Australian Region Celebrated Its 25th Anniversary

The Australian Region of the I.P.P.S. celebrated its 25th Anniversary at this Conference. The first technical session was a reflection by a group of our founding members on 25 years of plant propagation developments and how they have helped my business. It was a privilege to listen to some of the history of our Society recounted by these elder statesmen who have been inspirational mentors to many of the current membership.
Leisa J. Armstrong
Australian Region Editor

Fogging and Misting

Edward J. Bunker
Redlands Nursery, 905-907 German Church Road, REDLAND BAY QLD 4165

INTRODUCTION

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What is the history and background to our use of fog and mist? In preparing this paper I found in Volume 1 of the I.P.P.S. Proceedings from 1951, 46 years ago, a paper presented by Professor L.C. Chadwick of Ohio State University titled *Controlling Humidification as an Aid to Vegetative Propagation*. From the way this paper reads mist as a tool in propagation was still new in commercial applications but had been used in research at Ohio State. The paper outlines systems available at that time. The first commercial application is outlined by James S. Wells in his book *Plant Propagation Practices* published in 1955. He also outlines early work at Rutgers and Michigan State as well as Ohio State Universities.

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Therefore there is little need to address the benefits of fog and/or mist. There are many technical papers in the I.P.P.S. Proceedings already. These are case histories of the day-to-day experiences of propagators with specific plants. They are an invaluable resource.

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Our own experiences may be of some interest. Our first propagation some 40 years ago was carried out in darkened sections of a shadehouse on a bench which was unheated. We planted only in summer. Cuttings were sprayed by hand each hour on the hour on a hot day. Some trays of small cuttings were planted in deep trays which were covered with clear glass. What a step forward it was when we purchased our first mist unit. It ran on a balance arm which, when it dried, rose and turned the control on. Some of these are still in use in the industry today. We now run several separate propagation units in our business. Each endeavours to supply a specific microclimate for the crops grown therein. We classify them as:

1) Simple outdoor misting
2) Misting in a glasshouse
3) Fogging in a greenhouse
4) Planting without the use of mist or fog
5) Misting as an aid to grafting

I will outline to you the uses of each system and how they have helped in our business over the last 40 years.

THE SYSTEMS AND HOW THEY WORK

Simple Outdoor Misting. This is carried out on crops such as *Rhododendron* (azalea) and *Camellia*. Mist lines are mounted on wire benches which are about 70 cm from the ground and under 50% woven shadecloth. Mist is applied through simple jets at 50/60 psi. Summer propagation is carried out in January, February, and March. Rooting occurs in 4 to 6 weeks for azaleas and 6 to 8 weeks for camellias. No bottom heat is used. Mist is controlled by time clocks. With large areas under propagation we use time clocks for our on/off control in all mist applications.

Misting in a Glasshouse. Misting in a glasshouse is used for year-round production of a wide range of our crops. Most shrubs including *Mandevilla, Grevillea*, daisies, and perennials grown from cuttings are placed on benches under which hot water is circulated to hold our bottom heat regime between 20C and 23C. This system is controlled by thermostats. Mist lines are suspended above the crop well above head height. Mist pressure is held at 50/60 psi. Rooting varies depending on the crop in question. It can be as little as 4 to 6 days for some crops and as much as 12 weeks at some times of year for some slow-to-root plants like *Rhaphiolepis*.

Fogging in a Greenhouse. Our fog area is controlled by a humidistat coming on when the humidity drops below 78% and going off when it reaches 84%. Benches are constructed similarly to those in our glasshouse mist areas with bottom heat supplied in the same way at similar temperatures. Fog pressure is held at 600 psi. Crops which really like our fog conditions include all indoor foliage crops we grow and several selected shrubs which through experience we find produce better results in this environment. We also use our fog house for transfer of tissue-cultured plant material from Stage 3 tissue culture vessels and for the rooting of microcuttings (Stage 2 tissue culture). A range of ferns, foliage, and shrubs are treated in this way with good transfer results. We have very little loss. We have also discovered that very good germination of palm seed occurs in our fog house so whenever there are any spare benches, trays of seed are placed on the heated benches to germinate.

Propagation Without the Use of Fog or Mist on Bottom Heat

When the spring and summer temperatures take away the chill of winter there are some crops that will root satisfactorily when placed on wire benches under a glass roof to keep off heavy rains. A covering of perforated plastic or marex cloth often helps retain moisture in the cuttings. We use this system for some plants such as some *Metrosideros, Kalanchoe, Hedera,* and other easy-to-root plant material.

Misting as an Aid to Grafting. It is only in recent times that we have begun to graft to any marked degree. This is our second season. Preliminary results seem to show a marked improvement in the number of grafts that take under intermittent mist lines. The area used is in a high shed with the mist lines mounted under the roof line. The mist is controlled by time clocks. The crop grafted is azaleas using a simple side graft. The graft is placed on the top of the plant, tied in place and then we cover it with a clear plastic sandwich bag tied off around the stem. After 3 weeks the tie is removed to allow some air to circulate around the graft but still keeping it protected from heavy rain. Another 3 weeks and we remove the bag entirely. One can see clearly the graft union has taken and the scion is growing away.

CONCLUSION

All in all we take the facilities we have in propagation houses of today for granted. We do not realise that the advances in simple things like mist and fog houses are of recent times. Because the system is so simple we tend to accept that we now have the best and cheapest way to root our cuttings.

A lot of on-the-spot observation suggests that better results can be achieved with a strict regimen in moving cuttings off once rooting commences. Mist, after rooting is achieved, is detrimental to the new plant establishing quickly. Listings of a range of crops with optimum misting times tied together with other rooting aids would be of great benefit to propagators. All of us have some knowledge in this regard. I see a benefit to all members and the Society in establishing a register as a data bank. All members of the Society could contribute some inputs to give us all a clear guideline for all the crops that we grow.

How Has Plant Propagation Helped My Business?

Ian S. Tolley
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It helps to be born curious, and the thought of "I wonder what would happen if ... ?" is the constant focus for my nursery innovations and breakthroughs.

I have been teaching horticulture under varying conditions for the past 30 years, and I have constantly encouraged my students to strive for a qualification. My earlier training in civil engineering and surveying has proven invaluable in dealing with facts and maintaining objectivity. All learning courses have a common thread, and should teach one to think with a trained mind.

It has been my observation, and certainty in my own case, that those of us who enjoy what we are doing tend to achieve more. And I am never bored ! I continue to enjoy two specific facets of my life in plant propagation:

1) The rigour of assessing and evaluating current events related to my field of interest on the broadest possible plane in Australia and internationally.
2) The more difficult rigour of questioning one's beliefs in what and why and how one lives, and develops in a chosen field and lifestyle.

Our profession gives us an opportunity to create a product which enhances our environment, plus the opportunity to mix in harmonious surroundings with people of all persuasions who love plants and trees. This we need to grasp, to influence people to make the best use of shared resources and to improve the world around us.

Plant propagation now covers a vast field of endeavour, influence, and potential for growth not only on a personal level, but also for our internationally focused Society. In review I can trace a series of events which together have built a pattern enabling me to utilise my propagation experience to teach in a wide range of environments, both within Australia and internationally.

For the first few years I was isolated within my region, which forced me to innovate, without the benefits we now (45 years later) have to communicate in so many ways.

I was fortunate to become associated with the Waite Agricultural Research Institute, a division of the University of Adelaide at that time, and in particular the Departments of Plant Pathology and Plant Physiology. I was particularly encouraged when I was later appointed a Field Associate of this University, for cooperative research endeavours, and for my involvement in some 30 years of voluntary teaching of horticulture to students. There is now the new University of Adelaide Department of Horticulture, Viticulture and Oenology, Waite Campus, where I am privileged to be a current Advisory Board member.

Successful plant propagation is not only the plant — it is combined with how you transfer technology to do it well. My engineering training and mechanical skills assisted here — and for the original open-ground nursery I developed the first mechanical winch for field tree digging, adapted a planter, and invented a slow-geared platform to carry budders and nursery workers along the rows.

In the late 50s and early 60s I became increasingly concerned about the many problems associated with field-grown citrus trees. The requirement to change sites regularly, and diminishing availability of suitable land, induced me to develop a radically new concept of complete container growing from seed to sale. I believe ours was the first commercial citrus nursery in the world to do so. I produced some of the first plastic igloos, and invented a geared overhead watering system. Trees were produced in shorter times, with reproducible non-soil media, and a guarantee of uniformity. By the late 1970s we were producing in containers 100,000 budded trees and a quarter of a million seedlings annually.

In 1960 I created and chaired South Australia's first Bud Selection Society and ran it for 15 years. Its influence can be seen in the far more necessary and sophisticated approaches of today to plant propagation improvement programmes.

In 1965 my earlier activities led to an award as one of the first 35 Churchill Fellows to study citriculture world-wide over a period of 5 months. That study provided contacts and friendships which have continued to the present day, set the course of my future development in plant propagation, and led me to be invited to become a member of the Western Region of I.P.P.S. in 1966.

By 1966 I had developed a propagation system I named micro-budding. This practise is now widely used throughout the world. It wasn't brilliant inspiration, but a response to a need to use as many buds as possible from carefully selected mother trees.

In the 1980s I invented and manufactured a systematic Tolley "Plantmaster" potting machine to provide efficient, regular out-turn of potting plants on time.

In 1981 I became involved with the development of the International Society of Citrus Nurserymen. These Congresses are now held every 4 years on different continents. We have just completed the 5th successful International Congress in France, with pre- and post-tours of Mediterranean citrus regions, and over 300 delegates attending from 40 countries.

As a learning environment these societies are unexcelled, which is why I have only missed one I.P.P.S. conference in 25 years. So many times I hear people say "this is not my field so I don't need to attend". But it is precisely the cross-fertilization of ideas that opens your own mind to approach and solve challenges in your own propagation. I know I always gain some new insight.

President Ross Hall's report in the March 1997 issue of our newsletter expresses that aspect, critical to our success as propagators, and I quote — "our conference has become one of the major methods of technology transfer with the emphasis on plant propagation. But a characteristic of our conference should always be that there is a blend of the latest technology and the 'nitty-gritty' papers by our experienced members. Getting this blend right is one of the more difficult tasks of the conference organiser."

A combination of my propagation experiences over the past 20 years has lead to increasing nursery and horticultural consulting within Australia, and overseas, and for me this process has always been a two-way learning experience .

Occasionally over the 25 years within I.P.P.S. we have wavered in focus. Members' reactions have been palpable, and we re-balanced again. How then has I.P.P.S. helped our business? The answer is that in our 25 years we have stuck to the core values of plant propagation, of its principles and practises.

I hope that combined with the other talks, this provides a segment of experience, particularly for our newer members, for the next 25 years.

The Multiplication and Distribution of Improved Clonal Selections of Fruiting Plants

Peter Smith
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INTRODUCTION

To confine my view to the last 25 years I unhesitatingly nominate the multiplication and distribution of selected clones of fruiting plants as the most important development that has assisted our business. As supporters of schemes dedicated to improving quality and performance of fruit-bearing plants we are a vital link between plant breeders, research workers, and the Australian fruit industries.

Our nursery is located in the Sunraysia district, which is at the heart of the Murray/Darling river basin. We aim to service the needs of fruit growers in this basin. This river system supports Australia's two largest, fully irrigated fruit-production industries, grapes (*Vitis*) and citrus. These two industries contribute significantly to our gross national product. It is fundamental to the sustainable success of these industries that we grow the most improved clones with the best possible health status.

The first 10 years of my working life were with the Commonwealth Scientific Industrial Research Organisation (CSIRO). During this time I was involved with their grapevine clonal selection program. This made me very aware of the genetic imprisonment a grower locked himself into when establishing a fruit producing plantation — which may be the source of his income for the whole of his working life, or at least until he decides to refurbish his original plantation — and the significance of this to the industry as a whole. There are many instances of a 25% to 35% yield increase from one clone to another in any one fruit variety.

When I left CSIRO in 1962 to further develop our small nursery I found, to my dismay, the only source of recommended propagules (bud wood, cuttings, and seed) was from vineyards and orchards considered "good performers". Obviously an individual plants' success was related to productive soil types and good farming practices and had nothing whatsoever to do with improved genetic performance and health status.

INDUSTRY FRUIT IMPROVEMENT ASSOCIATIONS

Over the last 50 years Australian citrus production has increased by 50% per hectare mainly due to improved health status of high yielding clonal selections. Citrus industry involvement in the multiplication and distribution of selected propagules began in New South Wales in 1948. Of recent years that scheme has become part of the Australian Citrus Improvement Association and now serves as the Australian Citrus Propagation Association.

With these facts so apparent I have devoted the past 25 years to serving as a director on a number of fruit-improvement association boards. The Victorian and Murray Valley Vine Improvement Association (VAMVVIA) was established in 1986 to handle the gathering and distribution of cuttings from clonal selections of grape varieties to grape growers and nurseries. The Association is a nonprofit organisation directed by representatives of various grapevine industry groups — dried fruit, table grape, and wine grape industries and their respective scientific support and advisory groups. Similar regional associations now exist throughout Australia. They are brought together under a national organisation titled the Australian Vine Improvement Association (AVIA). Its role is to import new and improved clones of grapevines and to hand the multiplication and distribution organisation over to the regional associations. It also supervises a national accreditation scheme which will ensure all players adhere to standard protocols.

All of these associations bring together industry and research people with the common goal of varietal improvement via selection, plant breeding, and plant health. This role model has now been adopted by most fruit industries such as citrus, stone, pome, nut fruits, etc.

The Australian Olive Industry Association (AOIA) is currently developing a similar organisation. Repositories of DNA-fingerprinted varieties are being established as the initial "mother plants" from which propagules will be distributed. Even the infant Australian Quandong Industry Association (AQIA) is part way down the same road.

HEALTH STATUS OF MOTHER PLANTS

Giant steps forward are being achieved in the science of virus assay and elimination. Also inoculation to ward off severe strains, together with elimination of viroids, phytoplasmas, and bacterial organisms. The Nurseryman's attention to plant hygiene plays a vital role in ensuring clean stock is being planted by our Australian fruit industries.

The role of the fruit industry improvement associations is to multiply the improved selections by establishing registered mother plantings which are monitored for "trueness to type" and health status. This is achieved in cooperation with our research organisations which provide the services of plant virologists, bio-physicists, entomologists, and the like. Monitoring is ongoing and usually mother plantings are visited twice annually by professional staff. The distribution of propagules — cuttings, bud wood, and seeds — requires the organisation of collection, grading, packaging, and shipment of propagules to nurseries all over Australia.

In the case of the AVIA the national repository of varieties, the gene bank, is planted on state owned land. Whereas the registered multiplication plantings are on both private and state-owned land. In the case of the Australian Citrus Propagation Association both the national repository and multiplication plantings are on state owned land.

Today we have the emergence of companies like the Australian Nursery Fruit Improvement Company (ANFIC) which not only concerns itself with the introduction of new and improved varieties of fruiting plants to Australia, but also brings together the plant breeder, propagule multiplication, the nurseryman, the fruit grower, and the fruit marketing chain.

CONCLUSION

Today's fruit growers are very aware of the genetic improvements of the clonal selections they grow, both in rootstocks and scions. They are also prepared, via a levy on fruit sold, to fund schemes which improve, monitor and maintain superior health status of the mother plants from which their plants are propagated.

In the world of fruit production each commodity industry is at the forefront of plant selection and improvement. Growers are constantly refurbishing orchards and vineyards in response to market-driven demands.

I believe similar schemes could improve the planting material standards in ornamental horticulture. To the best of my knowledge we do not have an establishment similar to the English RHS Wisley Gardens in Australia.

As a consequence of my wife, Lois, and my deep involvement in the establishment of the Australian Inland Botanic Gardens, in the Sunraysia district, I propose to the Australian nursery industry that a sophisticated propagule multiplication and distribution organisation be established in concert with our Australian Botanic Gardens and/or our universities. We, the propagators, can make this happen.

Finally, I must comment that I have the greatest respect for the professional dedication displayed by all of the researchers with whom I have worked over so many years. Without this dedication I doubt we would have the standard of excellence which now exists in the grapevine and citrus propagule production and distribution schemes.

25 Years of Plant Propagation and How They Have Helped my Business

Vic Levey
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It is now 25 years since the W.O.G.G (Wholesale Ornamental Growers Group) of Queensland, now W.O.N (Wholesale Ornamental Nurserymen Pty Ltd), requested a mandate from the Annual Conference of the Federation of Australian Nurserymen in Sydney in March of 1973 to organise the inaugural meeting of the I.P.P.S. in Australia. This was granted by that Conference and the W.O.G.G (W.O.N) went ahead. The first Conference of the I.P.P.S. in Australia took place at Leura, NSW in October of that year.

The rest is now history, but I feel we should not forget the part played by those involved, many of whom are no longer with us. People such as the late Jack Pike, Alan Newport, Roy Rumsey, and Peter Spinks. Re-reading the papers from that Conference is quite illuminating. There is just as much relevance in them today as then. Jim Wells, the Founder of I.P.P.S., made a special trip from the U.S.A. for the occasion and his words certainly bear repeating. Jim titled his address "The plant propagator holds the future in his hands" and I would particularly like to quote the following:

"The Plant Propagator, the man who originates plants of all kinds is the corner-stone upon which all other parts of this vast industry depend. Without him, without his work and products there would be no horticultural industry."

Jim Wells is a man of great vision and today, although retired and confined to a wheelchair, enjoys reasonable health and still putters around with his bulbs. I would like to send "Greetings and Best Wishes to both Jim and his wife Cecil" from this Conference.

Twenty-five years seems unbelievable — until I look in the mirror! What a wealth of information comes to each of us in the Proceedings each year. When you consider that most of these articles are presented by people with many years experience over such a vast range of subjects covering all climatic conditions, the cost of belonging to the I.P.P.S. is very cheap indeed.

Certainly things change over time and a quarter of a century is quite a long time. In Leura I talked about *Grevillea* propagation, a very important part of our business at that time. Some types were readily propagated and others proved to be very difficult. Nothing has changed there except the cultivars but now the demand for *Grevillea* taxa with our nursery is practically nil.

In the years following that conference many propagators were kind enough to tell me that I had given them the best advice they were likely to get. I had suggested that if you felt like trying to propagate some of the difficult types you should put a couch in your propagation shed, so if (or when) the feeling came upon you, you could go and lie down until the feeling went away! This advice holds true for lots of other difficult species too.

But how has 25 years of I.P.P.S. helped my business?

The answer is — many ways, not the least being the opportunity of meeting people and discussing various problems and ideas. However, the most significant thing for me was listening to a wonderful lady called Olga Goss, then the Head of Plant Pathology in WA at the Perth Conference in 1978. Dr. Goss was discussing the problems of *Phytophthora* and other water-borne diseases, and suggested that a lot of these problems could be effectively and economically controlled by the use of filters (in water lines). Further conversation with Dr. Goss got us started on filtering and this together with the use of aerated steam (also discussed in detail at the Inaugural Meeting at Leura by Jack Pike and Alan Newport) has kept us virtually disease free for over 25 years.

Hand in hand with aerated steam was the need to find an economical potting mix that would fit in with Dr. Ken Baker's U.C. System for producing healthy container plants. The way to this was pointed out to me by Kim Lassock, and so helped to start us on hammermilled pine bark as a most satisfactory soilless potting mix.

In conclusion, I can't help but make this observation. When I.P.P.S. commenced in this country the concept was eagerly embraced by the non-nursery side of horticulture. The sordid activities of the commercial nurseryman and the allied traders were frowned upon, and to be kept at bay at all costs. The fact that the Society was founded by nurserymen for nurserymen (plant propagators) was of no consequence — commercial words like nurseries were to be barred.

A display of allied products providing information for plant propagators' at this conference was indeed a sign of the times, changing times, but of course we have had these trade displays as part of our activities for some time now, and how welcome they are. It really hammers home the point of Jim Wells' philosophy, "The future of this Industry is in the hands of the plant propagators" and they need all the information they can get.

Irrigation Setup and Reducing Water Use

Chris Rolfe
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To grow a quality plant in the shortest time in a given climate, the water and air content of the potting mix should be in balance and adequate fertiliser should be available throughout the crop cycle. Supplying the right amount of water at the right time to all plants in a production area is the key. This requires an irrigation system that applies water evenly and a control system that allows the required flexibility to match climatic and crop variations.

How does your system measure up? For fixed overhead sprinkler systems, which are still the most popular system in the industry, there are irrigation standards that you can calculate for each block.

Your irrigation system should have:

- Mean application rate — less than 15 mm per hour
- Coefficient of uniformity of sprinklers — more than 85%
- Scheduling coefficient of application — less than 1.5

What is the significance of these measurements? Well let's take them one at a time.

If you apply water at less than 15 mm h^{-1} then it is likely that the application rate will be slow enough for the potting mix to absorb the water as it is applied. This means that when the water starts draining from the bottom of the container, the moisture content of the mix is at its optimum. This can then be a useful guide to irrigation timing.

If the coefficient of uniformity of the sprinklers is above 85% (and the application rate is below 15 mm h^{-1}) then you probably have sprinklers well suited to the spacing you have selected and operating at a pressure that provides a range of droplet sizes.

