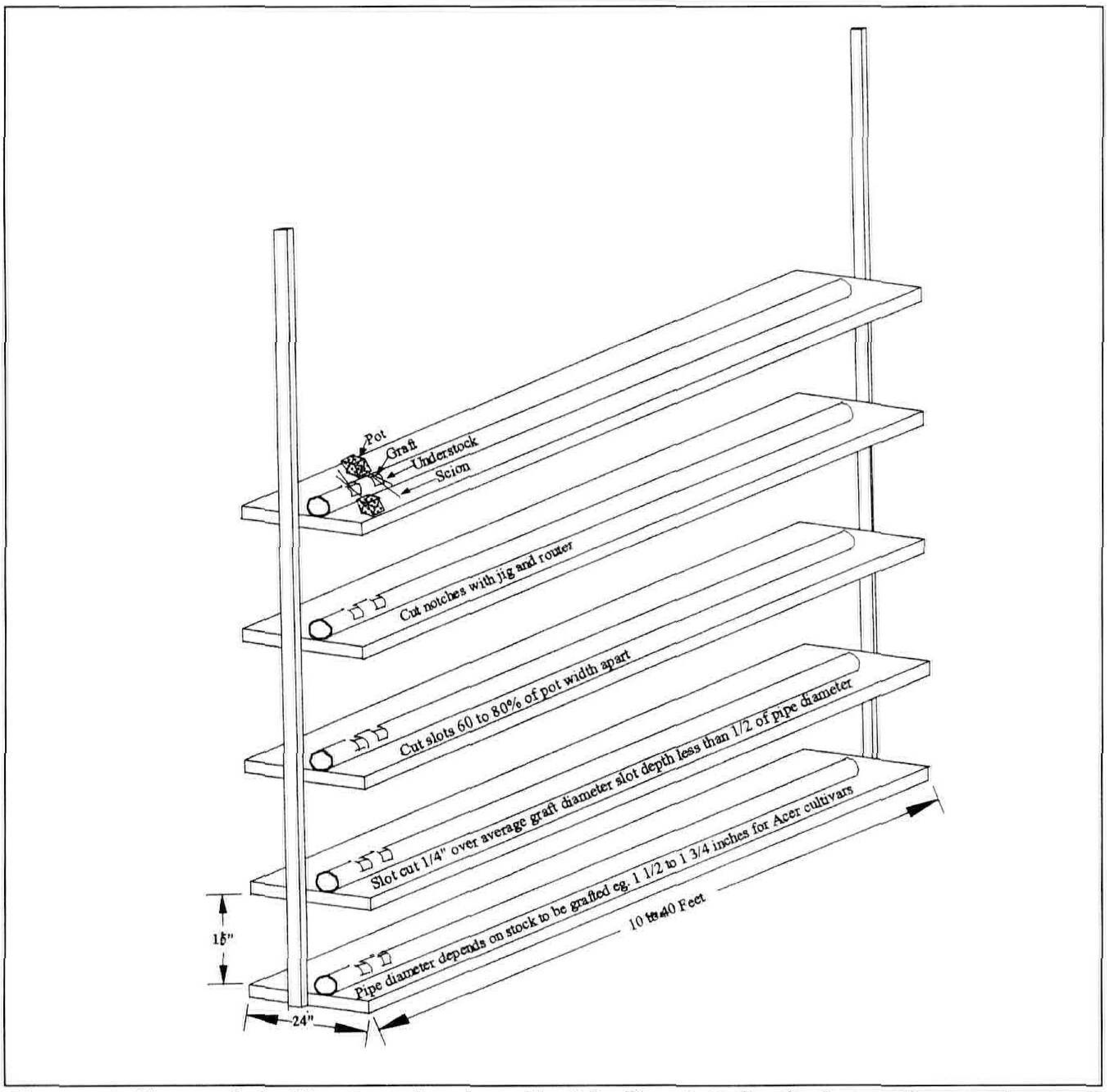

Figure 1. Pipe and shelf system developed by Mr. Frank Byles for hot-callusing the graft unions of containerized maples. The bottom shelf rests on the ground and the upright attaches to the roof. All dimensions of the system can be varied to suit the needs of the grower and/or the crop.

determined by the grower's available resources and the crop being produced. (Please refer to the articles by Dunn (1995) or Lagerstedt (1981) for detailed information on hot callusing.)

Mr. Byles veneer (side) grafts dormant scion using budding tape or budding bands on dormant rootstock grown in 2⅞-inch (7.3-cm) or 4-inch (10.2-cm) containers. The container is laid on its side on a shelf with the top of the plant horizontal and oriented so that the graft union is placed in a notch made in a thermostatically controlled 1½-inch (3.8-cm) PVC pipe. The roots and top portion of the scion are left cold while the graft union is heated between 68 and 72°F (20 and 22°C). A sponge plug placed in the notch insulates the graft union from the cold air. A diagram of Mr. Byles system for hot callusing maple grafts is shown in Fig. 1. The PVC pipe runs down the center of a 2-ft-wide shelf. Heat is delivered to the graft union by attaching a calibrated electrical heating cable to the bottom of the outside of the PVC pipe. The cable runs the length of the pipe and is enclosed with the pipe inside pipe insulation. Notches to accommodate the graft union are cut in both the pipe and the insulation. Mr. Byles believes that a better alternative to heat the graft unions may be to pump 68 to 72°F water through seven spaghetti (drip) tubes laid on the bottom of the inside of the notched pipe. A water source and return at both ends of the pipe would allow water to be pumped through three tubes from one end and through the other four tubes from the other end in a closed (self-contained) water system. This would prove satisfactory to equilibrate the temperature throughout the length of the pipe. Another system that also appears to work is to lay a hot-water pipe in sawdust on the ground outdoors and place graft unions on top of the pipe then lightly cover everything with a layer of sawdust. According to Mr. Byles there is no "one" right or perfect method for delivering heat to the graft union but improved success seemed to be coming from all methods he observed.

Mr. Byles indicated that he produces 3000 to 4000 trees per year on his system of five 20-ft shelves which has a maximum capacity of 645 plants per loading. The graft unions must be monitored during use because it can take up to 22 days in December and as few as 10 days in March to callus maple grafts. Mr. Byles hot-callus system is very energy efficient and produces winter grafting results that are comparable or better than in a heated greenhouse at a much lower cost.

A discussion of the materials used to tie-in buds ensued. A grower of filberts in Oregon indicated that he used black electric tape with better success than budding bands because the tape helped to heat the bud union. The tape is put on tightly but must be removed so that it does not girdle the stem. A California grower reported using white latex paint to keep the union of scion and rootstock cool. A large Oregon nursery reported that flagging tape (also called surveyors tape) was inexpensive, would stretch and worked well for them. They use 500 to 600 rolls per year and believe that the color blue gives the best results. The flagging tape is easily tied off by looping through itself and cinching-up. It must be cut off to prevent girdling, but is reported to come off easily.

Some growers reported timing their budding with the phases of the moon. In Oregon, budding during the new moon has been successful, while in California, walnuts have been successfully budded during the dark of the moon. Another participant considered timing of budding to the phases of the moon to be superstition. Growers from California and Israel cautioned against budding when the plant is wet. Growers from Oregon indicated weather conditions often did not give them a choice.

Placement of the bud was discussed. In Oregon, a large grower places the bud on the southwest face of the tree toward the prevailing wind and rain. This keeps the bud clean and works for all but those varieties that have poor take when the bud gets too hot. In those varieties, the bud is placed on the north side of the stem. In Modesto, California, sunburn can damage buds placed on the south side of the tree.

One of the participants asked if there was any chemical treatment that could be applied to a graft union to promote cambial tissue growth and callusing. None of the participants in either session knew of a treatment that could be successfully used for such a purpose.

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What More Can Tissue Culture Do for Us?

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For nearly 30 years plant propagators and growers around the world have utilized the benefits of plant micropropagation. Indeed, some of these nursery people even have developed their own tissue-culture laboratories to mass produce choice selections for their own nursery, while others have decided to work with independent micropropagation labs. Many areas of horticulture have benefited from this technology.

This paper is not intended to be a review of plant micropropagation. Rather, it is an examination of the relatively unexploited benefits plant tissue culture may provide our plant growing industry. In the following text we will examine two areas:

1) Producing and maintaining high health plants.
2) Producing, screening, and preserving beneficial variation.

PRODUCING AND MAINTAINING HIGH HEALTH PLANTS

A number of pathogenic disease organisms may be found systemically in plants. They may be slightly or severely debilitating to the plant. These pathogens may include: bacteria, phytoplasma, and viruses.

There are systemic bacteria that can be quite toxic to plants. Reuther (1988) used meristem culture to successfully free *Pelargonium* free of systemic *Xanthomonas* bacteria. A scheme for screening and maintaining *Pelargonium* free of this bacteria was also developed.

Citrus with a phytoplasma (mycoplasma) infection were freed using meristem apex grafting as reported by Murashige (1972). This technology might be useful in freeing many selections of *Syringa* from the ash yellows phytoplasma.

The list of plant pathogenic viruses is quite long. Several herbaceous and woody ornamental plants have been shown to be affected by this group of pathogens. Morel was one of the first researchers to use plant tissue culture techniques to rid certain orchids of virus. This landmark work was then used to develop micropropagation protocols for *Cymbidium* orchids. Although meristems may not always be free of virus, the isolation and culture of meristems has proven to be a time-tested method to help rid plants of select viruses. By combining meristem culture with heat therapy or possibly chemotherapy, a greater degree of success may be achieved for freeing the select plant of virus. Using heat therapy, meristematic tissue or shoot cultures may be grown in an environment of elevated temperatures to free shoot tissue of virus. Plant cultures may be grown in an environment that is gradually exposed to elevated temperatures, up to a maximum of nearly 42°C. A wide variety of ornamental and small fruit plants have been freed of virus using meristem culture including: *Daphne*, *Fragaria*, orchids, *Rubus*, *Vaccinium*, *Dendranthema* (syn.*Chrysanthemum*), *Dianthus*, and *Petunia*.

PRODUCING, SCREENING, AND PRESERVING BENEFICIAL VARIATION

There are several fascinating and useful tissue-culture methods to induce or capture beneficial variation. They include:

1) *Somaclonal variation;*

2) Gene insertion technologies;
3) Use of plant mutagens;
4) Embryo culture;
5) Production of polyploid plants.

Somaclonal Variation. Somaclonal variation is clonal variation produced using any tissue-culture method (i.e., callus, shoot, embryo, or protoplast culture). There are several spectacular ornamental plants that are somaclones. Many choice *Hosta* selections that are now commercially available are somaclonal variants. *Daphne* 'Briggs Moonlight' is a highly variegated woody plant somaclone that I selected several years ago. This showy plant is a somaclonal variant that first appeared in a solitary shoot culture of *Daphne ×burkwoodii* 'Somerset'. A number of factors affect the occurrence and degree of somaclonal variation. They include:

1) Type of tissue used to initiate cultures;
2) In vitro method of propagation;
3) Type of growth regulator used and its concentration;
4) Number of subcultures or length of time in culture;
5) Genetic stability of the stock plant.

1) *Type of Tissue Used to Initiate Cultures.* Meristematic tissue is generally much more genetically stable and homogeneous than nonmeristematic tissue. Nonmeristematic explants that have been used by researchers to initiate cultures include: callus, protoplasts, floral parts, leaves, and stems without vegetative buds. Shoots produced adventitiously from these initially nonmeristematic explant tissues are likely to be variants from the original source genotype.

2) *In Vitro Method of Propagation.* As mentioned previously, adventitious shoot production may induce a greater frequency of somaclonal variation. Using an in vitro propagation method that encourages the production of adventitious shoots will ultimately cause a greater percentage of somaclones. This is especially true with shoots that arise from callus tissue or basal stem callus in shoot cultures. Shoot cultures and nodal stem culture are the most reliable micropropagation methods of preserving the genetic integrity of a select genotype.

3) *Type of Growth Regulator Used and its Concentration.* The use of plant growth regulators may lead to a greater percentage of somaclonal variants. Auxins, such as 2,4-dichorophenoxyacetic acid (2,4-D), are often added to cultures to maintain and enhance growth of callus or suspension cultures. As a rule, the use of powerful auxins such as: 2,4-D, 4-amino-3,5,6-trichloropicolinic acid (picloram), and 4-chlorophenoxyacetic acid (4-CPA) will cause greater somaclonal variation than using auxins such as: 3-indole-acetic acid (IAA) and 3-indolebutanoic (indolebutyric) acid (IBA).

Cytokinins enhance the frequency of cell division in vitro and as a consequence may encourage somaclonal variation. The use of potent cytokinins at high concentrations can lead to accelerated rates of adventitious bud formation.

4) *Number of Subcultures or Length of Time in Culture.* The longer cultures are kept actively growing and subcultured inside the tissue-culture lab, the greater the possibility variation will occur within those cultures. This is especially true when culturing nonmeristematic tissues, such as callus or suspension cultures. Frequent reinitiation from select stock plants will often minimize variation.

5) ***Genetic Stability of the Stock Plant.*** The genetic stability of the stock plant has a profound influence on the potential for somaclonal variants to be formed. Some mother plants may be inherently less genetically stable than others and as a consequence much more likely to produce variants. In addition, if the mother stock is chimeral in nature, the likelihood of off-types formed due to rearrangement of the chimera is very probable.

Gene Insertion Technologies. It is not the intent of this paper to examine this subject in depth. However, the use of various delivery systems to insert genes has made it possible to increase the genetic variation of select plants using foreign genes. We have seen the development of plants with enhanced color, longevity, herbicide tolerance, and disease and pest resistance. Many challenges still exist in this area, not the least will be the political and social acceptance of genetically modified organisms (GMO) developed from these technologies. This is a very controversial issue outside the United States especially with regards to genetically engineered food, fiber, and forestry crops. Many countries will not allow imports or growing of GMO within their borders. It will be interesting to see if this will be less of an issue with genetically modified ornamental plants produced from these technologies.

Use of Plant Mutagens. The very controlled and stable nature of the in vitro environment allows for easy exposure of plant tissue to mutagens. Generally, these cultures have rapidly growing tissue that is very receptive to a variety of mutagens. The large population that can be exposed in a small space increases the likelihood that the treatment will be a success. Mutagens can be either physical or chemical in nature. Handro (1981) mentions that physical mutagens can be either electromagnetic or particle radiation in nature. Chemical mutagens are very capable of inducing variation when used with in vitro cultures. Due to their nature, chemical mutagens are very potent materials, with many being carcinogenic, and must be handled appropriately.

Embryo Culture. The culturing of embryos using the embryo rescue technique has not been used with many woody or herbaceous ornamental crops. Embryo rescue is a technique developed to save genetic variation developed from crossing of relatively unrelated plants. In wide crosses, such as between two genera, the embryos often do not develop due to post zygotic incompatibility. In this case, the zygote is produced, but not accepted by the endosperm. As a consequence, the embryo not receiving adequate nutrients, aborts or withers. Using embryo rescue the percentage of success is usually quite low. But it certainly can be a method to preserve desirable and valuable variation produced by the plant breeder.

Production of Polyploid Plants. A simple definition of a polyploid is a cell that carries more than two sets of chromosomes in its nucleus. Most plants carry two sets of chromosomes in their nucleus. For example, the China rose (*Rosa chinensis*) has two sets of seven chromosomes, or a total of 14 in every somatic cell. Like *R. chinensis*, many plants contain two sets of chromosomes and are considered to be diploid (for two sets). The number of sets of chromosomes can be increased using an appropriate agent and increases to three sets (triploid), four sets (tetraploid), six sets (hexaploid), and eight sets (octoploid) are not uncommon.

In general, compared to their diploid counterparts, polyploid plants have:

- Foliage that is thicker, wider and generally deeper in color.
- Stems that are thicker and more stout.
- Flowers that are larger, but not twice as large. Petals increase in width greater than in length. Blossoms have greater substance due to thicker petals. Color changes in the petals can be slight or dramatic.
- Fruit size may or may not be significantly larger in size.
- Polyploidy can have a profound effect on plant sterility. Treatment of sterile diploids often yield extremely fertile tetraploids. And conversely, treatment of fertile diploids often result in sterile tetraploids.

Polyploidy can be induced in vitro using a variety of antimitotic agents, including: colchicine (Blakeslee and Avery, 1937) and oryzalin or 3,5-dinitro-N4,N4-dipropylsulfanilamide. Goldy and Lyrene (1984) developed a very effective protocol to produce polyploids of blueberries (*Vaccinium* sp.) using colchicine. Polyploids were induced by exposing in vitro microshoots to low levels of colchicine. Polyploids with their thicker shoots were screened visually in the culture vessels. Polyploids were later confirmed by chromosome counts using a microscope. In addition to microscopic verification, polyploidy can be confirmed using DNA flow cytometry. This technique measures the amount of DNA present in the unknown plant relative to a standard. It can be an extremely accurate measure for cells with high ploidy levels.

Tissue culture is a valuable tool for providing more new, unusual and healthy plants to our gardens and landscapes. Although variation from micropropagation is definitely not desirable, when used correctly it may be a useful source of exciting plants for the future.

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Tree Root Culturing in Polypropylene Pads with Protruding Roots

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INTRODUCTION

A small experimental nursery at Hazorea has for a number of years been developing techniques intended to produce lightweight nursery trees adapted for transportation to remote and possibly primitive destinations. Subtropical and tropical fruit and nut trees, such as are usually grown commercially in bags, are produced with highly compacted roots in pads whose dimensions are similar to thin pocketbooks. This flat configuration allows for efficient packing, insulation, air-freighting, and cartage under rough conditions. The rootpads can be used with wide-ranging tree-nursery-propagating systems.

Tests included both open ground and intensive greenhouse practices; all of the techniques involved air root pruning, copper root control, or spun-bonded polypropylene fabric as used in growbags. Most trees were vegetatively propagated.

Modifications were made recently to accommodate more efficient irrigation practices. These resulted in incorporating the rootpads into a kind of hydroponic/aeroponic system. It is becoming increasingly obvious that the rootpads function at their optimum potential under this system — consequentially it is this system which is described below. The trials were done with irregular numbers of assorted trees and changes in technique were made during the growing period. For this reason no statistics are supplied and results are of a generalized nature.

A trough containing a nutrient solution served as the basic structure. The rootpads were given rigid support by Styrofoam sections. Excellent growth conditions were induced by the constantly wet polypropylene enveloping an aerial rootmass. The tag ends of the polypropylene acted as wicks to suck up the solution.

MATERIALS AND METHODS

Individual Styrofoam sections 20 cm × 12 cm × 2 cm were used as rigid support for a flat root mass, wrapped, and grown in nonwoven thermo-bonded polypropylene fabric of similar dimensions after wrapping (Fig. 1). This fabric also acted as a wick when inserted about 5 cm into a nutrient solution. Roots grew well without any substrate in the polypropylene, or with about 100 cm^3 of an inert substance such as vermiculite or a vermiculite/peat/coconut fiber mixture. The nutrient solution was drawn up so that a film of water envelops the flat root mass. The wet polypropylene adhered to the Styrofoam sections provided the contents were not too bulky or heavy. The trees were held in place by pressure between the insulating Styrofoam sections.

The nutrient solution was contained in a trough 25 cm to 40 cm wide, of any convenient length and height. The floor of the trough was treated with Kocide/latex paint or spun-bonded polypropylene fabric for root control. Various refinements, such as polyethylene coverings, could be fixed to the trough. The density of the trees was adjusted according to their size. When the foliage became overcrowded some of the rows could be removed to another trough. Inserting and extracting the pads was

Figure 1. Rootpads clamped in groups in a trough. By another method, field scale troughs can be molded into the soil just above ground level, and covered by black plastic.

Figure 2. A cherimoya rootpad containing 400 cc of substrate. Flat rootpads are rapidly planted against a soil wall, or inserted into moist soil between a metal blade and a plastic strip.

not done individually, as the remaining pads would topple over due to the buoyancy of Styrofoam. They were handled in groups that were tightly clamped between the two sides of the trough.

It appeared advisable to use a dense quality Styrofoam, as this discouraged root penetration. Copper treatment of the Styrofoam was also possible but not essential.

The plants originated from various sources: seeds and cuttings planted directly in the pads or from plants started under other conditions, such as field-grown bare-rooted seedlings or graftlings, plugs, airlayers or from air root-pruned baskets, mist, fog, or tissue culture. These were inserted into a 35-cm length of polypropylene fabric folded into the desired dimensions to form pads, with or without substrate.

Even when rooted plants were intended for wrapping without substrate, it was advisable to retain just enough material around the roots to protect the white tips.

Some difficult-to-root cuttings had to be treated under more sophisticated conditions, but a technique that might help certain moderately difficult ones was by extending the polypropylene beyond the upper leaves.

Trees could be removed and grafted in the trough under a mobile shade structure on bicycle wheels. This shade device had a grafting table that held various grafting materials.

DISPATCH AND PLANTING OUT

The root pads were detached from the Styrofoam section when removed from the trough for despatch (Fig. 2). Foliage could be thinned out, pruned, and dipped in phytosanitary materials. The root pads were dipped in a gel to protect protruding rootlets during the critical moments when they were exposed to the elements at planting time. This was economically practical due to their compactness. The pads were compressed to reduce moisture content. The trees were inserted full length into polyethylene sleeves and packed in cartons with any necessary insulation. Instructions were sent with the trees regarding two possible planting alternatives as follows: (1) The rootpads were placed up against 15-cm soil walls. (2) A slit of loosened soil was prepared in advance with a pick axe. Planting took place after rainfall with the possible addition of a little water to completely saturate the soil. The tree was removed from the polyethylene sleeve. The tag end of the pad was placed flush over the end of the sleeve and directly over the slit. A 12-cm- wide blunted metal blade pressed on the tag end forced the rootpad downwards, clamped between the polyethylene and the blade. The blade and sleeve were then extracted. This operation was very fast and especially useful under rough, sloping, and rocky conditions.

Flat root mass tree roots have been examined a year after planting by extraction under water pressure. The root systems were found to have reverted to their natural configuration, sending down anchor roots in a symmetrical manner.

Propagation of Promising High-Elevation Species Native to the Colorado Plateau

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INTRODUCTION

The Arboretum at Flagstaff is located at an elevation of 7150 ft on 200 acres of the world's largest ponderosa pine forest. It is the mission of the Arboretum to study and display native plants and plant communities of the Colorado Plateau. It is also our mission to identify, evaluate, and introduce into cultivation plants adaptable to the climatic conditions of the Plateau.

With an area of 170,000 square miles, the Colorado Plateau includes elevations from 2000 to 14,000 ft. Parts of Arizona, New Mexico, Utah, and Colorado are located on the Plateau. Known throughout the world as the site of the Grand Canyon, the Plateau is one of the most environmentally varied and sought-after environments in North America. It was here that C. Hart Merriam pioneered his system of life zones, with all of the six zones represented on the Plateau.

PLANT COMMUNITIES AND CLIMATIC FACTORS

The Arboretum's living collections include plants from desert grassland, chaparral, pinyon-juniper, ponderosa pine and mixed conifer forests, and alpine plant communities, as well as from riparian zones, seasonal wetlands, and native grasslands.

Included in our collections are plants from USDA Temperature Zones 2 through 6, (Sunset Western Garden Zone 1) reflecting a range of recorded minimum temperatures between -20 and -50°F. Much of the average annual precipitation of less than 25 inches is lost to runoff and evaporation caused by strong winds, bright sun, and low relative humidity.

The Plateau has been described as a "a land of extremes and surprises." Native to the western great plains and mountains of New Mexico, Maximilian's were compressed to reduce moisture content. The trees were inserted full length into polyethylene sleeves and packed in cartons with any necessary insulation. Instructions were sent with the trees regarding two possible planting alternatives as follows: (1) The rootpads were placed up against 15-cm soil walls. (2) A slit of loosened soil was prepared in advance with a pick axe. Planting took place after rainfall with the possible addition of a little water to completely saturate the soil. The tree was removed from the polyethylene sleeve. The tag end of the pad was placed flush over the end of the sleeve and directly over the slit. A 12-cm- wide blunted metal blade pressed on the tag end forced the rootpad downwards, clamped between the polyethylene and the blade. The blade and sleeve were then extracted. This operation was very fast and especially useful under rough, sloping, and rocky conditions.

Flat root mass tree roots have been examined a year after planting by extraction under water pressure. The root systems were found to have reverted to their natural configuration, sending down anchor roots in a symmetrical manner.

Propagation of Promising High-Elevation Species Native to the Colorado Plateau

Janice K. Busco and Joyce Maschinski
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INTRODUCTION

The Arboretum at Flagstaff is located at an elevation of 7150 ft on 200 acres of the world's largest ponderosa pine forest. It is the mission of the Arboretum to study and display native plants and plant communities of the Colorado Plateau. It is also our mission to identify, evaluate, and introduce into cultivation plants adaptable to the climatic conditions of the Plateau.

With an area of 170,000 square miles, the Colorado Plateau includes elevations from 2000 to 14,000 ft. Parts of Arizona, New Mexico, Utah, and Colorado are located on the Plateau. Known throughout the world as the site of the Grand Canyon, the Plateau is one of the most environmentally varied and sought-after environments in North America. It was here that C. Hart Merriam pioneered his system of life zones, with all of the six zones represented on the Plateau.

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The Plateau has been described as a "a land of extremes and surprises." Native to the western great plains and mountains of New Mexico, Maximilian's sunflower (*Helianthus maximilianii*), like many Plateau natives, thrives on the extreme solar radiation and bright sun characteristic of the region. Clear night skies allow for fluctuations between night and daytime temperatures of as much as 50 or 60°F.

Winters can be cold and dry, with patchy snow cover, and early spring snows are usually heavy. The last spring frost may arrive as late as mid-June. Late spring and early summer are warm and dry until the advent of summer monsoons in July. With the onset of high humidity and rainfall from the monsoons, plants burst quickly into full growth. When the monsoons end, the earliest killing frost has been known to arrive in early August. A dry autumn rounds out the year.

COLLECTION OF PROPAGULES

When collecting propagules of native plants we are careful to obtain permission from landowners or government agencies and to abide by state and federal plant laws. We pay special attention to plant identification, characteristics of successful plant propagules, and proper timing of their collection.

With such a brief active growing season, summer is the time for most vegetative propagation. Cuttings from outdoor specimens must be taken between June and September, before the onset of plant dormancy. The seed collecting season runs from June into October or early November; its end is determined by the onset of the first snows.

DETERMINING CHOICE OF PROPAGULES

Two major considerations in determining which propagules to collect and use are ease of propagation and availability of propagules. Geranium-leaf larkspur (*Delphinium geraniifolium*) germinates readily from seed with 2 months cold stratification. New Mexico locust (*Robinia neomexicana*) will germinate with a combination of scarification and cold stratification. Wax currant (*Ribes cereum*) can be propagated from fresh seed, from stored seed with 3-months cold stratification, or from tip and stem cuttings. One decisive factor in our collecting efforts is always availability of propagules. Animals including elk, deer, grazing sheep, cattle, and grasshoppers abound on the Plateau. One of the challenges of wild collection is finding plants with seed, fruit, and tender shoots intact. Timing collection before the arrival of the elk herd or the movement of sheep through an area is often critical.

When germinating seeds with no known propagation information available, we consider when seeds mature, disperse, and germinate and what temperatures and environmental conditions occur in their habitat during seed maturation and germination.

SOME EASY PLANT PROPAGULES

An example of an easy-to-propagate native plant is *Petrophytum caespitosum* or rock mat. Rock mat is native to dry rock ledges and occurs naturally from South Dakota and Montana to New Mexico, Arizona, and California. It sets very fine seed that germinates with 3 months cold treatment. Cuttings root readily in 2 to 3 weeks. The plant forms adventitious roots easily and can be propagated by division. Although noted in The Jepson Manual (Hickman) as "difficult" to cultivate, it is easy to grow in the high, dry west.

A native of temperate regions of North America and Eurasia found in mountains of Northern Arizona at elevations above 8000 ft, common juniper (*Juniperus communis*) is easily propagated from cuttings in the autumn.

Nuttall's linanthus (*Linanthastrum nuttallii*), a showy perennial native to open pine forest at elevations of 5500 to 8000 ft, sets seeds one at a time as flowers bloom, so collection is difficult. Cuttings with #8 rooting hormone take readily when obtained during the early months of summer and circumvent the problems of seed collection.

While many dryland species of evening primrose (*Oenothera* spp.) show irregular seed germination, New Mexico evening primrose (*O. neomexicana*) and other native *Oenothera* species are easily grown from tip and stem cuttings during their active growing season.

Agrimony (*Agrimonia striata*) is another native plant where timing of collection determines the propagules to be used. During the early months of summer, the plant is easily grown from cuttings. Mid-season seed is available and germinates readily given 1 month cold stratification. Once the plant shows fall color, it is no longer easy to grow from cuttings, but can be divided readily.

HANDLING SEEDS OF THE HIGH AND DRY WEST

Once seed is collected, options for seed handling include storage in native soil or fruit and dry storage. Seed of some species should be planted immediately upon collection. For other species, seed handling decisions can be critical to success.

Common in southeastern and central Arizona at elevations of 4500 to 8000 ft, alligator juniper (*J. deppeana*) is difficult to propagate from seed or cutting. Preliminary studies conducted at the Arboretum indicate that storage of seed in native soil (following storage methods outlined in Keeley and Fatheringham, 1998) contributes substantially to increased percentage of seed germination. As alligator juniper is a stump-sprouter following fires, further germination tests involving subjecting the seeds to smoke treatment after storage in soil will be conducted at the Arboretum.

New Mexican raspberry (*Rubus neomexicanus*) is a deciduous shrub native to canyons and forest openings in New Mexico and Arizona. Tip and stem cuttings from young growth root rapidly; once the plant sets fruit in mid summer cuttings root more slowly, while seeds from macerated fruit germinate rapidly at 70°F.

Another native shrub, Fremont barberry (*Berberis fremontii* syn. *Mahonia fremontii*) is quite difficult to propagate from cuttings or cleaned, stored seed. Fresh seed stored briefly with fruit intact germinates readily upon maceration of the fruit and planting of the seed.

Many seeds of Plateau species will germinate readily when fresh seed is sown with light. Examples are willows (*Salix* sp.) with seed viability often as brief as 48 h from dispersal; Arizona alder (*Alnus oblongifolia*) and the autumn-blooming pleated gentian (*Gentiana affinis*). Fresh seed of the pleated gentian will germinate with or without a 3-month cold stratification.

DORMANCY AND SEED TREATMENTS

The most common methods employed at the Arboretum to break seed dormancy are cold stratification; scarification with hot water, sandpaper or sharp object; regimes allowing fluctuation of temperature including alternating periods of 40 and 70°F

(Deno, 1993), and overwintering outdoors for the entire cold season (November to May); and prolonged soaking for 3 to 5 days.

Alkali checkerbloom (*Sidalcea neomexicana*) germinates uniformly and readily when subjected to a 3-day cold-water soak. Without the soak, it germinates sporadically over a period of many months. Pearlseed (*Macromeria viridiflora*) germinates successfully after a 24-h cold water soak.

As is to be expected in a region with a long cold season, many species germinate readily after cold moist stratification of varying lengths. Agrimony (*Agrimonia striata*) requires 1 month cold. Depending on their environmental origin, native penstemons such as Sunset Crater penstemon (*Penstemon clutei*) may require 1 to 5-months cold treatment; treatment too long will actually diminish germination. Six-weeks cold treatment ensures uniform germination in James' golden buckwheat (*Eriogonum jamesii* var. *flavescens*). Two low-growing, high-elevation native perennials, sky pilot (*Polemonium viscosum*) and silvery cinquefoil (*Potentilla hippiana*) require 2 to 3 months cold stratification.

At the Arboretum, we routinely place seeds that will not otherwise germinate outside for a prolonged cold treatment throughout the entire winter season. Seeds are watered in, protected from rodents and birds, and placed where they experience outdoor seasonal weather fluctuations including snow, freezing, and thawing. Three species which have responded well to this treatment are spikenard (*Aralia racemosa*), winecups (*Callirhoe involucrata*), and Parry's primrose (*Primula parryi*).

We have had success germinating several species by allowing their seeds to experience natural diurnal temperature fluctuations during the active growing season. These species include Rocky Mountain beeplant (*Cleome serrulata*), golden aster (*Heterotheca foliolosa* syn. *Chrysopsis foliolosa*) and various coneflower species (*Echinacea* spp.)

CONCLUSION

There are many species native to the high elevations of the Colorado Plateau which warrant cultivation. As the "new west" continues to grow and develop, there is an unmet demand for plants which are native and adapted to the rigors of the high and dry west. At the Arboretum at Flagstaff, we have been experimenting with their cultivation and maintaining propagation records since our founding in 1981. It is our goal to place our propagation results on line at our web site: http://www.thearb.org by February 1999, and to link our site to the IPPS homepage.

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Propagation Safety

F. Allan Elliott
Carlton Plants, 14301 S.E. Wallace Rd., Dayton, Oregon 97114

As we strive to meet the needs of our nurseries and customers, we focus on production issues that directly affect our success. Production timing, efficiency, labor, supplies, climatic conditions, and inventory all demand attention. But how often do we consider safety or give it the attention, time, and resources deserved? After all, the most valuable asset of any operation is its people. Work related accidents and illnesses can rob the employee, his/her family and the nursery of health, livelihood, and productivity.

Health and safety issues are often perceived as time-consuming, costly, and nonproductive. This perception can become reality for the propagator/manager that adopts it with a negative attitude. However, for the nurseryperson who embraces a proactive approach, the rewards are significant and long-lasting.

This paper is not intended to be an instructional "how-to guide". It is, however, intended to encourage a second look at safety conditions in our nurseries and to reconsider the importance of safety issues and their impact.

Every type of business has its inherent safety risks and propagation facilities are no exception. Although the hazards may be all around us, they may be invisible to the untrained eye or preoccupied person. When safety awareness becomes a priority, safety issues seem to lurk everywhere.

OBSTACLES

Conditions in and around greenhouses offer hazards in the form of trips and falls from wet, slippery, and uneven surfaces, or improperly stored hoses. Greenhouse construction and maintenance many times requires a person to climb ladders or work from lifts to change poly, often under difficult weather conditions. Thus, ladder safety and proper use of restraints are important.

Many overhead obstacles are also present in the form of greenhouse bracing, heaters, traveling booms, and even hanging baskets.

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ELECTRICAL

Electricity powers a wide range of items in a propagation facility from fans and heaters to mist systems and lighting. As with the construction of greenhouses, much of the wiring may be handled by the nursery. This work is not always "to code" and may pose potential hazards. Such issues are further accentuated by the presence of wet conditions inside such structures. Extension cords are sometimes utilized as a "short term" solution and remain in place for lengthy periods of time, becoming shock and trip hazards. Consideration should also be given to utilizing electrical systems with low voltage relays and solenoids instead of 110-volt systems.

LIFTING

Although we have devised equipment to assist with the movement of materials, there are still many tasks that require lifting by employees. Using the proper technique for lifting and knowing when to seek assistance can make the difference between completion of the job and a back injury. Repetitive lifting of items like bales of peat moss, bags of fertilizer, and flats of liners are all potential problems if handled improperly. Training employees how to lift and cautioning them about tackling excessive weights go a long way toward reducing painful injuries.

HAND TOOLS

A propagation facility is loaded with hand tools. Many of them hold the potential to cut people as well as plants. Knives and pruners used for budding and grafting, making cuttings, or pruning stock are used thousands of times each day. Regular sharpening and maintenance can reduce problems as will proper storage in scabbards and cases when they are not in use. Protective gloves and properly applied tape on fingers also reduce cuts. Many other types of tools are used as well. Proper maintenance of handles, grips, and blades is critical to effective use as well as safety.

EQUIPMENT

Equipment comes in many forms and sizes and is a critical element of any propagation facility. However, along with usefulness and efficiency, there are also potential hazards. Fans, fan jets, heaters, mowers, and bandsaws equipped with high speed blades, belts, and pulleys are everywhere. Guarding of this type of equipment is critical. Many of our sprayers, tillers, mowers, and harvesters are powered units. Unguarded power take-off (PTO) shafts are a leading cause of farm-related injuries and they are usually of a serious nature. Although we consider new machinery to be "ready to use", it is not always the case. Close inspection may show that additional guarding is needed to make it "safe for use".

Also associated with machinery is noise. A single incident or exposure seems harmless, but the long-term cumulative effect can lead to permanent hearing loss. Ear protection goes hand in hand with equipment operation.

Operation of trucks, tractors, buses, forklifts, and trailers requires skilled and trained personnel. The operators must know the details of the equipment from pre-use inspection to equipment capabilities and potential hazards. The personal responsibility of an "authorized operator" goes beyond their own safety to that of employees around the equipment they are operating.

CHEMICALS

Chemicals have a wide range of usefulness to the propagator. Without them, sanitation would be difficult as would rooting of plants without rooting hormones. Chemicals are also utilized to fumigate soil, treat pests and disease, and as seed treatments. An attitude of caution and respect is prudent when working with chemicals. It is an area where personal protective equipment is essential. Education and training of personnel to become certified applicators is another safety tool.

If exposure should occur, having an emergency shower and eyewash in close proximity can be of great assistance. Posting of chemical application under the "Worker Protection Act" also warns other workers of potential hazards.

TEMPERATURE EXPOSURE

Temperature extremes can cause illness in workers regardless of whether under natural or manmade conditions. In winter, hypothermia is a concern. People working within cold storage facilities or outdoors can become wet and cold losing body heat. Monitoring working conditions and the use of proper clothing will reduce risk. Summer heat can take greenhouse temperatures to 10^0oF plus. Field temperatures in the 9^0oF range can quickly dehydrate people and raise body temperature where heat exhaustion or stroke can occur. Sunburn can also be a health issue, particularly when it becomes frequent. Several practices can reduce these risks: wearing proper clothing, adjusting work schedules, shading work areas, providing plenty of cold fluids for drinking, using sunscreen, sunglasses, hats, and monitoring workers closely for signs of over-exposure are all helpful.

ALLERGIC REACTIONS, DERMATITIS, AND RESPIRATORY PROBLEMS

This is an area where each individual's body responds differently. However, there are issues common enough to most of us to be mentioned. Chemical exposure to even common household cleaners will cause rashes for some people. Pesticides, rooting hormones, disinfectants, and fuels are others. But plants themselves can be problematic as with the fuzz from *Platanus* and *Elaeagnus* leaves that send people into sneezing fits. Sap from other plants like *Dieffenbachia* and *Euphorbia* can cause burning and rashes. Spines on *Berberis*, *Caragana*, *Ilex*, and other plants are also uncomfortable when encountered.

Respiratory concerns come in the form of microscopic particles from media components such as peatmoss, perlite, and bark dust. Another nursery activity that encompassed all of the concerns previously mentioned is that of seed collection, cleaning, and treatment. Exposures range from contact with spines and thorns to breathing microscopic dust and seed particles to stained and burned hands as a result of removing seed pulp and tissues. Seed treatments with sulfuric acid and boiling water have hazards as well. Respirators and gloves go a long way toward mitigating the discomforts previously mentioned.

REPETITIVE MOTION

Numerous activities within a nursery require repetitive activity. Those such as pruning, tying, sticking cuttings, and potting involve the critical area of hands and wrist. This sometimes leads to a condition called Carpal Tunnel Syndrome, which can be quite painful and debilitating. Factors to be considered are force, repetition, and duration.

SAFETY MANAGEMENT

Safety management is a complex issue requiring a multifaceted approach involving numerous resources.

Primary to any program is attitude and commitment. If management is not dedicated in principal and resources, don't expect anyone else to be serious about safety. Safety is also a long-term commitment and there are very few quick fixes with long-term results. Options available to the propagator fall into several categories: prevention, education, training, maintenance, preparedness, and organized response. The following is a description of these elements. Prevention can take the form of protective clothing such as safety glasses, ear protection, gloves, aprons, spray suits, rubber boots, and respirators. Or, it could be daily exercises, safety inspections, hearing tests, flu shots, signage, and guarding of machinery. Education through newsletters, safety committees, job safety analysis, accident investigation, or reminders in paychecks are all educational options.

Training, both initial and follow-up, are at the core of a viable safety program. With training you are not only showing the person right and wrong, but also reinforcing the issue that safety is important to the company as well as fulfilling some legal obligations. Some forms of training are CPR/first aid, tractor operation, pesticide application, hazard communication, respirator use, forklift use, and worker protection training. Maintenance is essential to stopping accidents before they occur. When something is worn or broken it has the potential to get worse causing damage to equipment and people. Preventative maintenance more than pays for itself when lost time and down time are eliminated.

When there is an accident, being prepared and responsive can be vital to mitigating damage and saving lives. Basic elements would be first aid kits, fire extinguishers, exit lighting, Material Safety Data Sheet (MSDS) forms, and posting of critical phone numbers. More comprehensive would be an emergency response plan that is coordinated with key people within the company and local emergency agencies.

Other sources of detailed information include OSHA, workers compensation insurance carrier, safety engineers and professionals, safety equipment suppliers, industry organizations, and employees.

I hope that as you review these ideas and examples it stimulates action toward providing a safer working environment for you and your employees. The rewards may not be identifiable initially, but will become evident with a long-term program.

Alternative Methods to Propagate Herbaceous Plants

John Dixon
Skagit Gardens, Inc., 3100 Old Highway 99 South, Mount Vernon, Washington 98273

THE NEED FOR AN ALTERNATIVE

The need for an alternative indicates there is a problem with the current method. Our need for an alternative has risen from the fact that the herbaceous liner market has become very crowded, and in most cases, our competition has a distinct climatic advantage at key times of the year. What I will discuss here is how we at Skagit Gardens try and counteract some of the disadvantages of propagating herbaceous plants at our latitude during the winter months.

WHERE WE ARE AND WHO WE ARE

Skagit Gardens is located in Mount Vernon, Washington, 60 miles north of Seattle, at Latitude 48° North. Our location is nearly 10 miles east of North Puget Sound, so we experience a West Coast marine environment. We are growers of herbaceous annuals and perennials, in finished (retail ready) and liner sizes. About 50% of our sales are of annuals, and 50% are of perennials; of those, 70% are to finished customers and 30% to liner customers. Half of our plants are asexually produced, the other half sexually propagated. In total, we grow approximately 30 million plants annually. Our production facility includes about 10 acres of covered space split between glass, double poly, and retractable-roof greenhouses, as well as 30 acres of outdoor growing beds. We are active in the market year-round.

COMPARING CLIMATES

Our location gives us production advantages and disadvantages depending on the season. From a propagator's point of view, during the late spring and summer months we experience a distinct environmental advantage over most other areas of the country because of our moderate climate and relatively long days. However, during the late fall and winter months we deal with these production challenges: an average temperature of 40°F, short day length, and heavy cloud cover 95% of the time. Since 80% of the annual cutting market is derived from cuttings produced during this cold, dark, damp period, we find ourselves at an extreme climatic disadvantage compared to cutting producers in California (Table 1). Of course, the people we compete with contend with problems of location as well, but from a winter climate standpoint, we are truly and figuratively in the basement.

One solution might be to buy unrooted cuttings from southern climates to fill our demand, but supply problems have shown this takes us out of control of our own destiny. It also leaves a large piece of our capital investment unused for a portion of the year. We could invest in lighting systems to force our stock plants, but this has proven to be economically unattractive. So we have developed alternative methods to offset some of the difficulties of producing annual cuttings in the dark.

ANNUALS OR TENDER PERENNIALS?

A large percentage of the cultivars that occupy the asexually produced annual market are not annuals at all; they are tender perennials (Table 2). If treated as

Table 1. Climate comparison for Seattle, San Francisco, and San Diego.

Average daily temperature in degrees Fahrenheit.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Maximum						
Seattle	50.5	45.5	45.0	49.5	52.7	57.2
San Francisco	62.4	56.1	55.6	59.4	60.8	63.9
San Diego	69.9	66.1	65.9	66.5	66.3	68.4
Minimum						
Seattle	40.1	35.8	35.2	37.4	38.5	41.2
San Francisco	47.1	42.7	41.8	45.0	45.8	47.2
San Diego	53.9	48.8	48.9	50.7	52.8	55.6
Mean						
Seattle	45.3	40.5	40.1	43.5	45.6	49.2
San Francisco	54.8	49.4	48.7	52.2	53.3	55.6
San Diego	62.0	57.4	57.4	58.6	59.6	62.0

Average sky cover	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Clear						
Seattle	2.5	2.3	2.8	2.9	3.4	2.7
San Francisco	11.1	9.4	8.5	7.8	9.6	10.8
San Diego	14.7	13.6	12.3	10.2	10.8	10.2
Partly Cloudy						
Seattle	4.7	3.9	3.9	4.2	5.8	7.3
San Francisco	8.3	7.5	7.6	7.4	8.6	9.3
San Diego	8.0	7.7	7.5	7.6	9.4	10.0
Cloudy						
Seattle	23.3	24.9	24.2	21.2	21.9	19.9
San Francisco	10.6	14.1	14.9	13.1	12.9	9.9
San Diego	7.3	9.6	11.2	10.4	10.8	9.8

Table 2. Perennial genera cold-treated at Skagit Gardens.

Anagallis	*Felicia*	*Nemesia*
Artemisia	*Fuchsia*	*Plectranthus*
Brachyscome	*Hedera*	*Rhodanthe*
Chlorophytum	*Ipomoea*	*Rosmarinus*
Cosmos	*Lamium* (syn. *Lamiastrum*)	*Verbena*
Glechoma	*Lotus*	*Vinca*
Diascia	*Lysimachia*	

such, they show greatly enhanced performance. Since the majority of hardy perennials require a dormant period in order to perform optimally, it follows that if tender perennials were given a typical dormancy period prior to the cutting season, one might see some of the same advantages. These include increased yields of carbohydrate-rich cuttings, and often, vernalized cuttings. Since carbohydrate-rich cuttings are nearly impossible to produce in low light, it became apparent to us that we needed to produce stock plants that have a store of carbohydrates that could be called upon when needed.

The so-called annual liner market demands a product that is actively growing; therefore, shipping a dormant plug is in most cases out of the question. However, for in-house use, dormant plugs are quite acceptable, if not preferred. We have decided to take a significant percentage of cuttings for our finished spring production in the fall and hold them in a 45°F area through the winter. Although we must care for the cuttings longer, the stock is not needed through the winter, nor is the space the cuttings utilize as expensive as stock space. We have found that two flats of 105-cell plugs take up the same amount of greenhouse space as a stock plant yielding 200 cuttings over the course of the season. The plug flat cuttings are taken in September and October and are produced with ambient heat and the available natural light. The cuttings taken from the stock plant in the dead of winter require supplemental heat and light for production. The cuttings in the 105-plug flats experience a dormant period when maintained through the winter at 45°F, so they often produce flowers earlier and in more abundance than cuttings taken in winter. Another advantage is we can also use the 105-plug flats as a cutting source in late winter if cutting demand is high.

SCHEDULING STOCK PLANTS: GROW-THROUGH VERSUS DORMANCY

Typically, cuttings are taken from clean stock around the middle of March. In mid-May the cuttings are transplanted into an intermediate size, usually a 32-cell tray. After 8 to 10 weeks (mid to late July), the young plants are transplanted into a 2-gal pot, at one, two or three plants per pot depending on the cultivar. The plants are allowed to establish until the middle of August. At this point, we break from the traditional grow-through method. We split the stock: a percentage of the stock is

Table 3. Cutting yields: grow-through versus revived dormant cutting per stock plant per week.

Week	48	49	50	51	52	1	2	3	4	5	6	7	8	9	10	Total
Lotus berthelotii																
Grow-through	26	26	20	20	18	18	16	16	14	14	14	16	16	16	18	268
Revive dormant	0	0	6	12	18	18	22	24	24	24	24	24	24	26	30	276
***Diascia* 'Coral Belle'**																
Grow-through	16	16	14	14	14	10	8	8	8	8	6	6	8	8	8	152
Revive dormant	0	0	0	6	10	12	14	18	18	20	22	22	22	26	26	216

grown on in the greenhouse and the balance is placed in a protected area in ambient outdoor temperatures. The ratio is determined by the need for cuttings in the periods before and after the 1st of the year. The stock grown through inside is manicured to produce cuttings between the first of October and the end of December. The stock grown at outdoor temperatures is prepared to produce after the first of the year. Temperatures on stock maintained inside run between 55 and 80°F. Stock maintained outdoors is grown at our climate's ambient temperature, as long as it stays above 28°F. At temperatures below 28°F, some form of protection is provided. The first week of December, stock maintained outside is groomed and moved to a 55°F greenhouse. An assessment is made of the potential of the stock as a whole and a harvest plan is made to fill our needs. Typically, the grown-through stock is beginning to produce fewer, weaker cuttings by mid-December, and we start to cull the weakest plants. At this point, the outside plants coming out of dormancy are beginning to produce useable cuttings.

THE CUTTINGS

We have learned not to mix cold-grown and warm-grown cuttings during the crossover period in December and January. Cuttings from the cold-grown stock root faster and at lower temperatures than warm-grown cuttings. Usually, we root our warm-grown cuttings at 70°F soil temperature; for our cold-grown cuttings, we prefer 62°F soil temperature. Both are under computer-controlled mist. Cuttings from cold-grown stock root 2 to 3 days more quickly than cuttings from warm-grown stock. Cuttings from both regimes receive an overspray of Rhizopon® after sticking. We have found this to be as effective as a quick dip at the time of sticking, and far more efficient from a labor standpoint (not to mention that it's legal).

If everything goes as planned, by the second week of January we have shifted to the stock that has experienced dormancy. We need this stock until the end of February, at which point it is either discarded or moved back outside. A number of cultivars we cut in winter are also required in our summer programs, so winter stock is carried through to fill our summer cutting needs. In March we start the cycle anew.

We have found that the seasonal yield from stock that has experienced dormancy is as great or greater than plants grown through. That is to say that we can produce the same number of cuttings in 10 weeks, which we used to produce in 20 weeks, in the same amount of space (Table 3).

OTHER CHALLENGES

During all phases of production, care is taken to keep the stock disease free. Where possible, we start with virus-indexed stock and grow in protected environments. We test for viruses on a regular basis throughout the year.

A large part of the challenge in growing cost-effective stock comes from trying to keep the plants out of a reproductive mode. Considering that a large percentage of the cultivars we deal with are hybrids selected largely for their ability to stay in flower, convincing them to do otherwise can be tricky. Through manipulation of light and temperature, and by applying various plant hormones, we have become relatively successful.

CONCLUSION

We know we will probably never compete in the winter cutting market on an even footing with growers to the south. But growing the plants for what they are and developing the methods of which I have spoken has defrayed our variable costs enough to make the market tolerable. Through continual examination of the plants we grow and reassessment of our procedures, we will continue to experiment, discover, and move ahead.

Regulating Root Growth in Ericaceous Plant Propagation

Carolyn F. Scagel
USDA-ARS, Horticultural Crops Research Laboratory, 3420 NW Orchard Street, Corvallis, Oregon 97330

INTRODUCTION

Control of adventitious rooting is complex, involving regulation by several compounds which vary during stages of root development (De Klerk et al., 1999; Kevers et al., 1997). Regulation of rooting involves interactions between carbohydrates, nitrogen compounds, enzymes, and hormones (Haissig, 1982). In our lab, we are investigating hormonal and nutritional regulation of root growth during propagation of common ericaceous plants grown in Pacific Northwest nurseries. There is little available information describing hormonal and nutritional changes in ericaceous plants during vegetative propagation or during container production. This paper presents information on the relationship between rooting and tissue nitrogen and protein content of ericaceous plants.

NUTRIENT COMPOSITION OF CUTTINGS AND ROOTING

Total Nitrogen. Mineral requirements for rooting vary during the different stages of root initiation and growth (Blazich, 1989; Hartman et al., 1990). Nitrogen (N) is required during root initiation for nucleic acid and protein synthesis. In general, it is believed there are optimum N concentrations for rooting, above which rooting declines and below which rooting decreases. Reducing N fertilization to stock plants, reduces shoot growth, allows for carbohydrate accumulation, and increases rooting (Hartman et al., 1990). We are looking at the relationship between rooting and nutritional composition of several cultivars from genera in the Ericaceae (Table 1). Our results show a strong relationship between rooting and tissue levels of N (nitrogen), zinc (Zn), manganese (Mn), and sulphur (S) for most of the cultivars tested. There is also a cultivar-specific optimum N content above and below which root initiation is reduced (Fig. 1). The amount of new root growth on cuttings also shows a similar relationship to N content.

Protein. Quantitative and qualitative changes in macromolecules occur during rooting of cuttings (Dua et al., 1983; Haissig 1986). In some species, rooting only

CONCLUSION

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Table 1. Cultivars used in rooting and media experiments.

Taxa	Cultivar
Arctostaphylos uva-ursi	'Massachusetts'
Gaultheria shallon	
Kalmia latifolia	'Olympic Fire'
Kalmia latifolia	'Pink Charm'
Kalmia latifolia	'Freckles'
Pieris taiwanensis	'Snowdrift'
Rhododendron Exbury	'Strawberry Ice'
Rhododendron	'Mollala Red'
Rhododendron (smirnowii) × *(R. yakushimanum)*	'Crete'
Rhododendron (Dexter)	'Scintillation'
Rhododendron (Leach)	'Trinidad'
Vaccinium vitis-ideae	'Erntdank'

occurs when a pool of proteins in cuttings is of a specific size (Nanda et al., 1973). We have tested several cultivars of different ericaceous plants and found a positive linear relationship between stem protein concentrations and adventitious rooting. For example, *Kalmia latifolia* cuttings with high protein content had greater root initiation than cuttings with low protein (Fig. 1), and the amount of root growth showed a similar relationship. This suggests that although N plays an important role in adventitious rooting of cuttings, the proportion of N as proteins may be equally important.

CULTURAL MEANS OF MODIFYING PROTEIN LEVELS

Protein levels change with the time of year, tissue age, plant age, and nutritional status of plants. Growers may not have much flexibility in changing these factors when taking cuttings. We are looking at cultural methods of increasing protein levels including media composition, fertilizer types, and mycorrhizal fungi.

Media Composition. Media composition can change nutrient and water acquisition and availability to plants. Amending a bark-based medium with coconut fiber (coir) can increase protein levels in stems, leaves, and roots of plants. For example, *K. latifolia* growing in a mix of bark, perlite, and coir had higher protein levels in plants growing in a mix of bark, perlite, and peat, even though total nitrogen level was not increased (Fig. 2). Altering media composition may offer growers a means of changing protein levels and influencing adventitious rooting.

Fertilizer Types. Fertilizer types and formulation can change the composition of minerals and organic compounds in plant tissues. Ammonium, nitrate, and organic

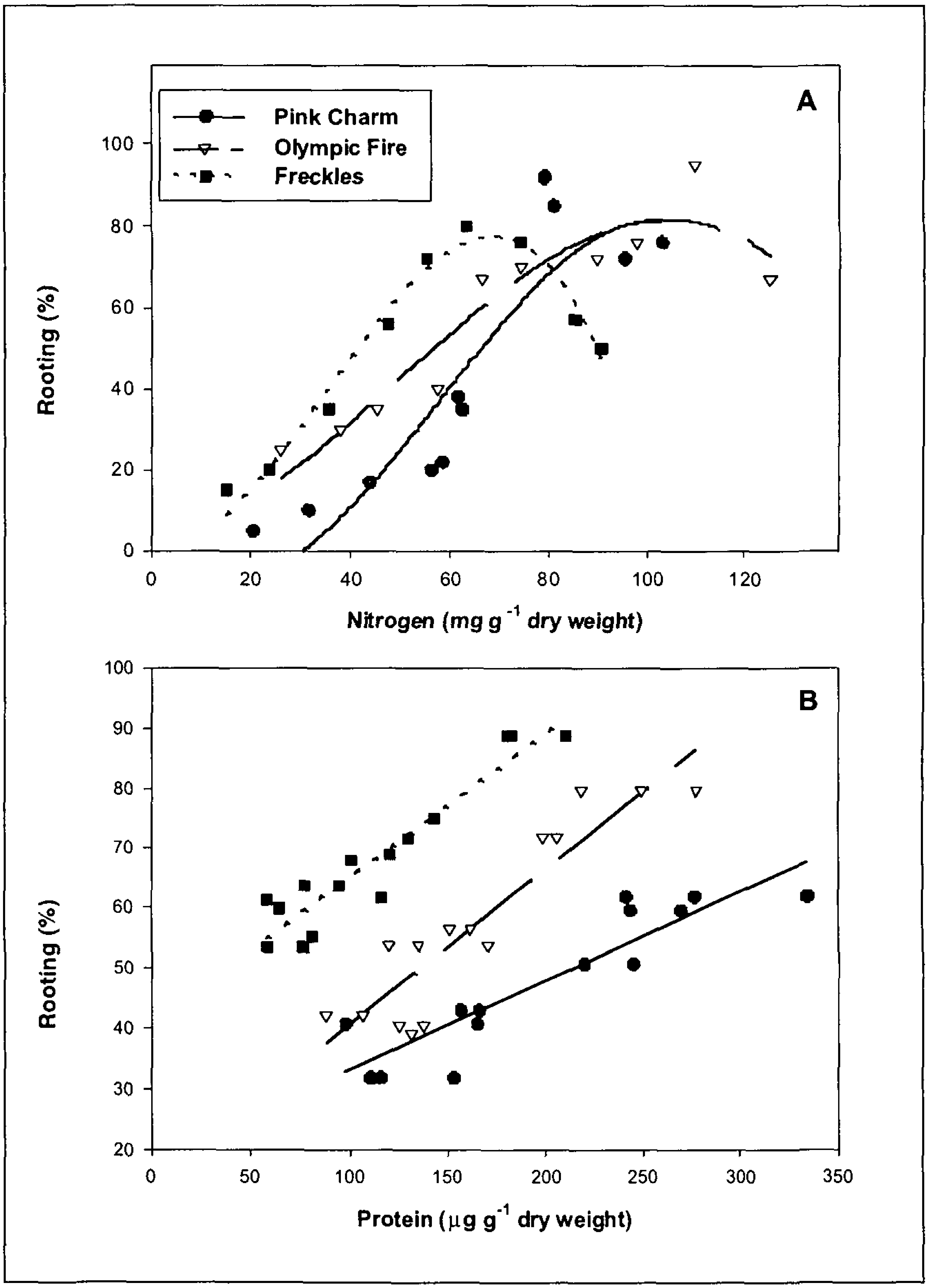

Figure 1. Relationships between stem nitrogen (A) and protein (B) content at cutting and percent rooted cuttings after 8 weeks of three *Kalmia latifolia* cultivars.

nitrogen forms all have different effects on the composition of nitrogen-containing compounds in plants. We have found that 6-month-old *Kalmia* and *Arctostaphylos* cultivars fertilized with pellets of organic fertilizer have higher protein content than plants fertilized with a slow-release inorganic fertilizer at a similar rate formulation.

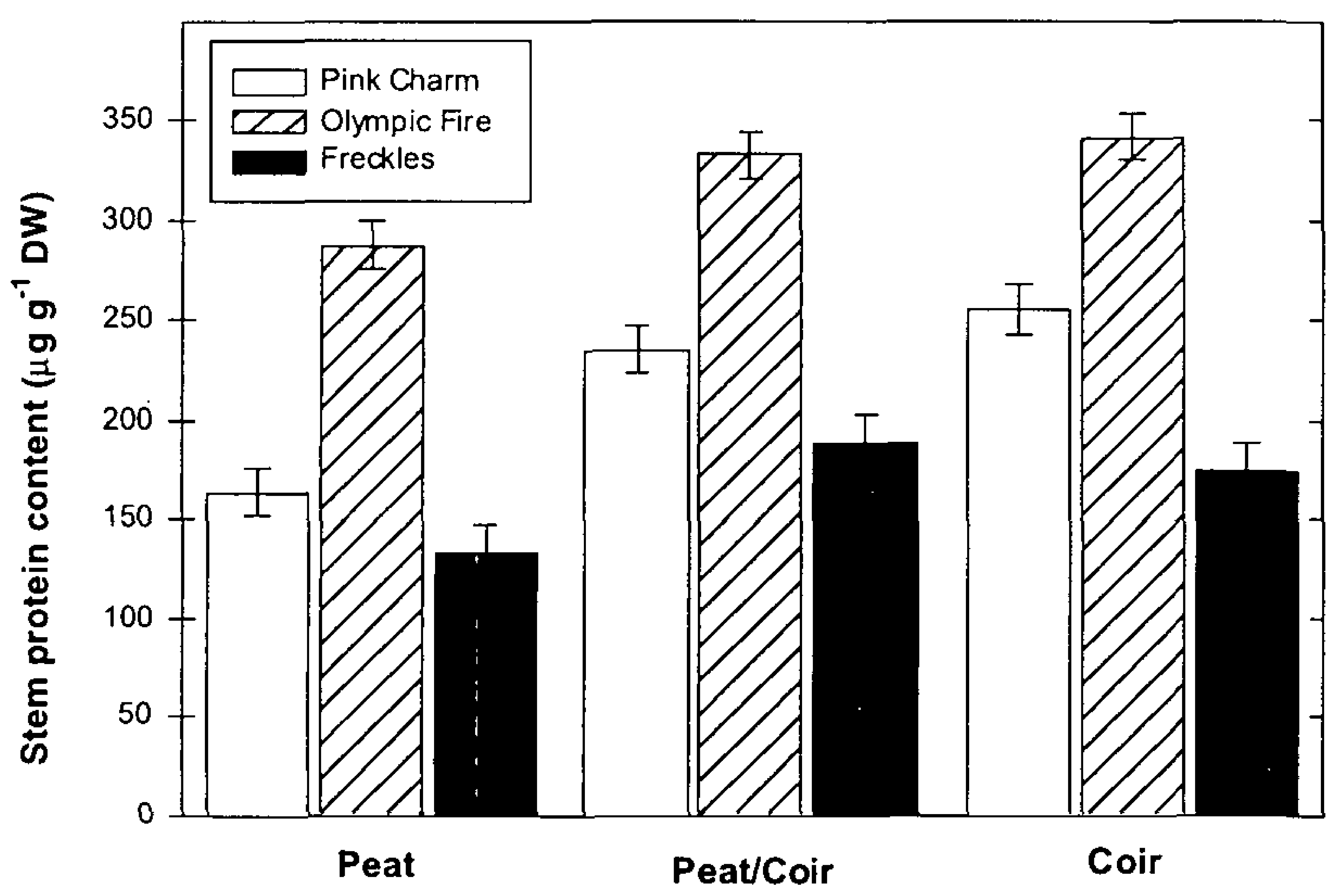

Figure 2. Stem protein content of three 1-year old *Kalmia latifolia* cultivars grown in bark and perlite (70 :10, v/v) with either 20% peat, or 10% peat and 10% coir, or 20% coir.

Altering fertilizer formulations may offer growers a means of changing tissue protein levels and influence root initiation.

Mycorrhizal Fungi. Mycorrhizal fungi can change nutrient and water acquisition and availability as well as plant hormone levels. Ericoid mycorrhizal fungi have been shown to preferentially take up organic forms of nitrogen as well as increase tissue protein levels of certain species (Bawja and Read, 1986). Inoculating plants with mycorrhizal fungi, or optimizing cultural programs to enhance mycorrhizal establishment could be used to change tissue protein levels and influence adventitious rooting.

SUMMARY

Nutrient composition of stock plants is one of many factors important to the rooting of cuttings. We have tested several cultivars of different ericaceous plants and found cultivar-specific differences in optimum nitrogen concentrations for adventitious rooting, and rooting increased linearly with increasing stem protein content. Altering media components, fertilizer formulations, or mycorrhizal fungi may potentially offer growers a means of changing tissue protein levels and influencing adventitious rooting.

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Making the Numbers for Production

Kerrie Aoki

Euro American Propagators, P.O. Box 289, Bonsall, CA 92003-0289

The first step is to set the sales goal. After setting the sales goal for each variety, we calculate: the total number of trays needed, the total number of pots to produce cuttings for the trays, and the curve of production relative to minimum/maximum ship weeks to meet availability for our sales goal.

ESTABLISHED PLANT

Our sales goal for each established plant is based on the previous year's sales, plus or minus, depending on the plant's past sales performance. The following percentages are applied to actual sales figures to determine our sales goal.

■ Sales greatly exceed previous Sales Goal	50% +
■ Sales exceed previous Sales Goal	50%
■ Sales meet or minimally exceed previous Sales Goal	30 to 35%
■ Sales minimally meet previous Sales Goal	10 to 20 %
■ Sales below previous Sales Goal	0-10%
■ Sales repeatedly decrease	Discontinue plant

Additional factors for consideration would be the overall increase in sales for your organization. This accounts for our decision to increase production over last year's actual sales on a plant that had sales below our sales goal. The plant could actually be increasing in total sales, but just not meeting our projection. Therefore, our sales goal actually declines, but production increases against previous years' sales.