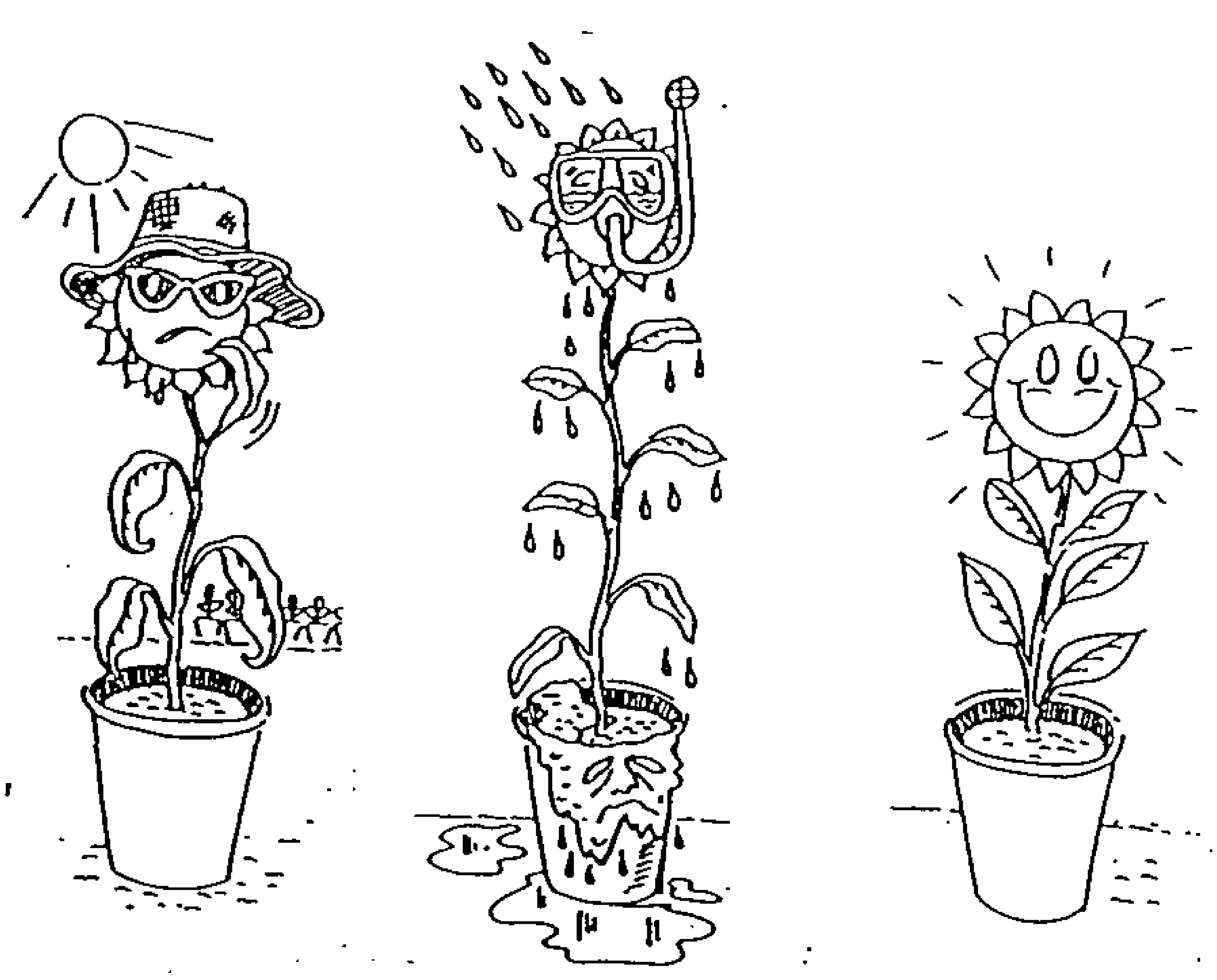

Figure 1. Uneven water application effects plant growth.

A scheduling coefficient of less than 1.5 will indicate that the location of the sprinklers in relationship to the containers being watered allows each container to receive water from 3 or 4 sprinklers. This means that to apply sufficient water to the driest container in the block the containers that are in the middle range receive less than 50% more water. This will minimise excessive leaching.

Apart from wasting water the work done by Cresswell and Huett (1996) suggests the higher the leaching volume, the higher the fertiliser volume in the drain. They found that under a typical summer irrigation level of 25 mm a day, up to 40% of the nutrients in controlled-release fertilisers were being wasted over 10 weeks. This of course has an effect on plant growth.

WHAT PERCENTAGE OF YOUR PLANTS FIT IN THE CATEGORIES SHOWN IN FIGURE 1

Uneven water will result in overwatering, excessive leaching, and uneven plant growth. This results in a higher percentage of throwaways and additional time at dispatch in selecting plants from the production area that are suitable for the order (about 8 cents/150-mm container)

How much does uneven watering cost you in lost production, dispatch cost, and water cost?

Much of the details of how to evaluate your irrigation system is covered in the *Waterwork Manual* used in the Waterwork workshops that are run nationally in the industry.

For now let's just look at one aspect that you can do on your nursery when you go home. What is a scheduling coefficient, how do I calculate it and what does it tell me about my system?

Most nursery operators will water a block of plants for long enough to put sufficient water in the driest pots which are usually located along the edges and ends of the blocks. The scheduling coefficient (Sc for short) is a measure of how much extra water you are putting on the majority of your plants to wet up the driest pots.

$$\text{Scheduling coefficient} = \frac{\text{average application rate}}{\text{driest pot application rate}}$$

To illustrate what this might tell you about your system, let's take a couple of common nursery layouts and check them out (Figures 2 and 3).

If these layouts are equipped with well designed irrigation systems with sprinklers operating at the correct pressure to provide a high coefficient of uniformity and an application rate of less than 15 mm h^{-1}, the scheduling coefficient, the edges, and ends of each layout will have significantly lower application rates than the middle areas. This can be best illustrated in the production bed area. This bed can be divided into three zones (Figure 4).

The scheduling coefficient to provide adequate water to zone C is 3.3. This means that 92% of the area is being overwatered to meet Zone C's requirement. Many operators will overcome this by hand watering which is an inefficient and expensive option.

The benches aren't quite as bad but the scheduling coefficient here will be 2.2 to meet the water requirements of the ends and edges which still overwaters most of the bench.

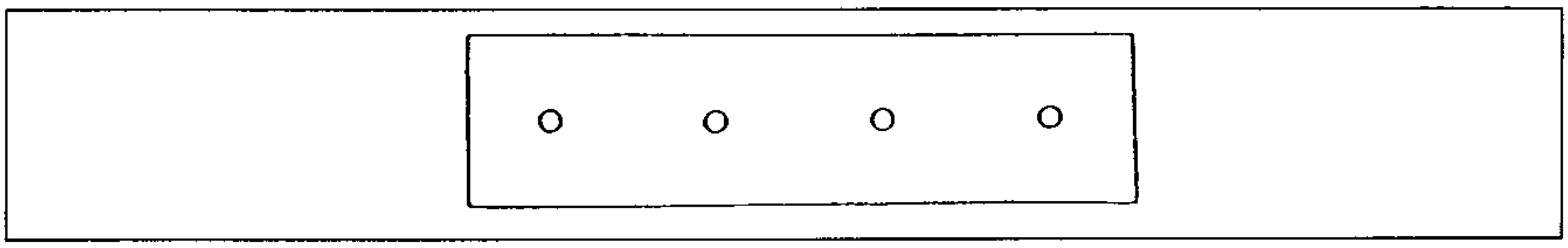

Figure 2. Common arrangement of sprinklers on benches.

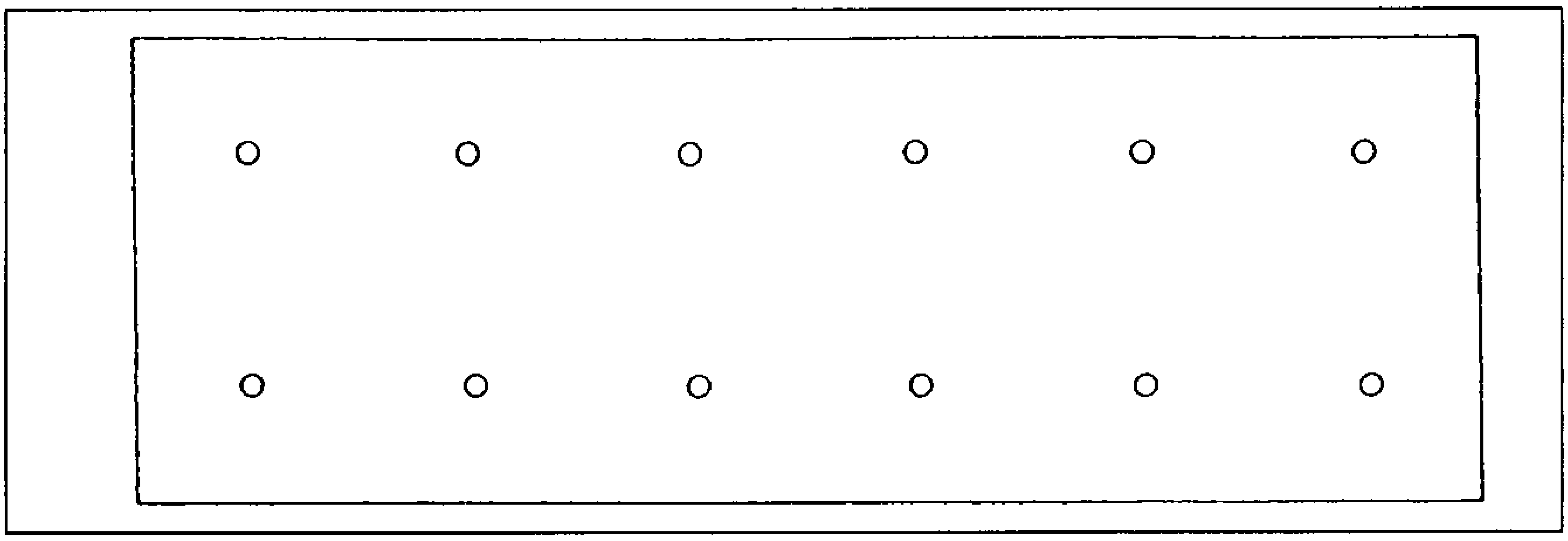

Figure 3. Typical arrangement of sprinklers on production beds.

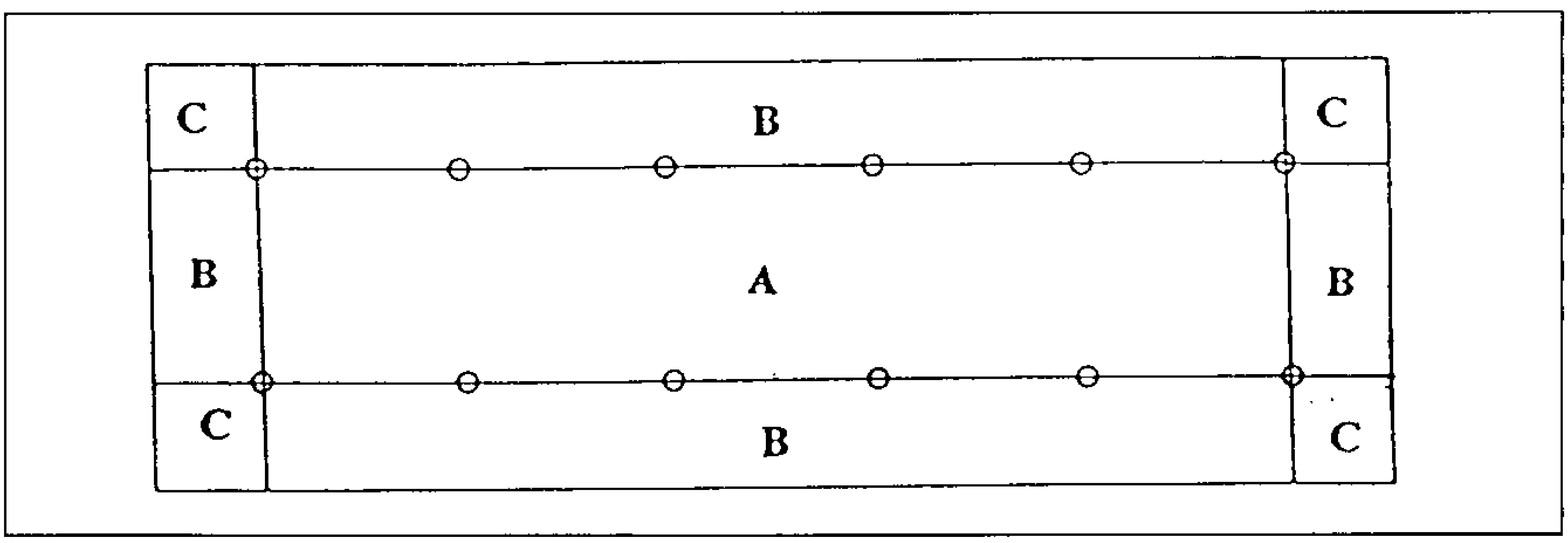

Figure 4. Zones within production area. Zone A - receives water from 4 sprinklers representing 42% of the area, Zone B - receives water from 2 sprinklers representing 50% of the area, and Zone C - receives water from 1 sprinkler representing 8% of the area.

The key to reducing the scheduling coefficient and hence the overwatering problem is to reposition the sprinklers so that each container receives water from four sprinklers so the layouts now look like those in Figures 5 and 6.

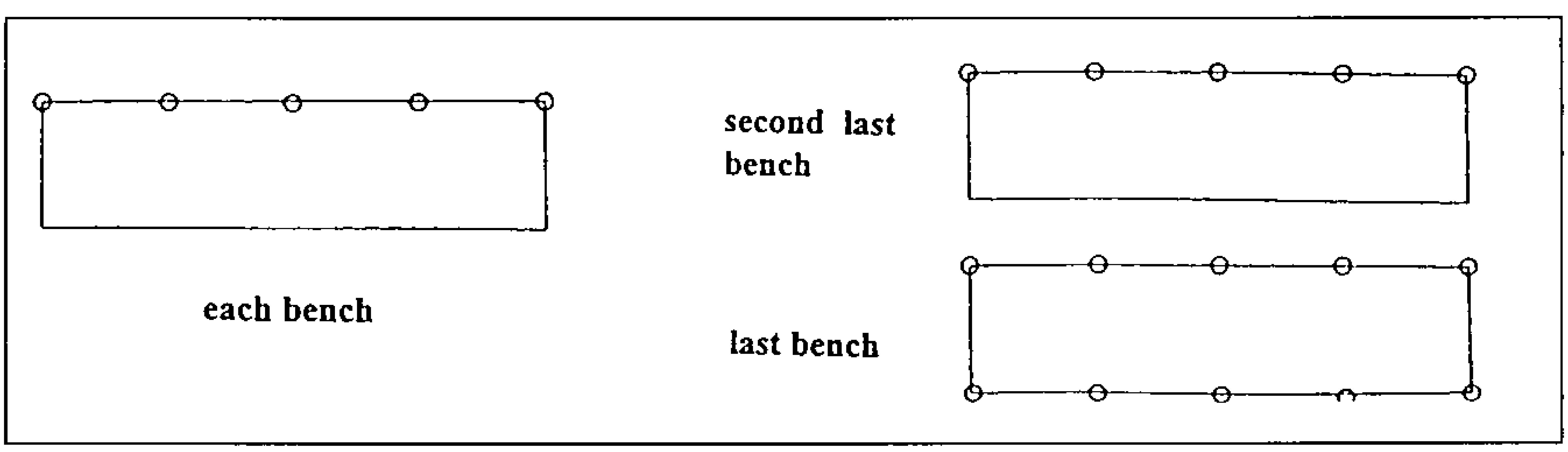

Figure 5. New sprinkler layout for benches.

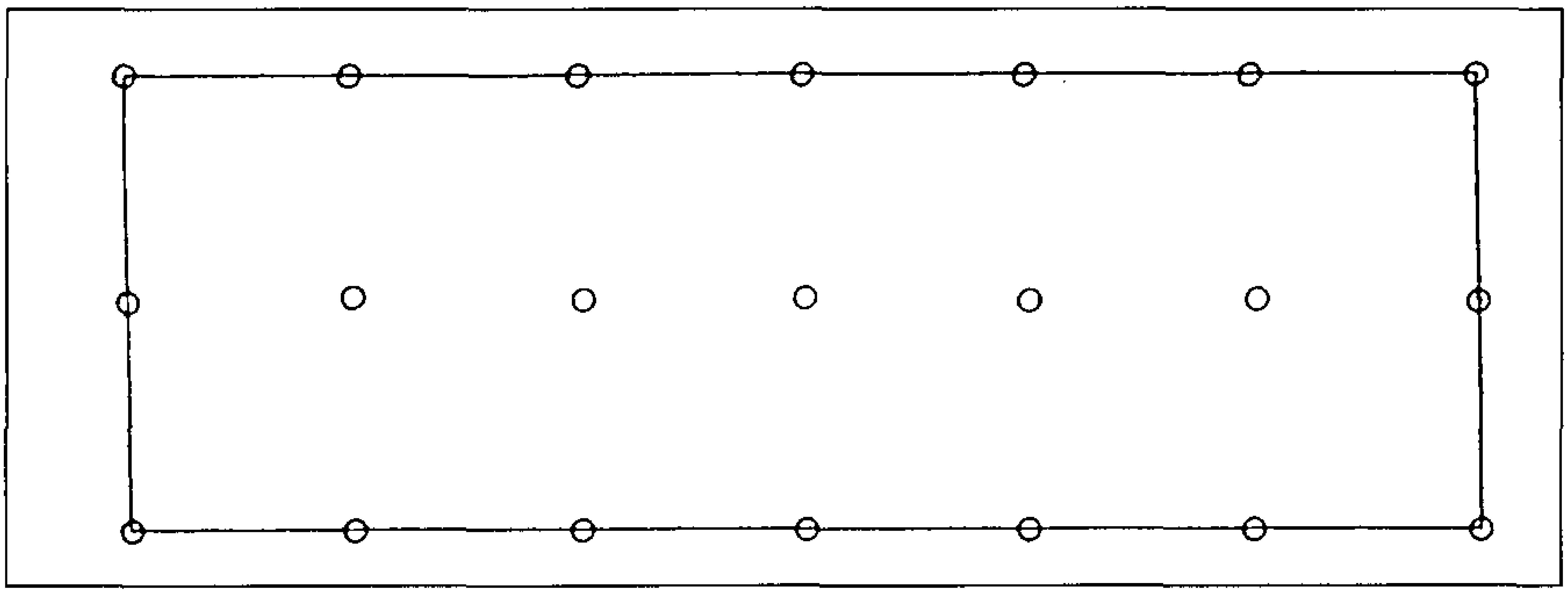

Figure 6. New sprinkler layout for production beds.

These new layouts use more sprinklers and wet a larger area outside the production areas, so how come they save water? Well the key is lower scheduling coefficients require less pumping time. This will save you water, provide more even watering, less fertiliser leaching, less throwaways, reduce selection time at dispatch, and produce better quality plants.

Still find it hard to believe? Well let's look at some figures.

Benches - 5 @ 1.8 m × 7.2 m = area of 64.8 m^2

	Conventional layout (Figure 2)	new layout (Figure 5)
Sprinkler discharge	46 litres h^{-1}	46 litres h^{-1}
Sprinkler spacing	1.8 M centres	1.8 × 2.7 M
Mean application rate	8.8 mm h^{-1}	9.5 mm h^{-1}
Scheduling coefficient	2.2	1.3
Time to apply 5 mm to driest container	$\frac{5 \times 60 \times 2.2}{8.8}$ = 75 min	$\frac{5 \times 60 \times 1.3}{9.5}$ = 41 min
No. of sprinklers	25	30
Volume applied	1438 litres	943 litres
Volume per m^2	22	14.6
Percentage saving	-	34%
Wettest container receives	12.5 mm	7.5 mm

Production beds - 12 m × 36 m bed = area of 432 m^2

	Conventional layout (Figure 3)	New layout (Figure 6)
Sprinkler discharge	318 litres h^{-1}	318 litres h^{-1}
Sprinkler spacing	6 m × 6 m (3 m from edges)	6 m × 6 m
Mean application rate	6.8 mm h^{-1}	8.8 mm h^{-1}
Scheduling coefficient	3.3	1.25
Time to apply 5 mm to driest container	$\frac{5 \times 60 \times 3.3}{6.8}$ = 145 min	$\frac{5 \times 60 \times 1.25}{8.8}$ = 43 min
No of sprinklers	12	21
Volume applied	9222 litres	4786 litres
Volume per m^2	21.3 litres	11.1 litres
Percentage saving		48%
Wettest container receives	24 mm	7.1 mm

So you're interested enough to calculate the Sc for your own system? It's a little time consuming to do so but quite simple. You will need some containers, in the Waterwork workshops we use round take-away food containers, but any container the same size will do. Lay them out on a 1 to 2 m grid over a good proportion of the area to be tested.

Now run the irrigation system for the normal length of time you might use. Using a reasonably accurate measuring cylinder, go around and measure how much water is in each container an record these on a sheet of paper. Total up the amounts recorded and divide by the number of containers you use. This will give you the average.