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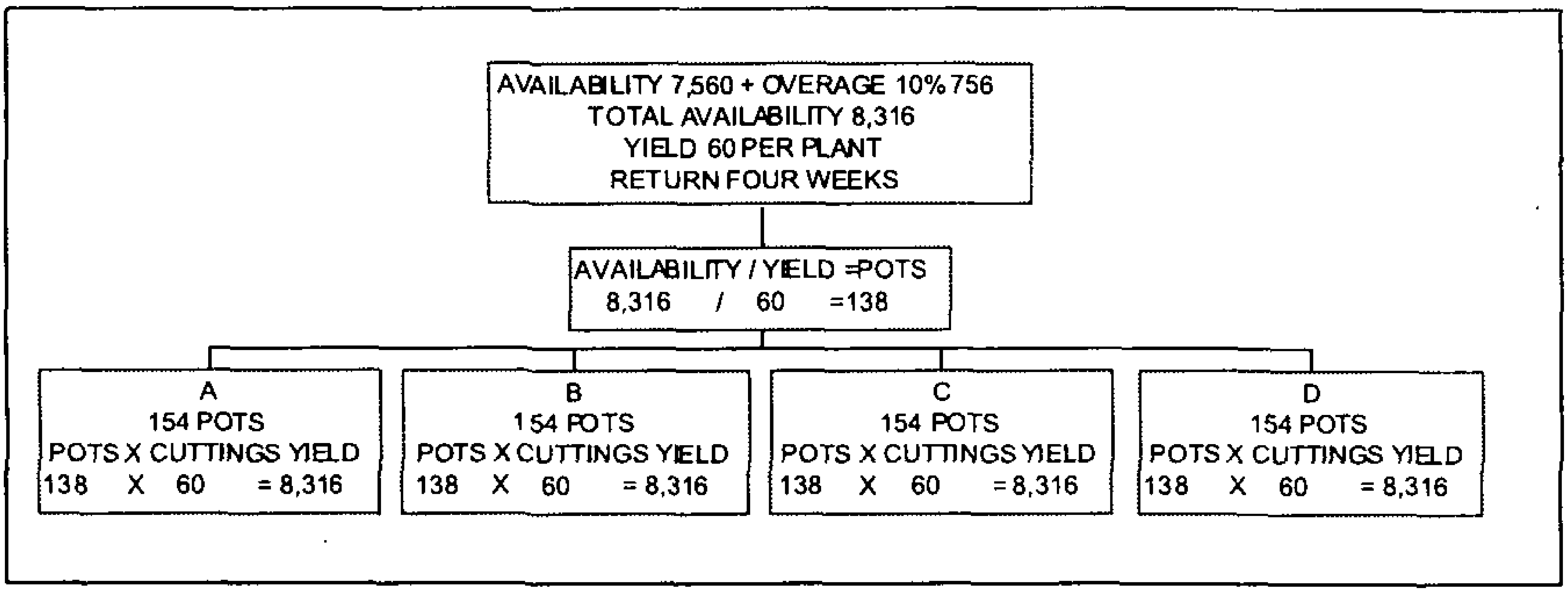

Figure 1. Calculations for an 84-cell tray with one cutting per cell.

NEW INTRODUCTIONS

Where no sales data is available, we rely heavily on the order processing and marketing teams, who consider the reactions to promotions, trade shows and pack trials. We also review early sales and if time allows, increase our availability where sales indicate a demand greater than our original sales goal.

Example (see Fig. 1). If our 1998-99 season availability for a given plant was 60 trays per weekand we sold 70 trays in the peak weeks of the season. We would consider an increase of 30% to our availability for the 1999-2000 season. The number of trays available per week would increase to approximately 90 trays, plus 10%, which covers any loss of cuttings (usually 3% to 5%). The final target availability for cuttings would be 100 trays.

RESEARCH CRITERIA

When we know the total availability needed, we are ready to determine the number of stock plants required to meet the demand. The two factors used are the "yield per pot" and the "return time". The yield per pot is the number of cuttings a plant can produce in a given period of time (return time).

During the research phase, we monitor plant health and count the cuttings per pot, harvesting at 2-, 4-, and 6-week intervals over several months to find the plant's return time and average yield per pot. Divide the total availability by yield per pot and plant one group of pots for each week of return.

PLANT DATES/YIELD

To determine the optimum plant date, we review the data we recorded at the time of each harvest during the research period. After a number of pinches, each plant's yield will reach a maximum yield and will produce this number of cuttings consistently through the season. This reflects the plant's "maturity." By counting the weeks from plant date, we see the weeks to maturity. Our greatest success is when we have plants reach maturity during peak sales. To determine the optimum date to plant potted stock, identify the week or weeks when sales are the greatest and subtract the number of weeks to maturity.

A plant's yield will generally decline after a period of time. This usually occurs approximately 8 months from the plant date. Because peak sales are over an extended time, we plant most varieties in three groups, first planting - 40%, second planting - 30%, and third planting - 30%. The three groups are staggered, but are targeted for availability during peak sales weeks. The first group provides most of the cuttings for early sales and through peak weeks and then is discarded when sales begin to decline. The second group to reach maturity at the peak shipping weeks and the third group maturing later and providing the cuttings for peak through final weeks of the season. Peak weeks are determined by the variety and sales history.

DO RIGHT BY THE PLANTS

As with a many other things, timing is everything. Finding the return time that will allow the plants to remain healthy is critical. Early return or heavy harvest puts extra stress on the plants, weakens cuttings, and lowers strike rates. Healthy plants produce healthy cuttings, reduce insect and disease problems, increase strike rates, and reduce labor requirements. By accurately determining a plant's ability to produce you can maximize production per square foot and meet the demands of an increasing market.

Germination and Growth of Acer Species

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BACKGROUND

Heritage Seedlings seed propagates more than 30 *Acer* species from Asia and North America. We focus on the more unusual, difficult-to-germinate species, but we also grow more easily germinated species, such as *A. palmatum*. This paper describes some of our experiences with maple seed, especially the effect of drying seed after collection. Selected maples are grouped by germination pre-treatments. Specific techniques to enhance germination results with difficult species are described.

SEED COLLECTION

Importance of Collecting Sound, Fresh Seed. Successful seed propagation depends first on acquiring fertile seed. Fertile maple seeds develop only after successful flower pollination and our experience is that highest seed quality is achieved when a genetically diverse, mixed population of stock plants is used in a seed orchard. For example, solitary landscape or arboretum specimens of *A. griseum* may produce a heavy crop of fruit, but it is normally of such low fertility (4% to 5%) that it is costly to collect or impractical to use for propagation. In our seedling block of 50, 15-year-old *A. griseum* trees, we harvest 95% fertile seeds annually.

Even when a relatively large population of stock plants is established, as in nursery culture, if the block is of one genotype, such as *A. palmatum* 'Bloodgood', regular fertile seed crops are unpredictable. On the other hand, it is possible to get over 90% fertile seeds, and annual, abundant amounts of seed if you set out a well cared for stock block of drip-irrigated, seedling-grown maple trees. If clonally propagated maple trees are used in a seed orchard, we find that mixing superior seedlings into the mother block (at least 20% of the total) can give dramatic improvements in the yield of fertile seed.

out for several maples to be about 25% moisture.) These maples tend to have a seed coat that becomes more leathery upon drying. The leathery material of the seed coat is quite hard to re-wet so that water and oxygen will penetrate the seed coat and promote the biochemical changes that enhance germination. Drying the seed may also cause other unknown changes in woody seed biochemistry.

Examples in this group are *A. saccharum*, *A. circinatum*, *A. glabrum*, *A. pseudo-sieboldianum*, *A. palmatum* var. *atropurpureum*, and *A. campestre*. We find that to germinate these easily, we must collect them while the "nut" of the samara is still green, clean the fruit/fiber off the seed coat, and then store the seeds naked in polyethylene sacks in the cooler. Another, easier strategy is to just fall plant them in the field, with care taken to mulch the seedbeds well so that the germinating seeds do not succumb to frost in the spring.

Group 4. Among the most difficult to germinate maples are those that have a thick, bony seed coat. The trifoliate maples *A. griseum*, *A. maximowiczianum*, and *A. triflorum* are notable examples. Rare species such as *A. sterculiaceum* and *A. sutchuense* are also included; these are within the Lithocarpa section, meaning "fruit like a stone". Allowing this seed to dry below 25% moisture will usually result in at least a year delay in germination. Most nurserymen don't have the patience for germination more than 2 years after collection of the seed. Dried seeds in the *A. griseum* group can take two, sometimes even three cycles of warm/cold pretreatment to prompt them to germinate.

Setting Up a Small-Scale Micropropagation Lab

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INTRODUCTION

During the past three decades, micropropagation has proven to be an economical and technically feasible method of propagation for some crops. However, individuals are often discouraged from setting up a lab because they believe it is very expensive. A large lab is expensive to set up. The cost to construct and equip a lab designed to produce 500,000 plants per year has been estimated to be $250,000 (Sluis and Walker, 1985). Establishing a small-scale lab to produce 100,000 plants per year should not be prohibitively expensive. In addition, it can provide an opportunity to train staff, develop culture protocols, and to evaluate the business with minimal capital inputs. If it shows promise, more expensive, specialized lab equipment can be purchased down the road to increase the lab's efficiency.

Before starting a lab, all propagation options should be considered, which includes hiring a lab to do contract micropropagation. Micropropagation is not an easy business to make successful. Many new labs do not survive more than a few years. One reason is the high operating costs the owner will have to cover in the early years while cultures are initiated and production protocols are perfected. It will take years for the lab to have a good selection of varieties available. Other obstacles to success are the availability of skilled staff, maintaining healthy and vigorous cultures, and being able to market all of the product for a fair price.

ADVANTAGES OF MICROPROPAGATION

Micropropagation has several advantages relative to traditional methods of propagation:

- The ability to propagate crops that are difficult to propagate.
- The high rate of multiplication (Table 1). Changes in the multiplication rate have a dramatic effect on shoot production (Table 1). Therefore, the protocol must be reliable and production figures need to be closely monitored in order to meet production targets.
- The high quality of micropropagated plants. This is due to their freedom from diseases and enhanced basal branching (e.g. bushiness). Increased bushiness is a result of the plant's short internodes and the hormone treatments used in the lab to promote multiplication. Bushiness is not always a desirable trait. For instance, basal branches interfere with mechanical harvesting of blueberries.

Other advantages are the ability to produce plants year-round, the low land requirement, and the elimination of the need for stool beds.

Table 1. Influence of the multiplication rate on shoot production with a 6-week subculture period.

Multiplication Rate	Week 1	Week 17	Week 34	Week 52
2.0	1	8	64	512
2.5	1	16	244	3,815
3.0	1	27	729	19,683*

*Almost a million shoots could be produced from 50 shoots in a year.

POINTS TO CONSIDER WHEN SETTING UP A LAB

Staffing. Staff will have a profound impact on the success of the business. Hiring skilled staff is important, but often can be difficult. For a lab that plans to produce crops commonly micropropagated, staff with a basic knowledge of sterile technique and micropropagation may be adequate, since media recipes and production protocols for such crops are often available in the literature (e.g. books, the Internet, government and post-secondary education institutions, and research journals). Nursery crops that are commonly micropropagated include *Acer rubrum, Betula nigra, Clematis, Hemerocallis, Heuchera sanguinea, Hosta, Kalmia latifolia, Leucothoe fontanesiana, Rhododendron,* and *Syringa vulgaris.* Since developing and refining media recipes is always required for new crops, and is needed at times for a protocol from the literature or for a different variety of a crop, hiring an experienced micropropagator should be a priority.

For training in micropropagation, good courses are offered by community colleges and private businesses. Western Biologicals Ltd. in Aldergrove, B.C., provides a 2-day training course that covers the basics; media preparation, subculturing, and building a laminar-air-flow (LAF) cabinet.

Lab Size and Layout. A small-scale micropropagation lab does not require a tremendous amount of space. Two to three rooms with a total area of 50 m^2 is sufficient. A kitchen works well as a media preparation area, since basic kitchen appliances and facilities are used, such as a sink, dishwasher, powerful microwave oven (1000 W) to melt agar, refrigerator, freezer, and sufficient storage area for glassware. A chemical storage cabinet is required, as is a stove if a pressure sterilizer is used.

Labs generate considerable heat, especially the growth room, which can kill cultures. One way to reduce the heat load in the growth room is to wire the lights' ballasts into a closet or adjoining room. Air conditioning is often still required, since fluorescent tubes produce a lot of heat. The amount of cooling required will depend on the number of light fixtures used and the room's normal temperature. Light shelf requirements will depend on total production, and the number ofcrops harvested per year. Shoots are grown at a density of 1200 to 1700 m^{-2}. Locating the growth room in a cool basement may eliminate the need for air conditioning.

A major requirement of the lab is cleanliness. Culture contamination is the most serious threat to a lab and all steps possible should be taken to reduce contamination. Perhaps the most serious and damaging contamination occurs when thrips or mites enter the cultures. It usually is not identified until the situation has become too severe to avoid major culture losses. To reduce the incidence of contamination, the lab should:

- Have flooring that is easy to clean (not carpeting),
- Frequently mop the floors with a mild disinfectant,
- Individually seal all cultures (e.g. Parafilm®, plastic wrap) or entire trays of cultures,
- Keep traffic in the lab to a minimum,
- Consider filtering all air entering the lab with a HEPA filter, and
- Never use houseplants as part of the lab decor.

Equipment and Lab Supplies: The two major pieces of lab equipment required are a sterilizer and a LAF cabinet. The two types of sterilizers commonly used are pressure sterilizers and autoclaves. An autoclave is the preferred option, since it can sterilize considerably more medium per hour. This is a result of their larger capacity and of being fully automatic. However, a new autoclave can cost more than $5000 and may require 3-phase power. A pressure sterilizer, such as the All American™ brand, is a relatively inexpensive alternative ($300 to $500). However, even with two 25-litre sterilizers, the maximum rate of media preparation is 2 liter h^{-1} with baby food jars. With this system, media preparation will account for about 25% of a lab's direct labor costs.

Attempts to mechanize the subculture process have not been successful, yet. Labs still rely on workers to aseptically divide cultures in a LAF cabinet. Therefore, there is not a significant difference in the subculture rate between large and small labs, as long as the LAF cabinet is well-illuminated and is a comfortable size (i.e. at least 3 ft wide). LAF cabinets are easy and inexpensive to build. All that is required is a blower, HEPA filter, furnace pre-filter, and plywood to build the cabinet. HEPA filters are sold by Western Biologicals Ltd. in Aldergrove, BC. A 4 ft cabinet can be built for $700, whereas a manufactured cabinet can cost $8000.

Other equipment required are forceps and scalpels ($150), a pH meter that has a resolution of at least 0.1($70 to $250), and a balance that can weigh to at least 0.01 grams ($450+). Two systems commonly used to sterilize the implements used during subculturing are dipping in ethanol and flaming, or electric heat units. Flaming works well and is relatively inexpensive, but it is hazardous due to the risk of fire. Electric units include glass bead sterilizers ($350 to $400), infra-red sterilizers ($450), or the Lee Precision Melter ($50). Melters are an inexpensive, variable-heat sterilizer. The chamber must be filled with a material to hold and distribute the heat, such as gravel, sand, or glass beads. They are available from Lee Precision Inc. (Tel: 414-673-3075).

A good supply of containers is also required. Container size is directly proportional to subculture rate and to the occurrence of culture contamination. Therefore, a tradeoff must be reached between subculture efficiency and culture losses through contamination. Test tubes are often used for the culture initiation stage to reduce the amount of material lost to contamination, which is often very high at initiation. Once a clean, proliferating culture is established, a larger container is used, such as baby food jars, canning jars, or polypropylene deli-tubs. Autoclavable lids for baby food jars are available from the Sigma Chemical Co. and cost $0.50 each.

A range of chemicals are used to make culture media. The lab can purchase *individual chemicals or prepared media powders. Individual chemicals provide the* lab with greater flexibility, and are essential to develop protocols in-house. The cost of media produced from individual chemicals is about $1.10 per liter, whereas prepared media cost over $5.00 per liter. One supplier of prepared media is the Sigma Chemical Co. Look in the Yellow Pages™ for chemical suppliers in your area. Purchasing chemicals is becoming more difficult and may restrict the operation of small labs. In Canada, chemical suppliers will only sell to businesses that have a chemical storage cabinet and that are located in a non-residential area.

Water is also required. For a small-scale lab, it is cheaper to purchase bottled water treated by reverse osmosis than to purchase a filter system. As a guide, about 250 liter of water is sufficient to produce 100,000 shoots.

CROP SELECTION

Micropropagation is not economically viable for most crops. It is labor intensive and, therefore, is a relatively expensive method of propagation. Labor can account for 40% to 50% of a lab's operating expenses. Costs of production vary between different varieties and labs. In general, the cost to produce an unrooted shoot is $0.15 to $0.25. Problems encountered during rooting can significantly increase production costs per plant.

The most appropriate plants to micropropagate are those that can demand a high price in the marketplace. Some micropropagated crops receive a high price as a result of their quality. However, labs usually need to select crops that are difficult to propagate or that are new introductions to the industry.

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Cleanliness in Propagation with the Use of Agribrom

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INTRODUCTION

Klupenger Nursery and Greenhouses, Inc. is a 50-year-old company specializing in rhododendrons, florist azaleas, Japanese maples, grafted conifers, and many other assorted shrubs. We have been in the same location for the past 37 years. Using houses and benches that have been used for many years creates some challenges, one of which is cleanliness. We do as much as we can to maintain a clean and usable propagation area. Our benches are treated yearly with wood preservative, the glass is cleaned on a regular basis, and the trails get top-dressed with gravel as needed. We even spray an entire area with chlorine prior to putting in a new crop. Despite these measures, the fact that things have been around for a while, disease has a lot of places to hide.

DISCUSSION

With our longer rooting crops such as rhododendron (8 to 12 weeks), florist azaleas (6 to 8 weeks), and conifers (12 to 18 weeks), we were starting to see algae growth and sometimes it would be very severe, covering the entire flat and bench just as the rooting was completing. We use some fertilizer to get the plants going and this just accentuates the problem. Our vent system creates a lot of air movement so a lot of mist is used to offset the drying. Again more water more algae. Another problem we were starting to experience was *Rhizoctonia* setting in on the rhododendron cuttings in a very short time after sticking. This was a major problem. After calling in the experts and checking everything from the water to the soil it was determined that *Rhizoctonia* spores were all over the greenhouse just waiting for a host. It was suggested to Vapam the greenhouse to kill all the propagules, but this was not practical. The alternative was a slow but steady treatment with bromide or more specifically Agribrom. Eventually it would knock out the population of the disease.

A few years earlier I attended a conference where Dr. Harry Tayama from Ohio State was making a presentation on the effects of bromide in the greenhouse and how there would be no more moss and algae on the walks, if you only used this product. This sounded great, but what was the application method? He came out and set up a trial in one of our cold frame houses and the results were somewhat dismal. Further experimentation was done by others and the eventual best use was in the propagation area, mainly because of the continual application required. If you used bromide injection in your misting lines, it was possible to keep the walks and pipes clean of moss and algae. It was also possible to get some disease control and was not phytotoxic to most crops.

MATERIALS AND METHODS

The method of application is to install an automatic pool chlorinator. The cost is about $100.00 and can be purchased at any pool or spa supply house. This is tapped into the main water source and meters a small amount of bromide into the misting system all the time. We try for 5 ppm to 25 ppm. Agribrom is available in tablet form so all you need to do is be sure your chlorinator remains full of tablets. There is a testing kit available to test the rate of bromine in the water. There is a manual regulator to adjust your flow but we have found that wide open is the best for us.

RESULTS

It did take some time to see the results. The chemical must clean up your pipes first then it will start to work on the other areas of the house. By the next year of sticking rhododendron cuttings we had very little problem with *Rhizoctonia*. There was also very little algae or moss. We have seen no phytotoxicity to any of our crops. The only evidence of the bromine use is a brownish color on the misting lines. We did think at one time that there may have been a phytotoxic problem so we turned it off. Shortly after turning it off, we saw an increase in disease on our *Acer* grafts so we knew it was having some effect on disease. In another instance we noticed it was not working and we had an increase in algae.

We have seen some additional uses of the bromine. For example, when cleaning our cuttings prior to sticking we add a couple of tablets to the rinse barrel. This has proven to be beneficial. Also, in some of our poly houses where we have them installed, the diseases that we get throughout the winter seem to be less. Bromine is not the answer to all of our problems and our place can always be cleaner, but it is an inexpensive tool that certainly makes a difference.

Propagating Clonal Rootstocks of *Pyrus communis*

William M. Proebsting and Luigi P. Meneghelli

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Pear is difficult to propagate efficiently by cuttings. This is due, in part, to the sensitivity of cuttings to the stresses associated with propagation and declining rooting potential as stock plants mature. We found that the expanded, subapical portion of softwood shoots is resistant to stress and roots well. Furthermore, cuttings from young stock plants have high rooting potential. Based on this and other information, we propose a set of guidelines for propagating softwood cuttings of pear.

INTRODUCTION

Clonal rootstocks of pear are typically propagated by hardwood cuttings. In Oregon, cuttings are collected either early or late in dormancy, callused for 2 or 3 weeks to induce root primordia and then refrigerated until soil conditions permit field planting. Developing alternative methods would complement this process and enhance the supply of high quality liners. We have been conducting a systematic study of softwood cuttings of clonal pear rootstocks. We report here effects of stock plant age and cutting type on rooting.

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MATERIALS AND METHODS

Pyrus communis L. 'Old Home × Farmingdale (OH × F) 40', OH × F 97, and clones 708-2, 708-12 and 708-36 were used for this study. Stock plants were hard-pruned in February, fertilized with 100 lb nitrogen (46N-0P-0K) per acre, and well irrigated throughout the summer. Date of cutting collection varied as described in Results. Apical cuttings comprised the first 10 inches of softwood shoots. Sub-apical cuttings were the second (and third, if available) 10-inch sections. Leaves were removed from the 1-inch portion of the cutting placed in the medium. Cutting bases were dipped for 5 sec in 20,000 ppm KIBA. The propagation medium was perlite and peat (3 : 1, v/v) plus 2.5 pounds Osmocote (14N-14P-14K, Type 100) yard^{-3} in 2¼ inch × 2¼ inch × 5 inch bands. Flats containing bands were placed in 4 ft × 17 ft benches enclosed on all sides by clear poly extending 3 ft above the bench. Mist was applied using the following program: 0700 to 0900 h, 24-min interval; 0900 to 1000 h, 16-min interval; 1000 to 1700 h, 8-min interval; 1700 to 1900 h, 16-min interval; and 1900 to 2000 h, 24-min interval, with 8-sec duration using a DE8PR2 mist controller (Davis Engineering, Canoga Park, California). Temperature of the medium was maintained at 70 to 75°F. Maximum air temperature was 85°F. Shading reduced light intensity to about 50% of ambient. Cuttings were evaluated the third week of September, unless otherwise stated. All rooting percentages were acceptably rooted cuttings, graded 7 on a 10-point scale. Cuttings rated 7 were well rooted, but had not grown to the wall of the band. Root systems rated 8, 9, or 10 contacted 25%, 50%, or 100% of the band wall, respectively.

Pear clones were established in tissue culture and micropropagated using the method of Dolcet-Sanjuan et al. (1990). After rooting, the plantlets were transplanted to clean potting medium (perlite, vermiculite, and peat, [1 : 1 : 2, by volume]), acclimated under mist, grown in a greenhouse, and ultimately planted in the field. Stock plants were also propagated by cuttings and by budding onto seedling rootstocks of pear.

RESULTS

In order to study the effect of stock plant age or maturity on rooting potential, we micropropagated stock plants of OH × F 40 and 97. The first year cuttings were available, cuttings of both clones collected from 2-year-old micropropagated stock plants rooted better than cuttings collected from 6-year-old, cutting-propagated

Table 1. Effect of stock plant age and propagation method on rooting of apical cuttings of pear. Cuttings were collected 23 June 1998. Data are percentages of acceptably rooted cuttings.

Clone	Stock Plant	Rooting (%)
40	6 yr, cutting	62.5
	2 yr, micro	78.6
97	6 yr, cutting	60.4
	2 yr, micro	90.2

Table 2. Effect of stock plant age and propagation method on rooting of apical cuttings of pear. Cuttings were collected 23 June 1998. Data are percentages of acceptably rooted cuttings.

	Clone		
Stock Plant	708-2	708-12	708-36
4 yr, grafted	81.5	81.3	61.0
2 yr, grafted	82.9	95.0	77.1
2 yr, cutting	79.2	93.8	N.A.*
2 yr, micro	95.8	N.A.*	83.3

*Not available

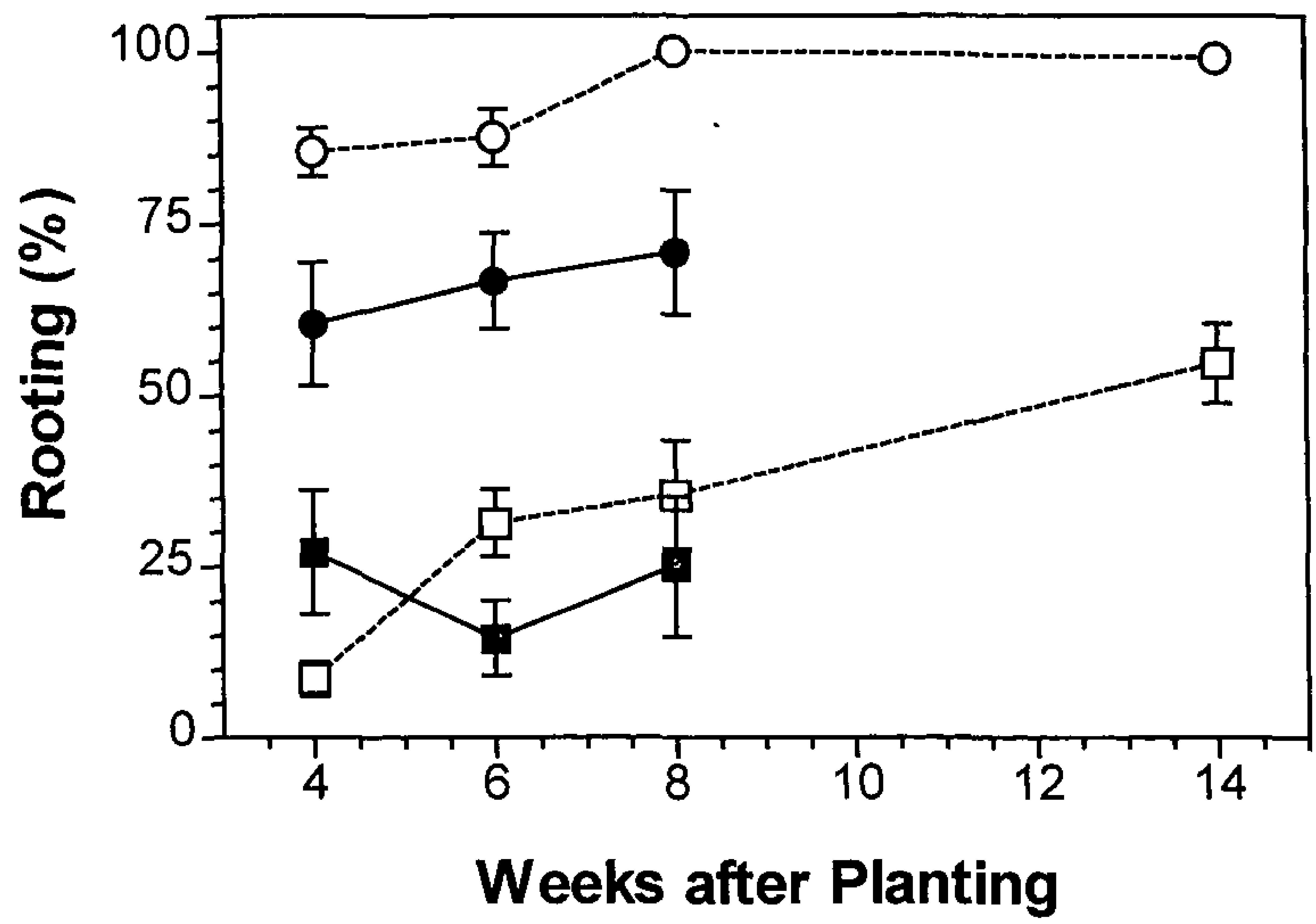

Figure 1. Rate of root formation following sticking of softwood cuttings of clone 708-12. Cuttings were collected from 5-year-old cutting-propagated stock plants and divided into apical (■) and sub-apical (●) cuttings, or collected from 3-year-old micropropagated stock plants and divided into apical (□) and sub-apical (O) cuttings.

stock plants (Table 1). The 708 series of pear clones root well. However, 2-year-old stock plants, whether grafted, cutting, or micropropagated, produced cuttings that rooted as well as, or better, than those from the original stock plants which were 4-years old at the time (Table 2).

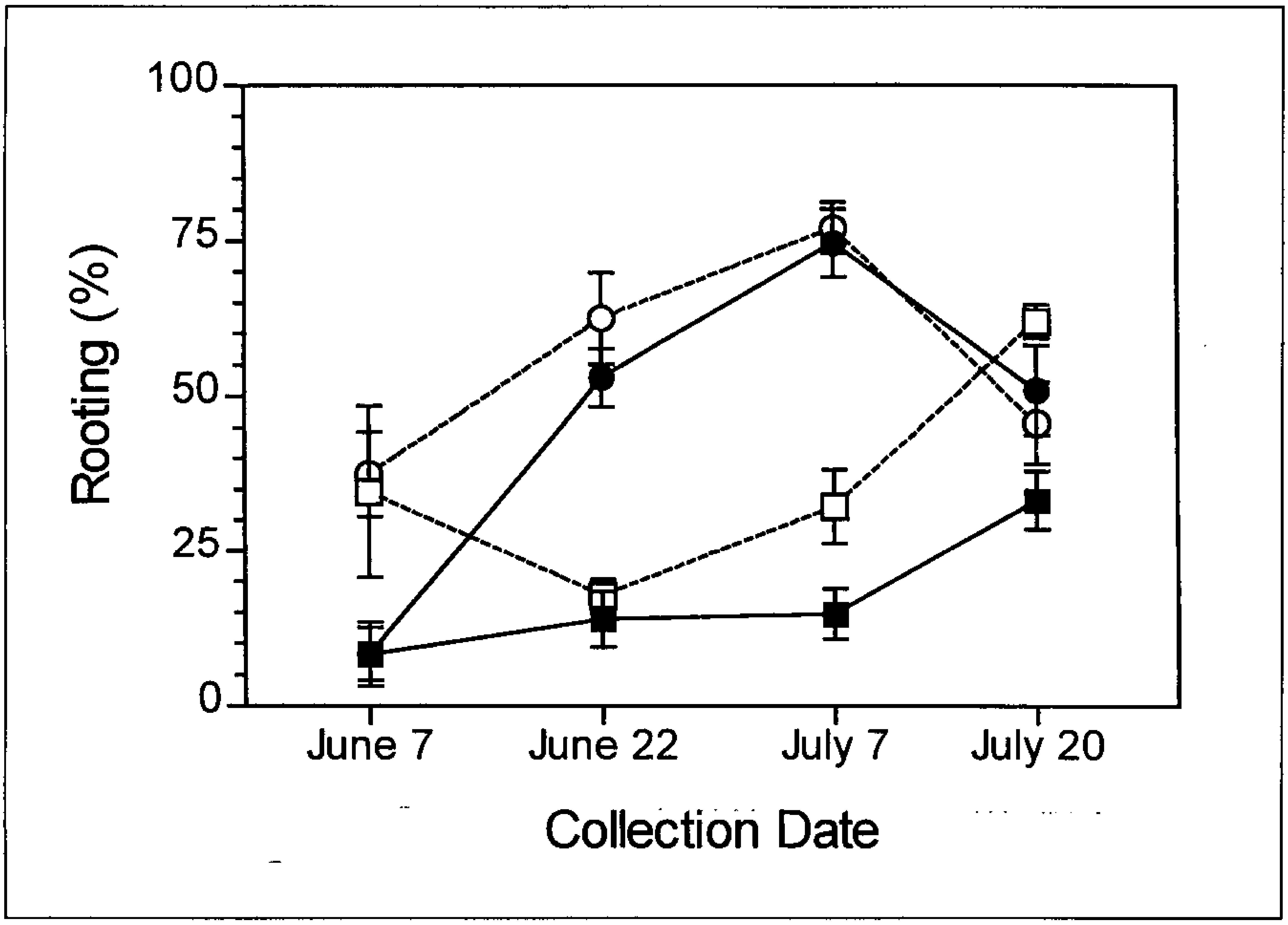

Figure 2. Relationship of cutting collection date, stock plant age and cutting type to the percentage of acceptable rooted cuttings of 'Old Home × Farmingdale 97'. Cuttings were collected from 7-year-old cutting-propagated stock plants and divided into apical (■) and sub-apical (●) cuttings, or collected from 3-year-old micropropagated stock plants and divided into apical (□) and sub-apical (O) cuttings.

In a separate set of experiments, we tested the relationship of cutting position on a shoot to rooting. Fifty-five percent of apical cuttings rooted acceptably, whereas 92% of sub-apical cuttings rooted acceptably. We observed that sub-apical cuttings rooted quickly and remained healthier than the apical cuttings.

The following year we studied the interaction of stock plant age and cutting position. Root development on apical and sub-apical cuttings from 3- and 5-year-old stock plants was evaluated by sampling cuttings beginning 4 weeks after sticking and at intervals thereafter. Most rooting on sub-apical cuttings occurred within 4 weeks and was complete by 8 weeks (Fig. 1). Apical cuttings from 3-year-old stock plants rooted slowly and did not match the performance of the sub-apical cuttings. Overall, cuttings from 3-year-old, micropropagated stock plants rooted better than cuttings from 5-year-old, grafted stock plants. However, sub-apical cuttings from the older plants were superior to the apical cuttings, but did not match the sub-apical cuttings from the younger source.

Similar sets of cuttings from OH × F 97 were collected and stuck on four dates in June and July. Rooting of sub-apical cuttings was best in late June and early July and was superior to rooting of apical cuttings during this period (Fig. 2). During this optimal period, sub-apical cuttings from 7-year-old, cutting-propagated stock plants rooted about as well as sub-apical cuttings from 3-year-old, micropropagated stock plants.

DISCUSSION

In initial studies of several Old Home × Farmingdale clones, we observed that softwood pear cuttings were very sensitive to propagation environment, in particular mist frequency and duration, medium composition, and air movement. The conditions described in the methods section reflected our attempts to optimize these factors. Furthermore, auxin treatment of pear was very important. Gilliam et al. (1988) reported the differential response of *P. calleryana* to IBA and KIBA treatment. We have confirmed that 20,000 mM KIBA is the optimal auxin treatment for *P. communis*, as well.

Stock plant age or maturity is increasingly recognized as a factor limiting cutting propagation of many species. Various methods have been used to improve rooting potential, but micropropagation has proven particularly effective for several species (Howard et al., 1988; Struve and Lineberger, 1988), including pear (Jones and Webster, 1989). Jones and Webster observed small effects of micropropagated stock plants on rooting of two very difficult-to-root clones. The clones we worked with were less difficult and micropropagation significantly improved rooting potential. We also observed that grafting and cutting propagation of stock plants resulted in comparable improvement. The long-term effects of these propagation methods remained undetermined, however.

Pear cuttings taken from the fully expanded, sub-apical, portion of the shoot rooted better than the apical section. Sub-apical cuttings are more resistant to stress and also retained high rooting potential. Rooted cuttings can be transplanted directly to the field. If moved early enough in the summer, shoot growth resumed and substantial growth obtained.

SUMMARY

We have identified several factors important to rooting softwood cuttings of pear. One of these is the use of young stock plants. A simple, optimal propagation strategy would use recentlymicropropagated stock plants as the source of sub-apical cuttings that would be handled as we described. Current results of these studies are also discussed on our web page at http://www.orst.edu/dept/hort/faculty/proebst.htm

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Dealing With Disease in High Humidity Environments: Strategies for Control in Fog and Mist Zones

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INTRODUCTION

The purpose of this presentation is to discuss, in practical terms, the nature of plant disease in high humidity propagation houses utilizing fog and mist systems, and to present workable, tested control strategies from both research and personal experience. An integrated approach to disease management is crucial, since chemical control alone is seldom effective. There is no one strategy that will, by itself, control pathogens under the intense disease pressure that exists in fog and mist houses. However, good control is possible by utilizing many different strategies.

DEFINITION OF DISEASE

Disease, in the broad sense of the word, refers to any negative deviation from normal growth patterns and development. Diseases are usually classified as biotic – those caused by a pathogen — and abiotic — those caused by something other than a pathogen (such as nutritional disorders, insect damage, water stress, or mechanical injury). The focus of this discussion is on biotic, or pathogenic diseases. Some factors which increase the likelihood of disease in propagation houses are the wounding of plants (an unavoidable part of stem cutting), plant stress due to lack of roots for water uptake, a humid environment which is conducive to certain pathogens, presence of insect vectors of disease such as fungus gnats and shore flies, and high temperatures.

THE DISEASE TRIANGLE

In order for a disease to develop, three factors must be present; the host plant, the pathogen, and a favorable environment. Taken together these are referred to as the disease triangle. Disease cannot develop in the absence of one of these factors. The host is the susceptible plant, the environment must be conducive to the growth, development, and reproduction of the pathogen, and of course the pathogen must be present. Disease can be prevented or curtailed by interrupting one or more of these factors. This applies to disease control in general, and we will look at how to apply this in the special challenge of a high humidity propagation environment. Strategies have been categorized based on which part of the disease triangle they impact.

STRATEGIES TO LIMIT OR ELIMINATE DISEASE DEVELOPMENT

The Host. Leg 1 of the triangle – the host. A susceptible host must be present for disease development.

Cultivar Selection. There are some diseases that are not very host-specific and others that are. We can see differences in susceptibility within a species of plant. Therefore, one strategy for disease control is to select resistant cultivars. However, under conditions in which the plant is stressed, and the environment is very favorable for disease development, even resistant plants can succumb to disease. Cultivar selection based on disease susceptibility alone may not always be feasible. For example, within the species *Salvia ×sylvestris* 'Mainacht' (syn. *S. nemorosa*), the cultivar 'May Night' is highly susceptible to *Rhizoctonia* stem and leaf rot in a high humidity environment. But we do not want to eliminate that cultivar from production – it was the Perennial Plant Association's Plant of the Year in 1997 – a very popular cultivar. In this case, the only alternative is to learn to control the disease.

Stock Plant Selection. Another important factor in manipulating the "host" leg of the triangle is to be sure to take cuttings from healthy, vigorous stock plants. Many times a plant only becomes a susceptible host when it is under stress. How well trained is the crew that actually takes the cuttings? Do they know how to distinguish between a healthy stock plant and one that is under some kind of stress? They should be trained to look for warning signs such as chlorosis, wilt, leaf spot, insect infestations, and stunted or distorted growth. Sometimes there will be a significant difference among plants of the same cultivar growing in fields or stock gardens. The differences can be a result of uneven irrigation, insect infestation, uneven fertilizer application, or some other cause. Cuttings taken from a stressed stock plant are going to be much more susceptible to disease once in the high humidity environment.

The Pathogen. Disease cannot develop without the presence of the pathogenic organism. There are many strategies for excluding or reducing the number of pathogenic organisms in the propagation house.

Stock Plant Health Management. Never bring diseased plant material into the propagation area. Stock plants should be scouted and treated for disease prior to cuttings being taken. Since fungicides are most effective as a preventive treatment, it may be feasible to have all stock plants on a regular fungicide treatment schedule. One thing to remember, though, is that the specific diseases that occur in a propagation house may be different from the diseases to which the plants are susceptible in their regular growing environment. Therefore, the general or broad-spectrum fungicide that is routinely applied to the stock plants may not be effective for the specific diseases that will be encountered in fog or mist zones.

Sanitation. Sanitation begins with the area in which the cuttings are being stuck. Diseases can easily be spread from plant to plant by not disinfecting cutting tools or workers' hands. Cutting benches should be disinfected regularly. There are products available to disinfect both the work space and tools and even the plant material being brought in. We dip cuttings before sticking them in a 0.5% to 1.0% solution of Zero Tol to kill any disease spores that may be present on the plants. Work benches are cleaned daily with either Naccosan or Green Shield. All the workers wear disposable gloves.

Make sure your medium is clean. Do not store your media where it can be contaminated with soil. Flats and pots should be new or have been cleaned with a disinfectant before re-use. The propagation house should be thoroughly cleaned and disinfected when it is empty. If there is a time in summer when a section of the house is not in use, disinfect or sterilize it, then allow it to bake. If possible, close vents and allow the temperature to rise. Not too many disease organisms are going to survive above 100°F. for any length of time.

Even if the fog or mist zone is in use, there are still some products you can use. Bromine (Agribrom) and Zero Tol are safe to use on most plants and both kill or prevent algae. These products have no residual, so frequent applications are necessary. These can be injected directly into the fog or mist system at low rates or can be sprayed over the top of the plants.

Water Quality. Water can bring in a whole host of problems, including spores of *Pythium* and *Phytophthora*, algae and liverwort spores, pH problems that affect nutrient uptake and toxicities from heavy metals. It is important to have water tested to know what potential problems may arise in order to take the necessary measures to correct the problem. Some water sources will never be acceptable for propagation and it is good to know that before investing money in a facility. There are many labs available that will do an "irrigation suitability" battery of tests. Testing for particular pathogens is done by some laboratories. OSU Extension offices have a list of local labs for Oregon.

There are many products that can be injected directly into the water being used for fog, mist, and irrigation in order to kill spores of fungus, bacteria, moss, and liverwort. We are trying a fairly new system that injects charged copper ions into the water system. Zero Tol, bromine, and chlorine are other options for injecting into irrigation water. Injecting some type of disinfectant/sterilant into the water system is useful for sanitizing the water itself, and to some degree the surfaces that the water touches, so it may be useful in controlling algae and foliar fungi. This strategy will not control soil-borne pathogens, however. Most of these products will neutralize quickly once in contact with organic matter.

Pest Control. Controlling pests is an important element in controlling diseases, since many insects are vectors of disease. One of the most important pests in propagation houses is fungus gnats. Not only will the larvae cause damage to young plants by feeding on the developing roots and invading cut stems, but the adults vector fungal and bacterial diseases. Since the adults are primarily algae feeders, controlling algae will help to control these pests. This can be done by removing flats as soon as the plants start to root – the longer the plants are in the propagation area, the more algae will develop.

Fungus gnats can be controlled biologically and chemically. We use predatory mites that feed on the larvae (*Hypoaspis miles*), and that program has been very successful in suppressing populations. There is also a parasitic nematode (*Steinernema* spp.) available, under the trade name Nemasys, that gives more effective knock-down if you already have high populations of gnats. Gnatrol is a Bt (*Bacillus thuringiensis*) product also useful for fungus-gnat larvae control. Several insect growth regulators target the larval stage, including Distance, Precision, and Enstar. In order to contact the larvae, these can be applied as a spray and then watered in.

Biological Disease Control. Controlling disease microorganisms with beneficial microorganisms is another strategy. This is especially useful for soil-borne diseases. Many products are available to inoculate the media with beneficial fungi and bacteria. Some of them work by actually antagonizing the disease organisms and others work by out-competing them for available space, nutrients, etc. When using sterile media, it is important to be aware that the first microorganisms to invade that media will have a competitive advantage. Incorporating beneficials into the media prior to planting will give these organisms a chance to establish prior to invasion of the media by pathogenic organisms.

Chemical Control. When treating with preventive fungicides, it is generally preferable to treat stock plants prior to taking cuttings. However, there are circumstances where chemical sprays in the propagation house are in order. Some diseases will only develop when the plants are exposed to high humidity. For example, *Rhizoctonia* may be present in the field and never cause a problem on the plants, but once the cuttings of a susceptible plant are taken and put in 95% humidity, disease may occur. In that case, a very specific fungicide will protect those cuttings. Good record keeping will help in determining, over time, which plants will have problems in the fog/mist zones. It is important to correctly identify the disease organisms that are causing the problems, in order to treat them effectively. Guesswork can end up costing a lot of money, so it is best to use a lab to get a confirmed diagnosis.

Why not just treat everything in the propagation house with a broad-spectrum fungicide? First, such a treatment would be a waste of chemical and time. Many crops won't require the fungicide treatment. Also, narrow-spectrum fungicides that target a particular organism are often much more effective against that organism. This is the case especially with *Botrytis* and *Rhizoctonia*. There are many chemicals labeled for these diseases, but many of the broad-spectrum products are not very effective. And it is not cost effective to spray the whole house with narrow spectrum products, unless a specific organism is causing wide-spread problems. To control specific known organisms on hosts that are only susceptible in the high humidity environment, a chemical application immediately after sticking with a chemical which specifically targets that pathogen is often the least expensive and most effective option. In addition, the repeated use of fungicides may cause resistant strains of pathogens to develop. Finally, the use of chemicals reduces the amount of time that employees can work in the greenhouse due to re-entry intervals and increases employee exposure to chemical residues.

THE ENVIRONMENT

The environment must be conducive to the growth and development of the disease-causing organism for disease to occur, so that is one area that can potentially be manipulated to suppress disease. However, the environment also has a great effect on rooting percentages and the time it takes for cuttings to root. Sometimes the choice must be made whether to manipulate the environment to the detriment of disease or to the benefit of the plants. In general, the environment in a propagation house should be manipulated for optimum rooting and growth of the crop plants, regardless of the effect on disease organisms. It must be remembered that disease is the result of interplay between the pathogen and the host. The conditions that favor pathogen development in a laboratory will not necessarily favor disease development in a crop production system. For example, it was shown under laboratory conditions that the fungus *Pythium ultimum* had optimum growth at 27°C. So one would think that avoiding that temperature range would suppress that disease. But in a crop of poinsettias, it was found that the optimum temperature for disease development was 17°C (Bateman and Dimock, 1959). The difference could be due to the fact that 26°C was the optimum temperature for root development of the poinsettias, so at that temperature the plant was growing vigorously, making it less susceptible to disease. In this case, the environmental conditions that would ordinarily have favored the pathogen did not lead to disease development, because the plant was able to outgrow the pathogen.

Temperature. The warm temperatures usually maintained in a propagation house are in the optimum range for several important pathogens. One can look at a table to determine the temperatures at which certain diseases are likely to develop in a particular crop. This information is, in practicality, of limited use to most growers. It is often specific to a particular crop and varies with geographical location and other variable growing conditions. Although it may not be practical to regulate greenhouse temperatures according to information in a table, in order to avoid a particular disease, the information is still useful to determine which organisms are likely to be present and active in the propagation house. Fungal organisms whose optimum temperatures for pathogenicity are in the range found in most propagation houses (70 to 90°F) include *Alternaria, Fusarium, Rhizoctonia, Botrytis*, and *Pythium aphanidermatum*. *Xanthomonas, Pseudomonas*, and *Erwinia* are important bacterial diseases that also develop under high temperature conditions. (Jarvis, 1992)

Humidity. Humidity plays a crucial role in the rooting of stem cuttings. High humidity also favors a myriad of fungal and bacterial disease organisms. For the majority of plants propagated by stem cuttings, humidity around the cuttings must be high in order to maintain turgidity and prevent desiccation. This is especially true of soft material, both woody and herbaceous. We have seen a positive correlation between increased humidity and speed of rooting in many species of plants. It is important to maintain humidity around the cuttings from the time they are cut from the stock plants until they are rooted. We experienced an increase in rooting percentages of many crops as humidity was raised in the fog house to over 95%. Of course, this is not true for all plants. Having a choice of zones for propagation is important if you are propagating a wide variety of plant material. We use fog in four zones, each with separate humidity controls, as well as greenhouse and outdoor mist beds. In most areas, humidity is maintained to promote rapid rooting. For some succulents and plants that do not require high humidity, the zone is maintained to prevent desiccation, but at low enough levels to suppress disease.

It may be possible to delay the onset of disease by maintaining a lower humidity, but if this delays root development and causes the plants further stress, you may end up with more loss from disease and from desiccation in the long run.

Soil Moisture. Most soil-borne diseases are affected in one way or another by the amount of moisture in the soil. Diseases which are more prevalent under conditions of high soil moisture content include *Pythium, Phytophthora*, and *Thielaviopsis*. It may be possible to reduce the incidence of these diseases by maintaining soil moisture at lower levels. However, since some water is taken up by the cut stem, in the absence of roots, adequate moisture in the media is necessary in order to maintain turgidity of the cuttings.

Several factors need to be taken into account when considering irrigation. If the humidity is too low, more irrigation is necessary. The splashing from overhead watering can spread disease. Therefore, any disease suppression benefit obtained from lower humidity may be lost due to movement of fungal spores by splashing water.

If irrigation can be managed without overhead watering, that will help in disease suppression. Work has been done using subirrigation in conjunction with fog and mist, and without fog or mist, in propagation of stem cuttings. If the humidity is high enough, depending on the time of year, additional irrigation may not be necessary.

Air Movement. Good air circulation is crucial in controlling disease. Air movement can be created using fans, or will occur as a result of natural ventilation (i.e., roof vents). Using wire mesh benches encourages air movement in the area around the plants. Since warm air rises, using bottom heat causes an upwards movement of air in the canopy. Horizontal air flow fans will keep air in circulation. In a fog house, it is not desirable to keep up a strong draft because that will create uneven humidity that can lead to uneven rooting. The house should be properly ventilated with gentle air movement in and around the plant canopy.

TIME

Time is a factor that may turn the disease triangle into a 4-sided pyramid. It takes time for disease development. The longer plants are kept in fog or mist, the more susceptible they become to certain diseases. We have seen that in cases of uneven rooting within a flat of plants, the more vigorous plants, which rooted first, may succumb to disease because they are left in the fog too long waiting for the stragglers to root. When this happens, the best plants are lost for the sake of the weakest! It is wiser to move the flats out before disease can get started on the first plants to root, and if plants are lost, it will be the weaker ones which are taking longer to root. It is a good idea to get the plants out of the high humidity environment as soon as possible. Of course, use good judgement concerning the time of year; don't move plants with few roots to a dry area when it's 90°F. Often, an intermediate area where the young plants are protected by shadecloth until they are well rooted is advisable.

CONCLUSION

From the time stem cuttings are placed in a high humidity environment, a race begins between the host plant and the pathogens. If the conditions are such that the host plant will root quickly, it may win the race and be able to be moved out of the humid environment prior to the onset of disease. However, if the host is slow to root, due to some type of stress or to the genetic nature of the plant, the pathogen may "outrun" the host, and the cutting may be lost to disease.

We must do everything we can to "stack the odds" in favor of the plant. This can be done by manipulating the environment such that it favors rapid root development, protecting the cutting with fungicide to slow or prevent disease development, lowering the population of the pathogenic organisms through sanitation, selecting only the strongest, healthiest cutting material, inoculating the cutting media with beneficial microorganisms to suppress pathogens, and selecting cultivars which have genetic resistance to disease organisms.

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Seedling Production in the Northern Plains

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Lincoln-Oakes Nurseries is an association-owned nursery producing woody plant conservation materials for the Northern and Central Plains and surrounding states. Our production sites are located in Bismarck and Oakes, North Dakota and have been in production for nearly 50 years. Customers consist of soil conservation districts, public agencies, and other conservation nurseries.

We are located in the North Central U.S. and so are heavily influenced by an inland continental climate. The growing season is 125 days on average and can vary from about 115 to 145 days. The average frost free days are probably our greatest limiting factor in seedling production in North Dakota.

Climate is rated as USDA Zone 3 with winter lows below -30°F in at least 7 out of 10 years, occasional lows dip below -40°F. Moisture averages 16 inches annually in Bismarck to 20 inches at our nursery in Oakes. Snow cover may range from heavy to nearly non-existent in some years, typical of the plains environment.

The nurseries' production mix consists of approximately 70 deciduous species and cultivars of trees and shrubs hardy in our distribution area that ranges from climatic Zones 3 through 6. To ensure hardiness of the stock produced, we maintain our own seed production belts and orchards and also collect from established plants in the area. Very little seed is purchased from non-regional collectors or companies. Examples of species produced include *Acer, Crataegus, Cornus, Fraxinus, Prunus, Populus, Quercus, Rhus, Rosa,* and others.

Stock is grown as 1-0, 2-0, 2-1, and 3-0 seedlings and 1-yr rooted hardwood cuttings.

Seedling propagation requires high-quality, cleaned seed as a starting point. Fleshy fruits such as *Prunus, Malus,* and *Amelanchier* require de-pulping, drying, and fanning to remove all pulp and fruit skins. We have built a Dybvig type mascerator with a four-cylinder engine and three-speed transmission to accomplish the de-pulping of large fruit lots. Seed is bagged after cleaning and stored at 35°F until use. We can normally store seed for up to 3 years in advance of use to insure yearly crops of required species.

Seeding of nursery crops is undertaken using stratified or non-stratified seed depending upon treatment required to initiate germination. Seeding takes place in the months May through October. Warm stratification requirements are met by summer and early fall planting of dry seed in mulched moist beds, cold stratification occurs over the winter months. Examples of summer seeded crops are *Crataegus, Cotoneaster*, and *Rosa*, most *Prunus* species are early fall planted for a short-warm stratification. Several species are given warm and cold stratification treatments artificially in plastic bags for 8 to 10 months before summer or fall planting to simulate a years treatment in outside conditions, examples include *Viburnum* spp., *Fraxinus nigra*, and *Symphoricarpos occidentalis*. Many crops can simply be given a cold stratification treatment in a cooler to initiate germination, this may range from 30 to 120 days in a damp media.

Winged seeds, acorns, nuts, and large *Prunus* seeds are seeded using a tractor drawn 2 row belt seeder which is ground driven. Metering to obtain the desired seeding rate per linear foot is done by adjustable gates. Rows are planted on a 32 inch spacing and hilled with soil to maintain moisture and provide protection over the winter.

Many small-seeded shrub species are planted in four row beds on a 12 inch spacing between the rows. The four seeding units have adjustable planting plates which allows use for a wide range of seed sizes. Seeded beds are sanded to lesson soil crusting and then may be mulched with rye straw.

Seed germination and seedling emergence takes place in late April and early May; damaging freezes can occur at this time and some night irrigation may be required for crop protection.

Cultural inputs during the growing season include chemical applications for disease and insect control, cultivation, weeding, fertilization, and irrigation. Our irrigation water source at Bismarck is the Missouri river about 2½ miles west of the nursery. This high quality irrigation water is pumped through a 16-inch underground pipeline and utilized by the nursery and two additional cooperators.

The previous nursery water supply was well water that was very high in sodium. Sodium gradually accumulated in the soil and by 1990 it was very difficult to grow a number of salt-sensitive plant species at the Bismarck site. Several water supply alternatives were considered to address the problem, the plan chosen was to run a pipeline from the Missouri River to bring in fresh water and begin gradually to leach the accumulated sodium below the root zone. Heavy irrigation of soil building crops and fallow fields was suggested as a way to begin the leaching process. The irrigation system was completed in 1991 with river water making a tremendous difference.

At that same time we wanted to address the soil condition and what could be done to improve water permeability, alleviate crusting, reduce soil pH, and increase organic matter. The city of Bismarck was looking for an alternative to burying lawn waste which accounted for up to 40% of the materials deposited at the city landfill during the summer months. In cooperation with the city, we opened a stockpiling area for thatch, lawn clippings, and leaves. These were spread heavily on open production fields several times during the summer and fall months and disced into the top growing layer of the soil. No plowing is done, this eliminates bringing salts back up to the soil surface.

Fields may be applied with organic material for 1 or 2 years depending upon field condition. Rye is fall planted after spreading is completed and grown as a cover crop. The rye crop is either chopped for use as mulch the next summer or disced under.

Improvement in our soil has been rapid and noticeable in improved seedling growth, water permeability, and root system quality.

Propagation of poplars, cottonwood, and willows is accomplished by growing cutting material in stooling blocks, harvesting after defoliation, and processing into 7-inch cuttings over the winter months for spring planting. We utilize a fabricated four-row mechanical planter for placement of the cuttings at planting time in late May.

Growth is rapid during the growing season and 1-year-old rooted cuttings are 3 to 6 ft in height at season's end.

Plains cottonwood, *Populus deltoides* subsp. *monilifera* (syn. *P. deltoides* var. *occidentalis*), often roots in poor percentages from hardwood cuttings in the field, due to this most of our cottonwood is grown from seed as a 2-0 crop.

Cottonwood seed is dispersed in June from native stands along the Missouri River. Seed is collected by using a shop vacuum type cleaner that removes the hairs from the small seeds as they are vacuumed into the cleaner. The seed is very short-lived and after some preliminary cleaning to remove debris, is seeded directly onto the surface of raised, packed beds.

Under natural conditions, cottonwood seed lands on the bare surface of sub-irrigated soil or sand along riparian areas. To successfully germinate the seed under nursery conditions, a continually moist soil surface must be maintained for the first 5 to 7 days after seeding for germination and root development to occur. To maintain this moist soil surface under our low humidity conditions, erosion mats are rolled onto the beds and pinned down to prevent removal by winds. Irrigation is applied two to three times daily and germination begins at 2 to 3 days. It is complete at 7 days after planting. The mats are removed from the beds at approximately 10 to 14 days after seeding.

Cultural inputs for cottonwood seedlings after mat removal are the same as for other seedling crops. Plains cottonwood is initially slow-growing as measured by seedling top growth, but much of the first year plant growth is in the deep taproot. Height at the end of the first season is 10 to 24 inches, but reaches 5 to 8 ft at the end of the second season.

Harvest of our nursery crops begins around the first of October after several hard frosts have initiated defoliation of species such as green ash and caragana that drop leaves fairly early in the fall. Most crops of seedlings are topped with a modified forage chopper to a height of approximately 20 inches to provide a uniform seedling size and a top to root ratio of about 2 to 1 to 3 to 1.

Undercutting and lifting is accomplished by a single row lifter used on our 32-inch row spacing and a Lundeby plant lifter for our four-row beds. As stock is lifted, it is quickly placed in wooden field boxes, misted, and transported to our grading facility with a fabricated box carrier.

Our lifting season lasts until soil freeze up halts digging that occurs on the average about the second to third week of November. About 65% of our stock is fall lifted with the remainder dug after thaw in spring.

Seedlings are graded, bundled, and then placed in cooler crates with a poly bag liner. Grading is for the most part based on a conservation grade seedling of 12 to 20 inches in height and corresponding caliper. Additional sizing is done for customers with specific size needs.

Storage of graded stock overwinter is accomplished by the use of two cooler/freezer units. Units freeze stock at 25 to 27°F during the winter months and act as coolers in the spring at 35°F. Stock is pulled for orders as needed and shipped by nursery or customer truck and by United Parcel Service.

Propagation of Endangered Species: Variable Germination of Pink Sandverbena from Pacific Coast Beaches

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Pink sandverbena (*Abronia umbellata* ssp. *breviflora*) is an endangered plant of Pacific Coast beaches. Restoration efforts have focused on the development of seed germination and field propagation techniques. Germination in the laboratory was highest when seeds were removed from the fruit and received alternating temperatures (20°C/30 C) and photoperiods. Benefits from cold stratification differed strongly from site to site and year to year. Field-sowing of seeds is also a viable propagation method.

INTRODUCTION

Reintroduction may be essential for endangered plant conservation, especially for species with few remaining wild populations. Descriptions of effective procedures for rare plant propagation and establishment in the field are crucial for advancing the practice of species re-establishment (Falk et al., 1996).

Many sandverbenas (*Abronia* spp., Nyctaginaceae) are rare and prone to extinction, a characteristic that led Wilson (1972) to call them "disappearing species." Pink sandverbena (*A. umbellata* ssp. *breviflora*) is indigenous to the Pacific Coast of North America from British Columbia to northern California. Due to the invasion and subsequent stabilization of foredune systems by European beachgrass (*Ammophila arenaria*) (Wiedemann, 1984) and disturbance by off-road vehicles, pink sandverbena is now restricted to three wild populations on the southern Oregon Coast and perhaps a dozen in California. It is listed by the state of Oregon as endangered and it is considered a Species of Concern by the U.S. Fish and Wildlife Service. The primary goal of this report is to document germination techniques for pink sandverbena under laboratory and field conditions.

MATERIALS AND METHODS

Pink sandverbena is a low-growing, herbaceous annual plant with a central taproot (Kaye et al., 1999). Each flower produces a single-seeded fruit (achene) with 3 to 5 broad wings that presumably promote dispersal. Germination experiments were performed at Oregon State University's Seed Lab and at two field sites on the Oregon Coast. Field sites included dredged sand placed on the beach at Port Orford on the southern Oregon coast and a natural beach at Greggs Creek, about 20 miles south of Port Orford. Seeds for germination tests came from naturally occurring populations at Port Orford, Harris Beach, and Gearhart, Oregon, as well as a population at Coos Bay that was restored with seeds originally collected at Port Orford.

I conducted a series of germination tests to develop an effective protocol for producing large numbers of seedlings. Prior to germination tests, viability of seeds collected in 1991 and 1992 from Port Orford were analyzed with tetrazolium chloride; viability in these tests was nearly 100%.

In the first experiment, seeds from Port Orford received alternating temperatures and photoperiods (20°C, 16 h dark/30°C, 8 h flourescent light) as recommended by Chirco and Turner (1986). I compared germination of seeds with the following treatments: whole fruits on moist sand, clipped fruits on moist sand, dry-stored seeds on moist germination paper, dry-stored seeds on paper soaked with 0.2% potassium nitrate solution (KNO_3, see Copeland and McDonald [1995]); cold-stratified seeds on moist paper, stratified seeds on paper with KNO_3, dry-stored seeds on moist sand, and dry-stored seeds on sand with KNO_3 solution. Each treatment was replicated 6 times, with 40 seeds per replicate in the first six treatments and 25 seeds per replicate in the last two. Germination, defined as 5 mm growth of the radical, was recorded after 2 weeks. I used ANOVA to test for a treatment effect and Tukey's multiple range test to compare means.

To compare germination of seeds from different natural populations, a second experiment used seeds collected from Harris Beach, Port Orford, and Gearhart, Oregon, in 1993. These seeds were removed from the fruit and subjected to alternating temperatures and photoperiods (20°C, 16 h dark/30°C, as above). Each population was replicated 6 times, with 40 seeds per replicate.

A third experiment was conducted in 1997 and 1999 to re-examine seed dormancy and effects of stratification. In 1997, six replicates of 20 seeds each from Port Orford (1996) were stored dry while an identical set of replicates were cold-stratified on moist pads at 4°C for 8 weeks. I used a *t*-test to compare mean percentage

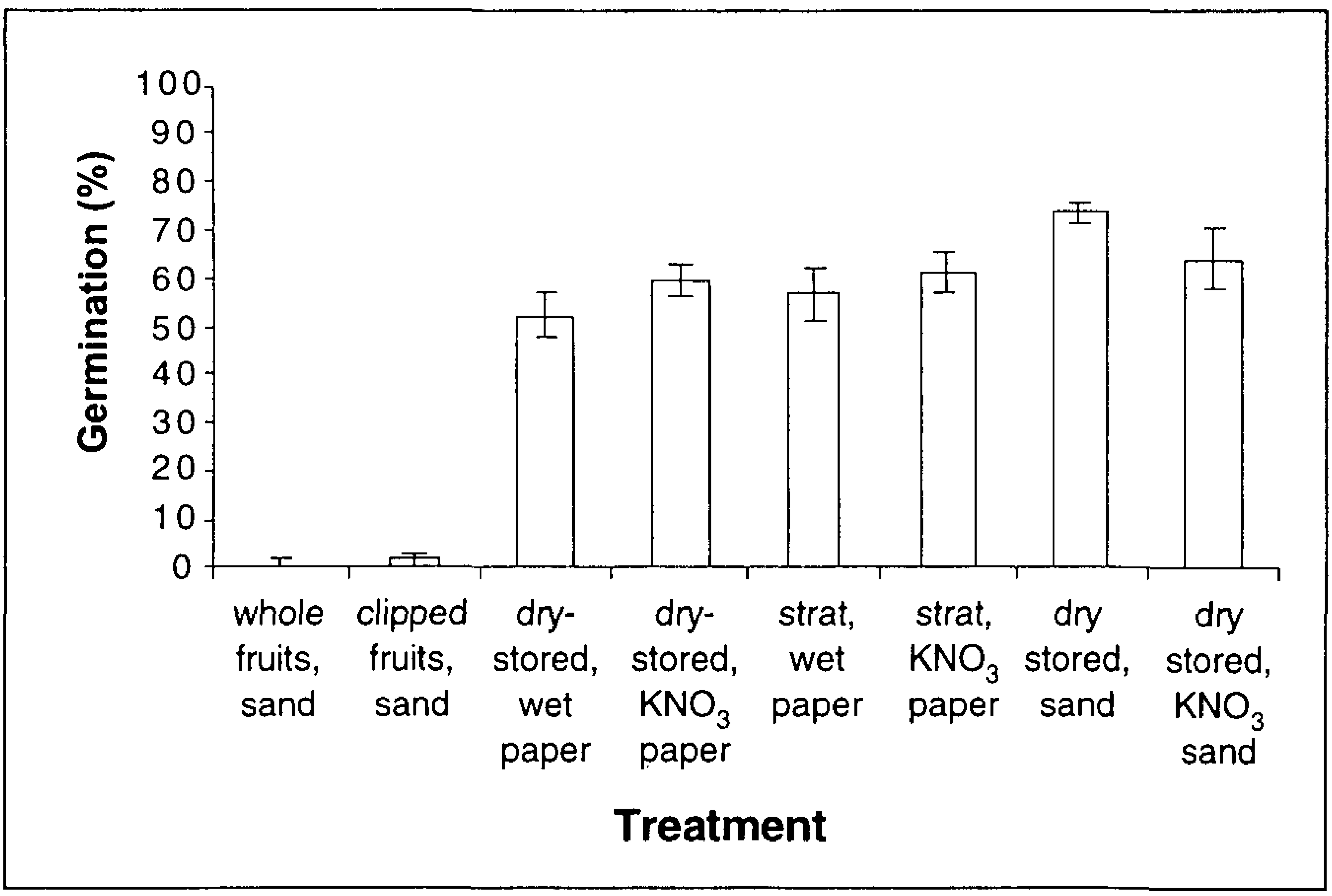

Figure 1. Germination of sandverbena seeds in various treatments (error bars represent ±1 SE). See text for explanation of treatments.