Now look at the original figures to find the smallest amount of water you measured. Get your calculator and find out the Sc by dividing the average by this smallest volume. If you have a result of less than 1.5 then congratulations. If not you are probably overwatering and leaching excessive fertilisers from your containers. Time spent at a Waterwork workshop could be time well spent.

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Experiences With Drip Irrigation

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In the early 1980s we decided to change our nursery from a field growing to a container growing nursery. One of the decisions we had to make was what style of irrigation to use. Some of the factors affecting this decision were:

1) The amount of available water. One dam and the town water supply. The dam was not enough for our needs and the town supply too expensive for overhead irrigation.
2) Plants are generously spaced making overhead watering very wasteful.
3) A system of rows and blocks of plants made a drip system easy to design.
4) The length of time plants remained in one position was a minimum of 18 months.
5) Use of a large polybag container suited the use of drippers.
6) Although it was much more costly to install drip irrigation, it meant that water was not a limiting factor.

One block was set up as a trial simply connected to the town water and manually turned on and off. This worked well apart from, as you would expect, the manual on/off. An automatic controller was added and from then on we have been continually developing our system. At present the system consists of:

- Two concrete tanks which fill from the town water supply, each holding 22,000 litres.
- Two 1000-litre poly tanks for nutrient solutions.
- Two controllers each covering half of the nursery.

Valves at each station open and close by hydraulic lines to solenoids positioned near the controllers inside a shed. Our site is prone to lightning strike which caused problems with wiring and solenoids when they were in the field. Valves are set above the ground making repairs and maintenance easy.

A fertiliser injector is connected to two poly tanks. Operation is manual at present with the return of clean water going back into the main tank.

Each station has 5000 outlets which are fed from a central manifold with 20-mm poly lateral mains. Tees connected to the dripper by 3/5 poly tube deliver the water to the plant. Drippers are rated at 2 litre h^{-1} but this will vary depending on the pressure of the system. Our output is 2.6 litre h^{-1}. As you may expect, irrigation times vary with plant species and season. Our range would be from 3 min once a day to 8 min twice a day.

All systems need to be maintained if you expect results. With overhead irrigation blockages or timing problems are very apparent. This is not the case with drip irrigation. Often it takes some time to see a problem. The mix may become very dry, particularly if the dry plant is hidden by those around it. Particular attention needs to be given to the following:

- Replacing blocked drippers. If staff are observant and carry some drippers when doing their regular work this can be carried out as part of their daily routine.

- The 3/5 poly tube can sometimes become brittle and break. These breakages are repaired before the line is put back into use. The main trouble we have had with this tube is that rabbits love to bite it off. They don't just bite one either, they can bite up to 100 in a small area. This not only effects the immediate plants but also reduces the pressure in the whole block. Many hours can be spent repairing this damage, as it is more difficult to make repairs in between plants.
- When bringing lines back into use it is important to flush first and then water test to find any leaks or blockages.
- Filters must be cleaned on a regular basis or the pressure in the system will be low and plants will be under stress. This is more of a problem if you are on a sloping site. The higher end of the block will be under stress from too little water, while the lower end will suffer from water logging. Maintaining the pressure at the appropriate level will keep this problem to a minimum. Filters must be cleaned more often if nutrients are delivered through this system. Since we began liquid feeding it has become increasingly important to chlorinate the system to reduce algal buildup. Self cleaning filters would save time and may be a better option.

Many things must be considered when deciding how to irrigate your plants. Along with those I have outlined in this paper, run-off from nursery sites is becoming an important environmental concern. Drip irrigation can help greatly if you have trouble collecting run-off from overhead systems. It is worth considering drip when you next have to design an irrigation system or are planning an extension.

Pre-Treatment of Bulk Samples of Certain *Eucalyptus* Species to Enhance Germination

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Increases in germination percentages were achieved when seeds of several *Eucalyptus* species were subjected to a pregermination treatment and then separated in sugar solutions. In one species, *E. pilularis* Smith, an increase in germination percentage of 29% was achieved.

INTRODUCTION

With an upsurge in demand for seedlings of *Eucalyptus* for the establishment of forestry plantations, there has been a need to develop techniques to increase seed viability. A number of species, which have in the past been propagated via broadcast and pricking in techniques, do not lend themselves to the single seeding practices needed for the economic production of cell-raised seedlings. The more commonly propagated species, such as *E. globulus* Labill. ssp. *globulus* and *E. nitens* (Deane & Maiden) Maiden, belong to the subgenera *Symphyomyrtus*. This group has seed that is usually of high viability, 780 and 2710 germinants per 10 g, respectively (Langkamp, 1987). Two species that are currently in demand for planting along the New South Wales north coast are *E. pilularis* Smith and *E. cloeziana* F. Muell., both of which belong to the subgenera *Monocalyptus*. These species have been tested at 550 and 1210 germinants per 10 g, respectively (Langkamp, 1987).

Seed of *Eucalyptus* is collected by harvesting mature capsules from the tree. Once the capsule has opened and its contents expelled, the spent capsules and opercula are sieved from the bulk and the remaining sample is used for sowing. This sample contains not only seed but large amounts of chaff comprising aborted seed and other small parts of the inner capsule. In many species, in particular those associated with the subgenera *Symphomyrtus*, it is possible to separate the chaff from the seed by mechanical means. Fractionating aspirators, winnowers, gravity tables, and sieves will give a clean sample that can be single seeded using needle type vacuum seeding equipment.

With the subgenera *Monocalyptus*, there are often large amounts of aborted seed present in the sample, even after a lengthy cleaning process. Microscopic examination reveals that the differential of mass, shape, and size between the viable and nonviable portions are so small as to be almost unmeasurable. Part of the technique of fluid drilling (Currah et al., 1974) employs the process of imbibition and germination of seed to a point where the radical just emerges. The differences in weight between those seeds that have imbibed and those that have not, can be exploited by introducing the seedlots into a solution of approximately the same relative density (Darby and Salter, 1976). Those seeds that have imbibed and have a changed specific gravity will float, those that have not, because they lack endosperm and therefore the ability to absorb moisture, will sink (Salter, 1978). This process can be utilised to separate imbibed seedlots of *E. pilularis* and *E. cloeziana* but before radical emergence. The heavier portion can then be surface dried and sown immediately using vacuum type sowers.

MATERIALS AND METHODS

Seed capsules of *E. pilularis* were collected from mature trees and the seed extracted from the capsules after drying in direct sunlight. The bulk sample was sieved to eliminate expelled capsules, opercula, and other large material. Gravity table and fractionating aspiration separation was then employed to eliminate the lighter fraction of the seed sample, containing chaff, dust, and small aborted seed. Immediately before the start of the imbibition process the seed was immersed in a solution of 10 ml of 12% commercial bleach, one litre of tap water and 1 ml of detergent, for 3 min. The sample was then rinsed with tap water to remove the bleach and detergent.

Approximately 30 g of the sample was then placed into stainless steel baskets each 230 mm long, 80 mm wide, and 15 mm deep with a fine-mesh bottom small enough to retain the seed and let excess water pass through. Eighteen of these baskets were then placed on a frame inside a germinator constructed from a domestic chest freezer. The freezer was connected to the water supply and filled to a depth of 300 mm. An overflow at the 300 mm level allowed water to flow through the germinator. A heating element and thermostat regulated water temperature and the water reservoir was circulated by a small pump to ensure adequate aeration. A misting system using a timer and commercially available propagating mist nozzles was placed over the top of the baskets. The freezer itself was not operational for this experiment. Water flowed through the germinator at 500 ml min^{-1} and the reservoir for the treatment of *E. pilularis* was heated to 25C. Misting frequency was 10 sec every 20 min from two nozzles.

Treatment time for *E. pilularis* is usually 40 h. The testa of the seed starts to become translucent at this stage indicating that it is imbibing and that radical emergence is imminent. Germination must not proceed beyond this point or desiccation will occur during the surface drying process if the radical is allowed to emerge.

A separating solution was made by dissolving 1 kg of sugar in 1 litre of water. Five litres of this solution was then placed in a bell jar fitted with a large tap at its base. The imbibed seed was then emptied into the bell jar and lightly agitated. After a period of about 1 min, seed starts to separate into two fractions. There should be a clear delineation between the denser fraction on the surface and the lighter fraction which falls to the bottom. The solution was then decanted through a sieve taking first the bottom fraction, either discarding it or placing it back in the germinator for a further period, and then the top fraction.

The seed from the top fraction was then washed thoroughly with fresh water prior to storage or surface drying. Separated seed from the top fraction can be stored for 4 to 5 days in containers with fresh water which must be sealed and kept in a refrigerator at a temperature of 3 to 4C. It is then placed into small net bags containing 100 g of seed each, placed in an air stream at ambient temperature for approximately 15 min and then sown.

RESULTS

Germination results for seed of *E. pilularis* treated by this method shows a significant improvement (McLeod pers. comm.).

Table 1. Comparison of germination tests for seed of *Eucalyptus pilularis* Smith before and after treatment (3 replicates).

Treatment	Germination (%) (after 14 days)
Gravity separated and aspirated	22
Manually separated (pure seed)	69
Aspirated, bleached and washed	29
Imbibed and separated in sugar solution	51
Residual seed left after separation	0
Squash test after separation	52

DISCUSSION

A significant increase in germination percentage has been obtained as a result of the imbibition and sugar separation treatment. However, it has been observed that there is a secondary phase of germination taking place approximately 30 days after sowing bringing the percentage of germinants into line with the results shown in Table 1 for manually separated, i.e. 69%. This phenomenon seems to occur with a number of the subgenera *Monocalyptus*; in particular, *E.pilularis, E. cloeziana, E. obliqua,* and *E. laevopinea* when they are subjected to this treatment. From a nurseryman's point of view, an increase in the percentage of germinants of 29% for a given sample, allows for single or double seeding. Using specially designed seeders for this purpose, there are considerable savings to be had in the cost of production. Our results to date have been encouraging although a point has been reached, where we believe it may not be possible to further increase the percentage of germinants in samples of *E. pilularis*, via this process (McLeod pers. comm.).

It is quite possible that the species we are dealing with experience inherent problems during the reproduction process, particularly at pollination. Viability may also be affected by environmental factors prevailing during that period and timing of harvest (McLeod and Schoer pers. comm.).

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Propagation of the Tree Waratah, *Alloxylon flammeum* P. H. Weston and Crisp

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Alloxylon flammeum P. Weston and Crisp (family Proteaceae) is a native Australian rain forest plant which is classified as a rare and threatened species (Briggs and Leigh, 1996). It is not widely cultivated, but has attracted the interest of the cut flower industry and may also be a good rootstock for the more sensitive *A. pinnatum*. Both are showy flowering trees with large spectacular flowers ranging in colour from pink to red. There is limited published material on *Alloxylon* species and little is known with regards to their propagation. There is also a lack of availability of propagation material which prevents commercial production and makes research difficult. The purpose of this study was to determine the best procedures for the propagation of *A. flammeum*.

Alloxylon flammeum, also known as a tree waratah, is closely related to the NSW waratah (*Telopea speciosissima* R. Br.). The primary horticultural use of waratah is for cut flower production, with blooms being highly sought after on both local and export markets (Worrall, 1994). A great deal of work has been conducted with regard to the cultivation and propagation of the waratah in recent years, leading to a steady increase in the number of waratah plants in cultivation and the number of blooms available. These are more consistent in quality and quantity than the bush-picked blooms that were relied upon in the past (Offord and Campbell, 1994).

Waratah, banksia, and protea blooms belong to the feature flower market, but there is a definite shortage of Australian native feature flowers (Gollnow et al., 1995). Australian native cut flowers are attractive to overseas buyers because they are different. New species that would be suitable as cut flowers need to be developed to maintain the interest of export markets, and to expand the choice available on both the domestic and export scene. Recently there has been considerable interest in developing *Alloxylon* spp. as a feature flower to fill this niche.

The main limitation to waratah production is the restricted marketing period. Blooms are only available from September to October (Moody, 1993) with supply dropping off before the pre-Christmas market peak. *Alloxylon* species have a long flowering period from spring to early summer (Wrigley and Fagg, 1989), therefore the blooms are still available once the supply of waratah has finished. The spectacular red blooms of *Alloxylon* are similar to those of the NSW Waratah, but more importantly they possess the red-green colour combination that is highly sought after in the pre-Christmas market. This suggests that *Alloxylon*, in particular *A. flammeum*, has the potential to complement *Telopea* production and expand the native cut flower industry.

The development of a successful propagation system for *Alloxylon* is not only motivated by potential commercial gain, but also for conservation purposes. *Alloxylon* *flammeum* is classified as a rare species (Briggs and Leigh, 1996) which is not widely cultivated. The biology of the species is not well understood. Widespread cultivation would help to increase our knowledge base and alleviate the threat of exploitation of remaining stands of the species. In addition, *A. flammeum* may be a good rootstock for the more sensitive *A. pinnatum* (P. Weston pers. comm.), another rare but beautiful species which also has commercial potential. The latter will be the subject of subsequent investigations.

The purpose of this study was to investigate whether *A. flammeum* may be propagated vegetatively by cuttings and micropropagation, and if so, what are the best procedures. Since little was known about the cultivation and propagation of *Alloxylon*, the techniques used were largely adapted from those employed in the propagation of *Telopea* species. Seed propagation was not investigated. *Alloxylon flammeum* seed is difficult to obtain due to their limited distribution in the wild and cultivated sources cannot supply sufficient seed for possible commercial plantations. It is also likely that *Alloxylon* populations grown from seed would show a great deal of variation, as has been documented in seedling populations of *Telopea* (Burnett and Mullins, 1985; Worrall, 1983). The development of an effective clonal propagation system for *A. flammeum* would allow selected genotypes to be propagated and commercial plantations to be established.

CUTTING PROPAGATION

Two basic experiments were performed looking at the effect of environmental conditions and rooting hormones on propagation by cuttings. A root zone temperature of 24±2C gave superior rooting of *A. flammeum* cuttings compared to 18±2C, and there was no difference found between mist and fog, with mist being the most commercially viable alternative. *Telopea* waratahs are generally propagated using similar root zone temperatures, although no information is available comparing the rooting of waratah under mist and fog.

Clonex® Red (8000 ppm IBA gel) gave significantly better rooting of mature *A. flammeum* cuttings than the other hormones tested, which were Clonex® Green (1500 ppm IBA gel), Clonex® Purple (3000 ppm IBA gel), and a 5-sec dip in 500 ppm IBA/500 ppm NAA in 50% ethanol. However, less woody material may respond to lower auxin concentrations since *Telopea* may be struck at more moderate IBA levels of 2000 to 3000 ppm with toxicity occurring above 4000 ppm (Worrall, 1976).

MICROPROPAGATION

Two experiments were performed concentrating on the stages of initiation and multiplication. It was found that pre-treatment of *A. flammeum* material with gibberellins (GA_{4+7}) prior to initiation into culture improved the success of initiation. It was also established that a higher quality of explant is achieved using stem segments taken from the tip and a few centimetres below for initiation, and 1% bleach for 15 minutes is adequate for surface disinfestation of material. These results are similar to those for *Telopea* (Offord et al., 1992) and there is potential to use growth regulator pre-treatment for preparation of many other woody species.

The value of BA (6-benzyladenine), 2iP (6-dimethylallyaminopurine), and TDZ (thidiazuron) as growth regulators for shoot multiplication in vitro was investigated. BA at 0.6 μM produced the best results for *A. flammeum* explants. This concentration of BA is lower than the 1.25 μM used for *Telopea* (Offord et al., 1992), but is closer to that used for some other Proteaceous species such as *Stirlingia latifolia* which prefers 0.5 μM BA (Bunn and Dixon, 1992). 2iP produced good elongation and quality of shoots, but the shoot number was not as high as for BA. TDZ, even at the lowest end of the accepted working concentration (0.035 μM) produced very bushy explants with many short unusable shoots. Preliminary studies suggest that rooting conditions for *A. flammeum* explants are similar to those required by *Telopea* (Offord and Campbell, 1994).

Propagation of *A. flammeum* was achieved in this study by cuttings and tissue culture. Basic parameters for propagation by these techniques have now been established and the system chosen by plant propagators will depend on the number of plants required and the facilities available. Studies on postharvest and cultivation across a range of environment and cultural regimes should be the next stage in the development of tree waratahs.

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Propagation of the Wollemi Pine

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The Wollemi pine, *Wollemia nobilis*, is a newly discovered genus and species of the southern hemisphere family Araucariaceae. It is a rare and endangered species, with fewer than 40 adult trees existing in the wild. There is considerable horticultural interest in this species and research at Mount Annan Botanic Garden is concentrating on propagation of this species by seed, cuttings, and tissue culture. Of these techniques, cutting propagation of orthotropic juvenile shoots is the most promising.

INTRODUCTION

The Wollemi pine (*Wollemia nobilis* W.G, Jones, K.D. Hill, and J.M. Allen) was discovered in a rough and difficult-to-access gorge in the Wollemi National Park by park worker David Noble in late 1994. Wollemi National Park is located 150 km north-west of Sydney, the largest city in Australia. Only two small populations of the species have been discovered and the number of trees total no more than 40.

The existence of the Wollemi pine was previously only hinted at by fossil records and its closest relative is found as a fossil record from Bass Strait and is dated to 2 million years BP (Hill, 1996). It belongs to the family Araucariaceae, once a widespread conifer group during part of the Cretaceous–Jurassic period (94 to 30 million years BP), that is now confined to parts of the southern hemisphere such as eastern Australia, New Guinea, New Caledonia, and South America. Many of these species have economic value for forestry or ornamental horticulture. The Wollemi pine is unique and it is so different from the other extant species of Araucariaceae, *Agathis* (the Kauri pines) and *Araucaria* (which include the Norfolk Island pine and monkey puzzle tree), as to be classified as a new genus (Jones et al., 1995).

The restriction of the Wollemi pine to a sheltered gorge, may be the result of the frequent fire regime that accompanied the drying of the Australian continent over time rather than a preference for this type of habitat. The plants existence there is tenuous due to the fragile soil, rock falls, and now, by the discovery by man. The Wollemi pine is extremely rare and endangered, but paradoxically its discovery has generated an enormous amount of interest in it as subject for cultivation, which may in fact further endanger the species through pressure to view and cultivate the plant.

The New South Wales National Parks and Wildlife Service and Royal Botanic Gardens Sydney have devised strategies for conservation of this species which include limited access to the site (Offord, 1996). Very few seeds are produced and material for vegetative propagation is also limited. Therefore, a propagation research project is in progress at Mount Annan Botanic Garden (the Australian Native Plant Garden of the Royal Botanic Gardens, Sydney) which aims to eventually produce plant material for distribution. Emphasis is on minimal collecting from the natural site and mass propagation from stock plant material.

SEED PROPAGATION

The Wollemi pine is monecious and bears female cones high up in the crown of the tree, whilst male cones are located some metres below. All cones are borne terminally. Male cones release their pollen in spring and the embryos develop for approximately 18 months before the cones ripen and shatter, dropping seeds over a period of weeks. Very few potential seed develop in the cones and there are only approximately 10 seeds per cone. Trees do not produce many cones, and, as there are very few trees, the total number of seeds that can be harvested is inadequate for large-scale propagation.

Only a small amount of seed has been collected. However, there has been enough to determine the basic parameters for germination. Adequate germination is achieved through sowing fresh seed at 25C. There is a considerable lag period for all seeds to germinate and studies are now concentrating on breaking dormancy through temperature control and chemical treatment. Plants propagated by seed are being studied for growth characteristics and used as a source of cutting material. They are also being used for DNA fingerprinting studies to determine the genetic variability within the species.

VEGETATIVE PROPAGATION

By far the best material for propagation is the juvenile orthotropic (upright) material that is found growing on the trunks of the trees. This material is in short supply in the wild and we have now produced stockplants from which this material can be harvested. Juvenile material is easily distinguished in this species because of the two-ranked leaves arranged on either side of the branch, similar to *Cephalotaxus* branches, whilst adult material has four ranks on each branch. It is necessary to use the orthotropic material to achieve the "seedling" or upright shape of the plant. Wollemi pines axillary buds appear to be strongly determined in their orientation, as for many conifer species, and plagiotropic (lateral) branches continue to grow sideways giving a lopsided plant that may have some use as ground cover or rockery specimen.

Cutting material can be propagated using a range of auxin treatments and glasshouse environment conditions, and the optimum conditions for propagation are currently being examined.

TISSUE CULTURE

There are very few reports of successful propagation of species of Araucariaceae and research so far indicates that the use of this method will be limited for Wollemi Pine. Axillary bud growth and root production is slow. Cell lines have been established from cotyledons and organogenesis and somatic embryogenesis are being investigated.

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Germination of Native Grasses and Their Establishment

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INTRODUCTION

There are about 1000 species of native grasses in Australia which must be well adapted to this environment in order to persist. An important feature of this adaption is the ability to reproduce and survive despite variable rainfall and the generally low level of available plant nutrients in Australian soils.

Different species have evolved strategies which allow them to survive in a wide range of physical and biological environments. Grime (1977) suggested that the two most important groups of factors affecting the survival of plants are stress and disturbance. He also suggested that plants have developed strategies to cope with three of the four possible combinations of high and low stress and disturbance (Table 1).

Table 1. Plant strategies associated with the four possible combinations of high and low stress and disturbance (after Grime 1977).

Intensity of disturbance	Intensity of stress	
	High	Low
Low	Competitors (C)	Stress-tolerators (S)
High	Ruderal (R)	(No viable strategy)

The level of stress is determined by factors such as the level of soil fertility, the amount of soil water available, and similar features of the environment. Disturbance, on the other hand, refers to processes such as physical disturbance of the soil or defoliation by grazing animals. A feature of stress-tolerators (Table 1) is low seedling relative growth rate, of competitors is a somewhat higher seedling relative growth rate while the seedling relative growth rate of ruderals is the highest of the three (Table 2).

The stressful Australian environment in terms of a high probability of the occurrence of seasonal or aseasonal drought coupled with generally low soil fertility has led to the evolution of a flora containing a high proportion of stress tolerators with low seedling relative growth rates and grasses are no exception. Jones (1996) demonstrated the slow early growth rate of Wakefield microlaena and *Taranna danthonia* in comparison with four exotic perennial grasses. This slow early growth rate means that competition from weeds (ruderal species) can inhibit the establishment of native grasses from commercial sowings.

ANCILLARY STRUCTURES

The ancillary structures surrounding grass caryopses are often associated with seed dispersal and have important effects on seed germination and the subsequent establishment of seedlings. Many authors, e.g. Lodge and Whalley (1981) have shown that the removal of the ancillary structures often reduces the proportion of dormant seeds. These structures can also be important in affecting the orientation of seeds grass dispersal units on the soil surface, and germination and subsequent seedling establishment. Peart (1984) has shown that the sterile lemmas and awns of microlaena result in the seeds dropping with the embryo end downwards and that seeds remaining in this position have better germination and better seedling establishment than seeds lying horizontal. Other species have ancillary structures which function to bury seed in the soil or to move the seed along the surface of the soil until it meets an obstruction giving it a preferred micro-environment for germination (Peart, 1984). The presence or absence of these ancillary structures can be of importance in the germination of seeds of native grasses in a nursery situation.

Table 2. Seedling relative growth rates (RGR) and established strategies of several species of grasses (from Grime et al., 1988).

Plant	Seedling RGR week^{-1}	Established strategy
Festuca ovina	0.5 - 0.9	S
Koeleria macrantha	0.5 - 0.9	S
Anthoxanthum odoratum	0.5 - 0.9	SR & CSR
Lolium perenne	1.0 - 1.4	CR & CSR
Dactylis glomerata	1.0 - 1.4	CSR & C
Phalaris arundinacea	1.0 - 1.4	C
Poa annua	1.5 - 1.9	R

SEED DORMANCY

Seed dormancy can be centred in the ancillary structures surrounding the caryopsis, be associated with impervious seed coats, or with the embryo or endosperm itself. Freshly harvested mature seed of many species of Australian grasses will not germinate immediately and possess primary dormancy (Whalley, 1987). This primary dormancy is sometimes broken by the passage of time or it may require a specific sequence of environmental conditions before the seeds will germinate. The uneven and delayed germination can lead to problems for the commercial propagation of species with primary dormancy.

Non-dormant seed planted in the soil will sometimes develop secondary dormancy depending on the time of the year it is planted and the subsequent environmental conditions. Secondary dormancy sometimes requires specific environmental sequences for it to be broken and is also associated with the sensitivity of seed in the soil seedbank to the existence of a plant canopy which may inhibit seed germination.

A number of techniques including seed storage under room conditions, subjecting dry seeds to alternating temperatures between say 20 and 60C for several months, the use of gibberellic or sulphuric acid in seed treatments, or a number of scarification techniques have been used to break primary dormancy in seeds. When germinating fresh seed of an unfamiliar species of a native grass, it is advisable to attempt to find successful techniques which have been used in the past. An alternative approach is simply to store the seed for about 12 months before use and hope that the intervening time leads to a sufficient decrease in seed dormancy for the sample to be useful.

TEMPERATURE AND GERMINATION

Different species of native grasses will germinate over sometimes widely differing ranges of temperatures. Some have a narrow range whereas others have a far broader range. In addition, some species will germinate better under alternating than constant temperatures and there is no substitute for detailed knowledge of the germination conditions required for individual species. Whalley (1987) lists the temperature requirements for some Australian native grasses and the newly formed Australian Native Grass and Legume Seed Industry Association (ANGLSIA) hopes to start collating such information to make it generally available. In general terms, those species adapted for growth during the cool season of the year have lower germination requirements than warm season grasses.

SPACE, DEPTH OF PLANTING, AND GERMINATION

The importance of bare ground for the germination and establishment of plants ranging from rainforest species through to grasses is now well established. Most species will not germinate, or if they do the seedlings will not survive, beneath an established plant canopy. Depth of planting is also critical and in general terms, deeper plantings will be less successful with smaller seeds.

PROPAGATION OF AUSTRALIAN NATIVE GRASSES

Because the optimum conditions for the germination of seeds of many native grasses are simply not known, simply planting them in soil in a pot in a glasshouse and watering in the hope that the seeds will germinate is often a waste of time. It is better to attempt to germinate seeds on an appropriate medium in petri dishes so that some information can be obtained even from seeds which do not germinate. Many samples of native grass seed contain endogenous microorganisms both fungi or bacteria and which can be given appropriate treatment if the germination is observed on a daily basis. Successful seedlings can be carefully picked up with a pair of forceps when the radical is less than 1 cm long, planted in holes in soil and carefully watered. After establishment, many native grasses may be susceptible to over watering or the over application of nutrients particularly if the plants have become pot-bound. A good rule of thumb with established native grasses is to wait until the surface soil in the pot is dry before watering.

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Propagation of Flannel Flowers (*Actinotus helianthi*)

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INTRODUCTION

Flannel flowers (*Actinotus helianthi*) are attractive plants endemic to the eastern regions of Australia, particularly on the sandstone areas along the coast of NSW. They are an emerging cut flower crop and there is also considerable interest in this species as a potted plant. For the past 2 years, work carried out at Mount Annan Botanic Garden with the support of the Rural Industries Research and Development Corporation, has concentrated on the development of flannel flowers for horticulture with emphasis on cut flower production.

Flannel flowers were often considered difficult to grow (Offord and Tyler, 1993) and various methods have been assessed for the commercial development of this perennial herbaceous species. Propagation, previously considered one of the major limitations to the development of this species for horticulture, is now a matter of choosing the appropriate technique and plant material.

SEED GERMINATION

Extensive experiments have determined the nature of unreliable germination of flannel flower seeds. *Actinotus* seeds are often dormant at dispersal and they require a period of after-ripening to mature and improve germination. It was found that dry storage for several months increased the germinability and germination could also be promoted by removing the seed coat and testa (Lee, 1996). There is also considerable variation in the germination of seeds collected from different sites. Flannel flower seed may be germinated in dark or light and the optimum temperature is between 12 and 15C (Offord and Tyler, 1993; Lee, 1996). Armed with this information we set out to determine a simple and robust system that can be adopted commercially.

We have found that chemical treatment of seed has been very successful in improving seed germination of flannel flowers. The most promising treatment is the "Instant Smoke Plus" seed primer produced by Kirstenbosch National Botanical Institute in South Africa. These filter papers contain various water soluble substances particularly smoke and other common seed germination stimulators (Brown et al., 1995). These substances are leached out of the filter paper in 50 ml of water and the seeds soaked for 24 h before sowing. Ten different seed collections tested using the seed primer showed improved germination compared with seeds soaked overnight in water. The final germination percentages for these ten seed lots varied between 68% and 96% for the treated seeds and 5% and 59% for the untreated seeds.

The success of smoking alone on seed germination of this species appears to be highly dependant on the application conditions. Smoking of seed for various lengths of time (using a bee-smoker and an enclosed unit) and application of smoked water (Roche et al., 1994) have been evaluated for germination stimulation of *A. helianthi*, however the results are variable and inconclusive. Some seed collections did not respond while others were inhibited by these pretreatments.

Different germination results for various seed collections indicate that genetic and environmental factors play an important role in the viability of flannel flower seeds. It is important now to select lines with consistently high germination rates and blooms suitable for sale as cut flowers.

CUTTING PROPAGATION

Research at Mount Annan Botanic Garden has established that flannel flowers can be successfully propagated vegetatively. Cuttings can be taken throughout the year, although the new growth occurring after flowering is ideal once it is hardened off. This occurs in autumn (March to May). Softwood tip cuttings 10 cm long, with the apex removed to encourage new shoot development, perform best. The lower leaves need to be removed below each new bud carefully avoiding damage to the stem tissue, leaving approximately 3 to 4 leaves near the top. Decreasing the foliage will help reduce fungal problems.

Mist (5 sec every 15 min) is a superior glasshouse treatment to fog as many cuttings rot in the latter environment. During cooler weather, the root zone temperature needs to be maintained above 20C. A well drained mix such as perlite , sand, and coir (4 : 1 : 1, by volume) is required (Offord and Tyler, 1996). Roots appear within several weeks under optimum conditions. Although not essential, cuttings root faster if IBA up to 3000 ppm is applied as a gel or alcohol dip. Roots are easily damaged and care must be taken when potting on.

MICROPROPAGATION

Micropropagation techniques have been developed to commercial standard for one variety of flannel flower and a number of other varieties are currently being assessed. The basic medium used is Murashige and Skoog (MS) medium containing a cytokinin, either BA (benzyladenine) at 5 μM or 2iP (dimethylallyamino purine) at 10 to 12 μM in combination with an auxin like IBA at 0.2 μM. A multiplication rate of at least three times is possible after a 6-week period. Microcuttings can be planted out under a standard misting system and they will strike within 2 to 3 weeks. The use of a softwood rooting powder is beneficial although like conventional cuttings, flannel flowers from tissue culture will produce roots without auxin treatments. The most successful microcuttings are the apical sections, followed by the stem sections. Multiple stemmed microcuttings are unsuitable as they suffer from a higher incidences of fungal growth and consequently breakdown.

A general observation is that the taller growing forms of flannel flower adapt readily to tissue culture conditions. Shorter types have problems initially with microbial contamination due to the proximity to soil or potting mix and because of the short internodes. They are slower to grow once established and work is required to determine optimum growing conditions.

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Grafting Dwarf *Ixora* Standards

Des Boorman
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The *Ixora* genus belongs to the Rubiaceae family along with *Gardenia* and *Rondeletia* which are two other important ornamental genera (Bailey, 1976). However, unlike the other two, *Ixora* does not have a strong perfume.

The inflorescence of this genus consists of 50 to 80 waxy star shaped flowers held in dense terminal and axillary corymbs. All are extremely ornamental with the dwarf cultivars being no exception. Colour range is from red through orange, pink, yellow, and white.

Dwarf cultivars put on spectacular show during summer and autumn. They are used extensively in median strips and roundabouts in the tropics due to their low growth habit, hardiness, and colour. Several taxa are also used for hedges.

The object of grafting dwarf taxa onto hedge type *Ixora* rootstock is to produce a semistandard plant with compact growth and high impact flowers. These are ideal for use in tubs by the pool side and even up your driveway.

ROOTSTOCKS

Most *Ixora* taxa have a relatively short growing season which limits viability of rootstock production from tip cuttings.

Observation of a couple of unkempt hedges of *I. coccinea* L. revealed terminal growth 0.8 to 1.0 m in length. These looked ideal for instant rootstocks.

These long semihardwood growths were taken for preparation during wet weather to prevent excessive desiccation. On return to the propagation shed this material was placed in water containing 100 ppm chlorine.

The cuttings were prepared with a basal cut just below a node. The cutting length was standardised at 80 cm. The apical bud was left intact and any axillary branching removed. Eight to 10 pairs of top leaves were retained.

The cuttings were dipped into IBA (2000 ppm as Rootx-L®) and stuck into a double layer of LC3 Oasis® root cubes for stability and root depth. Baling twine was then used to tie the tops of the cuttings together. It is important not to let the cuttings desiccate during this process

Roots initiate in 6 to 8 weeks. After hardening the plants were potted into 125-mm containers filled with a medium composed of equal parts of composted pine bark fines and quincan (a crushed porous basaltic rock). Nutrients were supplied in the form of Osmocote Plus® 8 to 9 month at recommended rates.

Once established the rooted cuttings are now ready for grafting. All axillary growth is removed, with any leaves present retained on the main stem. The plants are held in a hothouse environment.

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SCIONS

Scions selected are 2 to 3 mm in diameter, soft to semihardwood with active growth and a length of 75 mm. They are immersed in water with chlorine (100 ppm) added for 5 min and then rinsed and drained before grafting. Leaf length is reduced by half.

GRAFTING TECHNIQUE

The plants are whip grafted. The object is to produce an instant "ball on stick" or standard *Ixora*. This means that the rootstock cuttings are 80 cm tall – the rootstock is in a gradient of semihard (2 year old) at one end (the rooted one) to increasingly soft towards the tip of the cutting (current years growth). So, it is important that the graft be made in the right spot, i.e. not right at the tip where the rootstock is so soft that it wilted and couldn't support the graft and not too far down in the harder older tissue where callus production is slow and the graft doesn't take either. The scions are prepared in a similar manner, with a match of both cambium layers preferred. The graft is wrapped with two to three layers of Nescofilm® lab tape using the "nail winding technique" (Boorman, 1991).

The newly grafted plants are placed into trays of water 20 mm deep under mist until callus forms and tape splits (3 to 4 weeks). They are then sun hardened. Rootstock growth is very vigorous and needs to be checked twice weekly and removed.

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Propagation of Mondo Grass

Michael Gleeson

Castle-Lyn Nursery, 1191 Old Northern Road, MIDDLE DURAL NSW 2158

I am here today to tell you how I propagate mondo grass (*Ophiopogon japonicus*)!!

Now you may ask why this guy is getting up here and telling us about something any propagator knows how to do? Why, it's so easy that the job is usually given to the junior staff to do. We know that all you have to do is stick a few bits into pots or in the ground, leave them there for a few years fighting with the weeds, and when you think about it go and get them and divide them. But what if the boss comes to you one day and tells you that you are to produce 5000 plants every year for the next 3 years in tubes. Your problem now is to know how much stock material you need to establish to produce the plants required, and how to do it in a specified time frame. This is where I may be of some use to you by presenting this paper.

We all know of course that mondo grass is propagated by division. It can also be grown from seed, and I will come to this later. I will start with the production of the stock plants. The best time of year to do this project is August (early spring). Stock plants are grown in 200-mm squat pots and are established by planting four tubes, that have been held over from last years output, into a good quality potting medium.

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A mix that is a bit on the sandy side is better as I find it easier to shake out later. A dose of 8-9 month Osmocote® (18-2.6-10) or similar is added at potting. These pots are then placed into the nursery in a position that is protected from the hottest part of the day. This group of stock plants is fed on a regular basis with the normal liquid feed programme which in my case is Peters® (Peat-Lite High N) fertilizer every 7 to 10 days. These plants will then be left to grow over the following season and will not be dealt with until next August. It is important to keep weeds under control.

It is now 12 months later and time to divide the stock plants. The pots are brought to the work area and the soil is shaken vigorously from the roots (it is easier to do if the soil is a bit on the dry side at the time). The clumps of material are now placed on the work bench where the job can be carried out in comfort. Division is done with an old pair of secateurs (blunt blades) or with a pair of cheap scissors. I cut off all the newest rhizomes first, then I cut the central clumps into as many plantable pieces as possible. The size of the plantlets varies considerably, the smallest being about 13mm high to pieces that may be difficult to fit into a tube. These pieces are then planted into 50-mm tubes. Trays of tubes are then placed out into the shadehouse to grow on and these are saleable about 4 to 5 months later.

Over the years I have been keeping a record of how many plants I can obtain from each stock pot and have found that a return of 15 to 1 has been a consistent figure. This means that every four tubes planted in an 200-mm pot returns 60 plantlets. Therefore, if you require 5000 a year you need to plant about 85 stockpots with 340 tubes. Every year it will be necessary to keep back from sale 340 tubes to plant on to obtain your required supply of stock for the following season.

Seed is also a useful way to propagate mondo grass and this can be done at the same time. My stock plants flower while they are in the growing on phase and the resulting fruit is ripe at the time the plants are divided. The seed is collected during the division process and put aside to be planted later. I don't clean the fruit pulp from the seed, I just sow it as it comes into a good quality potting media. Germination takes about 8 to 10 weeks and the germination rate is high. Seedlings are planted out when they are big enough to handle. Seedlings establish at a similar rate to the divided plantlets.

An Alternative Method of Budding *Fraxinus angustifolia* 'Raywood' (Claret Ash)

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UNDERSTOCK

The understock that I use is a cross between *Fraxinus americana* and *F. oxycarpa*. It was first introduced to the trade by Hazlewood Nursery, many years ago, for its superior root system and its ability to grow from hardwood cuttings. I obtained my original cuttings from an old tree in an old nursery at Mt. Irvine in the Blue Mountains of NSW. I wasn't sure of its species so I asked John Teulon to identify it. He had known about this tree for years but as this tree had died and he did not know of any others, he had assumed that it was no longer available in Australia.

My stockplants of this tree are now 7 years old and get pruned back to approximately 90 cm each winter. In spring, the many new water shoots grow rapidly to 1.2 to 1.8 m in length. They have a high percentage of inter nodal length of 200 mm or more.

BUDDING

Budding is done onto the stockplant in mid to late March (early autumn), after the branches have grown sufficiently but before the sap stops flowing.

I generally use a T- bud however last year I did a chip bud as the sap had stopped flowing. The success rates of both methods of budding are the same (very good).

The bud is positioned approximately 180 mm above each node along the length of the cane. This gives between 4 and 8 buds per cane. The beauty of budding like this is that I can stand beside the tree, mostly with my back straight, not kneeling on the ground with a bent back. When they are tied, I like to leave the bud exposed. They are then left until August (late winter).

CUTTINGS

In August, the canes are collected from the stock bed and taken to the shed for processing. The cuttings are made with a node at the bottom and the inserted claret ash bud at the top. The pair of bottom buds at the node are removed very deeply so there are no understock buds on the cutting and then treated with IBA at 8000 ppm.

PLANTING AND GROWING

The cuttings are planted in one of our standard hardwood cutting bed. This is 30 cm high by 90 cm wide and 40 m long. It is compost-enriched soil topped with strawberry mulch plastic (only 25 μM) which the cuttings are inserted straight through. They are planted on a 10-cm diagonal pattern and watered via a T-tape system and/or overhead sprinklers. All buds are faced to the south, as this reduces the incidence of "hockey-stick" trunks.

They start to shoot away at the end of September. At this stage the ties are removed. The plants generally grow nice and straight and rapidly throughout the year and reach between 1.2 and 1.6 m high.

DIGGING

We start digging in early July. We can not start earlier as most of our plants are 1 year old and have an in-built juvenility factor, so they tend to hang onto their leaves longer into winter.

We have a cable drawn digger which undercuts the plant and loosens the soil from the roots. They are then taken to the shed for grading and placing into orders. All our plants are dispatched free of soil to all parts of Australia.

REASONS FOR SUCCESS

1) Suckering is not a problem, on juvenile or mature trees, with this method.
2) Growth rates are very similar when using a clonal understock, not seedlings.
3) Budding is done at a time of year when there is less work to do in our nursery. Grafting is done in winter when we are busy. We have previously done claret ash by root grafting in winter.
4) It is cheaper to stick a hardwood cutting in the ground than to plant a 1-year-old seedling.
5) As the budding is done standing up, there are no sore backs from grovelling in the dirt.
6) Fits in well with our production as it is growing in the ground for 1 year.
7) Any member of staff can make up the cuttings.
8) Plants present well as all buds are 180 mm above root development.

Wildflowers of the Sydney Region and Their Suitability as Cut Flowers

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INTRODUCTION

There are over 6000 plant species throughout NSW with many showing tremendous horticultural merit. This paper will focus on several species with horticultural potential from the Sydney Region which have been of great interest to me for many years. In recent years there has been an escalating interest in our native species for use as cut flowers both on the domestic and export markets. With demand expanding, it has become essential for commercial row cropping to take place rather than rely on material harvested from wild populations. However, it has been from the harvesting of wildflowers from natural stands that the cut flower potential of many native plants has been realised.

For the development of a strong domestic and export market, the introduction of new and exciting species and cultivars is of utmost importance. When introducing a new cut flower species into cultivation it is essential that the plant has a suitable vase life when cut. As a guide 10 to 14 days is worthy of further investigation. Following this, the ease of propagation, adequate stem length, ease of production, and disease resistance are other significant considerations. From a marketing point of view, filling a period when little else is in flower is an added advantage.

In the past few years, export sales of Sydney region flora including, *Blandfordia* spp. (Christmas bells), *Ozothamnus diosmifolius* (rice flower), *Actinotus helianthi* (flannel flower), *Ceratopetalum gummiferum* (Christmas bush), *Telopea speciosissima* (waratah), and *Doryanthes excelsa* have yielded impressive returns. The strong overseas market demand for these products has meant that greater focus from growers and research institutions has been placed on the production and postharvest development of these species.