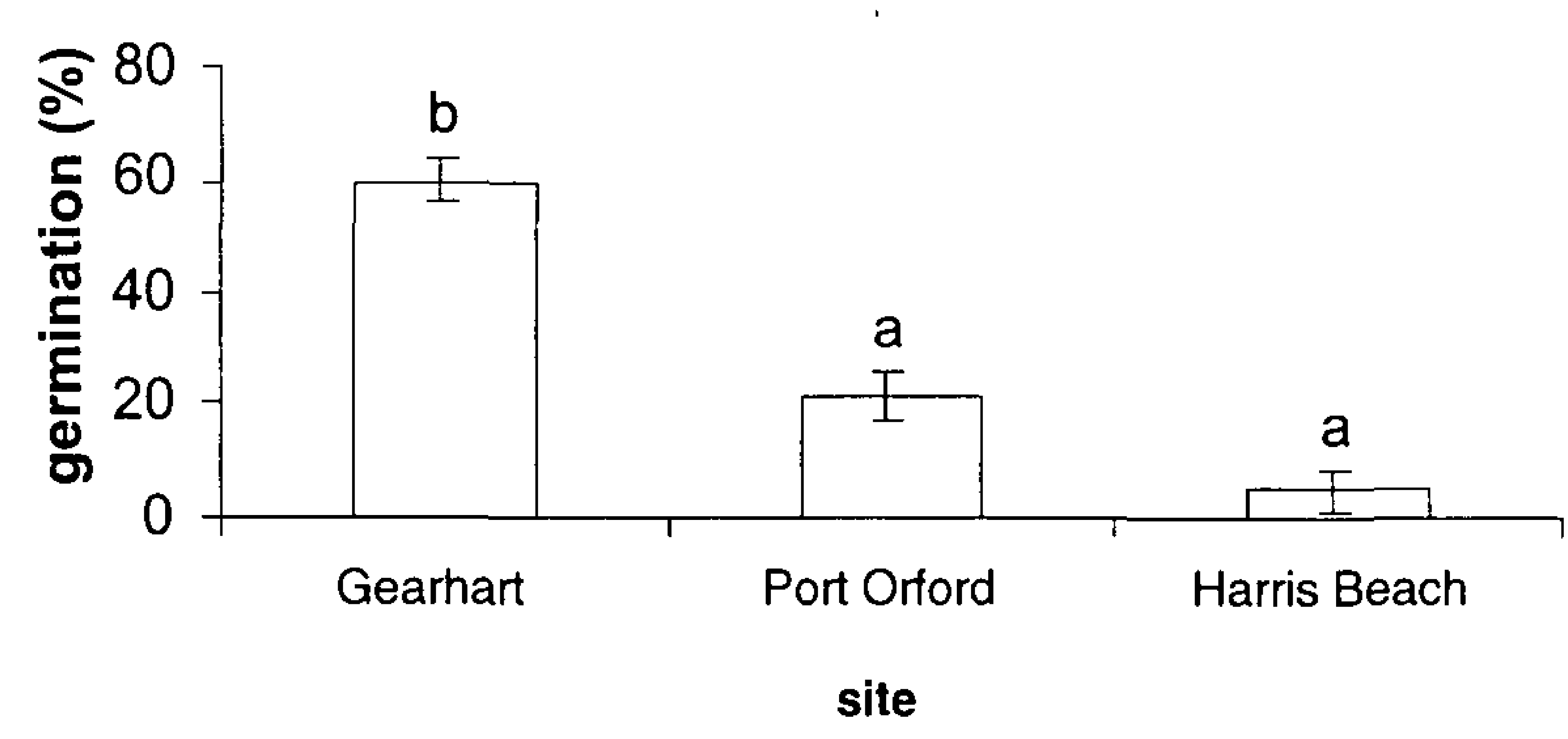

Figure 2. *Germination of seeds collected from three sites. Bars with the same letter are not significantly different.*

germination. In 1999, groups of 150 seeds from Port Orford (1997) and Coos Bay (1998) were chilled at 4°C for 0, 1, 2, 3, 4 , 6, and 8 weeks, then placed at alternating temperatures (20°C/30°C) to document minimum stratification periods.

Field experiments were performed in a fourth experiment. In November 1993, sandverbena fruits were sown on the sand surface, buried 3 cm, and buried 10 cm. In all of these treatments, 50seeds were placed in each plot. Each treatment was replicated 16 times in a randomized block design, duplicated at Port Orford and Greggs Creek. Seedlings occurring in these plots were counted in June 1993 to determine percentage seedling recruitment for each seeding treatment. For more details of field methods, see Kaye et al. (1999).

RESULTS

In Experiment 1, treating seeds prior to placing them in alternating temperatures had a significant effect on germination (df=7, F=34.73, P<0.0001). Specifically, removing the fruit from the seed increased germination several-fold: only 0.8% and 1.7% of seeds with fruit husks left intact or clipped germinated, while those with the fruit husks removed ranged in germination from 52% to 74% (Fig. 1). Differences among the other treatments were not significant. Experiment 2, however, suggests that germination of seeds collected the following year differed among populations (Fig. 2). Although seeds from Gearhart had relatively high germination (60%), those from Port Orford and Harris Beach had significantly (P<0.0001, one-way ANOVA) lower rates (5% to 22%). Seed germinability and/or dormancy clearly differed from site to site and year to year.

Tests performed in 1997 with seed collected in 1996 at Port Orford showed that stratification significantly improved germination from an average of 32.5% to 80.8% (df=10, t=2.23, P<0.0001). This is inconsistent with results from Experiment 1, in which stratification had no effect. Tests in 1999 with Port Orford (1997 collection) and Coos Bay (1998) seeds also showed a positive effect of stratification. Initial dormancy rates differed among the two populations (despite their genetic similarity). In this test, germination reached about 90% after 2 weeks of 4°C stratification (Fig. 3).

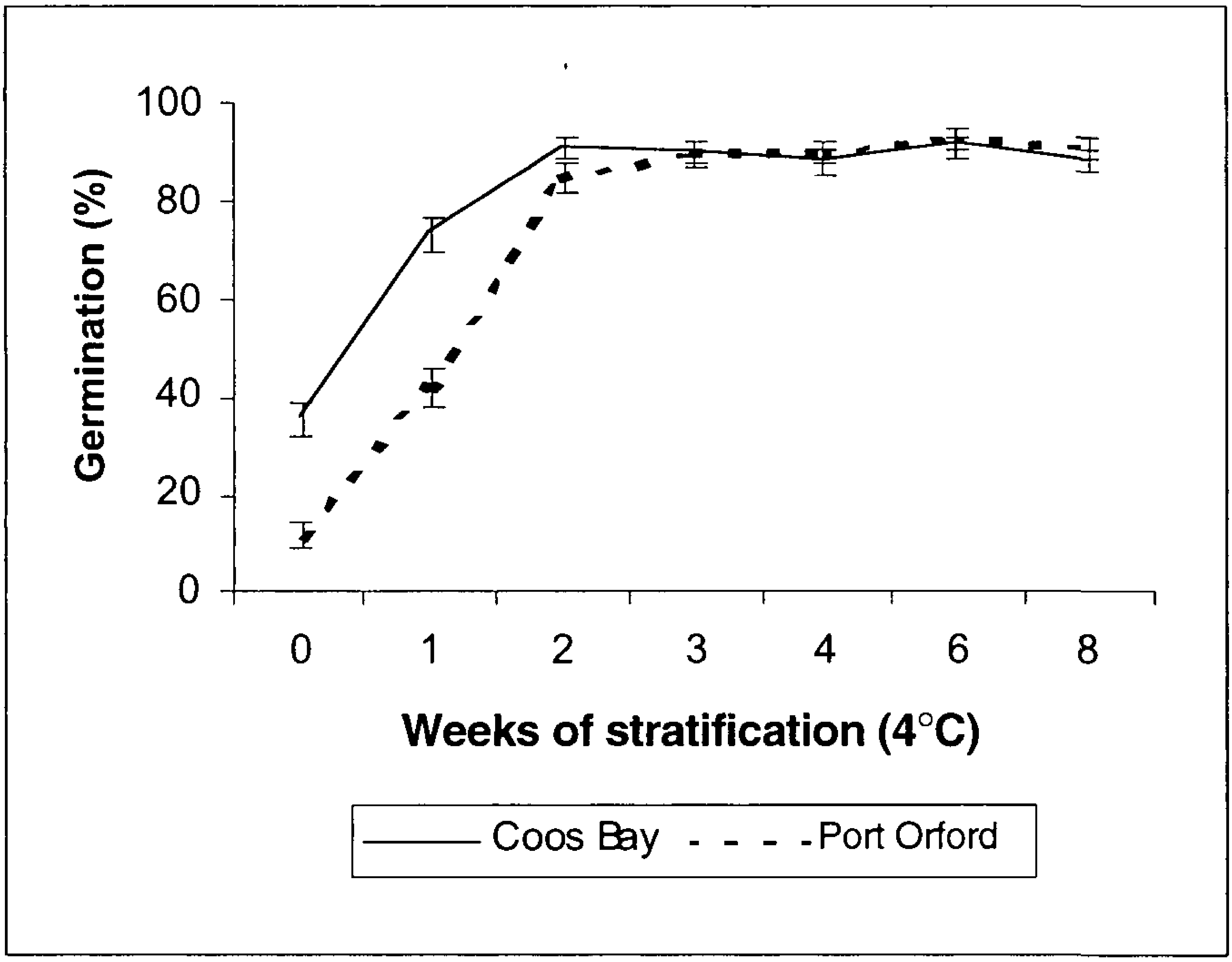

Figure 3. Effect of stratification period on germination of seeds from two populations. Error bars represent ±1 standard error.

Sowing seeds (in fruits) directly in plots in November was an effective method of producing seedlings the following June (Fig. 2). Seed burial at 3-cm produced the best results, with an average of 37.5% emergence at Port Orford and 25.9% at Greggs Creek. Seedling establishment from fruits buried 10 cm was significantly lower than shallow-buried or surface-sown seeds at Port Orford (df=2, F=22.3, P 0.0001) and Greggs Creek (df=2, F=8.02, P=0.002).

DISCUSSION

Seed germination in the laboratory was greatest when the seed was removed from the fruit. Once fruits were removed, germination of seeds collected in 1992 was not affected by stratification,exposure to KNO_3, or substrate (germination pad or sand), all of which yielded about 50% to 70% germination in alternating temperatures and photoperiods. However, stratification substantially improved germination of seeds collected from Port Orford in 1996 and 1997, and from Coos Bay in 1998. Apparently, germination requirements for this species differ from site to site and year to year. One possible explanation is annual variation in climate during seed maturation and while fruits are on the ground, prior to collection. Germination methods for this species may need to be revised periodically to propagate plants from different years and different locations. Fortunately, 2 weeks stratification at 4°C results in high germination rates, regardless of collection site and initial dormancy.

Sowing single-seeded fruits directly into appropriate habitat resulted in short-term plant establishment on dredged material and a natural beach. Sowing seeds or transplanting greenhouse-grown individuals on beaches may be effective methods for re-introducing pink sandverbena. Deep-burial of seeds should be avoided, however, because buried seeds may remain dormant or fail to emerge.

Acknowledgments. This research was supported by funds from the Army Corps of Engineers, Coos Bay District BLM, and the Oregon Department of Agriculture. The Oregon State University Seed Lab generously provided technical assistance and growth chamber facilities.

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Discussion Group: Direct Sticking of Cuttings Session

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The topics discussed during the Direct Sticking of Cuttings Session were the following; direct sticking into the final container for sales (#1 gal), coir versus peat, mortality when determining direct stick versus other methods, tray sizes and shapes, copper-treated trays, recycling of trays, paying piece rate, bromine, mist booms, and multiple cuttings per cell. Most of the discussion focused around the use of coir as a substitute for peat moss, this seems to be a big issue right now. The following are comments made during the discussion.

A question was posed to the group about the use of coconut coir. Most people in the session use peat moss, and many have tried coir. Quality problems with coir include; high salts potentially and coir may make nitrogen unavailable to the plant. It was suggested that when purchasing coir, use inland sources that may contain fewer salts. It was also discussed that coir may tie up nitrogen in the soil making it unavailable to the plants. A comment was also made about coir not breaking down as fast as peat and that it is easier to wet than peat. Bruce Briggs asked if anyone had used rice hulls and Rob Sloan answered that he had and they were cheap and did a good job.

Another topic discussed was direct sticking into the final saleable container (specifically a #1 gal container). Comments made indicated that *Hydrangea* was a genus where this worked well. Bruce Briggs commented on getting moss and liverwort growth in #1's and your wood could get used up quickly when direct sticking into them. It was determined that this may be a labor tradeoff.

Cindy Lou Pease posed a percent mortality question to the group. She has not done a lot of direct stick and was curious about at what percentage should you stick into open flats or direct stick. Three comments were made about this. One said 70% was the percent mortality that they used, another said space was the issue, and the third said that everything was direct stuck to avoid potting and transplant shock.

Sticking multiples of cuttings into a single cell or pot was also discussed. Bruce Lane commented that they do what the customer wants in the final product. Multiples will give a bushier plant quicker and give more cutting wood. Basically, what does a customer expect?

With increased use of plug trays, recycling can be a problem. Christine Ames suggested checking with manufacturer replicates to see if they can help find methods of disposal or recycling.

Arda Berryhill spoke about paying piece rate. She just recently toured the Southern Region and found out that many nurseries pay their employees based on piece rate. She asked if that was happening here and someone had seen it done but said they were disappointed with all of the paperwork required.

Bromine was brought up for discussion and many members said that they have used it for several years with good success. Phytotoxicity to certain varieties was a concern but had not been encountered yet. Bromine will corrode stainless steel.

Discussion Group: Native Plant Propagation

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The native plant propagation session began with a discussion centered on the definition of a native plant. Some participants questioned why native plants should be grown when there are other, nonindigenous plants that may be more attractive, more disease-free and/or more insect-resistant. It was suggested that the California Native Plant Society has provided an excellent definition of "native plant". To be considered a native plant in North America, the plant must have been present from the time of pre-European settlement. Reasons to grow native plants were cited; these included propagation of site-specific material to preserve the genetic integrity of a site and tolerance of naturally occurring climatic conditions, especially drought. Another question was "are native plants actually lower maintenance"? It was generally agreed that they use less water than many introduced species. More vigorous mulching and use of pre-emergents can keep maintenance down.

The next topic of discussion was the use of mycorrhizae. Endomycorrhizae make phosphorous readily available to plants in soils where phosphorous availability is low. Jeff Boehn of Tree of Life Nursery stated that in Southern California, the dominant form of mycorrhizae is endomycorrhizae which colonize root tips. Ectomychrrhizae are associated with forest trees. In nursery production, the intent is to get the mycorrhizae onto plants as soon as possible since it is least expensive to incorporate them in seed flats or at the time of first transplant. Jeff stated that in order to introduce mycorrhizae into a nursery, you must first look at the whole program. Different strains of mycorrhizae may require adjustment of soil pH, fertilizer program, etc. He recommended that you go with "weedy, dominant" strains of mycorrhizae and mentioned VAM-80. Tree of Life cultivates their own strains. When you get mycorrhizae from under plants in the wild you don't know what you are cultivating. He recommends you add mycorrhizae to your container plants in a solution of 1 tsp gal^{-1} of solution. In field-grown crops, ectomycorrhize blow back in after soil fumigation and will make a comeback in the 2nd year. Mycorrhiza.com was recommended as an excellent website. Bitterroot Nursery stated they innoculate. Another grower working with native endangered plants in Oregon stated that most don't require mycorrhizae, however *Astragalus applegatei* does respond to innoculation with field-collected soil. Osmocote18N-6P-12K works well with endomycorrhizae.

Wilbur Bluhm mentioned that Ben Holden had a poor rooting percentage on *Arctostaphylos uva-ursi*, but with inoculum of a slurry of native soil the rooting percentage nearly doubled from 50% to 95%.

Use of pumice versus vermiculite as a rooting medium was discussed, with denser rooting of Oregon grape occurring in vermiculite than in pumice. Douglas fir sawdust promoted good rooting, but tops showed nitrogen deficiency. It was mentioned that it is tough to mix different media in the same house.

Use of Root Shield fungicide (*Trichoderma*) was discussed. Bob Briggs requested clarification between the products "Green Shield", a disinfectant, and "Root Shield", a biological fungicide. APEX came out with a new fertilizer – "Native Mix" for native Northwestern species of plants, "native blend".

Another topic of discussion was how to determine when to take cuttings of native species and what type of cuttings to take. Bruce Briggs discussed the use of mature vs. softwood for *Arctostaphylos uva-ursi* (kinnikinick) and *Ceanothus* spp. and recommended that you run tests every few weeks to find out what's best for a species in your particular region. Sometimes you only have a successful window of 2 weeks. It always varies, but you work it out on a particular plant and go with that. Jeff Boehn agreed that "everybody tweaks plants." Every species has a specific cycle and we have to work with that in propagation. Tree of Life uses about 50% cuttings and 50% seed in their nursery. For site specific projects, they use mostly seed. Their market is half restoration and half landscaping. Landscape architects specify the same old plants and this leads to reduction of diversity of native species used in landscapes.

PROPAGATION OF THE FOLLOWING SPECIES WAS DISCUSSED:

***Mahonia aquifolium* (syn. *Berberis aquifolium*).** Wilbur Bluhm mentioned that at one time a propagator he knows was getting 25% take on cuttings. He gave some of the cuttings to an electrician who got 100% take when rooting them in vermiculite, rather than in pumice. For seed propagation, pick seed on the soft side.

***Chrysolepis sempervirens* (syn. *Castanopsis chrysophylla*).** Althouse Nursery stated they germinate, grow to a few inches, and then die over night. They collect seed from Hood National Forest to California and have a difficult time finding seed. They clean seed with a weed eater in a steel garbage can, then use a leaf blower to separate seed from casings. (This also works with *Cercis occidentalis*.) Direct plant seeds. Althouse uses warm stratification from Christmas to March. When asked what this meant, he stated you don't want the seeds to go dormant. Just plant them when warm and let the seedlings go dormant in winter. No one present had grown or heard of successful rooting of chinquapin (*Chrysolepis*) cuttings. It was mentioned that Matsutakes grow under madrone and *Chrysolepis* sp.

Chrysolepis chrysophylla (syn. *Castanopsis chrysophylla*) seed or *Garrya fremontii* and *G. elliptica* also germinate after warm stratification.

***Garrya elliptica* 'James Roof'.** This plant will root readily if you extend the bottom of the cutting below the node 1 inch. Take cuttings in fall and space far apart.

***Crataegus*.** Native *Crataegus* is a summer plant. Fruits in June or July. Trees seed every 2 to 3 years. *Crataegus douglasii* (black hawthorn) reacts like it is native to plains. Give 90 to 120 days warm, 150 to 180 days cold (there will be some germination), followed by 90 to120 warm, 150 to 180 days cold. (There will be higher germination.) Another recommended germination regime was acid treatment followed by 3 months cold stratification, then sow. It was mentioned that native hawthornes are used to make English hedges.

***Malus fusca*.** The native Oregon crabapple, (syn. *Pyrus fusca*, *P. diversifolia*, *Malus diversifolia*), found North of Port Orford was discussed. Leaves are dark green with a hairy petiole, or shiny with no hairs. Some wondered if it was a flowering crabapple that has gone wild. Wilbur Bluhm recommended collecting seed from one that has characteristics which "fit the mold best".

***Arctostaphylos* seed.** Anecdotal ways to get manzanita seed to germinate included fire and "force-feeding the bear". Several participants had heard of a propagator in Washington who gets *Arctostaphylos uva-ursi* to germinate from seed by collecting bear scat.

Another person mentioned a pasture mix in Tilamook of seed that would not germinate unless it went through a cow. Methods of burning flats were discussed. Excelsior was tried but didn't burn. Suggestions of trying a crock pot on low, boiling seed and using an electric fry pan to open closed-cone pines were discussed.

***Sphaeralcea rivularis* (syn. *Iliamna rivularis*) - stream-bank globe mallow.** Herbaceous native perennials. Burned every year for 5 years with no results. Finally oven-germinated.

***Trichostema lanatum*.** The Arboretum at Flagstaff got good germination with 3 to 5 months outdoor stratification through winter season.

***Oemleria cerasiformis* (syn. *Osmaronia cerasiformis*) - Indian plum or oso berry.** For seed germination, Craig of Althouse Nursery removes fruit from plant, takes seed out, and gives it a 21-day cold treatment. Seeds germinate readily, then he plants them. The hard part with *O. cerasiformis* is it doesn't go dormant for the winter. He has difficulty with "falling over disease". Jan Busco did tip cuttings with #8 IBA at Theodore Payne Foundation with good success. Bob Briggs took softwood cuttings of *O. cerasiformis* successfully for state highway planting.

Aristolochia californica does better growing with poison oak.

***Toxicodendron diversilobum* - poison oak.** Propagate from seed; excellent wildlife and restoration plant. Hard for nursery workers as they can only work with it for a limited time.

***Clematis armandii* - evergreen clematis.** Blooms in February. Pick seeds in May just before the winds come when seed is just starting to turn. Put in flats in June; plants come up in fall. Dr. Krause and Duane Sherwood harvest seed before it matures. "Mother nature puts dormancy into seed last." Plant seeds before dormancy.

***Abronia umbellata* subsp. *breviflora*.** Tom Kaye was asked about the germination of "pink sandverbena". How does the seed germinate with protective capsule? It was removed for the study. In nature, it would be scarified by blowing sand.

***Heterotheca foliolosa* (syn. *Chrysopsis foliolosa*).** Germinated when sown outdoors with fluctuating fall/winter temperatures.

***Ceanothus horizontalis*.** Timing of cutting was discussed. Slow to callus in June.

***Purshia* sp.** Timing of year critical to rooting percentage.
Carolyn Scagel – USDA –ARS Horticulture was asked about practical applications of the relationships between amino acids, plants, protein, microorganisms, and hormones. How do you test for protein? For total protein – do a colorimetric lab test. Nitrogen is used for protein regeneration. Les Fujigami recommended application of urea in fall for regrowth in the spring.

Discussion Group: Rootstocks of Choice

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The discussion group on "Rootstocks of Choice", Friday, 15 Oct. 1999, discussed several things over the two time periods; however, the connecting theme was conifer grafting. This article, therefore, focuses primarily on conifers with some mention of *Salix*. Some general discussions regarding the effects of understocks are also included. Table 1 is a list of conifers and their rootstocks of choice.

Grafting is a technique used to unite "parts" of different plants by bringing the cambium of each into contact and then creating a situation under which the cut surfaces can unite and grow together (Macdonald, 1986). Grafting is the main reason so many unique conifers with unusual forms can be offered in today's retail market. Conifer grafting usually involves bench grafting. Bench grafting covers grafting and budding techniques completed inside a covered structure, normally a shed or greenhouse (Macdonald, 1986). The type of bench grafting most often used on conifers is the side veneer graft. Side veneer grafts are also used for *Abies, Acer, Alnus, Betula, Picea, Pinus*, as well as the other conifers listed in the table below.

ROOTSTOCK EFFECTS

Rootstock or understock is the lower part of the graft. It usually possesses a root system that will support the subsequent shoot development from the scion (Macdonald, 1986). The scion is the part of the graft that will provide the new shoot system. Roots, unlike tops of plants, have no distinct period of dormancy and are able

Table 1. Listed are some of the rootstocks discussed by the groups that conifer and *Salix* growers in the Pacific Northwest have found best for the scion materials indicated.

Scion	Understock
Abies alba 'Compacta'	*Abies grandis* or *A. procera*
Abies alba 'Pendula'	" "
Abies alba 'Pyramidalis'	" "
Cedrus libani subsp. *atlantica* 'Aurea robusta'	*Cedrus deodara*
Cedrus deodara 'Golden Horizon'	"
Cedrus deodara 'Kashmir'	"
Chamaecyparis obtusa 'Gracilis'	*Thuja occidentalis* 'Smaragd'
Chamaecyparis obtusa 'Nana Gracilis'	"
Juniperus squamata 'Blue Star'-std.[X]	*Juniperus scopulorum* 'Skyrocket'
Juniperus squamata 'Blue Carpet' - std.	"
Juniperus squamata 'Holger' - std.	"
Juniperus conferta 'Sea Green' - std.	"
Picea abies 'Acrocona'	*Picea abies* or *Picea glauca*

Picea abies 'Little Gem' - std.	"
Picea abies 'Nidiformis' – std.	"
Picea abies f. *pendula*	"
Picea abies pendula - std.	"
Picea abies 'Willy Klippert'	"
Picea glauca 'Little Globe'	"
Picea glauca 'Golden Harber'	"
Picea pungens 'Bakeri'	"
Picea pungens 'Baby Blueeyes'	"
Picea pungens 'Iseli Fastigiate'	"
Picea pungens 'Nana'	"
Picea pungens 'Nana' std.	"
Pinus aristata 'Sherwood Compact'	*Pinus strobus*
Pinus bungeana	*Pinus slyvestris*
Pinus cembra 'Glauca'	*Pinus strobus*
Pinus cembra 'Landis'	*Pinus strobus*
Pinus coulteri	*Pinus sylvestris*
Pinus contorta 'Spaan's Dwarf'	*Pinus sylvestris*
Pinus densiflora 'Pendula'	"
Pinus densiflora 'Tanyo-sho' & std.	"
Pinus flexilis 'Vanderwolf's Pyramid'	*Pinus strobus* and *P. flexilis*
Pinus flexilis 'Glauca Pendula'	" "
Pinus heldreichii var. *leucodermis* 'Compact Gem'	*Pinus sylvestris*
Pinus mugo - std.	"
Pinus mugo 'Aurea'	"
Pinus mugo 'Aurea' - std.	"
Pinus mugo 'Mops'	"
Pinus mugo 'Mops' - std.	"
Pinus mugo 'Prostrata'	"
Pinus mugo 'Prostrata' - std.	"
Pinus nigra 'Hornibrookiana'	"
Pinus nigra compact green form	"
Pinus strobus 'Blue Shag'	"
Pinus strobus 'Contorta'	" or *P.koraiensis*
Pinus strobus 'Fastigiata'	"
Pinus strobus 'Horsford Nana'	"
Pinus strobus 'Horsford Nana'- std.	"
Pinus strobus 'Pendula'	"
Pinus strobus 'White Mountain'	"
Pinus strobus 'White Tip'	"
Pinus sylvestris 'Beacon Hill'	*Pinus sylvestris*
Salix caprea 'Weeping Sally' (syn. 'Pendula') - std.	*Salix* ×*stipularis* (syn. *S. smithiana*)
Salix caprea 'Weeping Sally' - 41 std.	*Salix* ×*stipularis*
Salix fargesii	*Salix* ×*stipularis*
Salix integra 'Hakuro-nishiki'- std.	*Salix* ×*stipularis*
Salix integra 'Hakuro-nishiki' - 2411 std.	*Salix* ×*stipularis*
Salix integra 'Hakuro-nishiki' - 41 std.	*Salix* ×*stipularis*
Salix magnifica	*Salix* ×*stipularis*
Salix purpurea 'Nana' - std.	*Salix* ×*stipularis*
Salix purpurea 'Nana' - 2411 std.	*Salix* ×*stipularis*

[x] std = standard

to grow whenever temperatures, moisture, and other conditions are favorable (Westwood, 1978). The root system therefore can have a tremendous impact on the plants overall health and quality. Rootstocks, in fruit tree and ornamental production, are selected for their ability to increase stress tolerance, including cold, drought, heat, flooding, and/or salt stress. In the area of cold stress, rootstocks can have several effects including influence on chilling requirements. Chilling requirements in turn affect flowering and time of propagation (Kester, pers. commun. 1999). Rootstocks are also selected for their ability to impart resistance to pests including insects and diseases. An example of this would be in choosing an understock for five-needle pines such as *Pinus strobus*. The understock for *P. strobus* cultivars was always *P. strobus* but now *P. koraiensis* is used because *P. strobus* is so susceptible to root rot. Rootstock choice can also influence the root anchorage ability. Some understocks can provide better root architecture for certain locations such as street plantings. Dave Burger is examining these root architecture differences at the University of California, Davis. Rootstocks can be selected for reducing suckering, increasing tolerance to different soil conditions and types, and increasing tree performance including vigor and nutrient utilization. Rootstocks are also selected for ease of propagation and graft compatibility.

TIMING

Most nurseries start conifer grafting in early December with *Thuja* and *Sequoia* cultivars. *Thuja* and *Sequoia* cultivars should be finished before any heavy frosts occur. Heavy frosts may lead to tissue damage. Tissue damage, if it occurs, can result in poor graft unions and low growing percentages. In early January, five-needle pines are grafted. After the five-needle pines, grafting priorities are set by which understock is in the best condition in terms of its root development. To determine the condition of the understock, signs of budding out or breaking dormancy are observed.

Discussion Group: Propagating Plants Outside the Greenhouse

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DIRECT STICK

Pots. Unrooted cuttings can be stuck in 2¼-inch pots filled with standard rooting medium, placed in flats and arranged on beds made of concrete or gravel. Fifty-percent shade is used. Bottom heat is required in the winter (Southern California). Mist intervals were set from 1 to 60 min depending on weather conditions. A 30-inch wind barrier helps prevent the mist from drifting. Animal control is necessary. Success has been achieved with a select group of plants: *Berberis, Camellia, Buxus, Euonymus,* and *Juniperus*. Increased airflow was credited when *Bougainvillea* cuttings, stuck in summer in outdoor beds, resulted in increased rooting success.

Field Beds. Semi-ripe cuttings of plum, poplar, and willow can be stuck in raised beds in November, providing the soil is still warm. Rooting hormone is applied to the base before sticking and the cutting is inserted to its mid-point. The raised beds are covered with sawdust to prevent heaving.

Alternatively, cuttings (6 to 8 inches) can be collected in November and December, dipped in both liquid and powered rooting hormone, packed in perlite, boxed, and placed in cold storage (35°F) until spring. The cuttings are checked for callus in mid-April and stuck in beds as soon as the soil is warm. The stuck cuttings are covered with white plastic for the first 6 to 8 weeks. The plastic is sliced to increase air movement after this initial period every 3 to 4 weeks until it is finally removed.

Seed. Seed can be directly sown in prepared beds in fall or stratified indoors and sown in spring. Beds are mulched with either sand or sawdust.

Weed control is a big concern for outdoor seedling production. With the imminent disappearance of methyl bromide, alternative methods were discussed. Vapam works well if used in summer. Beds are kept clean until seeding. Round-up or Gramoxone can be used just before seeding the beds. Flaming off weeds was suggested, but is not generally practiced. Steaming raised beds has been attempted, but the amount of water required was excessive and the depth of penetration inadequate for control. Manure should not be used to improve the organic matter content of beds because of weed seed contamination. Instead, crops of hybrid sorghum, rye, or red clover varieties were suggested. Any green manure should not be allowed to set seed and must be killed prior to cultivation into the soil.

Rodent control was another concern raised for outdoor propagation. Inverted flats with mesh bottoms, fine chicken wire buried under flats, and placement of shade cloth both underneath and over the top of flats then stapled along the side, were suggested methods. Mouse bait in lengths of pipe or bamboo had general approval from the discussion group.

Propagation of Foliage and Flowering Plants in Guatemala

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As a pioneer country in the export of tropical ornamental plants, Guatemala has geared its production to primary markets, where it has rapidily gained a reputation for consistent quality and service.

Due to its unusually wide variety of excellent climatic conditions, Guatemala offers enormous possibilities for future expansion in the production and export of ornamental plants.

The central part of the country is mountainous and volcanic, excellent for production of *Aphelandra, Hedera, Cissus, Maranta,* and *Peperomia*. The hot and humid weather found in the coastal plains of the Pacific are ideal for the production of *Aglaonema, Schefflera* (syn. *Brassaia*), *Codiaeum, Dracaena, Ficus, Polyscias, Scindapsus* (see, also, *Epipremnum*), *Syngonium,* and *Philodendron.*

Phoenix and many other taxa of palms grow in the tropical rainforest of the northern region; and *Beaucarnea* (syn. *Nolina*), *Yucca, Cordyline,* and *Sansevieria* are being produced in the southeastern region.

Thanks to its many microclimates, Guatemala can successfully produce any type of ornamental plant.

Ornamental plants, flowers, and foliage are produced in Guatemala as part of the nontraditional agricultural export crops. The production of ornamental plants started in Guatemala in the 1940s with only two species in production in a very small area. The ornamental plant production sector has grown considerably since then, so much so that today Guatemala produces around 80 different species and approximately 300 cultivars.

The ornamental plant industry represents approximately 5% of the national income. In the agricultural field, it is in fifth place of importance among the nontraditional export products, which translates to a little more than 50 million dollars annually.

With its wide scope of vegetation, there is great diversity of species. The diversity is expressed in diminutive palms of the *Chamaedorea* genus, picturesque *Cephaelis*, of serene *Eustoma* (syn. *Lisianthus*) in a deep purple color, *Aphelandra, Pancratium, Zephyranthes, Juniperus standleyi, Tillandsia*, leather-leaf ferns and roses.

Guatemala, now known as the land of the forest, is the preferred country for wholesalers, amateur growers, and professional growers today because of its range of species and multiplicity of biological forms.

Its diversity covers plants and flowers with growing markets in Europe, North America, and outside the Orient.

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Methods, Systems, and Techniques of Hard- and Softwood Cuttings from the Perspective of a Hands-on Propagator

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The intent of this discussion is to explain my perspective of successful results as a hands-on plant propagator. People often ask me what my secrets and tricks are. There are no secrets or tricks. Successful propagation is the result of the following four factors:

1) Good cutting wood and cutting stock.
2) The experience of the person taking the wood.
3) Soils, hormones, and timing.
4) Methods and techniques.

GOOD CUTTING WOOD AND CUTTING STOCK

Good cutting wood comes from healthy plant material, whether from stock plants, field-grown material, or containerized plants. A propagator's success comes from experience and trial and error. The willingness to experiment with the hardness of wood, various lengths of cuttings, and first- or second-growth cuttings will result in improved success.

Fifteen years ago, when I started, everything I did was experimentation. My first priority was to make all cuttings the same size. I envisioned the cutting turning into a full-grown plant. It was important to me that as they grew they were a uniform size and they progressed at the same rate. During my time as a propagator, I have always watched the plants as they root. I constantly take notes to determine which wood hardness is most successful. Also, I watch where the roots emerge from the stem. It is best if the roots emerge from the entire stem, not restricted to one point.

THE EXPERIENCE OF THE PERSON TAKING THE WOOD

The person taking the cuttings must have the same perspective as the head propagator. He must know the different types of wood to take depending on the variety. They must agree on whether to take new growth or second growth. Some varieties will root easily with new or second growth, others require only new growth. Communication is key to provide size and quality in cutting wood.

SOILS, HORMONES, AND TIMING

Over the years, after much trial and error, I've narrowed down my soil media from six or more mixtures to two. I use a grade 6 pumice and peat/pumice mixture that is pumice and peat (17 : 3, v/v). I use the pumice for conifers and broadleaves that have a thick, heavy root system. The peat and pumice mixture is used for thin, fibrous roots, acid-loving plants, and very softwood cuttings.

A powdered hormone, called Hormodin 3, is used only on conifers. Ninety percent of the time I use a product called Woods, which is a liquid hormone. I've been able to cut down my hormone rates: for conifers I use 1 : 6 ratio, for broadleaves I use

1 : 8 or 1 : 10. Broadleaves done in the fall that are beginning to harden-off do best using a 1 : 8 rate. Summer cutting broadleaves, which are a medium-soft, more vigorous cutting, seem to thrive using a 1 : 10.

When it comes to timing, I believe you can propagate any plant at any time of the year, with three exceptions:

- I like to do conifers in late fall/winter because the wood needs to harden off. I don't do them in the summer because they stay growing and soft too long. They don't handle the constant mist and heat of a greenhouse well.
- I've never been able to do deciduous broadleaves once they've lost their leaves. I prefer to do them in early spring/early summer.
- Some other broadleafs, like conifers, stay too soft and don't handle the mist and heat well. I prefer to do them in early fall. Examples: *Buxus*, *Ilex*, *Pieris*, and *Arctostaphylos* taxa.

METHODS AND TECHNIQUES

When I teach my crew to propagate, I encourage a uniform size for every cutting. To teach them, I use a "hand-size" system. I either make my cuttings three- or four-fingers tall, while holding the cutting across the palm of my hand. The crew is told to strip leaves off 1 inch of the bottom of the stem, leaving leaves on the top 3 inches. Stripping leaves off only one inch of the stem insures that the cuttings will not get planted too deep. Prior to dipping the cutting into the hormone, workers make a fresh cut on the bottom of the cutting. This approach allows for uniform workmanship that all crew members can follow.

Grapevine Propagation with an Emphasis on Grafting

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You have probably heard people say that you can just stick a piece of grapevine in the ground and it will root and start growing. Well, after many years of grafting grapevines I tried it and it worked. I never doubted it. The fact is that plants in the genus *Vitis* readily lend themselves to all types of propagation techniques. Methods include seed, tissue culture, dormant cuttings, green cuttings, dormant bench grafts, green grafts, chip budding, T-budding, layering, and many more.

DORMANT CUTTINGS

Hardwood dormant cuttings have many uses such as producing grapevines that do not need to be grafted and rootstocks that are planted in the vineyard for a season and then chip budded. Wood for the cuttings is harvested in the winter, usually from December to February, and stored at 36°F until ready for use. The cuttings are processed into 14-inch long pieces, with a minimum of ¼ inches in diameter. The 14-inch cutting is to facilitate deep planting in the field.

The first step in rooting grape hardwood cuttings is to disbud. Leaving the top bud alone, remove all other buds using clippers, being careful not to disbud too deep. After disbudding recut stem ¼ inch below bottom node. A 1500 ppm (0.15%) IBA rooting hormone is applied using a 5-sec dip. Once the cuttings are prepared they are normally placed horizontally in a rooting bed covered with moist peat moss, at a temperature of 78°F. The cuttings are layered on top of each other to a depth of approximately 10 inches and monitored daily for temperature and moisture levels. Root growth should be sufficient for transplanting in 21 days.

Some grape cultivars are more difficult to root than others and the top bud will start to grow before the roots are initiated. An alternative method to root these varieties can be used. This method consists of the same cutting preparation as mentioned before, but instead of covering the cuttings with soil in the rooting bed, they are placed upright with roughly ⅓ of the cutting stuck in a peat and perlite (1 : 1, v/v) mix. Flats, pots, or beds can be used on top of a bottom heat source. Air temperature must be kept cool, between 50 and 55°F to prevent the top bud from growing while the base of the cutting is kept at 75°F to promote root development. Once roots are present the air temperature is increased to 75°F to let the bud break.

GREEN CUTTINGS

Green cutting propagation of grapevine is another easy method that is used to increase new varieties or for production of nongrafted grapevines. Green cuttings can be made year-round from greenhouse-grown stock plants or during the growing season from the field. Cuttings are made using a single node, so many can be made from one plant. These single node cuttings are cut leaving 1 inch of stem above the node and 2 inches below, with the leaf attached, sometimes called a "leaf and eye".

Green cuttings can be rooted from very soft tips all the way to lignified material, but best results come from recently hardened-off green stems.

Because grape leaves generally grow very large, the leaves should be reduced in size by at least half before placement in the rooting medium. Cuttings should receive a 5-sec dip in 1500 ppm IBA prior to sticking. Bottom heat should be kept between 75 and 85°F and the propagation soil is a peat and perlite (1 : 1, v/v) mix. Intermittent mist or fogging intervals depend on individual greenhouse conditions. Leaves should just be starting to dry off when they are re-wetted. Green grape cuttings can have ¼-inch roots as early as 7 days and it is very important to start backing off the mist when roots appear. One hundred percent rooting is not unusual especially when stock plants are started from tissue culture. Propagation houses should have 70% shade, high humidity, and a constant temperature of 80 to 85°F.

DORMANT BENCH GRAFTS

Dormant grafting is the most common method of grafting grapevines. It is sometimes referred to as bench grafting because it is normally done by a person sitting at a grafting machine, as opposed to field grafting. When grafting small numbers, it is not difficult to have a 90% to 95% graft success. With the larger nurseries who graft millions of vines of many different varieties and combinations, graft takes can range anywhere between 40% to 90%. Each year is different. The last 10 years have seen widespread vineyard expansion due to demand for wine grapes and extensive replanting due to the need for new rootstock that are resistant to the soil dwelling insect *Phylloxera*. Most grapevine nurseries old and new are constantly adjusting the following procedures in the quest for the elusive 100% graft success.

Scion budwood and rootstock cuttings are field harvested the months of December through February. Rootstocks are processed to 12 to 14 inches long and 5⁄16 to ½ inches in diameter at the top of the cutting. Scion budwood sticks are also 12 to 14 inches long, ¼ to ½ inches in diameter and contain a minimum of five buds. Long rootstocks are essential to prevent the formation of scion roots in the vineyard. After harvest, cuttings are soaked for 3 h in water, dipped in fungicide or disinfected, and stored at 36°F.

For 1 week before grafting, wood is pre-warmed to 70°F with 85% humidity to increase cell activity. During this time the cuttings must be monitored for temperature and moisture. The day before grafting, the rootstock must be disbudded and then soaked for 12 h in water. Just prior to grafting, budwood sticks are cut into one node cuttings, and rootstock is recut at the top. There are a wide variety of grafting machines and different types of graft cuts, but the goal is to have good cambium contact between the scion and rootstock. Most high volume nurseries use either the saw cut or the Omega grafting machines, which do not require any wrap around the graft union. These types of cuts are beveled so that when put together by the grafting machine the fit is tight and holds together on its own. When grafting by hand the whip and tongue, V-notch, or wedge grafts are used. These grafts require some type of rubber or elastic wrap to force cambium contact.

After grafting, the new grafts are immediately placed in callusing boxes. Callus box media consist of a peat moss and perlite mix (4 : 1, v/v). This must be moist, but not overly so. Grafts are layered horizontally in the callus box, with peat moss between grafts. Temperature should be maintained at 78°F for 21 days, which by this time 95% of grafts should have callus tissue formed completely around the graft union and some root initials showing. The grafts are then carefully removed from the callus box. Vines that are machine grafted and use a saw or Omega cut need their unions painted with wax. Another method to quick dip the union and scion in cheesecote-type wax that is heated to 150°F. This wax coating prevents desiccation. Graft unions that have been wrapped to hold the union together do not need to be waxed.

New grafts are planted in paper tubes or 4-inch × 5-inch deep pots and moved to a greenhouse for acclimation. The acclimation greenhouse should be 70-70-70, that is; 70% shade, 70% humidity and kept at 70°F. Once established the grafts are moved to a shade house or to full sun. The grafts in planting tubes are field planted in nursery rows, allowed to grow for a season and then harvested bare-root dormant. The grafts in 4-inch pots are either delivered to the customer soon after acclimation to full sun or grown for a season in the pot and delivered the next year dormant.

GREEN GRAFTING

Green grafting grapes is a technique that has been used to a limited degree for at least 50 years in Europe, New Zealand, and the United States. Green grafting is used in grape, citrus, and rose production but has potential to be used in other fruit crops and ornamentals. Green grafting grapes has many advantages. It allows introduction of large numbers of newly grafted varieties within the first year the new material is received. With traditional dormant bench grafting it takes several years to build up sufficient stock plants to graft in quantity. Green grafting can be done year round. Stock plants are grown in the greenhouse thus allowing for greater control of pests. The potential for producing disease-free vines is very high due to three factors. The first is that the stock plants are isolated from disease vectors. The second is that it would be very difficult for a diseased plant to survive the callusing and rooting process of green grafting. And third, diseased stock plants can be eliminated and replaced very quickly. The most important condition for successful green grafting is healthy rootstocks and scions with which to start. This is true for all plant propagation, but cannot be emphasized enough for green grafting. Green scion and rootstocks must be free of disease, have semihardened tissue, be in a vigorous state of growth and nutrient levels should be optimum. During the fall and winter, day and night temperatures must be kept at 70°F or above and lights used to provide long days. Greenhouse-grown stock plants must be rotated in and out of the greenhouse to allow dormancy and new stock plants started on a continual basis. A stock plant that has not been allowed to go dormant after several crops will yield very poor grafting material.

Harvesting stock in the greenhouse is very quick and easy compared to field harvesting, with very little damage or breakage. Stock plants are trellised 8 to 10 ft on string and kept free of lateral branches during growth. Plants are harvested early in the morning and no later than 10 AM. Once cut, the material is kept in a cool and moist environment.

Preparing the rootstock for grafting consists of cutting the rootstock into 12-inch sections, and disbudding all buds leaving one leaf attached. This leaf is trimmed down in size by two-thirds. The one bud scion piece is about 3 inches long with 1 inch above the bud and 2 inches below. The scion must also retain its leaf and it is also trimmed by two-thirds. The diameter of the rootstock and scion should be a minimum of ¼ inch. When preparing stock for grafting it is important to rogue out all cuttings that are too soft, thin, and/or damaged. If any material is questionable, it should be discarded immediately. Grafting time and greenhouse space are too valuable to waste on grafts that only have a slight chance of surviving.

For hand grafting, the wedge graft used for green grafting of grapes works quite well. The cut on the rootstock is a simple split down the middle of the stem that is ¾ inches deep. The scion cut, which takes quite a bit of skill, is a 20° angle cut on two sides of the scion. As with all grafting, matching the caliper of both scion and rootstock for good cambium contact is the number one goal of the grafter. Once the graft is made, the union must be held together tightly. Many different materials can be used for this purpose, from rubber budding strips to elastic or shrink-wrap-type materials. It is important not to cover the union completely, as this practice is believed to encourage decay. Leaving an opening also allows the union to be inspected for callus formation. Contrary to this, the top cut on the scion is sealed with liquid plastic graft seal, as water tends to collect on this horizontal cut in the propagation tent. Once the graft union is secured, the basal end of the rootstock is dipped in 1500 ppm IBA for 5 sec.

After grafting, the vines are planted and placed in a propagation tent. The soil that green grafts are planted in is a very porous mix of perlite and peat moss (4 : 1, v/v). The propagation flat is a 38 plug tray with 1¾-inch × 5-inch deep cells. After grafting and before planting, cuttings must be frequently syringed with water. The propagation greenhouse is covered with 70% shade cloth and equipped with both a fog system and mist system. The propagation tents are hoops covered with polyethylene plastic running the length of the benches. A hot water bottom heat system is used on top of the bench.

The goal during the callusing and rooting stage is to provide the grafts with a very constant hot and humid environment. The greenhouse itself must have this same environment but the propagation tents inside the greenhouse provide even more protection and less fluctuation in temperature and humidity. The temperature inside the tent should be kept at between 85 and 90°F. The humidity should be between 95 and 100°F. Grafts are kept in a closed tent for 10 to 14 days, rooting and callusing occur almost simultaneously. If the stock is not healthy and in peak condition when grafted it will become evident in the propagation tent in the form of disease and decay and these plants should be removed immediately. Grafts are checked several times daily for moisture and misted when needed. Any wilting or other stress during the first couple of weeks is almost certain graft failure. Once the grafts have visible callus around the graft union and roots are ½ inches long, the tent is opened. The grafts are gradually acclimated over a period of a week, using either fog or mist. A 200 ppm 20N-10P-20K fertilizer is also applied at this time. Once acclimated from high humidity, grafts are moved to a heated greenhouse with 55% shade and are potted to their final container. The final step is to move the grafts outside to full sun. This grafting process can take as little as 8 weeks.

Using Subirrigation to Root Stem Cuttings: A Project Review

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INTRODUCTION

As propagators, we were fascinated by the possibility of rooting cuttings without mist (Zhang and Graves, 1995) Subirrigation is a alternate method of propagation that can reduce labor costs and water use, (Wen-fei, et al , 1998) while promoting healthy cuttings with rooting percentages equivalent to mist Rooting cuttings without mist would help prevent water-logging of the rooting medium, eliminate dripping mist lines, and reduce disease We thought that one of the greatest advantages to the subirrigation system would be in managing the cuttings Multiple varieties of cuttings could be placed within a single propagation area The cuttings would use water as needed and therefore avoid the problems associated with controlling mist. In addition, using subirrigation to root stem cuttings may be an alternative method for approaching difficult-to-root cuttings (Mezitt, 1978) Since we were unable to find any literature based on studies in a northwest climate, we began a 4-year study to see if subirrigation propagation would work in the North Willamette Valley

The subirrigation method we used for the project consisted of a large (14 inches × 20 inches × 4 inches), sturdy tray without drainage holes made by Dyna-Tray. Two, $\frac{5}{32}$-inch drainage holes were drilled on opposite ends of each tray, 1 inch up from the bottom The tray was filled with rooting medium, and the water reservoir was maintained by hand watering one to three times a week Each individual tray was used as a treatment replicate Although we used several experimental designs, we always replicated each treatment four times with a minimum of 84 cuttings (240 maximum) per treatment

Stem cuttings were collected from several sources and were usually used within 6 h The maximum amount of time we would store the cuttings (40°F, 80% relative humidity) was 24 h. To prepare the cuttings, we soaked them in water for 30 min, then made a fresh cut and stripped off the lower leaves. All of the stem cuttings were dipped for about 10 sec in a solution of Dip N' Grow The concentration of rooting hormone varied depending on softness or hardness of the cutting. The stem cuttings were stuck in the trays about 1 inch into the medium so that they would be about 1.5 inches above the water level

The propagation greenhouse used for the study was located at the North Willamette Research and Extension Center, Aurora, Oregon It is a small (18 ft × 40 ft), double polyethylene structure recently renovated to improve the control of mist and bottom heat. Even with shading (47%), the air temperature was difficult to control and the weekly mean high temperatures during the summer approached 90°F. A small exhaust fan helped cool the air temperature but also lowered the relative humidity by bringing in drier air

METHODS AND RESULTS

Experiment 1. In 1995, to evaluate subirrigation as a method to root cuttings, we compared it to mist propagation We attempted to root about 20,000 cuttings from 19 diverse woody plants One-half of the cuttings was stuck in perlite and the other half in pumice We used a solar-input mist controller (Davis Engineering) to manage the intermittent mist Under this system mist frequency changed automatically based on bright or cloudy days. Generally, we felt our misted cuttings were not over-watered.

Our results from this initial study showed that eight of the nineteen plants we tested rooted "well" with subirrigation when compared to the misted controls Another six of the plants rooted "fair," while only *Acer*, *Rhododendron*, and *Magnolia* cuttings were rated as "poor." Overall, the type of rooting medium (perlite or pumice) did not have a major effect on rooting. We observed that many of the softwood cuttings would wilt immediately and some of the leaves burned in a matter of days (*Acer*, *Berberis*, and *Prunus*) Consequently, rooting was reduced compared to the misted cuttings. The misting of cuttings helps to maintain the water status of the cutting (foliar absorption) and reduce leaf temperatures (evaporative cooling)

Experiment 2. We were convinced that subirrigation could be used instead of mist to root woody stem cuttings of certain plants. Therefore, one of our goals in 1996, was to improve rooting percentages of cuttings propagated by subirrigation Softwood and semihardwood stem cuttings of *Berberis thunbergii* 'Atropurpurea Nana' (syn 'Crimson Pigmy'), *Cotinus coggygria* 'Royal Purple', *Daphne* ×*burkwoodii* 'Carol Mackie' were stuck in perlite under subirrigation every 3 to 4 weeks until August. Fall and winter propagation was conducted with hardwood cuttings of *Chamaecyparis nootkatensis* 'Pendula', *Picea glauca* var *albertiana* 'Conica', *Pieris japonica* 'Variegata', and *Rhododendron* 'The Hon Jean Marie de Montague'. A total of 600cuttings per plant was used for each sticking The propagation treatments consisted of covering the cuttings to reduce light and increase the relative humidity around the cutting The greenhouse was divided into three sections. One of the sections was covered with shade cloth (47%) which was suspended 0.7 m above the trays and the cloth draped over the ends of the bench creating sidewalls Within another section a lightweight spun-bonded polyester row cover (Reemay, Dupont) was laid directly above the cuttings. The last section was left uncovered and became the control treatment Six trays (30 cuttings per variety, per tray) were placed under each treatment and served as replicates. The treatments were also split in half by a fertilizer treatment. A nutrient solution of Peter's Liquid Feed 20N-20P-20K (100 ppm N) was used as the subirrigation water source for one-half of the cuttings, while the other half received only well water.

Experiment 3. In 1997, our attention turned to propagating stem cuttings of herbaceous perennials In the 1995 study, *Lavandula stoechas* var. *lusitanica* rooted at 81% under subirrigation with no stem or root rot during propagation. Beginning 2 July through 13 Aug., about 15,000 softwood cuttings were collected from plants considered to be difficult-to-root. The cuttings were prepared and placed under the following propagation treatments: (1) subirrigation in trays; (2) subirrigation in trays with 4-day mist, (3) mist propagation in standard propagation trays; (4) mist propagation in subirrigation trays, (5) subirrigation in cells under fog,

(6) subirrigation in trays under fog; (7) subirrigation in trays, no fog; (8) cells within subirrigation trays, no fog. The propagation media used for all treatments was perlite and peat (9 : 1, v/v). The treatments were replicated four times. After 6 to 10 weeks the cuttings were lifted and evaluated for rooting.

Cuttings from several of the plants rooted just as well under subirrigation as they did under mist or fog. Specific plants such as *Arctostaphylos* 'Alaska', *Cistus salvifolius*, *Eupatorium purpureum* var. *maculatum* 'Atropurpurem', and *Phlox paniculata* 'Franz Schubert' rooted best under one or more of the subirrigation treatments when compared to either mist or fog. While *Campanula carpatica* 'Karl Foerster' and *Geranium* 'Lawrence Trayman' did not root well under any of the treatments, only *Iberis sempervirens* 'Alexanders White' did not respond very well to subirrigation propagation. There were no treatment effects on the rooting of *Helianthemum* 'Raspberry Ripple', and *Rubus pentalobus* (syn. *calycinoides*) which all rooted at 80% or above. The best overall subirrigation treatment was subirrigation in trays with 4-day mist. Our earlier study with woody plants suggested that this initial mist period helped maintain the water status of the cutting resulting in higher rooting percentages. *Dendranthema weyrichii* 'White Bomb' (Syn. *Chrysanthemum weyrichii* 'White Bomb') and *Deutzia crenata* var. *nakaiana* 'Nikko' (syn. *D. gracilis* 'Nikko') rooted the best under subirrigation in fog.

Student Intern Experiments. In 1997 and 1998, student interns under our direction conducted three studies involving subirrigation propagation. These studies investigated subirrigation techniques applied to *Cotinus coggygria* 'Royal Purple' and *Daphne* ×*burkwoodii* 'Carol Mackie' and the influence of water quality on rooting. Although *Daphne* cuttings rooted best in the perlite medium, the cuttings had a higher amount of leaf browning and drop when compared to those in the perlite plus peat medium. There was large variability in successful rooting of *C. coggygria* 'Royal Purple'. Stem cuttings of *Eupatorium*, *Thyme*, *Phlox*, and *Deutzia* rooted in subirrigation trays showed a range of response to various waters. The elements found most often in water sources that influence rooting were bicarbonates, sodium, chloride, boron, and sulfur. Water pH and electrical conductivity are also important factors.

CUTTING PROPAGATION SUMMARY

***Acer rubrum* Autumn Flame® red maple.** Softwood cuttings taken in July rooted poorly in subirrigation. Rooting percentages were somewhat better using perlite as opposed to pumice as the rooting media. Stems seemed to desiccate quickly.

***Acer rubrum* 'Franksred', Red Sunset® red maple.** Semi-hardwood cuttings taken in June rooted poorly in subirrigation. Perlite was the better rooting media over pumice. Stems desiccated quickly.

***Arabis alpina* subsp. *caucasica* 'Variegata'.** Soft tip cuttings taken in August rooted poorly under subirrigation as well as in fog. Cuttings in subirrigation rooted better with four initial days of mist, although cuttings kept under mist the entire time had the highest rooting percentages. Cuttings in cells uniformly did poorly.

***Arctostaphylos* 'Alaska'.** Softwood cuttings taken in July consistently did poorly under subirrigation, mist, and fog. The one exception was the cuttings in cells; these cuttings showed the highest rooting percentages.

***Berberis thunbergii* 'Rose Glow'.** Softwood cuttings stuck in August rooted fairly well under subirrigation, although the initial occurrence of desiccation and leaf drop was deceptive. No significant difference showed up between the use of perlite or pumice as the rooting media.Cuttings placed under Reemay covers rooted somewhat better than cuttings under shade cloth or those left in the open.

***Betula utilis* var. *jacquemontii*.** A June sticking of softwood cuttings placed in subirrigation and mist rooted equally well by both methods. Pumice worked better than perlite for rooting *Betula*.

***Campanula carpatica* 'Karl Foerster'.** Soft tip cuttings stuck in July did poorly regardless if they were placed under subirrigation, mist, or fog. It made no difference whether trays or cells were used.

***Campanula lactiflora* 'Loddon Anna'.** A July sticking of soft tip cuttings placed in trays under subirrigation and mist rooted equally well and slightly better than cuttings placed in fog. Except under fog, cuttings rooted very poorly in cells.

***Campanula* 'Birch Hybrid'.** Soft tip cuttings taken in September rooted at 99% under subirrigation.

***Chamaecyparis nootkatensis* 'Pendula'.** Cuttings in subirrigation stuck on various dates over a 3-year period showed great rooting variability from low numbers up to over 70%. Cuttings fared equally well in subirrigation and mist. The rooting media (pumice, perlite or a perlite/peat combination) did not show significant differences in rooting nor did the use of coverings improve rooting.

***Dendranthema weyrichii* 'White Bomb' (syn. *Chrysanthemum weyrichii* 'White Bomb').** Cuttings taken in July rooted well under fog, mist and subirrigation. Cuttings placed in cells rooted at comparable rates.

***Cistus* 'Elma'.** Cuttings taken in August rooted equally well under subirrigation, mist, and fog. The rooting percentage of cuttings in cells lagged a little behind the cuttings in trays.

***Cistus salviifolius*.** The highest rooting percentage for *Cistus* (97%) occurred in subirrigation trays with an initial 4 days of mist. Even without the mist, the subirrigation trays rooted better than the mist or fog trays. Cell trays did not root as well under any of the systems. In the water quality studies, *Cistus* showed some sensitivity to water differences.

***Clematis* 'Etoile Violet'.** Semi-hardwood cuttings taken in June rooted equally well in subirrigation and mist trays, and tested in both systems, the pumice was the better rooting media over perlite.

***Cotinus coggygria* 'Royal Purple'.** Variability in rooting *Cotinus* indicated that there might be anarrow window for rooting this plant. Heal cuttings taken in May rooted equally well in subirrigation and under mist. Soft tips in subirrigation trays easily wilted, but this did not reduce overall rooting. Cuttings taken later dropped significantly in their rooting percentages. Adding shading or Reemay cloth did not improve rooting. Cuttings rooted equally well in pumice and perlite.

***Cotinus coggygria* 'Velvet Cloak'.** A single sticking of softwood cuttings taken in June rooted at poor rates in subirrigation. The use of coverings did not improve the rooting results.

***Daphne ×burkwoodii* 'Carol Mackie'.** Semihardwood cuttings taken in August rooted fairly well in both subirrigation and mist. Cuttings did better in a medium of straight perlite, as opposed to a peat/perlite combination or pumice alone. Shade cloth did not improve rooting; Reemay over the trays actually lowered rooting percentages.

***Deutzia crenata* var. *nakaiana* 'Nikko' (syn. *D. gracilis* 'Nikko').** Soft tip cuttings stuck in August rooted well under all three methods of propagation. The highest rooting percentages were produced under fog. However, mist and subirrigation rooted at high rates as well. Cuttings rooted in cells with no difficulty either.

***Erica cinerea* 'Atropurpurea'.** Semi-hardwood cuttings taken in October rooted well in subirrigation and at a higher percentage than under mist. Rooting was higher under perlite than pumice.

***Eupatorium purpureum* subsp. *maculatum* 'Atropurpureum'.** Summer soft tip cuttings suffered some leaf desiccation initially in subirrigation, but cuttings ended up rooting well and at higher percentages than those cuttings under mist or fog. Subirrigation cuttings also put on new vigorous growth by the time they were evaluated. Cuttings placed in cells rooted equally as well as cuttings in trays.

Geranium 'Lawrence Trayman' (*G. cinereum* × *G. argenteum*). Soft tip cuttings taken in July rooted poorly under subirrigation and fog and only slightly better under mist.

***Gypsophila paniculata* 'Bristol Fairy'.** Soft tip cuttings taken in September rooted at 90% under subirrigation.

***Helianthenum* 'Raspberry Ripple'.** Summer, soft, tip cuttings rooted at high percentages under subirrigation, mist and fog. Cuttings in cells under all three systems rooted at slightly lower but still acceptable rates.

***Helianthemum* 'Rhodanthe Carneum' (syn. *H. nummularium* 'Wisley Pink').** Soft tip cuttings taken in September rooted well in subirrigation, but showed sensitivity to water quality.

***Hypericum androsaemum* 'Glacier'.** Semihardwood cuttings stuck in October rooted at 100% both under subirrigation and in mist.

***Iberis sempervirens* 'Alexander's White'.** Softwood cuttings taken in July rooted poorly in subirrigation and fog and well below rooting percentages under mist.

***Juniperus scopulorum* 'Medora'.** Hardwood cuttings taken in January rooted poorly under all treatments (less than 10%). No real difference in the use of perlite or pumice as the rooting media was apparent.

***Juniperus squamata* 'Blue Star'.** Semihardwood cuttings taken in October rooted equally well in subirrigation as under mist (about 80%). Some stem rot occurred after 2 weeks in propagation. There was no difference in rooting rates between perlite or pumice used as the rooting media.

Lavandula stoechas **var. *lusitanica*.** Semi-hardwood cuttings taken in October rooted around 80% under subirrigation and mist.

Magnolia kobus **var. *stellata*** **'Royal Purple'.** Softwood cuttings propagated in June rooted better under mist than subirrigation. There was no clear difference in the use of pumice or perlite as the rooting media.

***Myrica pensylvanica*.** Softwood cuttings taken in August rooted only somewhat better under mist than subirrigation. Both only rated in a fair range of rooting percentages despite heavy callusing. Cuttings rooted better in a rooting media of pumice rather than perlite.

***Pelargonium ×hortorum*.** Softwood cuttings rooted at close to 100% in subirrigation with minimal desiccation from *Botrytis*.

Phlox paniulata **'Franz Schubert'.** Soft tip cuttings rooted well under subirrigation — in fact, better than under mist or fog. When cuttings were placed in cells for rooting, they did not root nearly so well in subirrigation but fared considerably better in mist and fog.

Phlox paniculata **'David'.** Soft tip cuttings taken in September rooted at close to 100% in subirrigation, but also showed sensitivity to water quality.

Picea glauca **var. *albertiana*** **'Conica'.** January hardwood cuttings rooted with only fair results under subirrigation. Better rooting results occurred in December the following year with no improvement brought by using shade or reemay coverings. A peat/perlite media provided betterrooting results than perlite or pumice alone.

Pieris japonica **'Variegata'.** Semihardwood cuttings rooted from fair to good in subirrigation, depending on the year. Perlite worked better than pumice as the rooting media. The use of shading and reemay did not improve rooting.