NEW WILDFLOWER CROPS

Having grown and introduced into cultivation many eastern Australian wildflowers for cut flowers, it is my experience that florists want variety of type, colour, form, and texture. Many species from the Sydney region exhibit these characteristics. However, some impediments that prevent some exciting introductions into cultivation are usually associated with difficulties in propagation techniques and the ability to be intensively farmed. For example, *Eriostemon australasius* is recognised as a showy focal filler flower that has been highly sought after by florists and exporters. However, the seed is hard to germinate and cuttings are slow and often difficult to root and thus the development and production of this species is limited.

Conversely, success in the development of rice flower, Christmas bells, and Waratah which do not have the same propagation difficulties, has meant that extensive plantings and selection are being undertaken. An important crop that was recognised at a Rural Industries Research & Development Corporation workshop in 1995 was *Ceratopetalum gummiferum*, the NSW Christmas bush. The cultivation, selection, and marketing of cut flower stems of this species has been a major success for our business.

For the past few years, our wildflower farm has been working on development and selection of cultivars of NSW Christmas bush. Our initial plantings of seedling stock have given us a sound base from which to draw new and interesting colours and forms. The export returns of cut stems from *Ceratopetalum gummiferum* 'Albery's Red' have been very promising and this recognised cultivar has acted as a benchmark for our new colour selections. There is some interest in the various colour forms that have been found amongst our seedling population, particularly the deep red, white, salmon, and pink types. We are now bulking up numbers of several types of these colours and investigating selections that exhibit increased vigour.

CONCLUSION

Recent export success has shown what can be achieved with several species that are indigenous to the Sydney region. However, to develop a sound industry base for both domestic and export sales, there needs to be an improvement in quality standards. The development of a strong grower base and the increased production under cultivation will ultimately allow for a consistent supply of uniform products of our unique flora.

Another important aspect in the development of new crops is that there needs to be a greater liaison between growers and researchers. It is almost impossible for a grower to adequately address all aspects of selection, propagation, nutritional requirements, and postharvest treatments for each individual species being trialed on their property.

As a grower of Australian flora we are faced with an exciting opportunity to provide native cut flower material for floral tributes for the Olympic games in the Year 2000. With this platform, Australian growers will be able to showcase the unique, diverse, and unusual flora this country has to offer. The international recognition associated with such an event will no doubt open up new export market avenues and in turn channel funding towards research and propagation of the many species with horticultural merit which have not yet been fully explored.

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Propagation Experiences With New Winter Flowering *Gladiolus* Cultivars

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Think of *Gladiolus* and most people immediately mention the incomparable Dame Edna Everage. Unfortunately the great Dame seems to have given "gladdies" something of an unfashionable image, although I can't imagine why. A comprehensive breeding programme by Mr. Fred Meyer of Escondido, California is set to change the image of *Gladiolus* once and for all.

The traditional horticultural *Gladiolus* are summer-flowering types with characteristic monster-sized blooms. These types tend to dominate our perception of "gladdies", but unfortunately they do not do justice to the extraordinary diversity and beauty of this large genus. There are some 250 species of *Gladiolus* found throughout Africa (including tropical areas) and the Mediterranean region. Of these only a small handful are represented in the commercially available *Gladiolus* cultivars. Species that have rarely if ever been used in breeding feature delectable perfumes (e.g. *G. caryophyllaceus*), orchid-like flowers (e.g., *G. orchidiflorus*), ornate markings, and multiple colours on the one flower. In addition, many of the species flower in late winter and spring — thus complementing the summer-flowering types from a grower's point of view.

The basic objective of Fred Meyer's breeding programme has been to incorporate the features of the more unusual and desirable species with the traditional summer flowering tetraploid cultivars that have dominated the scene for so long. This paper looks at some of the experience gained in the breeding and propagating of this unique group of hybrids.

The first problem to be overcome in the breeding programme was the fact that the parents of most of the hybrids flowered at different times. As most of the wild species used are winter- or spring-flowering, while the other parents were tetraploid summer-flowering types. Pollen storage was the obvious answer and to do this whole anthers were collected just before anthesis and were placed in gelatine capsules (obtainable from some chemists). The capsules were then placed in jars with moisture-absorbing silica gel and then stored in a freezer for up to 6 months. When the summer-flowering female parents were flowering the pollen was thawed out and applied to them.

Initial selections were made about 5 years ago from many thousands of hybrid seedlings. Cormlets from the initial selections were used to initiate tissue cultures to bulk up promising clones for trial work. Tissue culture has also been a great benefit for transporting the material to different countries. In addition the varieties were also indexed for viruses and keeping clean mother stock in culture means that virus free stock can always be maintained. *Gladiolus* are very responsive to standard tissue culture media and the techniques have been well documented in the past. The multiplication rate of different hybrids varies enormously with some clones being extremely prolific.

Hardening off tissue culture material can be done in a couple of different ways. Firstly, actively growing shoots without significant corm development are planted out and can be grown to flowering size in one season. Secondly, by elevating the amount of sugar in the medium, cultures can be induced to form corms in vitro thus making planting out less risky. Both techniques are very successful.

The next phase involves growing the plants through to flower. Once corms reach flowering size they produce cormlets at their base and these can be used for further multiplication. The growing seasons of the new hybrids has proven interesting. The fact that they are hybrids between winter and summer growers has meant that some selections have the ability to grow virtually year round. Other selections, on the other hand, have been better suited to either winter or summer but not both. There are obvious advantages to growers with the year-round types.

This project represents a very interesting breeding experiment in that it has incorporated germplasm from an extensive collection of wild diploid species with tried and trusted tetraploid cultivars. The result is a new range of triploid cultivars which gives them a series of useful characteristics. They are sterile and therefore will not set seed, meaning that they are highly unlikely to ever escape from cultivation. Triploids also tend to be easier to grow than tetraploids in that they are not quite so big and brittle. The flowers of the new cultivars are generally intermediate in size, something that makes them instantly distinguishable from the tetraploid cultivars.

In summary, the Fred Meyer *Gladiolus* hybrids represent a fascinating collection of new cultivars that have a diversity and charm that is far more representative of the whole genus. We can look forward to an array that features perfume and orchid-like flowers.

A Method for Germinating *Anthurium scherzerianum*

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INTRODUCTION

For some time it has been apparent that many growers of *Anthurium* were experiencing difficulty obtaining satisfactory germination of the seeds of this most desirable plant. Plant division was practised to a large extent to increase numbers, particularly in the cut flower industry. The advent of plant tissue culture and the subsequent development of satisfactory techniques that would produce reasonable multiplication rates, made this an economically viable proposition for growers to some extent.

However, some growers still like to produce their own seedlings, experimenting with specific cross hybridisation to produce plants that they hope will have unique characteristics — which is a great source of personal pride of achievement.

The very short viability of *Anthurium* seed meant that it was necessary to sow the berries very soon after ripening and harvest. As the berries in most cases contain only 3 to 4 seeds and these are covered in a sticky glutinous mass the process was messy and not altogether satisfactory.

With these difficulties in mind I set out to devise a method of handling fresh *Anthurium* seed and producing good results in germination. I will not go into the procedures of hybridisation and subsequent production of the seed, as this will probably be well known to *Anthurium* producers. The following will provide data on the methods that I employed to clean *Anthurium* seed and determine when optimum results could be obtained using inexpensive equipment available in most homes.

MATERIALS AND METHODS

The berries were harvested when mature and ripened. Most were fully developed and of a pink to red colour, and easily removed from the spadix.

These berries were gently mashed to break the outer coat and facilitate separation from the enclosed seed. The resultant gelatinous mass was then placed into a normal household flour sieve and immersed in a container of sterile water. Next the gelatinous mass was rubbed gently through the mesh of the sieve. This takes some time, but with perseverance the "jelly" will be dispersed in the water and the seed will be left behind in the sieve. This process was repeated a second time using a 1% bleach solution, it is recommended that rubber gloves be worn for this stage.

By this time the seed will be relatively clean with some of the outer skin of the berries still persisting. The next step is to spread the wet seed mass on to some layers of newspaper or other suitable material and place in a secure, well lit place to dry (preferably not in direct sunlight as the seed may over heat). The seed mass should be dry in about 24 h at which time it can be gently rubbed to completely separate the seed. If necessary the trash can be separated from the seed by gently blowing, however this is not absolutely necessary.

Ideally the seed should then be sown immediately on to a high peat University of California type media which has been treated with aerated steam at 63C for 30 min and then cooled. The trays of sown seed were placed on a greenhouse bench with bottom heat, which held the media at approximately 23C, and were kept moist. Some batches were sown without covering and some with a very light covering of vermiculite. The light covering appeared to be preferred under the conditions that we had available.

RESULTS

Trial #	Date of seed cleaning	Treatment	Date of sowing	Time to germinate (weeks)	Germination (%)
1	Jan 21	1% bleach	Jan 23	3	90
2	Jan 21	1% bleach	Jan 30	3-4	65
3	Jan 21	1% bleach	Feb 8	3-4	30
4	Feb 10	Nil	Feb 12	3-4	78
5	Feb 10	Nil	Feb 19	4-5	45
6	Feb 10	Nil	Feb 27	4-5	15

It was obvious that it was of paramount importance for the seed to be sown as soon as possible after collection. A number of replicates were carried out and similar results ±3% to 4% were obtained. There was also a significant improvement in germination when the seed was washed in the 1% bleach solution. This was probably due to the removal of a significant percentage of surface pathogens.

Fungicide Resistance In *Botrytis* Species

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INTRODUCTION

Growers in the nursery industry are faced with numerous problems everyday. One of these is the control of disease which can cost growers hundreds of thousands of dollars in lost revenue. Fungal diseases are a major concern and one fungus that constantly threatens crops is *Botrytis cinerea.*

Botrytis cinerea can affect a range of plant parts, particularly the flowers, when there is high relative humidity and cool temperatures (Jarvis, 1992; Fletcher, 1984). Conducive conditions are worsened by poor ventilation, hence it is beneficial for heating and ventilation at sunset when the vapour pressure deficit is low (Jarvis, 1992). Generally infection occurs after the plants have been harvested and during storage and transport. The first symptoms, however, are usually found on the plant in the greenhouse (Dirske, 1982; Fletcher, 1984). Commencement of the infection usually occurs due to the conidia of the pathogen and it serves as the initial inoculum point for the infection for most outbreaks of *Botrytis.* Once conditions are conducive for infection, the symptoms of the disease appear within a few days (Agrios, 1988; Jarvis, 1992).

Fungicides are an important element in controlling infection from *Botrytis*, however it is important to note that they do not substitute for poor sanitation practices and environmental management. Control of *Botrytis* is generally achieved by growers implementing a spraying program in conjunction with appropriate hygiene measures. Over the past decade however, some of the fungicides have not been successful in controlling *Botrytis* due to resistance problems. It appears that systemic fungicides cause the majority of resistance problems as they generally have a single-site mode of action (O'Connor, 1990). When resistance to the fungicides occurs, the disease is extremely difficult to control and whole crops can succumb to the infection of *Botrytis.*

Fungicide resistance occurs due to fungi developing and multiplying in the presence of the fungicide that would normally kill them. The fungicide acts as a selection pressure and when exerted on the fungi, mutations occur within the genes and this causes the fungicide resistance (O'Connor, 1990; Dekker, 1987). If a grower can determine at an early stage that the *Botrytis* isolates on their property are becoming resistant or that they are resistant, procedures can be implemented to combat the problem.

A trial was established to determine if isolates of *B. cinerea* from a commercial floriculture crop are resistant to certain fungicides. The trial will also investigate what are the best chemicals to use in a spraying program on this property.

METHODS AND MATERIALS

Paper Disc Technique. A spore suspension of 1×10^6 cfu ml^{-1} was made with 7-day-old cultures. The spore suspension (0.1 ml) was evenly seeded on 12 ml of

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potato dextrose agar (PDA). A 13-mm diameter sterile disc of Whatman No. 4 filter paper was soaked in a made-up mixture of commercial fungicide of known concentration. Twenty-one different fungicides were used with two being experimental — Ex 500 SU and KBR 2738. Some of the fungicides are not specifically used to control *Botrytis*, however, the grower for whom these trials were undertaken wanted them tested. Three concentrations were used:

1) Recommended rate
2) 0.5X recommended rate
3) 0.1X recommended rate

The filter paper discs were air dried slightly and then placed in the centre of the seeded PDA plate.

There were three replicates for each treatment. The plates were incubated at 21±1C with 8 h of light per 24 h for a period of 72 h.

After the incubation period, fungal activity was assessed by measuring the diameter of the inhibition zones surrounding the paper discs. If there is no inhibition at the recommended rate, the *Botrytis* was classified as resistant to the particular fungicide. For other concentrations, if there was no inhibition zone, the dosage was determined to be too low if at the full rate there had been an inhibition zone. The inhibition zones were measured three times to give an average diameter of the inhibition zone. They were placed back into the incubator for a further 7 days when they would be assessed again at 10 days after the initial inoculation.

RESULTS AND DISCUSSION

Results indicated that the fungicides performed best against the *Botrytis cinerea* at full and 0.5 times the recommended rate. The 0.1X of the recommended rate performed poorly in the majority of the fungicides so were dropped from subsequent testing.

Results indicated that at the recommended rate, the following fungicides performed the best at 72 h:

Total inhibition	Alto® (a.i. Cyproconazole)
	Scarla® (a.i. Pyrimethanil)
	Plantvax® (a.i. Oxycarboxin)
66.1% inhibition	Octave® (a.i. Prochloraz)
53.6% inhibition	KBR 2738 (a.i. Fenhexamid)

After 10 days, Scarla® had the greatest inhibition followed by Alto®, Octave®, then Plantvax®.

As shown in Figure 1, there was a significant range in the efficacy of the chemicals tested. An interesting result is that Plantvax® had total inhibition. Plantvax® is a systemic fungicide that is used primarily for the treatment of rust, its ability to also inhibit the growth of *Botrytis* is therefore surprising.

Results from the laboratory assay appear to indicate there is a resistance to the benzimidazoles (e.g. Benlate) which is almost universal. Other fungicides tested showing good efficacy were Octave, Thiram (a.i. Thiram), and the test fungicide KRB 2738. The other test fungicide Ex 500 SU showed very poor efficacy. Resistance occurred in one of the dicarboximide fungicides (Sumisclex® a.i. Procymidone) and the other (Rovral® a.i. Iprodione) had very poor efficacy. After 10 days, the Rovral® had no inhibition zone. Fungicides belonging to the demethylation-inhibiting

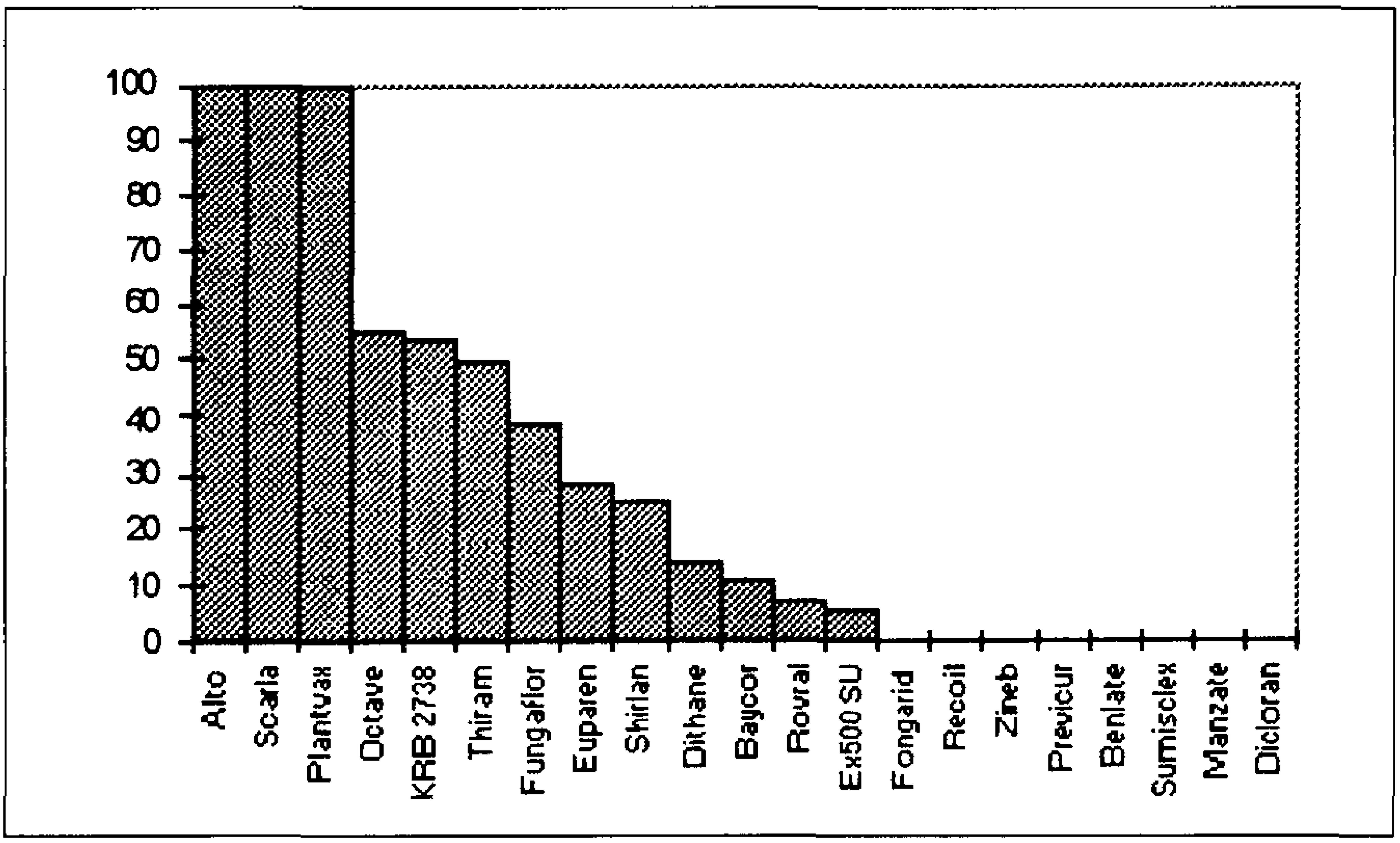

Figure 1: Inhibition zone percentage from 72-h plates at recommended rate.

fungicides (DMIs) appeared to be quite effective with such fungicide as Alto®, which is a triazole, performing well.

In the tests undertaken at 0.5 the recommended rate, Octave® with 48.1% inhibition on the plate and the experimental fungicide KBR 2738 with 43.8% inhibition were most effective and, even after 10 days, these were still the most effective plates.

These results indicate there are resistance problems with these *Botrytis* isolates. However, alternative fungicides may be used such as Alto® and Scarla®. Preliminary trials have indicated that there is the possibility that some fungicides may be effective at 0.5 rates as there appears to be good efficacy. It is important to note that these results must be carried out in the field as field results often vary significantly from laboratory tests. If an isolate is resistant to fungicides in the laboratory, it does not necessarily mean there will be resistance problems in the field.

Results show that benzimidazoles could be inappropriate to control *Botrytis* in the industry. Dicarboximides may be used with caution, however, other researchers have recommended that they only be used in peak periods of *Botrytis* infection. It appears that control of the fungus can be achieved by using chemicals from other fungicide groups, such as Alto® and Scarla® and also the test fungicide KBR 2738 which is soon to be released.

These results do highlight that effective control of *Botrytis* can not be achieved by fungicides alone and a fungicide spraying programme must be used in conjunction with environmental, sanitation, and cultural practices.

Trials are continuing and they will be carried out using the paper disc technique on *Botrytis* isolates that have had no fungicide applications. Another technique, the spore germination technique, will also be used. This measures the lengths of germ tubes of *Botrytis* on PDA plates amended with fungicides, and enables trials to be carried out within 24 h. This is highly beneficial to growers, who are then able to see outcomes of the trials within 48 h.

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Assessment of Rooting Hormone Formulations

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INTRODUCTION

Many trials are carried out to assess methods and rooting hormone formulations. However the results are not always what they seem. This paper aims to show how difficult it is to assess trials if the age of the hormone formulation is unknown and what can be done to overcome this problem.

MATERIALS AND METHODS

Propagation staff at the Australian National Botanic Gardens developed a method of preparing cuttings which involves re-cutting the stems to open up the transpiration stream before dipping. This method is thought to optimise the uptake of rooting hormone. A series of trials were conducted to assess which hormone formulation best suited the method. Formulations of IBA in alcohol, in powder form, and KIBA in water were compared. The conclusions are far more important than the results!

Trials. One trial with *Acacia baileyana* (prostrate form) compared powder (Rootex®) and alcohol formulations with a concentration of 3000 ppm. The results indicated that the alcohol solution was the most effective in terms of strike rate, 66% compared to 20% for the powder. The alcohol solution was freshly prepared for this trial. The powder had been purchased a few months prior to the trial.

In a more recent trial (1996) with *Acacia covenyi* two liquid formulations were used, an alcohol solution (Rootex®) and a potassium salt of IBA dissolved in distilled water, each with a concentration of 4000 ppm IBA. The results of this trial indicate that KIBA (46% strike) was more effective than the alcohol (28%).

Problems with assessment. Little was known about the powder used in the first trial. It was labelled as 3000 ppm IBA, but its age, and therefore the efficacy of the hormones contained within it , was unknown. It is impossible to assess trials such as the one conducted above unless this information is known. Many variations in rooting response may well be due to propagators using "old" solutions.