***Prunus ×cistena*.** Softwood cuttings taken in August rooted in subirrigation with only fair results; rooting under mist was higher for *Prunus* cuttings (66% as opposed to 85% rooting). The use of pumice or perlite did not seem to improve the results.

Rhododendron **'The Hon. Jean Marie de Montague'.** Attempts to root September hardwood cuttings of 'The Hon. Jean Marie de Montague' were unsuccessful in subirrigation. The cuttings formed heavy callus but rooted poorly in both peat and peat/perlite mixes. Coverings did not improve the rooting results.

Rhododendron **'Vulcan'.** Similar results to *R*. 'The Hon. Jean Marie de Montague' under the growing conditions at the NWREC.

***Ribes aureum*.** Softwood cuttings taken in July rooted better under mist than subirrigation and fog. Cells in subirrigation trays did poorer still.

Rosa **'John Davis'.** Semihardwood cuttings taken in August rooted well in subirrigation and mist. Loss of some lower leaves did not affect rooting results. Both perlite and pumice were used for rooting media with identical results.

Rubus pentalobus **(syn. *R. calycinoides*).** Softwood cuttings rooted in July at almost 100% in subirrigation, fog, and mist. Cuttings in cells rooted just as consistently.

***Saponaria ocymoides* 'Alba'.** Soft tip cuttings taken in July rooted poorly in both subirrigation and fog but did somewhat better under mist. Cells placed in subirrigation trays rooted at even lower rates.

***Saponaria* ×*olivana*.** Soft tip cuttings taken in August rooted poorly in subirrigation, mist, and fog. Cell trays containing cuttings placed in fog and mist did only slightly better at rooting.

***Saxifraga* ×*urbium* (syn. *S. umbrosa* 'London Pride').** Small tip cuttings taken in July rooted well in subirrigation as well as under mist and fog.

***Brachyglottis* (Dunedin Group) 'Sunshine' (syn. *Senecio grayii*).** Tip cuttings stuck in August rooted fairly well in mist and fog and slightly less effectively under subirrigation. There was some indication that water quality may have influenced rooting percentages.

***Thymus* ×*citriodorus* 'Argenteus' (syn. *T. argenteus*).** Soft tip cuttings taken in August and September rooted close to 100% under subirrigation and mist, but considerably less in fog. *Thymus* in propagation appeared sensitive to water quality. Both perlite and peat/perlite combinations worked well as propagation media.

***Thymus* 'Doone Valley'.** Soft tip cuttings started in July rooted well in subirrigation but at lower rates in fog and mist. These studies first indicated that *Thymus* was sensitive to water quality. Cuttings placed in cells did worse than cuttings rooted in trays.

***Viburnum opulus* 'Roseum' (syn. *V. opulus* 'Sterile').** Softwood cuttings taken in May rooted fairly well and at comparable rates under subirrigation and mist. There was less incidence of foliar disease in subirrigation trays than for those under mist.

***Viburnum trilobum* 'Wentworth' (syn. *V.* 'Triwentworth').** Softwood cuttings taken in May rooted well in subirrigation and mist. Foliar diseases developed at equally high rates among cuttings under both systems. However, rooting rates remained fairly high (around 80%).

***Vinca minor* 'La Grave' (syn. 'Bowles').** Soft tip cuttings taken in July rooted fairly well in subirrigation. The addition of 4 days under mist raised rooting percentages to about the same rooting levels as for mist and fog. Cuttings placed in cells rooted about the same. However, cuttings placed in cells inside of subirrigation trays and then set under a mist system rooted at higher rates than in trays alone.

DISCUSSION

Water uptake by an unrooted cutting takes place through the cut stem base or through the leaves and stem. Foliar uptake of water helps in part to maintain the water balance of cuttings, but may not be the major factor for most plants (Loach, 1988). A good example of this was demonstrated by softwood cuttings of *Betula*. These cuttings recover from wilting immediately after they are stuck in subirrigation trays, while the cuttings in the misted trays remain wilted for days. One explanation for this observation is that wilted leaves can absorb water, but very little of that water is conducted to the stems. Water uptake through a cut stem of a cutting increases as the moisture content of the rooting medium increases. Also, water uptake by wounded cuttings is improved due to more cut stem contact with the medium. The constant moisture level of the subirrigated trays could have favored stem water uptake.

Successful rooting of stem cuttings under subirrigation is influenced by the same factors that influence the rooting of cuttings under mist propagation. The timing when the cuttings are stuck is a major concern for both types of propagation. *Daphne* appears to be a good candidate for rooting under subirrigation and the best rooting occurred mid-June regardless of the treatments, except for those cuttings that received fertilizer. It appears that a more mature stem cutting of some woody plants root better than very soft cuttings. The first group of *Berberis* cuttings performed the worst with rooting seen only in the shaded treatment. Soft cuttings will lose water more rapidly than mature wood. As leaf temperatures increase so does water loss, especially leafy stem cuttings under bright sunlight conditions. Although some improvements with the shading and row cover treatments were seen at times, they were not consistent. *Chamaecyparis* rooted best under full light conditions. In addition, we found that using a nutrient solution as the water source in subirrigation was very detrimental to rooting of the cuttings. Regardless of plant, stick date, or environmental conditions, cuttings that received fertilizer in the irrigation water rooted very poorly with rooting percentages less than 10%.

Soft tip cuttings placed under subirrigation may at first seem to go through a period of decline. Appearances can be deceptive. For instance, cuttings of *Eupatorium* after initial desiccation on the leaf edges, turned around by evaluation time, put on new growth and in fact rooted at higher percentages than mist or fog.

CONCLUSION

It is our belief that subirrigation propagation is an alternative method to root stem cuttings of many woody and herbaceous perennial plants. In some cases, supplemental mist or using fog with subirrigation is of benefit. We also found evidence that water quality is a very important factor in using subirrigation to root cuttings. In addition, cuttings under subirrigation propagation usually developed strong healthy root systems.

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Artifical Seed Technology Application in Propagation of Forest Trees

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Artifical seed production in forest trees using somatic embryos has been reported in *Eucalyptus citriodora, Santalum album, Pinus lambertiana, P. taeda,* and *Picea abies* usually with a very low regeneration rate (Gupta and Kreitinger, 1993). We utilized artificial seed production on selected tropical forest trees for which somatic embryos have not been produced. In our research the encapsulation of shoot-tip and/ or axillary buds provided an alternative for the production of artificial seeds. In an attempt to improve the regeneration rate from artificial seeds two types of beads with a single or double layer were tested. The best result was obtained with double-layered beads containing media in the inner layer at a concentration of 10 times normal supplemented with 0.5% (w/v) activated charcoal and at normal concentration in the outer layer. High rates of bud emergence and shoot growth were achieved; 60% and 60% for *Cedrela odorata*, 100% and 80% for *Guazuma crinita*, and 100% and 100% for *Jacaranda mimosifolia*, respectively, (Maruyama et al., 1997). These techniques were also applied to *Paulownia tomentosa* and *Eucalyptus citriodora*. Encapsulated axillary buds were germinated under outside condition.

Development of a suitable coating for the artificial seeds, which will allow the artificial seeds to survive under non-aseptic condition, is required for practical implementation.

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Growth Promotion of In Vitro Woody Plants Under Photoautotrophic Conditions

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INTRODUCTION

Demand for high quality woody transplants has been increasing worldwide in forestation and reforestation for global environment conservation and energy/food production. Transplant production by micropropagation methods is more beneficial than transplant production using seeds or vegetative methods with respect to genetic uniformity, virus-free or pathogen-free propagules, and scheduled year-round production. However, producing woody transplants using micropropagation techniques will only become cost effective when: (1) the photosynthetic ability of the transplants is fully expressed; (2) no symptoms of hyperhydricity or physiological and morphological disorders exits; (3) normal root development (formation of lateral roots and normal vascular systems) in the in vitro stage occurs; and thus, higher percent survival of transplants in the ex vitro; and (4) no acclimatization is required.

RESEARCH

Our recent research has shown that the growth of in vitro woody transplants, such as paulownia (*Paulownia fortunei*) and coffee (*Coffea ×arabusta*), can be greatly promoted in photoautotrophic (PA) culture (no sugar in the culture medium) as compared with that of heterotrophic culture (with sugar in the culture medium). In this paper, we also demonstrate advantages of air-porous supporting materials, such as Florialite (a mixture of vermiculite and cellulose fibers, Nisshinbo Industries Inc., Japan) and vermiculite, and a forced ventilation system applied to large culture vessels in the photoautotrophic micropropagation of these species.

Paulownia. Paulownia (*P. fortunei*) plantlets significantly showed a high potential of in vitro photoautotrophy when leafy explants were used. There were significant differences in growth of single nodal cuttings for 30 days on a half-strength MS medium with (20 g liter^{-1}) or without (0 g liter^{-1}) sucrose when PPF (photosynthetic photon flux) was 120 µmol m^{-2} s^{-1} and a photoperiod of 16 h d^{-1}. Photoautotrophic plantlets on Day 30 of the culture period showed a significant increase in fresh weight, shoot length, root length, and multiplication rate as compared with those grown in heterotrophic conditions. The results emphasized that the in vitro plantlet could easily express its photosynthetic ability when cultured photoautrophically. An air-porous supporting material, such as Florialite or vermiculite, obviously contributed to the increase in the nutrient uptake of in vitro plantlets due to the activity of lateral roots formed in the culture stage. Furthermore, PA plantlets continued developing better when directly transplanted to plastic bags in the greenhouse. There was a significant difference in fresh and dry weight, shoot and root length, as well as, relative growth rate on Day 21 of the ex vitro transplants derived from PA and heterotrophic cultures.

Coffee. Growth of *C. xarabusta* plantlets in vitro under PA condition was shown in previous studies to be better than in conventional micropropagations (heterotrophic and photomixotrophic). In the present study, the photoautotrophic growth of single-node cuttings, cuttings having two opposite leaves, was promoted with a significant increase in dry weight and shoot length when Florialite was used as a supporting material. Moreover, the net photosynthetic rate of PA coffee plants was much higher under the CO_2-enriched condition (1500 μmol mol^{-1} in the culture room) and PPF of 150 μmol m^{-2} s^{-1}. These conditions resulted in a significant increase in fresh weight, shoot length, and leaf area. However, a higher PPF (250 μmol m^{-2} s^{-1}) did not result in better plant growth with coffee.

The application of forced ventilation by directly pumping a gas mixture into the large culture vessels (V = 11.14 liters) greatly enhanced the growth of coffee plantlets with significant increases in fresh weight, leaf area, and shoot length as compared with that under natural ventilation (air diffusion through milliporous membrane on the vessel lid). The effect of ventilation systems applied during the in vitro stage was still valid on the growth of coffee transplants in the greenhouse.

These results demonstrate that the production of high quality woody transplants by PA micropropagation is possible and strongly recommended for consideration by propagators.

The Growth and Respiratory Activity of Root Systems on Pot-Grown Apple Transplants

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To determine the respiratory activity of root systems in relation to root growth during transplant production periods on apple nursery trees, a comparative study was made on apple transplants grown in field and pot conditions from June to September. The growth of root systems, expressed by number of newly generated roots, showed that white roots tended to have a peak in June and a subsequent decline by late-July with either apple transplants grown in the field or pots. After that root growth was increased in the pot-grown trees whereas the field-grown trees did not show an increase. The volume of new roots was obviously smaller in pot-grown than in field-grown apples. While the shoot growth was similar in the early period in both pot- and field-grown apple transplants, growth difference were evident by late-June; the pot-grown apple grew slowly, by contrast the field-grown apple continued to grow vigorously. In parallel with these growth states of the apple transplants, the tendency was for respiratory activities to coincide with the difference in shoot and root growth between the pot- and field-grown apple transplants. From these results, it is likely that root respiratory activity can be an indicator or a measure to understand root growth.

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Adventitious Bud Formation and Plant Regeneration from Leaf Explants of Balloon Flower (*Platycodon grandiflorus*)

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INTRODUCTION

Until now, adventitious bud formation has not been reported for balloon flower in tissue culture. The objective of the present study was to examine adventitious bud formation and plant regeneration as affected by cultivar, hormone, explant source, and culture conditions with *Platycodon grandflorus*.

MATERIALS AND METHODS

Experiment 1. Effect of plant growth regulators on the efficiency of adventitious bud formation from cotyledon explants was evaluated. Seeds of balloon flower 'Samidaremurasaki' were aseptically sown on Murashige and Skoog (MS) medium. Cotyledons were taken from 15- to 21-day-old seedlings. Cotylendon explants without petioles were cultured on MS medium supplemented with NAA and BAP at various concentrations. Cotyledons were cultured with the abaxial side in contact with the medium. Number of adventitious buds and shoots per explant was reported 60 days after cultivation.

Experiment 2. Effect of organ source on the efficiency of adventitious bud formation was examined. Cotyledons and hypocotyls were taken from 15- to 21-day-old seedlings, and foliage leaves were taken from 30- to 40-day old seedlings. The MS medium was supplemented with 1 mg liter^{-1} NAA and 1 mg liter^{-1} BAP with other culture conditions the same as Experiment 1. Cotyledons and foliage leaves were

Table 1. Effect of plant growth regulators on adventitious bud formation from cotyledons

NAA (mg liter^{-1})	BAP (mg liter^{-1})	No.of explants	No. (%) of adventitous bud	No. of shoots per explant
0	1	25	19.7 (78.8) ab	4.0 ab
1	0	25	0.7 (2.8) d	0.7 d
1	1	25	24.0 (96.0) a	4.2 a
0	5	25	15.3 (61.2) b	3.2 b
5	5	25	7.7 (30.8) c	2.2 c

Means with the same letter do not differ significantly (p=0.05) as indicated by one-way ANOVA followed by Duncan's multiple-range test cultured with their abaxial side in contact with the medium. The hypocotyls were placed flat on the medium. Culture conditions and experimental procedures were the same as with Experiment 1.

Experiment 3. Cultivar differences in adventitious bud formation were evaluated. Seeds of 'Samidaremurasaki', 'Samidaresiro', 'Shell Pink', and 'Misatomurasaki' were aseptically sown on MS medium. Regeneration medium was the same as used in Experiment 2. Cultures were kept at 20°C under 16-h photoperiod (3000 lux). All experiments were repeated three times.

Figure1. Adventitious bud formation on cotyledon.

Table 2. Effect of kind of organ on adventitious bud formation.

Organs	No.of explants	No. (%) of adventitous bud	No. of shoots per explant
Cotyledon	25	24.3 (97.2) a	4.4 a
Foliage leaf	25	22.3 (89.2) a	3.9 a
Hypocotyl	25	15.7 (62.8) b	3.0 a

Table 3. Varietal difference in adventitious bud formation

Genotypes	No.of explants	No. (%) of adventitous bud	No. of shoots per explant
Samidaremurasaki	25	24.0 (96.0) a	4.2 b
Samidaresiro	25	19.3 (77.2) b	3.2 c
Misatomurasaki	25	25.0 (100.0) a	5.0 a
Shellpink	25	24.0 (96.0) a	4.3 b

RESULTS AND DISCUSSIONS

Experiment 1. Higher adventitious bud formation from cotyledons was observed when MS medium was supplemented with 1 mg $liter^{-1}$ NAA + 1 mg $liter^{-1}$ BAP (96.0% and 78.8%) and 1 mg $liter^{-1}$ BAP, respectively. No significant difference was found between these two treatments. The shoot number showed a similar trend (Table 1).

Experiment 2. Although cotyledons showed the highest adventitious bud formation rate, it was not significantly different from that of leaves. Cotyledon explants produced the largest number of shoots per explant, however, there was no significant difference among organs (Table 2, Fig.1).

Experiment 3. Adventitious bud formation rate was significantly lower for 'Samidaresiro' compared to the other three cultivars with a rate of over 96.0% (Table 3).

Our results demonstrate that balloon flower is able to regenerate plants from cotyledons or true leaves through adventitious bud development on MS medium supplemented with 1 mg $liter^{-1}$ NAA and 1 mg $liter^{-1}$ BAP.

Studies on the Micropropagation of *Gloriosa superba* by in Vitro Tuber Culture

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Gloriosa superba L. belongs to the *Liliaceae* family. It is a showy, climbing perennial vine and important flowering ornamental. *Gloriosa* flowers are showy with petals that are reflexed (turning upwards and backwards) and are produced in a range of colors including red, yellow, orange, and purple. After the growing season, the aerial shoots die leaving a 10- to 20-cm tuberous rhizome in the soil. The rhizome is bifurcated with a meristem at the tip of each limb. The rhizome tips are commonly called tubers. In horticulture practice, *Gloriosa* is traditionally propagated via these tubers, however, this yields a very low multiplication rate. Therefore, the objective of this study was to develop a micropropagation system for *Gloriosa*. We examined plant material source and hormone effects on induction, multiplication, shoot formation and proliferation, and tuber formation.

The tuber tips with the meristem proved to be good explants for tuber culture of *Gloriosa*. When meristems were cultured on a medium with 5.0 µM BA shoots formed. It was possible to multiply the shoots in large quantities on the medium containing 20 µM BA and 0.05 µM NAA. New tubers were formed when the shoots were transplanted to 5 µM 2ip or 1 µM NAA containing media.

Slices from tuber tips cultured on 5 µM 2ip + 0.05 µM NAA containing medium produced callus. This callus was proliferated by subculture on 10 µM 2ip + 0.5 µM 2,4-D medium. Shoot clusters were produced by transplanting the proliferating callus masses to medium with 10 µM BA + 0.05 µM NAA. It was also possible to develop new tubers on 5 µM 2ip or 1 µM NAA containing media, or directly by transplanting the callus to 5 µM 2ip + 0.5 µM IBA medium. During the micropropagation of *Gloriosa*, 2ip promoted tuber formation and BA promoted shoot multiplication.

"Seek and Share" Around the World

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Wonderful people, great ideas, and lasting friendships — this is what I.P.P.S. is all about.

I (senior author) have been a member of I.P.P.S. for 15 years. While I am not now a plant propagator, I can travel the world and enjoy meeting new plant people and catching up with fellow I.P.P.S. members, see what is happening, and pick up new ideas I can share with others.

Here are two ideas that immediately come to mind:

1) Did you know that smoke helps many Australian and South African native seeds to germinate?
2) Petrol can be used to clean sticky seeds.

When I first came to Japan to the conference in Miyazaki 5 years ago I had a wonderful time. It was a totally new experience. I left, however, with an impression that Japan was very Americanized but how wrong that proved to be.

I met my dear friend Shozo Watanabe at an I.P.P.S. conference in New Zealand a few years back and since then my visits to Japan have been more than memorable. Shozo has shown me the real Japan. He has shared your culture and your horticulture with me. I find it absolutely fascinating, quite unique, and different from what happens back home in New Zealand. This is the kind of friendship and sharing that happens within I.P.P.S. worldwide. I.P.P.S. is a community, a family.

People who have been in the industry only a short time and those who have spent a life time in it have a place to share knowledge that will make our industry stronger and build on what our fathers passed on to us.

The aim of this paper is to expand the following concepts promoted by I.P.P.S.:

- That I.P.P.S. encourages and fosters horticultural information sharing and education.
- The long-term benefits to ornamental horticulture and the future of I.P.P.S. when young and skilled people are encouraged to join and participate.

I will now show a series of slides which start with a youngster and finishes with one of I.P.P.S.'s oldest members showing the contributions of people of all ages, abilities, and achievements.

This presentation also aims to demonstrate the international I.P.P.S. community and New Zealand I.P.P.S. activities.

Tondemonai Pot and Shozo-70 Nursery Soil

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K. Iida
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The Tondemonai pot's unique characteristics allow roots to actively grow throughout the entire container medium because of the removal of excess water by slits in the bottom of the pot and the supply of oxygen to the medium through the slits. Such root system development would not have occurred with the more traditional pot used before. In traditional pots, water remains in the bottom and the roots circle the pot. In addition, the upper part of the soil will dry and the oxygen will not be able to get into the soil. Root growth, therefore, will be restricted to the bottom and the medium-pot interface.

With the Tondemonai pot the container medium has the water evenly distributed throughout the pot. The medium in this pot is well drained and has a stable water content. The 24- and 30-cm-diameter pots have an octagon face and the 15-cm-diameter pot has a hexagon face. The stair-shape of the pot sides induces the roots to grow to the corner of the pot and the air. This structure is effective for avoiding the development of circling roots.

There are many advantages for the use of this pot.

- Because this pot increases the amount of root growth, plants can avoid wilting longer and recover faster from a water deficiency if wilting occurs.
- Growers can grow plants for a long time period because of the greater oxygen supply to the roots generated in the pot.
- Growers can directly plant a small seeding in a large pot, which will save time and cost for transplanting.

A nursery soil also has been developed. The name of this soil is "Shozo-70" nursery soil. The concept behind the production of this soil is that the root is an organ whose function is very important and similar to the internal organs for animals. Shozo-70 nursery soil is especially produced for improving plant growth. Media water retention, physical properties, and desiccation problems were considered during development of this potting substrate. This substrate can be used for all plants, including vegetables, annual bedding plants, flowering trees and shrubs, and foliage plants by mixing with other components. I recommend the use of this soil with 30% to 40% mountain sand for plant propagation.

Improvements in the Production of Rooted Cuttings in a Mist-irrigation Greenhouse

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INTRODUCTION

At my nursery plants are grown in containers for public landscaping. I grow mainly conifers.

Currently, the economic situation is very critical for nursery-stock growers because spending on public landscaping has been reduced. On the other hand, home gardening booms and people have a strong interest in green plants. However, there are very few plants available which satisfy this new demand of plant lovers. To find a way out of this critical situation nursery-stock producers are introducing new plant cultivars, producing new tree forms, and developing special tree standard forms. Not only are the plants that will be grown by nurseries changing but the systems required to produce those plants will have to be changed. This change will be promoted by using new types of labor-saving agricultural implements, materials, and facilities.

SUMMER PROPAGATION

During our summer propagation season the worst problem was reduced rooting related to excess humidity and high temperature. To overcome this problem in my nursery we have introduced a mist-irrigated greenhouse system. The system consisted of the following:

We set up the reversible sheets around the greenhouse for shading and preventing the wind flow from outside.

Roof vents and side ventilators were fully opened to lower the inside temperature.

Water irrigation was carried on using irrigation tubes to keep the humidity at an adequate level when the inside humidity become low (by using this method, the inside temperature was reduced 3°C).

Water irrigation on the top of greenhouse roof (by using this method, we lowered the inside temperature about 1°C and were able to reduce the number of times that we used the mist irrigation.

By the above treatments we were able to prevent the reduced rooting occurring during the summer propagation season.

WINTER PROPAGATION

In winter we used heating pipes to keep the propagation bed temperature higher for nursery stock production. In order to maintain uniform heat conduction from the heating pipes a layer of perlite was used. A problem developed in that the heated beds were prone to drying around the heating pipes; this eventually resulted in the temperature around the hot water pipes becoming higher and rooting became subsequently inconsistent. This problem was solved by placing plastic pipes with 2-mm-diameter holes on 20-cm diameters and running water through the pipes to keep the heated beds moist. This procedure allowed us to maintain the propagation-bed temperature and rooting of cuttings uniform.

The Japanese Tradition of Grafting

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Various methods for grafting have been created and inherited from previous generations for a long time in Japan. While some methods have spread widely, others have not done so and remain hidden within a nursery. Many of these grafting techniques are then lost when there is no successor to learn from the master. It is with regret that I recall this history of lost grafting techniques in Japan.

I have utilized various methods of grafting not only to propagate plants but also as a potential tool to introduce the indigenous character of the rootstock into the scion. Examples of my work are presented below.

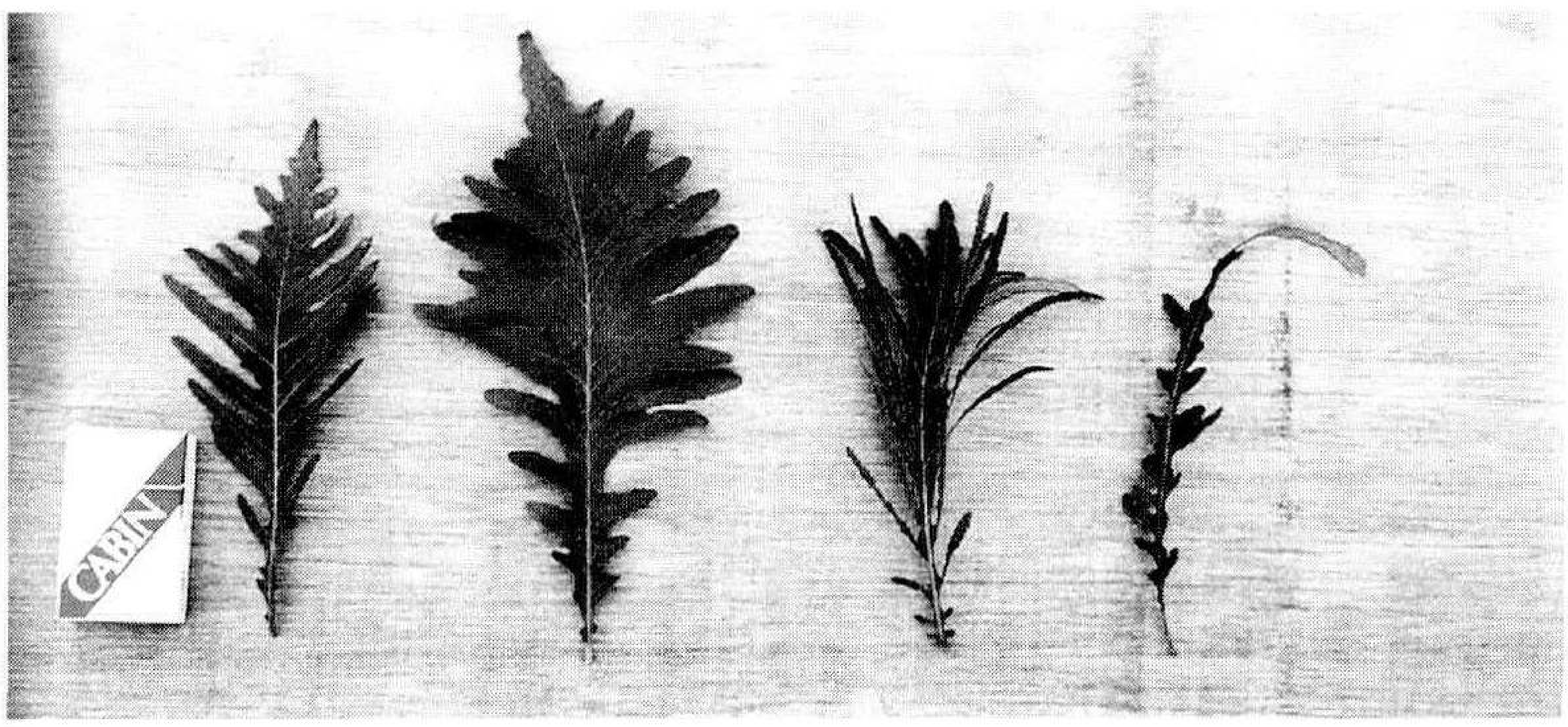

Figure 1. *Quercus dentata* 'Pinnatifida' leaf shapes observed when grafted onto a number of different *Quercus* species.

Figure 2. A grafted weeping silktree albizzia.

Quercus dentata 'Pinnatifida' was grafted onto a number of *Quercus* species [*Q. dentata*, *Q. aliena*, *Q. mongolica*, *Q. acutissima* (syn. *Q. serrata*), and *Q. variabilis*] with differing results. I observed that some *Q. dentata* f. *pinnatifida* grafted onto *Q. dentata* produced bigger leaves than on *Q. aliena* a year after grafting and leaves as strange as peacock feathers were observed in the 2nd year (Fig. 1). When grafted onto either *Q. acutissima* or *Q. mongolica* the leaves become thinner and curled at the tip like a phoenix. These results suggest that using different understocks may produce grafted plants with forms listed in the literature similar to *Q. dentata* f. *laciniata* and *Q. dentata* f. *pinnatiloba*. Further research will be needed to better understand these results. When grafted onto *Q. acutissima* and *Q. variabilis*, a beautiful golden leaf coloring developed which may have been affected by the inherent color of the rootstocks. In addition I am planning additional trials with different rootstocks aiming to improve fall color, reddish-brown in Japanese on European oaks, with scarlet oak and pin oak which have a natural red color.

In addition, I have had successful results with a weeping-type silktree albizzia which is difficult-to graft (Fig. 2).

Breeding of Spring Flowering Gladiolus for Cut Flower Production

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BREEDING AND MARKETING

Two types of demand dominate cut flower sales (more than 80%) in Japan; one is business occasions such as ceremonial needs and the other is domestic consumption such as casual flowers. The remaining approximately 20% is demand by flower fanciers who have a passion for flowers. They may have studied flower arranging and take it for granted that one decorates with flowers when visitors come. Flower fanciers have a higher sensitivity with regard to flowers, are better at flower arranging, and may act as a driving force in the flower market leading to the next generation of casual flower sales. Therefore, breeders should pay more attention to their demands and produce/introduce new plants that can create new images with flowers. Traditionally the forces driving plant breeding have been predominately productivity increases and disease resistance.

POTENTIAL OF SPRING GLADIOLUS

Images of the commonly grown gladiolus are the following. A large and gaudy flower that is conspicuous everywhere in summer, suitable for a hotel lobby but not for a family table, good for decoration at the front entrance of a home but not good for placing on a cupboard, and fading quickly.

Spring gladiolus are different. They flower from autumn to spring and have a long flower life. Stem diameter is less than 7 mm and height is less than 1 m; this is good for compact flower decorations. The range of flower colors is wide and includes most

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Spring gladiolus are different. They flower from autumn to spring and have a long flower life. Stem diameter is less than 7 mm and height is less than 1 m; this is good for compact flower decorations. The range of flower colors is wide and includes most colors except red. In addition, fragrant flowers can be produced by future breeding because wild types have a strong scent.

- Additional characteristics of spring gladiolus are the followings:
- There are many types about 20 cm in height (wild type).
- They are suited for planting in perennial borders because of cold hardiness.
- It is possible for them to be used as biennial herbs because of the genetic characters in seedlings for flowering in the 2nd year.

NEEDS IN THE BREEDING OF JAPANESE-STYLE FLOWERS

Today, many flowers such as rose, dahlia, lily, carnation, anemone, pansy, and alstromeria, are bred in the belief that large and brilliant flowers are beautiful. However, small flowers such as red clover, Persian speedwell, and hagi in Ikebana (Japanese flower arrangement) have unforgettable beauty and these remain in the minds of Japanese people in a nostalgic way. Therefore, we also need to produce the traditional Japanese-style flowers because the demand will be present because of nostalgic reasons.

Micropropagation of *Rhododendron yedoense* var. *yedoense* by Hypocotyl Culture

S. Yamaguchi, and N. Ozaka
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INTRODUCTION

Tissue culture has been adopted successfully for the mass production of many rhododendrons. However, the micropropagation of the tsutsusi group of evergreen rhododendrons is not commercially successful at the production level. We are conducting research to establish the protocol for the red-data species (threatened speices) found only in one spot on Shikoku Isle. In this paper we report preliminary results on the regeneration of shoots from seedling hypocotyls of *Rhododendron yedoense* var. *yedoense*.

MATERIALS AND METHODS

Seeds of *R. yedoense* var. *yedoense* were washed overnight in running tap water. Then, after sterilization with the calcium hypochloride solution and washing in the sterilized distilled water, the seeds were placed on solidified half-strength Murashige and Skoog medium supplemented with sugar (30 mg liter^{-1}). One-month-old seedlings were collected and hypocotyl explants were excised and placed on the previous medium supplemented with combinations of 2ip (0.5, 0.1, and 0.05) and NAA (0.1, 0.2, 0.4, and 0.8). After 1½ months we recorded the amount/number of callus, green spots, adventitious buds, and shoots present.

colors except red. In addition, fragrant flowers can be produced by future breeding because wild types have a strong scent.

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- There are many types about 20 cm in height (wild type).
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RESULTS

Shoot regeneration was observed in all hormonal combinations, however, the combinations with lower concentrations of 2ip and moderate concentrations of NAA was more efficient for the rapid regeneration from hypocotyl explants via callus (Table 1).

Table 1. Regeneration frequency in the hypocotyl culture of *R. yedoense* var. *yedodense* f. *poukhanense*.