Shelf Life. Some premixed formulations have "use by" dates which may give an indication of the shelf life of the hormones within. Hartmann and Kester (1975) suggested that trialing rooting hormones with tomato leaf cuttings was a good method of assessing the level of active ingredient. Robbins (1987) prepared solutions of IBA using isopropyl alcohol and stored these in clear or amber glass bottles at various temperatures to assess the degree of breakdown of the chemical. A significant breakdown was measured after 19 months stored at room temperature (22 to 25C). The effect of storage in plastic bottles or using water as the solvent was not reported.

Most professional propagators mix their own formulations. IBA and KIBA, in crystal form bought direct from Chemical supply companies, are less expensive than commercial premixed formulations, and mixing your own always guarantees access to fresh hormones. However it is necessary to accurately measure these concentrated chemicals, so access to a good set of scales is essential.

Knowing the age and therefore likely activity of rooting hormones means the propagator can eliminate one of the many "unknowns" and concentrate on other factors which may be limiting their success.

CONCLUSION

1) Mix your own rooting hormones. Plan it so that your rooting hormone is as fresh as possible, e.g. fill a series of bottles with enough chemical to make 100 ml of solution, keep them sealed and then add the solvent as required and always record the date of mixing on the container.
2) If you are unsure how effective your rooting hormones are, carry out a trial using tomato leaf cuttings (Hartmann and Kester, 1975). This will give a quick indication.
3) Use a dish that can be covered (petri dish) between dippings, this will minimise evaporation (thus increasing concentration) and lessen the possibility of contamination.
4) If buying premixed formulations choose only those that have a "use by" date. A good rule of thumb is to keep for a maximum of 12 months after opening, so don't forget to record the date of opening on the bottle.

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Propagation and Testing of Deciduous Fruit Trees for Viruses

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INTRODUCTION

In researching and diagnosing virus diseases of deciduous fruit trees several propagation techniques were utilised and integrated with virus testing and elimination procedures. The aim of this work is to avail nurserymen and do-it-yourself growers the benefits of healthy propagating and planting material: improved profitability through higher nursery and fruit production efficiency.

The present work involves viruses but the principles and general approaches also apply to other plant pathogens, such as bacteria, fungi, and other infectious agents. Two notable differences are:

1) Fruit tree viruses depend on living hosts for their survival and dispersal.
2) Remediation of virus-infected plants on a commercial scale is impractical and not cost-effective.

The use of healthy plant propagating material prevents the spread of pathogens, reduces production costs for both nurserymen and growers, and helps meet consumer demand for a consistent, high quality product.

DETECTION

Usually healthy trees are more vigorous and yield more foliage, flowers, and fruit than infected trees. In nursery rows, virus-infected trees can be stunted or weak. As trees mature visible symptoms can appear, such as twisting of trunk or branches and distortion of fruit. Most virus-infected deciduous fruit trees show no obvious visible symptoms of infection. Viruses symptomless in their hosts can be detected using biological, biochemical, and molecular methods.

Herbaceous or woody indicators are used for biological detection; these are plants which express visible, diagnostic symptoms of one or more virus infections. For example, cucumber seedlings mechanically inoculated with leaf sap from an infected tree can produce yellow lesions. If grafted into sensitive woody hosts, tatterleaf symptoms may be produced, indicative of prunus necrotic ringspot virus.

Biological virus indexing in woody hosts is commonly done by chip budding pieces of bark either directly into a branch of an indicator, testing multiple samples on each branch, or inoculating a rootstock previously budded with the virus indicator variety. The resulting symptoms depend on the virus and indicator, varying from yellowing to epinasty to graft union and xylem disorders to death. Use of controlled environmental conditions can expedite symptom expression and enhance sensitivity and reliability of detection, particularly for milder strains of viruses.

ELIMINATION

Various propagation methods are used in eliminating viruses from fruit trees to produce healthy propagating material:

1) Selection, i.e. propagating successive buds onto individual rootstocks and selecting healthy propagations after testing.
2) Use of nucellar embryony (more appropriate for citrus than deciduous fruit).
3) Hot, moist air treatment (37C for 3 to 12 weeks) of entire trees followed by removing buds or shoot tips for grafting.
4) Micropropagation, using tissue culture, macro shoot tip grafting or in-vitro micro-shoot-tip grafting.
5) Hot water immersion followed by grafting buds onto healthy rootstocks or direct planting of cuttings.

BENEFITS OF HEALTHY PROPAGATING MATERIAL

The benefits of using healthy propagating material can range from 10% to 90% or higher, depending on the pathogen, host, and environmental factors. With virus-infected material, root strike of cuttings can be reduced 75% while bud failure can occur in up to 87% of propagations. Virus-infected deciduous fruit trees can produce 20% to 50% less fruit, half the canopy density, and up to 30 times more fruit with skin blemishes. Healthy propagating material also minimises wastage, presently a critical environmental and social issue.

POSITIVE SPIN OFFS

Evaluation of deciduous fruit tree hybrid crosses can be expedited by in vitro germination of seed extracted immediately after harvest and growing it under controlled environmental conditions. It is possible to obtain about 1 m of growth before winter and enable fruit buds to form 1 year earlier than seed which is stratified to fulfil normal winter dormancy.

Another positive spin-off exists for commercial-scale hot water treatment of propagules infected by viruses, bacteria, or fungi to meet certification or quarantine standards or enhance propagation success.

PRESENT CHALLENGES

Challenges encountered here include (a) overcoming "buttoning-off", where apical meristems mature and cease growing until next season, (b) browning of micrografted tissue of in-vitro plants, (c) overcoming leaf symptoms apparently associated with inadequate chilling requirement in seedlings obtained from same-season germinated seed, and (d) developing a cost-effective pathogen elimination method, particularly on a commercial scale.

CONCLUSIONS

Some of the propagation and virus elimination methods discussed here have proven cost-ineffective in Australia, even though they were performed under rather pragmatic, low-cost conditions. This includes tissue culture, in-vitro micro-shoot-tip grafting, hot moist air treatment, and to a lesser extent selection. Macro-shoot-tip grafting, in combination with hot water treatment, offers considerable promise but requires further substantiation before general acceptance.

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Production of Transgenic Plants by Electrofusion of Single Plant Protoplasts

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The possibility of producing transgenic plants which incorporate genetic attributes from different plant species and/or genetic attributes from specific plant cell tissue, presents an exciting prospect. However, there are many technical difficulties which have limited progress in producing such transgenic plants. Here we discuss a new technique, based on somatic fusion of individual plant protoplasts using radio frequency electric fields, which has the potential to overcome many of these obstacles.

INTRODUCTION

The introduction of new and desirable genetic features into plant cells can be achieved to varying degrees using methods ranging from standard cross-fertilisation breeding to highly sophisticated DNA manipulation using molecular-biology-based techniques. Whilst these approaches have been (and are) used with considerable success, they also have limitations. For this reason the possibility of enhancing genetic variability using somatic fusion is an attractive alternative. The difficulties of inducing somatic fusion between cells, the problems associated with identifying and selecting individual cells for fusion and the isolation of the desired hybrid-fusing product has limited progress in this area. The production of transgenic plants by somatic fusion of cells requires the regeneration of the whole plant from a single hybrid cell. Until now the regeneration efforts were restricted largely to wild sunflower species in in-vitro culture or sunflower genotypes which were thought to have contributions from wild type genomes (Krasnyanski and Menczel, 1993).

Regeneration difficulties present a major obstacle to somatic hybridisation although recently a reproducible shoot and root regeneration protocol was developed for genotypes of *Helianthus annuus,* which had no wild type contributions (Wingender et al., 1996).

We have perfected a technique to fuse a pair of single, individually selected, protoplasts using radio frequency electric fields to manipulate and selectively fuse the protoplasts. The technique overcomes the problems of isolation and identification of hybrid fusates which are encountered in other commonly used methods to induce somatic cell fusion. Further, the fusates so produced have a high division potential and will proliferate in culture from a single cell without the need for feeder cells or conditioned media. We have used this technique to produce hybrid cells from broad bean guard cells and hypocotyl cells from sunflower. Guard cells have the C4-directed enzymatic apparatus which is known to be coupled with a reduction in photorespiration resulting in a higher survival rate and yield potential of crops. The possibility to enhance the genetic variability of agriculturally important plants using somatic hybridisation between a C4-specific guard cell protoplast and a C3-

equipped hypocotyl protoplast with a high division potential, has considerable appeal.

MATERIALS AND METHODS

Hypocotyl protoplasts were isolated from young plants of *H. annuus* L. grown under sterile conditions from seeds (cv. Sunshine, No.4, Royston Petrie Seeds Ltd. Kenthust, Australia) by a micro-isolation process (Schmitz and Schnabl, 1989). Protoplasts which showed good cytoplasmic streaming were picked up by drawing them individually into a micropipette/microsyringe from a mixture of debris and protoplasts. Guard-cell protoplasts from *Vicia faba L.* were isolated in a similar fashion.

When plant cells are exposed to alternating (AC) electric fields, the cells will undergo translation, rotation on their own axis, and will elongate. Each of these electro-mechanical responses is dependent in a complex manner on the frequency of the AC electric field, the gradients in this field, and the particular electrical properties of the cells (Mahaworasilpa et al., 1994). By choosing the field frequency and adjusting the field gradients it is possible to selectively manipulate individual cells in this manner. Cell rotation (on its own axis) occurs over two narrow bands of frequencies (Mahaworasilpa et al., 1996) and can be utilised to orient cells relative to each other prior to fusion. The translation effects can be used to bring two different cell species together and appress them tightly for subsequent fusion. The fusion of the two cells held together in tight contact by the AC field can be induced by the application of a very short-pulsed, intense, electric field. The latter, if of sufficient magnitude causes electrical breakdown of the (plasma) membrane envelopes of plant cells, at the point of contact of the two cells (Coster and Zimmermann 1975, 1976). This causes the cells to fuse.

For our experiments two vertical nickel alloy wire electrodes, 180 μm in diameter were lowered into the solution using micromanipulators; the two protoplasts being positioned approximately in the central region between the electrodes. These electrodes were used to generate radio frequency electric fields. The protoplasts were then positioned more precisely between the two electrodes by a combination of the application of electric fields of appropriate frequency and manipulation of the electrodes themselves. These operations were performed under an inverted microscope (Zeiss Telaval 31). The alignment of protoplasts was achieved by application of an AC field at a frequency of 0.5 to 1MHz and variable field strength. Prior to alignment the protoplasts were also subjected to electro-rotation by application of an AC field at frequencies of either around 1 kHz or 10 MHz to both obtain a relative cell orientation that produced good cell-to-cell contact as well as to evaluate cell viability (Arnold and Zimmermann, 1984; Mahaworasilpa et al., 1996). Fusion of selected protoplast pairs was induced by a DC pulse (100 μs, 50 to 100 kV/m, see Table 1) following alignment of the cells.

RESULTS

A sequence of the fusion of a pair of two different protoplasts (experiment 1) is shown in Figures 1a-1d. The time required for the fusion product to become spheroidal after the fusion pulse was typically 2 min (see Figures 1c to 1d). Immediately after fusion the fusate, which was ~35 μm in diameter (Figure 1d) was transferred, under the microscope using the micropipette system, from the mannitol solution into a liquid

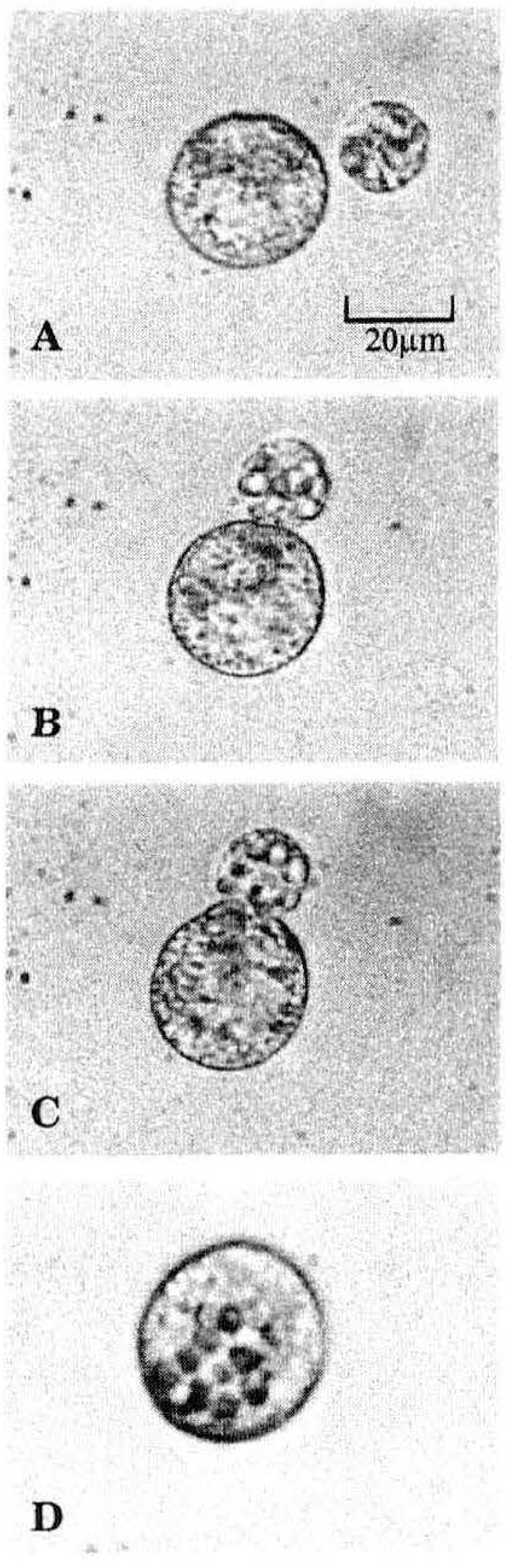

Figure 1. Fusion of two different protoplasts.

nutrient medium (Wingender et al., 1995) in a 300-μl microwell. The protoplasts were cultivated in the dark at 25C for 9 days without using feeder cells ("nursing culture") or conditioned medium.

The sequence of the formation of a microcolony (microcallus) over the first 9 days of cultivation is shown in Figures 2a - 2d. Between 30% and 60% of the hybrid fusates divided (Table 1), depending on the combination of parameters required to achieve fusion. The hybrid product budded for the first time after 3 days in culture (Figure 2a); On day 6 after the fusion event an identical arrangement of the starch-containing guard-cell plastids became visible in the daughter cell (Figure 2b). These large plastids (approximately 3 to 5 μm) play an important role as starch reservoirs during the volume regulation of guard cells (Schnabl et al., 1982; Schnabl, 1985; Schnabl, 1992). Due to their characteristic appearance (numbers, morphology, and arrangement) the plastids provided an excellent means of following the progress of fusion and formation of the colony of cells. Duplication of the nuclear materials from the mother to daughter cell occurred simultaneously with the appearance of the plastids (Figure 2b). On Day 7 a second budding was formed, but without the characteristic stomatal plastids (Figure 2c). Figure 2d shows the microcolonies of 5 cells which had developed (after a cultivation of 8 days); a day later (after 9 days in total) the microcallus consisted of eight cells showing the characteristic plastid equipment of guard cells (not shown).

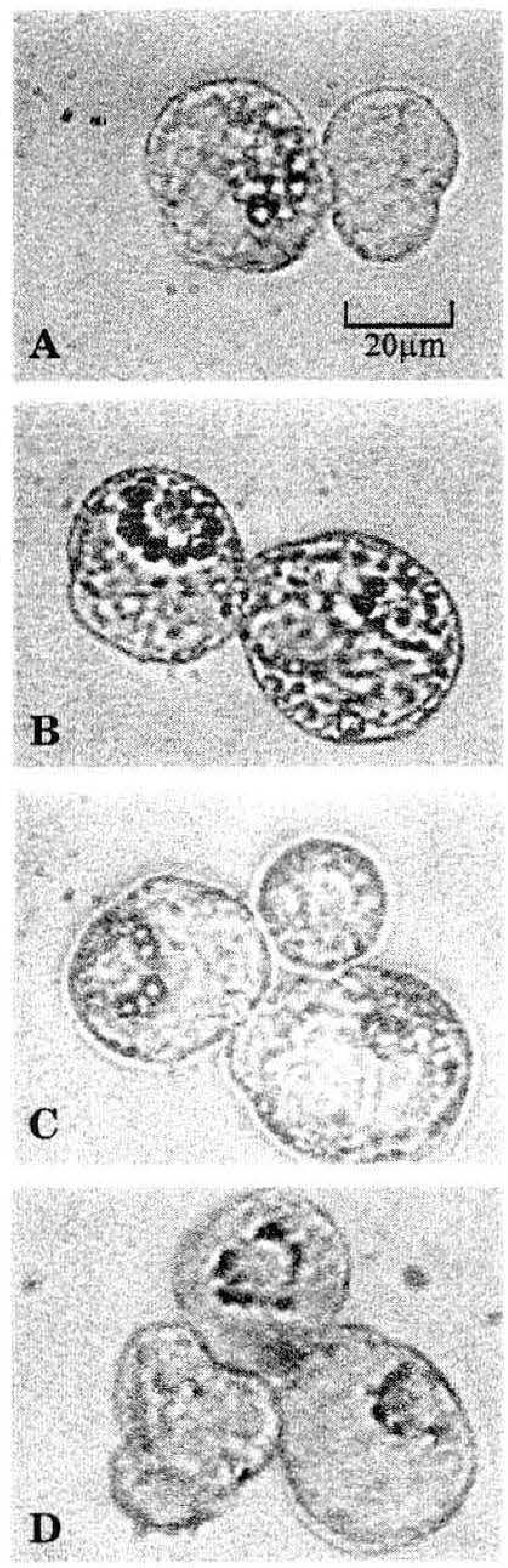

Figure 2. Formation of microcallus.

DISCUSSION

We have successfully produced, for the first time, microcolonies of a hybrid of two different plant species (sunflower and broad bean) and of two different tissues with different types of CO_2 fixation pathways; a C3-equipped hypocotyl protoplast of sunflower and a C4-equipped guard cell protoplast of broad bean. The hybrid products proliferated individually, or from groups of 2 or 3 cells, in a liquid nutrient medium; without feeder cells ("nursing") or conditioning. In contrast, single unfused hypocotyl and guard-cell protoplasts did not divide under these conditions but died.

ACKNOWLEDGMENTS

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Computers and Propagation

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A LITTLE ABOUT OUR COMPANY

Schotte Nurseries is an indoor plant propagation and production nursery. We have approximately 2 acres (8000 m^2) under production in five glasshouses, 1 Hi-Vent house (openable polyhouse) and two shade houses. Indoor foliage is our main production with some flowering lines and "unique living gift" lines. "Growlines" our propagated stock in trays, 5-cm, and 8-cm pots accounts for approximately 25% of the nursery turnover. The nursery has a PRIVA climate control computer operating the climate and water controls which has been in operation since 1981. Control systems in use before the computer were analogue controllers, thermostats, and manual systems.

Commercial Glasshouse manufactures installs and services glasshouses and all manner of related horticultural equipment. PRIVA computers have been sold installed and commissioned since 1981. We have to date installed 65 climate and or water control computers throughout Australia and New Zealand.

In the two businesses at Kellyville we have 19 computers in operation, not including embedded controllers. Propagation nurseries are able to utilise computers in many ways including:

- Bookkeeping (accounts) and business computers
- Data bases and spread sheets for data storage, collection and calculation sheets
- Environment or climate control computers to control heating, ventilation, cooling, humidity, CO_2 monitoring and/or dosing, lighting cyclic or grow, screens for shading, energy saving and blackout, etc.
- Control computers, irrigation, fertilising, substrate, NFT, etc. (fertigation).
- In or on many different types of equipment in the form of embedded computers or PLCs (programmable logic controllers), i.e. printers, fax machines, washing machines etc.

WHY A COMPUTER OR ANY SORT OF AUTOMATIC CONTROL?

Well, it is comforting to know that you can go to church, visit mum, or leave the nursery for any one of a thousand reasons secure in the knowledge that while you are absent your crops will not fry, freeze, wilt, drown, or otherwise succumb to misadventure through neglect. I cannot guarantee that a good controlling computer in the hands of a poor nurseryperson will make him/her an instant success, but a successful nursery operator will definitely benefit from improved computer control.

Business Computers. This is not really part of todays discussion, other than to mention very importantly that sales, orders, and accounts related information are used in production planning, along with past production plans.

Data Bases and Spread Sheets. We use many data base systems for recording, storing, and retrieving in an efficient manner various types of information. For instance, all of our production information is kept in a database. The information kept is the date, product code (with the description from the product file), quantity produced, operators identifier (initials), the source of the material, special treatments (commented on), destination, and time taken to do the whole operation. Similarly, information on spraying, fertilising, and incoming orders is also kept. Most of the databases are cross referenced to other databases where applicable.

Propagation of Cuttings. Cutting propagation relies on promoting root initiation and growth, etc. on the cutting before the energy balance is depleted. All procedures that influence this positively will increase the strike rate and/or yield.

Sunlight, water (H_2O), and carbon dioxide (CO_2) are the main raw materials for plants to produce chemical energy by photosynthesis. Carbohydrate and oxygen (O_2) being the main products of photosynthesis. Respiration is the opposite of photosynthesis where oxygen is combined with carbohydrates to produce energy, with the waste products being carbon dioxide and water.

We use glasshouses with PRIVA computer control to provide us with a well-controlled climate for optimum strike rates and production. The PRIVA control system works with up to 120 settings per climate compartment, and with numerous controlled possibilities that include: misting, irrigation, fertilising, substrate, ebb and flood, and NFT.

Temperature. The primary control parameter to keep effectively in hand is the temperature. This is also one of the easiest parameters to control. If the temperature varies too greatly the humidity will change rapidly and be hard to maintain correctly. The temperature does not need to be, and indeed should not be, flat or the same throughout day and night. However, the temperature should not change quickly. Maximum change rates should be no more than 4 or 5C h^{-1}. The night or low light periods may have a lower temperature. Day to night with a variation of 3 to 5C lower at night is desirable for most crops.

Humidity. With cutting propagation prevention of excessive water loss is the prime objective. Yield is maximised (growth and developed, root initiation) by keeping water moving through the cutting within a temperature range that the plant is "comfortable with" so the cutting is performing at optimal physiological activity. This means not too cold so that some internal systems slow down (i.e., transpiration or photosynthesis) nor so hot that systems go into overload and shutdown (i.e., guard cells close, etc.). If the cutting suffers water stress then its internal systems will also slow, or shutdown, or wilting/death may occur. Therefore, when keeping the temperature up to maintain optimal physiological activity (and therefore yield), sufficient water must also be provided to prevent wilting. These two factors (temperature and water) are in conflict and a balance must be struck to achieve maximum yield (strike rate, continued growth).

Propagation. There are three main areas we place our cuttings.

Dry Bench. Cuttings that can readily control their evaporation in a glasshouse with stable temperature and humidity may be propagated in the normal growing area. In our production facilities this is applicable with 25% of the plants grown, such as with *Peperomia, Draceana, Begonia* Rex, St. Paulia, and *Pedilanthus.*

Mist. Mist is used for plants where maintaining a light layer of water on the foliage is sufficient to prevent excessive moisture loss from the cutting. We use California type mist nozzles with mains (town) water controlled with the PRIVA computer and electrical water solenoid valves. The control parameters the computer uses are misting between start time and stop time with the times shifted astronomically as the day length varies and using accumulated light count (light sum). Light measurement in mWatt/cm^2 is multiplied by time providing a light sum accumulator, J/cm^2. Should the light sum accumulate to the amount set the mist cycle will operate. Should the weather be very dull the maximum rest time may also instigate a mist cycle. On a hot summers day our misting would operate 8 to 12 cycles per day and on dull summer days 5 to 6 times per day. The valves operate for 10 sec each. Mist benches are filled with newly propagated plants and the mist is turned off when the majority of cuttings have rooted (80% to 90%).

The aim of our misting system is to keep a layer of water on the foliage without appreciably wetting the soil. This has the effect of maintaining reasonably good transpiration rates (production) without wilting and without water logging. We do have a little loss of turgidity with some softer cuttings initially which usually recovers in 24 to 48 h. This is more of a problem on particularly hot days. Some hand held hose watering is still required on the mist benches. Liquid fertilising takes place regularly in the glasshouse except in the first 2 weeks after propagation. We use this system for approximately 40% of our cutting grown plants, such as *Pilea, Fitonia, Coleus, Poinsettia,* and others.

Enclosed Tent. This system, tents over the benches, relies on trapping within the confines of the tent the evaporation from the soil, etc. and some transpiration of the cuttings with the intent of keeping the humidity high (usually above 90%). The principle being that if the surrounding air is fully saturated there can be no further evaporation, consequently the cuttings do not wilt or dry out. In reality there will be condensation on the surfaces of the tent and foliage as temperatures change outside and within the tent, this causes the humidity to fluctuate between 80 and 100%. This system relies on having slow changing temperatures and good control of the surrounding environment. Temperature within the tents on summer days may reach 35C or more.

The majority of our seed germinated lines are in seed trays on bottom heat benches. Some types are covered with glass. For a warmer environment. The majority of our tray, tube, pot and hanger lines are grown from cuttings and are propagated directly into the finished pot.

Heating System. With all of the above propagation systems we use bottom heating with 25 mm NB hot water pipes making up most of the support for the bench tops. There are 12 benches to each heating system. Each heating system is fitted with a three-way modulation valve, circulation water pump, and water temperature sensor. These systems are connected to two boilers.

The water temperature sensor measures the water temperature in the heating pipe after the pump. The computer, taking into account the settings programmed and other influences, calculates the water temperature required in the heating pipes should heating be required. The computer drives the three-way valve to a position that mixes the correct amounts of return water from the heating system and from the boiler to provide the wanted heating water temperature to an accuracy of 1C.

The control principles the computer uses is Pre Control and PID control, (Proportional, Integral and Derivative). The Pre Control works on the basis of outside temperature, wind speed, and wind chill factor setting the base heating water temperature and proportional band, i.e. the lower the outside temperature, the higher the basic minimum water temperature will be and along with a higher wind speed would increase the basic water temperature. There are also a number of settings in the computer to set the glass house characteristics in the computer, most of which are set by the installer, ie. the size, effectiveness, driving speed, running time, compass direction, wind side or single side vents, hysterisis, and many others.

Proportional control calculates an offset temperature relative to the temperature difference to outside. The integral control calculates the step size that is required to move the mixing valve to the correct position. The integral component calculates the time dependent variations for the P and I control components to have the temperature as accurately as possible follow the calculated heating temperature. This type of heating control calculates a desired water temperature in the heating pipes to equalise the energy losses from the glasshouse very closely.

Research has shown that for the average glasshouse if the temperature is approximately 2.5C higher than it should be whilst heating then double the energy is being consumed. At 5C too warm, energy usage will be approximately four times higher. The computer control system we use keeps the house or the bench temperature within 1C of the desired calculated heating temperature.

The ventilation is controlled in a similar manner with the computer calculating the required vent position. Shading systems for shade and energy saving usage have a more specific control system, operating between start and end times with light, temperature, humidity, heat loss, and many other factors. Effective shading control is one of the more complicated systems.

Computer. Some of the settings applicable for a controlled growing area such as a glasshouse or greenhouse are: heating temperature day, heating temperature night, ventilation temperature day, ventilation temperature night, light increase/decrease heating, light increase/decrease ventilation, relative humidity day, relative humidity night, heating limits, and ventilation position limits. There are many more settings.

For the new "Integro" range the 24 h period is able to be divided into periods denoted by a start time. Up to four periods are possible.

THE NITTY GRITTY

Climate and Hydro Control Computers.

1) From the simplest, doing it manually. Opening a vent or turning on/off a heater. Usually done when the person doing it remembers, and this is usually too late. Sometimes forgotten. Capital expenditure almost zero. Running expenses extremely high, 7 days a week with penalty rates etc. without even taking into account the loss of production. Results—fair at the very best.

2) A simple on/off thermostat. (Actually a binary switch). Works 24 h a day. Has the problem of a differential (i.e. turns on at different temperature than it turns off heating on at say 16 off at 20); a differential of 2C is better than a larger one. Over and under shoot

may also be a problem. When the heating turns on there is a delay before the heating actually catches up, during which time the temperature continues to fall. A similar condition happens at the turn off end. This may cause temperature cycling of more than 4C, i.e. 2.5C overshoot for say 25% of the heating period, adds approximately 25% to the heating costs. The problem being accentuated when heating loads are small. Time switches do not have the differential and over/under shoot problems. Capital expenditure moderate, thermostats of good quality approximately $75, timers approx. $50 to $150 plus installation costs. Running expenses much improved. Thermostats with day/night capabilities have more improved running expenses. Results—fair to good.

3) Simple controllers computerised or analogue. Usually operate a single controllable item, i.e. a heating system or a ventilation system. Proportional or PID control is the usual method. Sometimes fitted with day/night switching. Capital expenditure for the control system, sensor/s and actuators is usually more than $2000 per controlled parameter. Running expenses on a well designed system would be 5% to 15% less than thermostat. Some quick calculations on the running expenses (energy usage, etc.) will show if this type of option is economical. Results are usually very good.

   All of the above systems usually work on a single unit of control, i.e. one heating system or one vent. There is also no interconnection between parameters. With larger amounts of controlled parameters having them set correctly relative to one another may also be problematic.

4) Computers of the PLC types. There are a number of growers tackling the control of their environments with PLCs. With the Omron or Hitachi types the capital expense is usually much lower than purpose built horticultural computers. The software development of these systems with simple control is usually quite extensive while full, Pre and PID control across the many parameters is rarely achieved. Controller costs per house depending on input and output parameters would be $600 to $2500. Software and debugging costs vary depending on the programmer. Nil for the home developer to an almost endless cost for consultant development. The running costs of the controlled environment vary between thermostat type control to the best possible.

   A further possibility is the use of PCs (personal computers) fitted with input and output capabilities. The programmability is somewhat easier than PLCs. The software development is similar to PLCs. The ability of the equipment to keep running reliably day after day for many years is still a serious question (without needing resets or reloading of programs). The capital equipment costs vary depending on system development from $4000 to prices similar to specifically designed computers.

5) Computers of the type specifically designed for horticultural use. Usually have the programs in Firmware, i.e. in EPROMs or similar, with simple and dedicated user interfaces. Will have been designed with extreme reliability in mind (in amongst rural mains voltage supply variations, lightning, and a myriad of other consequences.) The main consideration being that a grower's livelihood and ability to make profits relies heavily on effective control of all of the parameters of the growing climate and water regimes. The software development has been extremely well worked out with R&D and grower feedback continuing. Capital costs depend on the size, compartments, and hydro requirements. A nursery with say three compartments climate control would be approximately $20,000. A hydro controller irrigation and fertilising for say three controllers and 100 valves would be about $19,000. For a hydroponics installation NFT, one system about $14,000. These include installation, commissioning, and grower training. The gains in running costs are high, i.e. for a heating system a minimum 15% in energy savings. Increases in productivity are always noted. Growers using this type of equipment have distinct market advantages with the ability to control the climate and consequently cropping. With the above the equipment to be controlled, i.e. mixing valves screens or vents, etc. are not included.

This is by no means an exhaustive study of computer control in nurseries and propagation facilities. There is a publication available in Europe that discusses, climate control in glass and greenhouses. "Computerised Environmental Control in Greenhouses" a step by step approach. The author is P.G.H. Kamp/G.J. Timmerman. The publication is in English.

Acknowledgments. I wish to thank my wife for her help and patience in compiling these notes, and also the staff of our company for their contribution.

Industry Training, Doing it Our Way

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Ensuring the next crop of nursery propagators has the right skills is an important issue. We need to have a training system that turns out professional propagators ready to face the challenges of the future. That training system is changing and our involvement is crucial if the level of professionalism is to be retained and even improved.

Changes to the Australian training system have been happening for some time. If you are not involved in education then you may not have caught up with some of the latest developments. We now have Competency Based Training and Assessment, National Curriculum, and a different way of government funding arrangements. "Doing it my way" for a trainer is vastly different to what it was even a few years ago. The changes are not complete and I see that we will never go back to the old ways, good or bad. Even our present and new system will come in for further changes. Being adaptable is now a good trait for a horticultural trainer.

Competency based training is possibly the most radical aspect of the new system. Here you pass a module (or subject) if you become competent at some specific tasks, rather than attending lessons and just passing written tests. It is not possible to fail at competency based training and it is also not possible to pass without knowing all the skills necessary.

Learners can ask to have their competency assessed at any time during the lessons as it is no longer time based. A competency is able to be assessed without going to classes at all! I like competency based training although it is definitely more complex and time consuming for horticultural trainers.

Accepting this approach requires that the necessary skills are well defined and that the assessment event to ascertain if the skill has been learnt is fair. I feel we have the first aspect in hand but as yet have not come fully to grips with the assessment side of things.

The nursery industry has a national curriculum, a list of competencies, developed over time with educators and industry leaders. We all owe a debt of gratitude to those who gave their time to this project. Courses based on these competencies are being developed and will become available in the next few years. In Victoria, Queensland, and Western Australia pilot programs of the first course are being run, with full implementation expected next year.

An integral basic in competency based training is that each learner needs to be assessed to see if a skill has been learnt. Producing a fair assessment event to determine if the person has the skills is the key here. It is easy if it is a skill like digging a trench. Just give them access to the tools and say "dig". If the trench is straight, deep enough, completed in time, and the tools used were correct you can be sure they have the necessary skill. Now think what you would need to do to assess a learners ability to take semihardwood cuttings, or even hand watering a propagation bench? Ask two propagators that one, and I'm sure you will end up with three answers.

Saying "not yet competent" in competency based assessment is difficult. No one likes to be told they have not yet demonstrated a skill well enough. It is easier to pass than not to, particularly if the skill is almost learnt. Also it may reflect on the ability of the trainer to teach the skill and usually means extra work to reassess at a later time. In a perfect world assessors would not also be trainers. I view this aspect of training in a different light. Saying "yes" when the person is not good enough is more difficult in the long term. You let yourself down by not being honest, you also let the learner down who then believes they have the skill, and you let our industry down for they will accept your say so when the person applies for a job and produces a credential that certifies competency.

Driven by escalating costs under the new training system there is 'deregulation' of the training market. Putting this in more basic terms, courses funded by public money (and that includes apprenticeships) will be available for a large number of providers to deliver. The federal government sees three types of training provider: state, private, and industry. They will, and are, in open competition to train your new workers.

In theory they all deliver the same course to the same standards. In reality the truth is somewhat different. It is not that difficult to become an accredited provider of a horticulture training course. There are 14 at least in NSW and many of these offer no input from industry and do not have the background or experienced trainers that instil confidence. We as an industry need to support competition in training, so long as this is not at the expense of quality or industry relevance.

Obviously there is a need for a clarity in the decision-making process of who becomes your training provider. I can foresee some pretty disillusioned students and employers until the situation settles.

At the end of a course or assessment procedure a credential is produced. It will indicate which skills the graduate is competent at and whether they have achieved the right to receive a certificate, etc. This is a vast improvement on the old way, as now potential workers are able to describe in detail their level of competency. A certificate in Horticulture will indicate EXACTLY what skills the graduate has.

Despite the rhetoric of some politicians, I see a fair and National Training and Assessment System as a major challenge for the nursery industry. We need to be sure that a propagator's skills are taught and assessed the same way in southern WA, northern QLD, and every other state or region. Leadership by industry associations (state and national), backed up by much goodwill will be the only solution to this challenge.

The nursery industry association has already shown that they see training as a major issue. Australian Horticultural Training (AHT — a "not-for-profit" division of NIAA) has been established to develop and deliver national training courses and workshops. Quality training providers as well as individual trainers are being sought to become involved in this development and delivery. AHT's aim is to get the best bang for industry from the training buck.

This task of providing quality training is impossible if you as professionals are unwilling to become involved in the process of transferring skills to others in the industry.

The greatest strength of this industry is the pool of knowledge and love of plants that we share. We are the best people to introduce new workers to the joy of propagation. You can be involved. The rewards can be most exciting and are not just monetary. You could enthuse a youngster into propagation, and they could go on to win a Rod Tallis Award (I did). I cannot emphasise too strongly the value that a new propagator gets from seeing an old hand still enjoying their craft even after decades on a bench.

Being a trainer or an assessor with AHT requires that certain requirements are met. This is more than what is needed as a basic requirement for most courses.

First you will need an in-depth knowledge of the module area you wish to deliver. This may include a credential such as a trade certificate or higher along with extensive experience. For propagation trainers membership of I.P.P.S. is a specific requirement. Second is a training and assessment credential or equivalent. Workplace Trainer Category II is preferred, as it allows the trainer to not only deliver effectively, but also to assess competencies. This credential will soon be offered through Australian Horticultural Training to industry using industry-relevant examples of training and assessment.

Another criteria is that you demonstrate that you are able to remain up to date in your area of expertise. Out-of-date methods not only waste time they also reflect poorly on the training organisation generally and the individual involved. A common complaint from employers is that their workers are taught methods that have long ago been replaced. Attending and involvement in I.P.P.S. is a good way to keep abreast of industry changes, but here I am talking to the converted.

"Doing it my way" in training is really "doing it the way of the Australian Nursery Industry". Having professional, "hands-on" propagators involved is the only way that this can happen. The alternative will destroy the existing skills base and go against all that I.P.P.S. has built up in Australia over the last 25 years.

Climate for Change: What Opportunities do Phenology Gardens Provide for Propagators?

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Over the past 25 years of I.P.P.S. Australian Region Meetings there has been change in the behaviour of plants. Only in a few instances have the plants been watched closely enough in all this time for anyone to notice the changes. The "first leaf date" in spring in northeastern U.S.A. has moved 14 days earlier (Schwartz, 1994). In tropical rain forests around the world the mortality of trees and their recruitment has increased (Phillips and Gentry, 1994).

Whether these changes were the result of cyclical fluctuation in climate, or were part of a long-term shift in global conditions caused by greenhouse gases, they illustrate how observations of the phenology of plant development can be used as a sensitive detector of environmental conditions.

Economic analysis can identify opportunities which contribute to remediation to climate change (Bureau of Industry Economics, 1996), but involvement of community groups in recording responses of plants to changes in weather is, intuitively, more likely to provoke a response. In Alberta, Canada, a recording scheme is well advanced (Beaubien and Johnson, 1994). In Australia, phenology gardens of clonal plants the length and breadth of the country, could engage community participation. The Australian Flora Foundation (GPO Box 205, Sydney 2001 NSW Australia) is exploring this option.

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SPF? - So What?

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Legislation has been passed to approve SPF (sun protection factor) ratings to now have a maximum labelling of up to 30+. This will bring Australia in line with international ratings of above 15+. Until now Australian standards required that the maximum SPF rating was 15. So how will this affect all the sun-bronzed Aussie nursery people?

The SPF is a measure of the protection of sunscreens. To arrive at this value the sunscreen had to be tested in laboratory conditions using a solar simulator, with all other variables as constants. The unit measured is the "minimal erythematous dose" or MED, which is a measure of the time taken to produce redness in an average skin. From this the SPF is calculated as:

$$\text{SPF} = \text{MED with sunscreen} \div \text{MED without sunscreen}$$

In other words, SPF is defined as the exposure time to produce redness on protected skin divided by the exposure time to produce redness on unprotected skin. It is an indicator of the ability of a sunscreen to prolong sun exposure without the danger of sunburn, e.g. for a sunscreen with SPF 15, this would mean that if burning occurs without sunscreen in 10 min then one could expect that with this sunscreen one could have 150-min sun exposure without burning.

Does this mean then, by changing the label of a bottle, that we can stay in the sun for a longer time without any danger? Let's look more closely at the whole issue. Solar radiation is made up of ultraviolet radiation, visible light, and infrared radiation. UV light is divided into three parts, UVA (320-400 nm), UVB (280-320 nm), and UVC (100-280 nm). The ozone layer filters out most of the high energy, damaging rays of the UVC and some of the UVB. While most of the UVA and higher wavelengths are transmitted through the skin, and cause damage in their own way.

For the determination of the SPF rating, a minimum of 10 people, which is a very small sample, with sun-sensitive to normal skins are exposed to artificial light. The light is directed on their backs, with a mixture of protected and unprotected skin areas. Twenty-four hours later they are examined for areas of redness. The artificial light source used is UVB only. How does this equate with reality? Obviously a standard is just that, a standard. It provides a measure. Now let's look at the real situation:

1) The sun has different intensities at different times of the year.
2) UVB is only a very small part of total radiation from the sun.
3) The concentration and choices of ingredients can influence effectiveness of sunscreens.
4) The thickness of the film applied can be variable.
5) Medications can greatly influence burning and sun sensitivity, e.g. sulfonamides, antibiotics, and antihypertensive medications; some cardiac, antidiabetic, tranquillising, and antifungal medications.
6) State of skin — skin integrity, wetness, sweating or rubbing can alter effectiveness.
7) Altitude and latitude are variables — ozone layer depletion now is important.

Table 1. Sunscreen ingredients, their spectrum of activity, the concentration necessary for protection, and some specific properties.

Product	Absorbance (nm)	Concentration	Comment
PABA (para-amino benzoic acid)	260 - 320	5 to 15%	Can stain clothing and cause allergies.
PABA ESTERS			
Padimate A	290 - 315	1% to 5%	Safer to use than PABA. Still can cause allergies.
Padimate O	290 - 315	1.4 to 8%	
CINNAMATES			
Cinoxate	270 - 328+	1% to 3%	Not as sensitising but not as effective as PABA. Ability to penetrate varies on formulation.
SALICYLATES			
Homosalate	294 - 315	4% to 15%	Sensitisation is rare. In right concentration very effective.
BENZOPHENONES			
Dioxybenzene	260 - 380 (UVA UVB)	3%	Best when used in combination with other sunscreens
Oxybenzone	270 - 350	2% to 6%	
UVA ABSORBERS			
Parasol 1789	360 and above		Must be used in combination with a UVB blocker.
Eusolex 8020	360 and above		
PHYSICAL BARRIERS			
Zinc oxide	290 -700	Enough to cover barrier.	Cosmetic difficulties, though excellent
Titanium dioxide	290 - 700	3% to 8%	Reflects & scatters UV, visible & IR. Protects & soothes. Excellent product.
Light-weight summer clothing			Some only have SPF of 5 or 7 - even less when wet.