Hormone		Callus with regenenation (%)			
2ip (mg liter^{-1})	NAA (mg liter^{-1})	Green spot stage	Bud stage	Shoot stage	Total
0.05	0.05	8.7	25	33.3	66.7
	0.1	22.2	22.2	44.4	88.9
	0.2	15.4	19.2	46.2	80.7
	0.8	20	20	60	100
0.1	0.05	0	66.7	33.3	100
	0.1	0	50	0	50
	0.2	0	0	0	0

Promoting Germination of Seeds from Oriental Lily Hybrids: Effect of Developmental Stage and Scarification in Immature Seed

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INTRODUCTION

Hybrid lily cultivars with new characteristics have recently been developed from wide crosses by pollinating cut styles and embryo culture. We have tried many wide cross to produce improved cultivars. However, the life cycle in lily from crossing till anthesis takes several years and it was felt that shortening this long life cycle would increase breeding efficiency. In this research the most suitable seed developmental stage and promoting effect of scarification were studied for the efficient rearing of oriental hybrid lilies.

MATERIALS AND METHODS

Oriental hybrid lily crosses, *Lilium* 'Darling' × *L.* 'Trance' and *L.* 'Darling' × *L.* 'Miss Burma', were used as materials after crossing on 27 May 1994. Capsules containing immature seeds were harvested every 10 days from 40 to 70 days after pollination. Immature embryos for culture were excised under a microscope and scarified by pricking the upper and lower seed coats with a sharp knife. Murashige and Skoog nutrient medium (1962) supplemented with 30 g $liter^{-1}$ sucrose and 4 g $liter^{-1}$ Gellan gum was used. Medium pH was adjusted to 5.7 and a 10-ml aliquot was used per test tube (25 mm × 100 mm). All explants were cultured under 12-h day length, 2500 lx, and 25±1°C.

Table 1. Effect of development stage on germination of immature embryo ('Darling' × 'Trance').

Days after crossing	Number of plants	Number germinated	Germination rate (%)
40	10	2	20
50	10	4	40
60	6	5	83
70	5	5	100

Table 2. Effect of developing stage on germination of immature embryo ('Darling' × 'Miss Burma').

Days after crossing	Number of plants	Number germinated	Germination rate (%)
40	10	0	0
60	8	8	100

Table 3. *Effect of developing stage and scarification treatment on germination of* immature seed ('Darling' × 'Trace').

Days	No. plants	Control no. germinated	Germination rate (%)	No. plant.	Scarification no. germinated	Germination rate (%)
40	120	51	43	-	-	-
50	120	43	67	-	-	-
60	60	11	18	60	27	45
70	60	7	12	60	29	48

Table 4. Effect of developing stage and scarification treatment on germination of immature seed ('Darling' × 'Miss Burma').

Days	No. plants	Control no. germinated	Germination rate (%)	No. plant.	Scarification no. germinated	Germination rate (%)
40	120	20	17	-	-	-
50	99	56	57	-	-	-
60	60	19	32	60	50	83
70	60	9	15	36	22	61

RESULTS AND DISCUSSION

Tables 1 and 2 show that 60 or 70 days after crossing was the best for embryo culture. Tables 3 and 4 show that the treatment of scarification to immature seed 60 or 70 days after crossing remarkably promoted seed germination. The germination rate in the control seeds was highest at 50 days after crossing and decreased rapidly at later harvest dates. The decline in germination vigor might be caused by an inhibitor or hardening of the immature seed coat. We feel that scarification is easier and more practical than excision of immature embryos.

LITERATURE CITED

Murashige, T. and **F. Skoog**. 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultured. Physiol. Plant. 15:473-497.

Kusumoto, M.1992. Embryo culture of plants—the object and method. Sanseido Science Study. 22:1-3.

Promoting Germination from Four Cross Combinations of Immature Oriental-Hybrid-Lily Seeds by Embryo Culture and Scarification Treatment

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INTORODUCTION

In a previous study on oriental-hybrid-lily seed germination it was ascertained that the most suitable developmental stage for embryo culture was 60 or 70 days after crossing. It was also shown for in vitro culture that scarification of immature seeds promoted germination of immature embryos. In this study we investigated whether the scarification method was also the best for four additional hybrid combinations.

MATERIALS AND METHODS

In this research four cross combinations were carried out between May and July 1997 (Table 1). Capsules from the four hybrid combinations were harvested every 10 days (between 40 and 70 days) after crossing and used for aseptic culture of immature embryos and scarification studies. Seed scarification was carried out by cutting seed coats near the embryo with scissors; this method was subsequently improved by pricking the upper and lower seed coat with a sharp knife. The medium was half strength Murashige and Skoog supplemented with 30 g liter^{-1} sucrose and 4 g liter^{-1} Gellan gum. Medium pH was adjusted to 5.7 and a 10-ml aliquot was used per test tube (25 mm × 100 mm). All explants were cultured under a 12-h day length, 2500 lx, and 25±1°C.

RESULTS AND DISCUSSION

Table 1 shows the germination results of the immature embryos from the four cross combinations. The rate of germination for immature embryos was low at 40 days but maintained a high level, 90% to 100%, with few exceptions between 50 and 70 days after crossing. From this data we believe that the most suitable time after crossing

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Table 1. Comparison of germination abirity in immature embryo and scarificated immature seed cultured in vitro in four hybrid lily.

Days after crossing	'Miss Birma' X 'Stargazer'						'Stargazer' X 'Early Rose'					
	Embryo culture			Culture of scar. seed			Embryo culture			Culture of scar. seed		
	No. planted	No. germ.	Rate (%)	No. planted	No. germ.	Rate (%)	No. planted	No. germ.	Rate (%)	No. planted	No. germ.	Rate (%)
40	12	5	42	15	3	20	4	1	25	-	-	-
50	50	50	100	25	20	80	36	36	100	25	19	76
60	50	50	100	25	20	80	50	50	100	25	16	64
70	50	49	98	25	2	8	50	50	100	25	14	56

Days after crossing	'Little Girl' X L. rubellum						'Miss America' X 'Stargazer'					
	Embryo culture			Culture of scar. seed			Embryo culture			Culture of scar. seed		
	No. planted	No. germ.	Rate (%)	No. planted	No. germ.	Rate (%)	No. planted	No. germ.	Rate (%)	No. planted	No. germ.	Rate (%)
40	-	-	-	-	-	-	12	1	8	12	5	42
50	15	8	53	-	-	-	20	18	90	20	17	85
60	25	25	100	25	23	92	-	-	-	-	-	-
70	50	50	100	25	18	72	-	-	-	-	-	-

for immature embryo culture of oriental hybrid lilies is at 50 and 60 days after crossing. It should be noted that excision of lily embryos became gradually more difficult with increasing growth of the seed and endosperm development.The germination rate of scarified immature seeds was also high at 50 and 60 days after crossing. We feel from these experimental results that scarification is a useful method for in vitro seed germination of lily seeds as it is more efficient and yields almost as good results when compared to embryo culture.

LITERATURE CITED

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The New World of Horticulture and Greening of the Environment

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INTRODUCTION

The concept of "greening" has been well established in Japan for 30 years, however, its role has change recently. The initial aim of greening was to provide a more comfortable atmosphere for people through free plantings. Public areas such as parks and street-tree planting locations, as well as private enterprises such as golf links and tree-planted factories were developed on a large scale. Until now, because of these types of demands, production of standardized and inexpensive nursery plants replaced traditional ones to a great extent. Recent demands from consumers for new tree shapes adapted to Western-style gardens and the emphasis on plants for their foliage and flower characteristics have been increasing. Such demands will often require different horticultural production techniques and thus the producers who are only currently growing standardized plants are suffering at this time because of decreased demand for their product. Today I will discuss the difference between the two production systems in Japan and the need for cooperation between these two segments of the industry.

PRODUCTION SYSTEMS

The production systems have different final targets for sale.

Greening. Sales are mainly through plant traders and major transactions are negotiated. In the green industry segment plants are standardized, prices are stable, production is stable, and good keeping quality for a long time is necessary. Large-scale production of a small range of plants occurs.

Horticulture. Sales for this segment come mainly from individual consumers through the retail market trade. Price fluctuates heavily by the demand, supply, season, and quality. Ornamental quality is the major selling factor for the plants, however, the quality after purchase is not as important. Small-scale production of a wide range of plants occurs.

Differences between the two segments can be seen from the characteristics mentioned above. Unless some changes in the current systems for sale and production are made potential growth will be reduced.

CONCLUSION

In conclusion, I would suggest that greening and horticulture production industries including the flower-production industry should cooperate with each other to determine the potential needs and develop the new forms of plant production. I believe that new production systems will be established by combining the techniques of greening and horticultural industries which is adaptable for various natural conditions and also possess ornamental values.

I believe I.P.P.S. is the only organization that will enable segment of the industry to cooperate with each other. Why don't you make the necessary changes in the plant industry with our collaboration?

Nonsymbiotic Seed Propagation of Two Japanese Native Orchids for Native Restoration

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INTRODUCTION

According to the Red Data Book there are 5300 species of native plant in Japan. However, 895 of these species are threatened with extinction; of these 144 species are orchids (Japan Society of Plant Taxonomists, 1993).

In Mito Municipal Horticulture Center two Japanese native orchids, *Pecteilis radiata* (syn. *Habenaria radiata*), which is categorized as endangered in Red Data Book and *Vandopsis luchuensis*, have been propagated by nonsymbiotic seed propagation for the restoration.

PROPAGATION OF THE SPECIES

Pecteilis radiata. In Mito City, Ibaraki Pref., there were several native populations of *P. radiata* about 20 years ago. These have been decimented because of changes in the environment around their native growing locations and over-collecting by heartless collectors. However, from 1990 *Pecteilis* has been conserved and propagated by nonsymbiotic seed propagation. Currently, there is a marshland which was formerly the home of this species and its environment is still satisfactory for growth of this orchid. The marshland is part of an agricultural reservoir and a local association, which maintains the reservoir, has been interested in restoration of the habitat for *P. radiata*. Therefore, the Horticulture Center has been cooperating with the local association for habitat restoration.

Non-symbiotic Propagation Methology.

- ***Medium.*** Hyponex 0.3%, sucrose 3%, hormone free.
- ***Method of Seeding*:** Nonmature seeds are routinely collected from nondehisced pods 25 to 30 days after pollination. The seeds from one pod are distributed into three 300-ml culture flasks.
- ***Acclimatization***. Tubers develop in the flask by April to May. These tubers are easily planted without acclimatization.

Vandopsis luchuensis. *Vandopsis luchuensis* is the only large vanda-type orchid native to Japan and it is found on Iriomote Island, Ishigaki Island, and the Senkaku Archipelago. This *Vandopsis* species is also threatened with extinction by over collecting, therefore, two plants were transported to the Horticulture Center for propagation on June 1994. These plants are growing in a greenhouse and one of them flowered in Feb. 1995; it was pollinated for seed propagation.

Propagation was successful and 1000 young plants were transported to Iriomote Island in 1997. They were planted in their native tropical forest by the Forest Tree Breeding Center.

Non-symbiotic Propagation Methology.

- ***Hybridization.*** March 1995.
- ***Seeding.*** 30 Nov. to 22 Dec. 1995.
- ***Micropropagation Medium.*** Hyponex 0.3%, peptone 0.2%, sucrose 3.5%, hormone free.
- ***Enhancement of Seed Germination.*** Purelux 3% (sodium hypochrorite solution, 0.18% as available chlorine) for 5 min.
- ***Method of Seeding*:** Nonmature seeds were collected from nondehisced pods 250 to 270 days after hybridization.
- ***Acclimatization.*** April 1997.

LITERATURE CITED

Japan Society of Plant Taxonomists. 1993. Red data book. (in Japanese). Nouson Bunka-Sha, Tokyo.

Studies on Micropropagation of *Phalaenopsis* Alliance

S. Ichihashi, M. Tsuzuki and C. R. Aswath

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Micropropagation of *Phalaenopsis* through flower stalk explant culture was investigated.

Bracts of flower stalks were removed before or after sterilization. Decontamination rate of nodal sections was higher when they were sterilized with bract. Subsequent growth of lateral buds was affected by the timing of bract removal. More lateral buds developed vegetative shoots when bracts were removed before sterilization.

Micropropagation from a plantet was also investigated using in vitro cloned plantlets. The basal 1.5-cm part of a plantlet was cut into 2.5-mm or 5-mm sliced segments which were cultured on new phalaenopsis medium (Hirose, 1998) with or without coconut water (CW) and/or 6-benzylaminoprine (BA). Regeneration of shoot(s) and callus-like body was dominant in the slice segments derived from 5 to 10 mm part from the base of the shoot and was promoted by addition of CW and/or BA.

LITERATURE CITED

Hirose, M., S. Sigemura, and **S. Ichihashi.** 1998. Plant regeneration from protoplasts derived from callus of Phalaenopsis alliance. Comb. Proc. Intl. Plant Prop. Soc. 48:552.

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Effects of Cold Pretreatment and Potting Materials on Growth of Acclimated Plantlets of *Cypripedium macranthum* var. *speciosum*

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To achieve effective seedling production of the endangered orchid, *Cypripedium macranthum* var. *speciosum*, the effects of cold pretreatment duration and potting substrate type on seedling growth and survival were investigated. With over 12 weeks of cold treatment at 5°C, approximately 90% of the in vitro plantlets formed shoots and rooted. However, following 24 weeks or more of cold treatment, the acclimated plantlets showed a lower survival rate after 26 weeks of cultivation and less new bud formation. Potting substrate influenced survival rate and new bud formation. A sandy loam soil mixed with a soil rich in clay and/or rock wool was more effective than the single use of each potting material.

INTRODUCTION

Cypripedium spp. (Orchidaceae) have become endangered around the world due to indiscriminate overharvesting and destruction of their habitat. Cypripediums native to Japan are gravely affected (Japan Society of Plant Taxonomists, 1993). In recent years, there have been a number of reports dealing with the in vitro production of the Japanese cypripediums from the standpoint of gene resource conservation and in response to nursery demand (Takahashi and Tsutsui, 1992; Hoshi et al., 1994; Tomita, 1997; Tomita and Tomita, 1997b). A cold treatment before acclimation has been reported to be effective for in vitro plantlet acclimation (Frosch, 1985; Malmgrem, 1996; Ramsay and Stewart, 1998; Stewart and Mitchell, 1991). Few studies on plantlet acclimation have been reported on the Japanese cypripediums (Takahashi and Tsutsui, 1992; Tomita, 1997; Tomita and Tomita, 1997a, 1997b). Also, no reports have been made on the influence of cold treatment on the growth of the plantlets post-acclimation or the cultivation conditions required have not been reported. One method of protecting wild terrestrial orchids is by growing them in cultivation in order to supplement the natural population (Ramsay and Stewart, 1998). In order to form a basis for development of an effective method to propagate orchids of the *Cypripedium* genus, in vitro plantlets of *C. macranthum* Sw. var. *speciosum* (Rolfe) Koidz. were used to investigate the effects of both the duration of cold treatment before acclimation. The effect of the composition of potting materials on post-acclimation plantlet growth was also investigated.

MATERIALS AND METHODS

Immature seeds of *C. macranthum* var. *speciosum* were sown on ½ Norstog medium (Tomita and Tomita, 1997b) in July of 1994 and 1995. The resulting plantlets were transferred every 12 weeks onto the same medium. All cultures were incubated in the dark at 20°C. The effect of cold treatment was investigated in 1996 on plantlets derived from seeds sown in 1994, and the effect of potting materials was investigated in 1997 on plantlets from seeds sown in 1995.

Experiment 1. Effects of Cold Stratification on Growth of Acclimatized Plantlets. Plantlets derived from seed sown in 1994 were utilized. Plantlets of uniform size (dormant bud size, 5 to 10 mm; fresh weight, 200 to 300 mg) were selected at weekly intervals from July of 1995 through January of 1996, and removed from flasks. The plantlets were placed in sterilized vermiculite in vinyl bags. The plantlets were subjected to cold treatment at 5°C. Control (untreated) plantlets were selected in March 1996. After cold stratification for 0 (untreated control), 8, 12, 16, 20, 24, 28, and 32 weeks the plantlets were placed in 12-cm-diameter pots with "towadasuna" (3 plantlets were placed in each pots) in March. Towadasuna is a kind of sandy loam, the particle size used was 5 mm or less, and it was sterilized by autoclaving after lumps were removed (Tomita, 1997). Plantlets were moved to a shaded (below 10,000 lux), nonheated greenhouse, watered regularly to prevent drying out, and dilute liquid fertilizer (Hyponex; 5N : 10P : 5K) was applied every 2 weeks.

Experiment 2. Effect of Potting Materials on Acclimated Plantlet Growth. Plantlets derived from seeds sown in 1995 were used for this experiment. As for the first experiment, plantlets of uniform size were selected between November through December of 1996. Cold treatment at 5°C was conducted for 12 weeks. The date of initiation of the cold treatment varied between different replicates within each treatment, between late February of 1997 and mid-March of the same year. Following cold treatment three plantlets were placed per each 12-cm-diameter pot. Each replicate was made up of 4 pots (a total of 12 plants). For each treatment four replicates were used. Six different potting materials were used for cultivation:

- A) Towadasuna (same as in Experiment 1).
- B) Kanumatsuchi (clay-rich soil, 5- to 10-mm granules after dust removal).
- C) Rockwool fiber.
- D) Towadasuna + kanumatsuchi (1:1, v/v).
- E) Towadasuna + rock wool (1:1, v/v),
- F) Towadasuna + kanumatsuchi + rock wool (1 : 1 : 1, by volume).

All materials were sterilized by autoclaving. Cultivation conditions were the same as those in Experiment 1. Shoot formation was considered to have occurred when buds pushed their way to the surface, turned green, and the first leaves appeared (Takahashi and Tsutsui, 1992). Plantlets were observed after shoot formation, and dug up after 26 weeks of cultivation. The survival rate and fresh weight of survivors, along with the new bud formation rate, were recorded.

RESULTS

Experiment 1. Effects of Duration of Cold Treatment on Plantlet Growth. The results are shown in Table 1. No shoot formation was observed on untreated control. The shoot formation rate where the cold treatment was applied for more than 12 weeks was significantly higher than in the 8-week cold treatment. No significant differences were noted in leaf number or height of the shoot (data not shown) between the treatments. After 18 weeks of cultivation, there were noticeable differences between the treatments. Plants which were exposed to 20 or more weeks of cold treatment showed some discoloration of the leaves. Moreover, when the investigation ended in the 26th week of cultivation, the above-ground portion of the plantlets had withered away. The survival rate, fresh weight of survivors, and new bud formation rate of plantlets after acclimation and 26 weeks of cultivation were high in the cold-treatment plots of 20 weeks or less duration. With longer treatment, these levels decreased as the cold treatment time was prolonged. In the 32-week treatment, all plantlets had withered and died when dug up, and there was no bud formation.

Experiment 2. Effect of Potting Materials on Acclimated Plantlet Growth. The results are shown in Table 2. The rate of shoot production was around 90% with no significant difference between the treatments. This was also true of the height and number of leaves after shoot formation (data not shown). Discoloration of the above-ground portion was recognized earliest in treatment B after 16 weeks of cultivation. With treatment F, yellowing was not observed until 23 weeks of cultivation. When dug up after 26 weeks of cultivation, over half the plantlets still had green foliage (data not shown). At 26 weeks, the survival rate, plantlet fresh weight, and new bud formation rate tended to be higher using treatments D-F, where composites were used, than in treatments A-C, in which only a given type of soil was used in each. In treatment B, there was poor formation of new roots, and many of the roots formed were discolored. Moreover, at 26 weeks, these plantlets had a significantly reduced survival rate, fresh weight, and new bud formation rate when compared with the other five treatments.

DISCUSSION

In vitro plantlets of *Cypripedium* genus have a type of epicotyl dormancy (Takahashi and Tsutsui, 1992) and cold treatment is necessary for shoot formation (Frosch, 1985; Malmgrem, 1996; Ramsay and Stewart, 1998; Stewart and Mitchell, 1991; Takahashi and Tsutsui, 1992; Tomita, 1997). In the present experiments using *C. macranthos* var. *speciosum*, as for other cypripediums, dormancy breaking was achieved in the in vitro plantlets given 12 or more weeks of cold treatment at 5°C.

Given the post-acclimation-growth efficiency, the acclimation period should preferably be winter for the in vitro plantlets given cold treatment (Malmgrem, 1989). However, in cypripediums the rate of germination and development is highly variable and the uneven growth of the post-germination plantlet (Ballard, 1987; Butcher and Marlow, 1989; Tomita, unpublished data) may be considered to hinder effective seedling production. Thus, in Experiment 1, we attempted to adjust the plantlet acclimation phase to spring, for the convenience of following cultivation, by prolonging the cold treatment time, and then investigated the effects on plantlet growth after acclimation. In the cold treatments given for 12 weeks or more, no difference was noticed in the shoot formation rate or ostensible growth following formation of the shoot. But when the treatment was prolonged to 24 weeks or more, there was an adverse effect on the survival rate and new bud formation in the plantlets following acclimation. This was thought to be caused by the weakening of the plantlets by the long cold treatment. There is the need to achieve greater seedling production efficiency by considering the various conditions in cultivating plants. For example, one can adjust the acclimation time in the in vitro condition by maintaining its growth through various adjustments, or post-acclimation methods such as use of fertilizer are worth considering.

Table 1. Effects of time exposure to cold treatment time on the growth of acclimated plantlets of *Cypripedium macranthum* var. *speciosum*.

Cold treatment period (weeks)	Shoot formation rate (%)[1]	After 26 weeks of cultivation		
		Survival rate (%)	Fresh weight (mg)	New bud formation (%)
0	0 c[2]	0 c[2]	-	-
8	66.7 b	83.0 a	198 a[2]	63.1 a[2]
12	89.6 a	80.9 a	216 a	58.1 a
16	91.7 a	70.1 a	212 a	49.8 a
20	89.6 a	70.1 a	200 a	46.6 a
24	87.5 a	38.2 b	174 ab	34.2 ab
28	89.6 a	30.0 b	140 b	6.3 b
32	87.5 a	0 c	-	-

[1] Percentage of plants with buds appearing on surface, turning green and producing leafs (Takahashi and Tsutsui, 1992).

[2] Mean separation within column by Duncan's multiple range test at 5% level.

Table 2. Effects of potting materials on growth of acclimated plantlets of *Cypripedium macranthum* var. *speciosum*.

Cold treatment period (weeks)	Shoot formation rate (%)[2]	After 26 weeks of cultivation		
		Survival rate (%)	Fresh weight (mg)	New bud formation (%)
A	93.8 NS[3]	77.3 a[3]	261 b[3]	55.7 b[3]
B	89.6	32.8 b	125 c	14.6 c
C	91.7	45.5 b	301 b	45.0 b
D	91.7	86.4 a	333 ab	81.4 a
E	91.7	90.9 a	397 a	80.4 a
F	93.8	91.1 a	415 a	83.2 a

[1] A: "towadasuna"; B: "kanumatuchi"; C: rock wool; D: "towadasuna" + "kanumatuchi" (1:1); E: "towadasuna" + rock wool (1:1); F: "towadasuna" + "kanumatuchi" + rock wool (1:1:1).

[2] Percentage of plants with buds appearing on surface, turning green and producing leafs (Takahashi and Tsutsui, 1992).

[3] Mean separation within column by Duncan's multiple range test at 5% level; NS: not significant.

There are few examples in the literature of the detailed cultivation conditions required for the post-acclimation plantlets of cypripediums (Malmgrem, 1996; Ramsay and Stewart, 1998). InExperiment 2, the type of potting materials used had a marked effect on plantlet growth. As a potting medium for cultivation of the seedlings of *C. macranthos* var. *speciosum*, it was found that the sandy loam mixed with clay-rich soil, and/or rock wool was most effective, rather than the sandy-loam-based media reported as being successful for other *C. macranthos* variants (Takahashi and Tsutsui, 1992; Tomita, 1997; Tomita and Tomita, 1997a). The physico-chemical characteristics of these potting materials were considered to have influenced the plantlet growth like other terrestrial orchids (Mckendrick, 1996). Further studies will be needed.

To establish an effective method to reproduce the endangered *Cypripedium* genus, the present investigators intend to continue their studies, based on the above results, of the culture conditions from 2 years after acclimation until flowering.

Acknowledgements. The authors are grateful to Ms. Margaret M. Ramsay, Head of Micropropagation Unit, Royal Botanic Gardens, Kew (U.K.) for her useful comments and a critical reading of this manuscript.

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Understanding New Market Trends and Their Impact on Distribution and Future Product Needs

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CHANGES IN THE FIELD OF MARKETING

Consumer tastes and market preferences have changed time after time and these changes were based on social elements, economic environments, and so on. Because of this the strategy of many companies, at first, was to have a reliable marketing research division as a defense mechanism against alternative markets.

THE MARKETING PHILOSOPHY DRIVING PRODUCERS AND CONSUMERS DURING THE PERIOD OF HIGH ECONOMIC GROWTH

During the high economic growth period in Japan production was driven by the ability to construct mass-production systems; it was an age when demand was high. In this period the markets favorably expanded, and because demand exceeded supply, goods sold without difficulty. The strategy of producers was to reduce costs to manufacture larger quantities of goods. Consumers were satisfied with the new goods that they purchased as they also had a sense of superiority with the economic boom. Therefore, the market relationship during the boom period between consumers and producers was a satisfying one.

MARKETING TO TODAY'S CUSTOMERS

Today, consumers are tending to think "what they need" and "what is of value for me" and so more carefully select among the many goods available and buy carefully. This has occurred because markets have matured with consumers having satisfied their wants; in addition, the collapse of Japanese economic bubble has contributed to this change. Therefore, producers must change from a marketing strategy based on unmet demand by consumers to one based on selling what consumers want. That is to say, I think that producers in this age must research consumer needs and wants and must be more targeted in their marketing.

Marketing today is more aimed at "value" than "price". The creation of additional value separates goods from each other and stimulates consumer consciousness. Now, keywords such as "what's new" are stimulating consumers consciousness today.

In summary, today the concept in the retailing system (department stores, shopping centers, specialty stores, and so on) has changed from "what goods to sell" to "what life style to sell" or "what is of value to sell".

Utilization of New Light Selective Materials to Control the Ratio of Red and Far-Red Light in Plant Production

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INTRODUCTION

It is generally known that a plant grows to a small size when the plant is grown under light that has a high red to far-red ratio in the spectrum. Mitsui Chemical Inc. utilized this phenomenon to development new types of covering materials for plant-height-growth regulation. For growth inhibition the film and panel material types have a high capacity to absorb light in the red spectral range present in the sun's radiation. We have tested those panel and film materials on ornamental and vegetable crops. In this report we report the potential of utilizing this material in plant production.

MATERIALS AND METHODS

In our research we used a growth chamber with panel-type cover materials (YBM1, R: FR=2.43; YBM6, R: FR=2.43, Mitsui Chemical Inc.) for the ornamental-plant-growth studies and film-type cover materials (YXE-4#75E, R: FR=1.44, Mitsui Chemical Inc.) for the plastic-tunnel culture of some leafy vegetable crop seedlings grown in plug trays.

RESULTS AND DISCUSSION

Ornamental Plants. Plant heights of poinsettia, geranium, petunia, morning glory, and pansy were lower under high R : FR ratio conditions. The effects of high R : FR ratio light condition on plant heights were especially high in poinsettia and geranium plants, and their plant forms appeared to be very compact. In the dwarf-type cultivars of same species the light treatment had little effect. The plant height of petunia resumed normal elongation after the light treatment ended. The light treatment also altered the number of the days to flowering. In poinsettia the flowering day come about 10 to 15 days earlier; on the other hand, flowering of petunia was delayed under the same conditions.

Vegetable Crops Seedlings. Cabbage, Chinese cabbage, and lettuce seedlings were grown in plug tray under a high R : FR ratio light condition. The plant height of cabbage and Chinese cabbage was small under the light treatment. On the other hand, lettuce plant height was higher with stem growth of the lettuce enhanced by the light treatment. It was thought that the low light intensity under the film might have caused a more succulent growth of the lettuce stems. In those crops, the root fresh weight was lower and the T/R ratio became higher under high R : FR ratio condition.

It was clear that the light-selective materials could inhibit the plant height of some ornamental and vegetable crops. But the response difference among plant species and cultivars, and effects on the other factors like number of days to flowering have not been completely evaluated. Before applying these materials in commercial cropping systems, it is necessary to study the plant growth response to R : FR light conditions more thoroughly.

The Greatest Azalea Park in the World: Tsutsuji-ga-oka Park, Tatebayashi, Gunma

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Tsutsuji-ga-oka Park in Tatebayashi City, Gunma Prefecture, is an important and unique azalea park in terms of its history and traditional preservation of old azaleas. The successive lords of Tatebayashi castle, the 7th Lord, Yasumasa Sakakibara, the 9th Lord, Tadatsugu Matsudaira, the 12th Lord, Tsunayoshi Tokugawa, and up until the present administrator have planted additional azaleas in the native wild azalea habitat here and permanently maintained this park.

About 1200 unpruned plants, which are over 100 years old, of *Rhododendron kaempferi*, *R. transiens*, *R.* ×*obtusum*, and others are growing in this park. The oldest azalea is over 800 years and 5 m in height and 9 m in width. Local personages in Meiji and Taisho Era also planted valuable cultivars Edo-Kirishima bred in the Edo period. These old shrubs are a valuable genetic resource because of the accumulated flower mutations and other characters. At the end of April the park is in full bloom with azalea flowers which make this park into a crimson world and we have the wonderful spectacle of azaleas from the Edo Period to the present time.

The azaleas in Tsutsuji-ga-oka Park are a world cultural heritage and a symbol of traditional floriculture in Japan.

The research station in this park has an azalea breeding program using native taxa and recently produced the following two new azalea cultivars.

1) Hanayama series No. 1: A flower color mutant of *R. kaempferi* having single opera-pink flowers containing a white center; a medium to small shrub.
2) Hanayama series No. 2: A flower color mutant of *R. transiens* with fuchsia-pink and purplish blotches, middle-early flowering, medium-large single flowers.

Commercial Production of Orchids: Future Prospect

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THE BACKGROUND

I entered the orchid growing business when the Japanese economy was very prosperous. Until the downturn came at the end of the economic peak their market value increased because the demand for orchids as gifts was high. Prior to the downturn it was hoped that orchid production would become a large horticultural industry bringing in as much as a trillion dollars per year. During this rapid growth in demand for orchids many nonhorticulturists, such as people working in electric companies, began producing orchids.

Interest was further stimulated during this period when the world's largest orchid conference, World Orchid Conference, was successfully held in Tokyo. In addition, many books on orchids covering topics from picture books of orchids to specifics about raising them were published. So, it seemed that even the book publishing companies would make a lot of money from orchids not just those who raised, marketed, or traded them.

However, the economy took a downturn taking the orchid market with it. The market price for orchids fell because of oversupply from tissue-culture propagation, as well as from large volume retailers being unable to sell orchids. Rectifying the economic problem caused by the oversupply will not be an easy task.

THE FUTURE

There are three primary reasons for the decrease in the purchase of orchids:

1) The prices are higher for orchids than they are for regular pot plants.
2) The aftercare of orchids by customers is not easy.
3) The range of plant forms and flower colors is limited when compared to most other plants.

The current "gardening boom" is supposedly a reaction to these things. Or, in other words, the "orchid boom" has ended.

For commercial growers to survive in the future I believe that they will have to meet the following five necessary criteria:

1) Must have a large amount of property.
2) Must have advanced growing technology to produce a high quality orchid; this is evident to those who deal in this market. Of course, a growing environment conducive to producing this quality is necessary.
3) Must have the ability to produce orchids from the propagation stage through to the finished product internally within your company.
4) Must have marketing avenues other than selling plants directly to the market.
5) Must have a young successor.

It is expected that in the future there will be a demand for orchids as gifts, however, the demand may be lower. I also expected that *Cymbidium, Phalaenopsis*, and

Dendrobium taxa will be the three biggest in demand. The biggest change will be a shift in the market towards limited types of orchids. So, fewer orchids will be needed.

Before the downturn there was a market for growers to sell lower quality orchids to large-volume retailers at a low price as an additional source of income. Growers should not expect this to continue in the future.

There is also a view that growing orchids is not cost efficient in Japan because of environmental constraints and the economic costs required to produce them. Currently, some taxa of orchids are imported from Thailand, Singapore, and various other Asian countries. We in Japan should strive to learn which orchids grow best in which environment or country.

In Japan we need to re-evaluate the market. Growers need to view themselves as a company not just as individual growers. Then, each of these companies need to create a profit-making environment independent of these other companies. As a result, some companies will dissolve while others will merge. Finally, there will be a change in the marketing system.