8) Reflection of sunlight is very important, especially by sand, snow, and water.

Short wave UVC is mainly scattered or absorbed before reaching the Earth's surface. However, as the ozone layer thins, we must be aware of the potential harm. UVC is also produced by welding equipment, therapeutic sun lamps, and some quartz halogen lamps.

UVB is recognised as the most harmful of UV radiation causing burning, blistering, initiation of sun cancers, and premature aging. It is also responsible for tanning with the so called "healthy tan" being the bodies damage response to exposure to sunlight. UVB stimulates melanin, hence causing tanning about 10 h after exposure. The epidermis or top layer of the skin also thickens as the body tries to protect itself.

UVA causes premature aging and wrinkling of the skin. It also darkens pigment already in the skin but does not produce new pigment. UVA is used in tanning parlours, promoting tanning without burning. However new research suggests that UVA also contributes to skin cancers not just aging of the skin. It would be very wise to use a sunscreen which adequately controls all UV radiation, not just UVB!.

Sun exposure is a total package — it is a total lifetime accumulation. The damage done in the first two decades of life impacts greatly on the individual and sun tolerance in middle life. Also the greater the amount of burn damage in early life, the more sun-related problems later. This can be in the form of skin aging and precancerous solar keratoses, cancerous conditions such as basal cell carcinoma, squamous cell carcinoma, or malignant melanoma.

Let's see what we can do to minimise the damage. Sunscreens slow the rate at which the electromagnetic energy of the sun is absorbed, by either reflecting, absorbing, or scattering UV rays. This can be done by either physical or chemical means. We need to understand the active ingredients in sunscreens and how best to apply them.

The most common form of chemical sunscreens are UV absorbers which act by penetrating the epidermis and bind in the skin in such a way as to reduce the intensity of sunlight striking the skin. The following is a table of ingredients, their spectrum of activity, the concentrations necessary for protection, and some specific properties.

TIPS FOR APPLICATION OF SUNSCREEN

- Apply up to 2 h before exposure for UV absorbers to give them time to bind onto the skin. Titanium dioxide can be applied just prior to exposure.
- Re-apply while in the sun at regular intervals, but remember that reapplication does not bring you back to the start, it is total cumulative exposure.

If sunburn does happen the best thing to do is cool it with water — not ice, keep up adequate fluid intake, apply mild hydrocortisone cream, and give antiinflammatory medications, e.g. aspirin or ibuprofen (always after food and never if the patient has ulcers or asthma). If blistering has occurred, leave intact if small or, if large gently and aseptically break and treat with chlorhexidine cream. Topical sprays of local anaesthetic are usually ineffective and can cause contact dermatitis.

In conclusion I would like to stress that sun exposure is a total cumulative package. There is some help from sunscreen products but without judicious precautions limiting exposure we can't expect to have a lifetime of trouble-free skin. Let's leave the sunlight to our plants chlorophyll and protect ourselves!

Getting the Message out

Ian C. Atkinson
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COMMUNICATION THEORY

The diagram in Figure 1 was developed by Berlo (1960) to help explain the process of communication.

SOURCE ⇒	MESSAGE ⇒	CHANNEL ⇒	RECEIVER
Comm. skills	Content	Seeing	Comm. skills
Attitudes	Treatment	Hearing	Attitudes
Knowledge	Code	Touching	Knowledge
Social system	Elements	Smelling	Social system
Culture	Structure	Tasting	Culture

Figure 1. Berlo's model of the process of communication.

The source formulates the message and transmits it via a channel to the receiver. Berlo emphasises the need for the source to be in control of the process and know its pitfalls. For the process to be successful the source must understand the attributes of the receiver in order to select the correct message and channel.

THE SOURCE

The Australian nursery industry pays a levy on all containers used for growing plants for resale and part of this levy is used to fund research and development (R&D) for industry. The Australian Federal Government matches this money $1 for $1 so that in 1997-98 industry had access to nearly $1 M for R&D. Projects are submitted for consideration to, or alternatively commissioned by, the Nursery Industry Association of Australia's (NIAA) Technical Committee and the Horticultural Research and Development Corporation (HRDC).

So the sources of information are HRDC, NIAA, and the R&D providers who are working on levy-funded projects. The R&D providers include mainly government organisations such as the Institute for Horticultural Development, in Victoria. Lets look at the characteristics of the people that work for these organisations.

Researchers often have good scientific written communication skills but poor verbal skills, their attitudes tend to reflect their academic and institutional backgrounds, they commonly possess high levels of specialised knowledge, and their social system and culture tend to be inward looking, focussed on their place of work rather than their clients. This assessment is naturally very broad and there are always exceptions, but I'm sure everyone here has seen elements of these characteristics in researchers they have met.

In conclusion I would like to stress that sun exposure is a total cumulative package. There is some help from sunscreen products but without judicious precautions limiting exposure we can't expect to have a lifetime of trouble-free skin. Let's leave the sunlight to our plants chlorophyll and protect ourselves!

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THE RECEIVER

NIAA's Technical Committee and HRDC have been very clear in their new 5 year R&D Plan about who the message is to be targeted at — the professional nursery industry. The 1993-94 survey by the Australian Bureau of Statistics, funded by the pot levy and HRDC, identified 3046 businesses involved in production and wholesaling of nursery greenstock.

Growers represent such a wide range of characteristics that the broad brush approach to describe them is fairly meaningless. Their communication skills range from brilliant to appalling, attitudes vary tremendously with age and background, they tend to be much more generalist in their knowledge, and often know what works without necessarily knowing why.

In terms of developing appropriate messages and channels to "get the message across," knowing the diversity of our target audience isn't much use. Fortunately we have access to the results of a study commissioned in 1995, by NIAA and HRDC, on the information needs and wants of growers. The results of project NY531 "survey of nursery industry information needs" is available from HRDC and here are some of the relevant findings.

Growers were asked to rate a range of information sources in terms of how often they used them and their level of satisfaction with the information. Of those questioned 70% used personal networks and rated them as their most useful source of information. In addition 62% used and commented favourably about conferences, workshops, and trade days. Most (73%) said they wanted a nationally coordinated information network including magazines or newsletters.

Regarding published information on levy-funded projects, there were two clear findings. Firstly, there was a high demand for useful information from projects including financial implications. Secondly, there was a consistent criticism of the scientific style of presentation of the information they had seen from projects.

THE MESSAGE

A good example of how NIAA and HRDC are crafting the message is to be found in "The *Nursery* Papers", consisting of a series of two and four A4 page leaflets published in *Australian Nursery Manager*. The authors and editors guide for "The *Nursery* Papers"(TNPs) says "The publication is designed to stimulate interest and provide enough information for nursery operators to be able to take some action to improve their business" (Atkinson, 1996).

Remember the growers wanted to see useful information from projects; this then determines much of the content of TNPs. Researchers are forced, partly by the format, to concentrate on the most useful and practical outcomes of their work, and discouraged from simply saying what was done. The treatment or style is "... more like a good magazine article and less like a (scientific) paper...". This is often the hardest point for researchers and their peer reviewers to come to terms with as they have often spent years developing their scientific writing habits.

THE CHANNEL

The choice of medium is important if we are to achieve the best results with our target group. The most favoured mediums in the survey were, in order of preference; personal networks, workshops, and magazines.

The 5-year R&D Plan has as an outcome under the heading of Communication and Technology transfer "strong, focussed, and adequately resourced networks that encourage the seeking and sharing of knowledge aimed at improving business profitability and professionalism." So we will be making use of mediums such as I.P.P.S. conferences and workshops to get the message across.

One recent example of our use of networks and workshops is the successful series of "WaterWork" workshops conducted throughout Australia. These hands on workshops required growers to use nearly all their senses, except taste unless delicious morning teas can be counted! This successful series is now moving into its third phase of training new presenters and developing distance education packages to allow even more growers to partake. WaterWork is also being used as the model for development of future workshops.

In the publications area NIAA have completely refurbished *Australian Nursery Magazine* including the recent name change to *Australian Nursery Manager*. Not only has it been the vehicle for publishing "The *Nursery* Papers" but the general content has been improved to better meet the information needs of growers and other sectors.

Never shy of new opportunities, NIAA and HRDC have also embarked on the famous or infamous Internet. The two main aims of this project are to:

1) Create a worldwide web site for the provision of information to the Australian professional nursery industry.
2) Encourage and facilitate use of the Internet and World Wide Web as a major information resource within the Australian nursery industry.

We have again concentrated on the information needs of industry and resisted the temptation to use all the bells and whistles. Our World Wide Web site at www.niaa.org.au is deliberately a simple but effective site concentrating on quality content not flashy style.

FEEDBACK

Like all models Berlo's has its drawbacks and its critics. Probably the most obvious omission is the lack of a feedback channel. So I suggest we redraw it because without feedback from you as users, we can easily get lost.

	SOURCE	⇒	MESSAGE
⇑	feedback		⇓
	RECEIVER	⇐	CHANNEL

Figure 2. Modified model.

We need your feedback, both formally and informally, in order to fine tune our efforts. Formal feedback may be in the form of fax or phone surveys, so if you are asked to participate then please give it some thought and effort because you will be representing your peers. Informally if you see something useful in a TNP or something wrong on the web site please send me or NIAA a fax or an e-mail message so we know how are efforts are going.

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Tomorrow's Nurseries

Peter Albery
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Although this meeting is held for the purpose of passing on plant propagation knowledge, this paper is of a different subject, and is based on my 45-year involvement in the nursery industry. The title of this paper is "Tomorrow's Nurseries", as never before have I seen so many challenges facing both production and retail nurseries.

To give you some idea as to why I made that statement one has to consider Australia's economic situation, and what our future economic situation might possibly be. This will enable nurseries of the future to steer in the right direction to ensure survival.

Multinational companies seem to be able to move their profits off shore, thus avoiding paying tax in Australia. These large companies can usually afford to use the latest technology, and in real terms, are not the bigger employers of people in this country. The tax burden therefore falls on the smaller Australian-owned industries, which most horticultural enterprises are. Couple this with the removal of tariffs and it becomes increasingly difficult for small business to survive.

The other big cost impact on our industry is that of services, e.g. power, water, drainage. The direct and ongoing cost of obtaining these services is ever increasing. Environmental laws will close in on Australian industries, the legislation is mostly in place, but as yet not well policed. I think that we all realise that we can not continue to pollute the earth that we live on, and in particular the waterways. So tomorrow's nurseries are in the making today. But in the future it will be difficult for anyone to start up a new wholesale nursery and comply with the requirements to satisfy the environmental laws. The capital investment needed would hardly present a worthwhile business proposition given the present pricing structure of our commodities.

Existing nurseries that already own their land and have access or pumping rights to good clean water will survive the next decade. But only if they look at the changes going on around them and alter not only the types of plants being produced but also their production methods to some extent. There probably is not one nursery in the world using all the technology that is available to them at this time, as some of this technology may not yet be cost effective. However, to remain in the industry changes to production techniques and methods will be essential to be able to produce plants economically.

Over the years that I have been involved with this industry I have seen a number of changes. Today we would consider it primitive to root cuttings without the aid of mist or tying grafts with raffia binding, using greenhouses with closed sash frames or loam-based soils in terracotta pots with fairly rudimentary nutritional maintenance. Were the plants any good? Yes they were, in fact I believe them to be more durable than their modern counterparts. But there is no nursery that can turn back to the old ways and survive economically today. When we look back in 15 years time at our present systems of production, we will probably say the same thing. Robotics and engineering technologies are already available and can be made applicable to the nursery industry in so many ways, e.g. automatic transplanting machines, water and nutrient application controlled by sophisticated sensing equipment. Impossible? These technologies are already available and becoming increasingly cost effective with time.

The nurseries of tomorrow will probably have closed watering systems. At the present time production nurseries rely heavily on controlled-release fertilisers (CRF). With closed watering systems CRFs will still be used as a base, but the production manager will become more of a scientist, calculating the nutrient requirements precisely, and using both CRFs and liquid feed to achieve this. My vision of a futuristic greenhouse will not only be fitted out with the retractable screens we have today, but will have a retractable roof, supplementary lighting and far more accurate heating devices that we are currently using. Science will determine precise resting times for plants, so that winter greenhouse temperatures can be lowered with great energy savings.

What sort of plants will people want in the future? Can you see them wanting the trees and shrubs that we see growing in the older suburbs? I think not. The trends are already changing, smaller blocks of land with cottage gardens, common playgrounds for all the neighbourhood children rather than individual backyards. Can you visualise the changes that are taking place now and how we can cope with these changing needs? What about reafforestation of our horrifically denuded pastoral and agricultural lands? Will our river systems be running in the next 200 years? Unless we plant trees in the near future, I think not.

So tomorrow's nurseries will be more precision production orientated. They will keep their eye on requirements for wetland planting, reafforestation programs, and the changing trends for home gardeners. Tomorrow's retail garden centres will also have to keep pace. Already we are seeing these combined with allied equipment sales, cafe/restaurants, amusement centres for children, and professional advice sessions on growing and maintaining plant purchases. Garden centres are becoming much more service orientated.

Who would have imagined all the changes that have happened since back when I started in this industry. And who can really tell how technologically advanced our society will become. One thing is sure though, this industry needs to advance with technology.

An Update on Greenhouse Environmental Control

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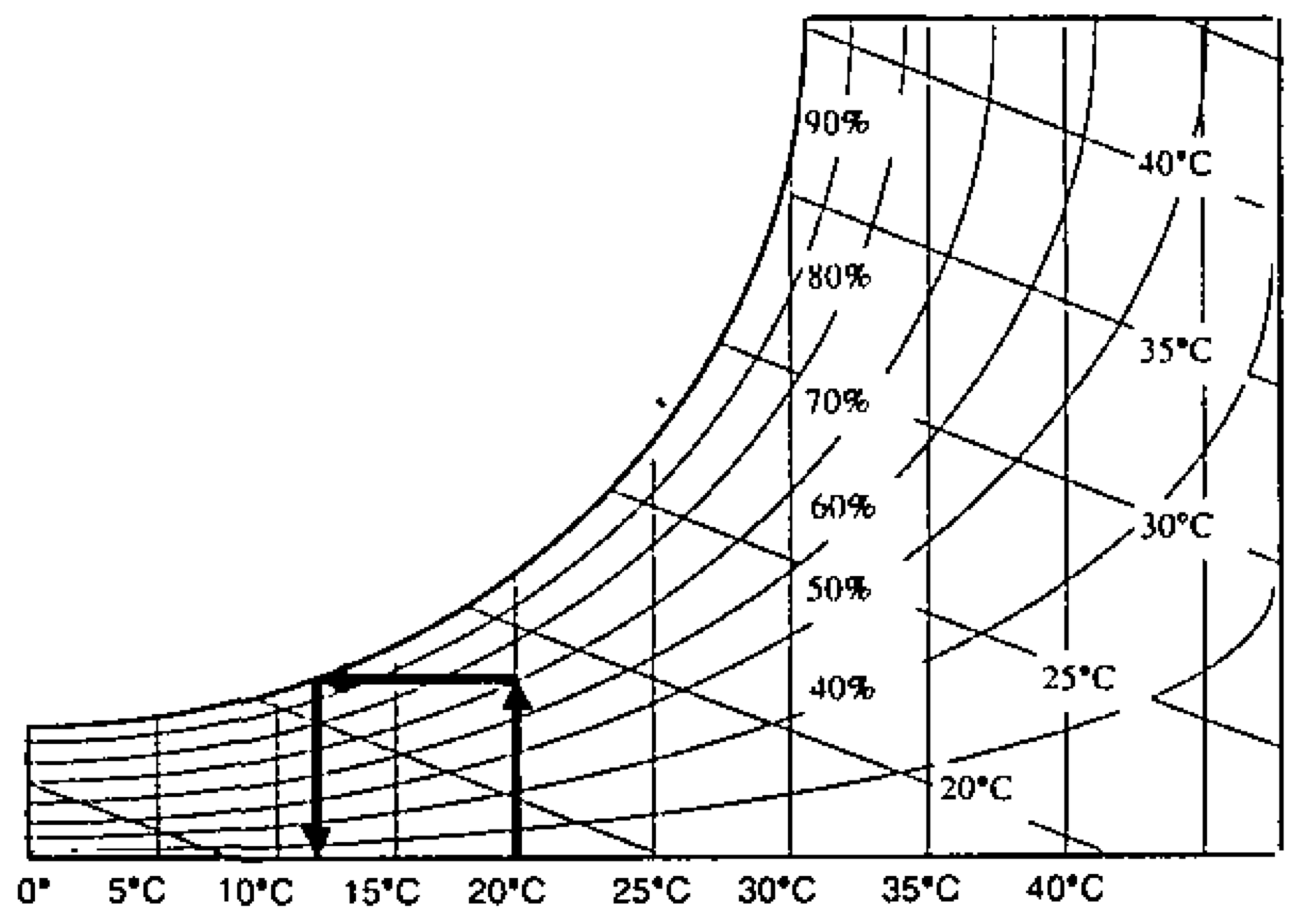
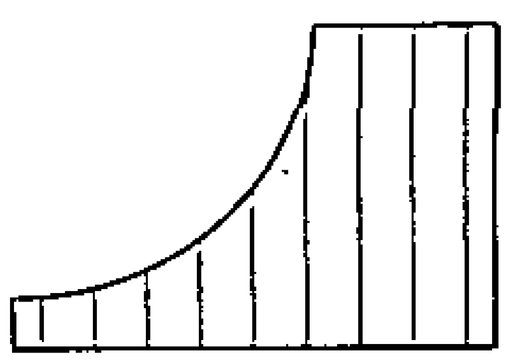
AN INTRODUCTION TO PSYCHROMETRICS

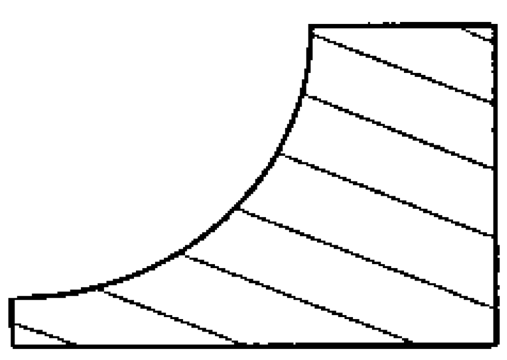
A greenhouse manager cannot maximise control of the greenhouse without some understanding of the relationship between temperature, light, and humidity. This paper will mainly discuss the relationship between temperature and humidity. A good understanding of these processes starts with the psychrometric chart.



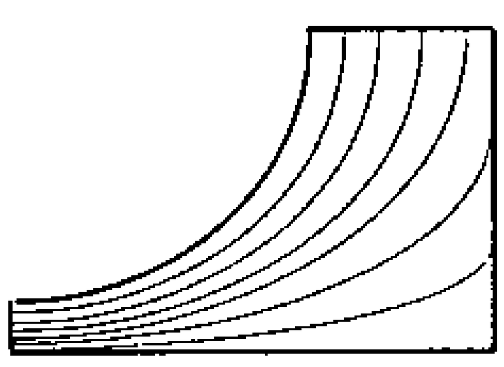
HOW IT WORKS



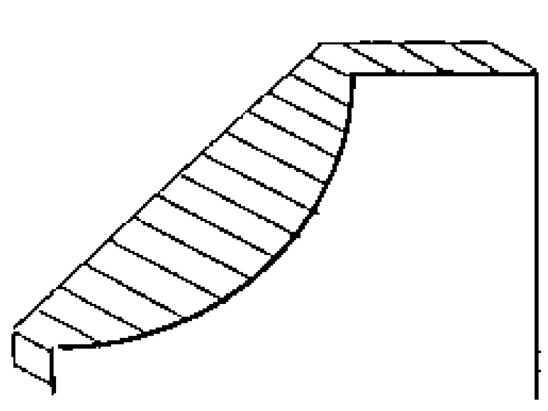
The vertical lines represent the dry bulb temperature (air temperature measured with a dry thermometer).



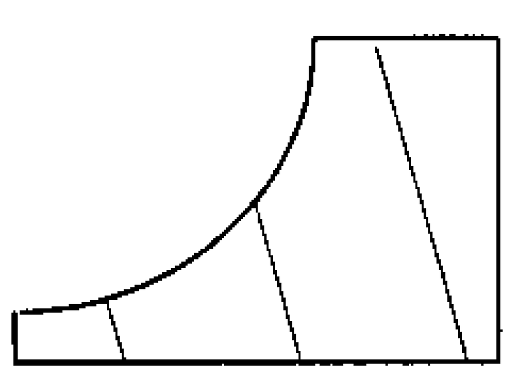
These lines represent the wet bulb temperature (air temperature measured with a thermometer with a wet wick — usually also involves a fan blowing air on the wick to make water evaporate).



The curved lines represent the relative humidity of the air (amount of water vapour in air expressed as a percentage of amount of water vapour in 100% saturated air)



These diagonal lines represent enthalpy (total energy of the air in kilojoules kg^{-1} — used to calculate heat loads in greenhouses, especially when sizing heaters and refrigerative coolers)

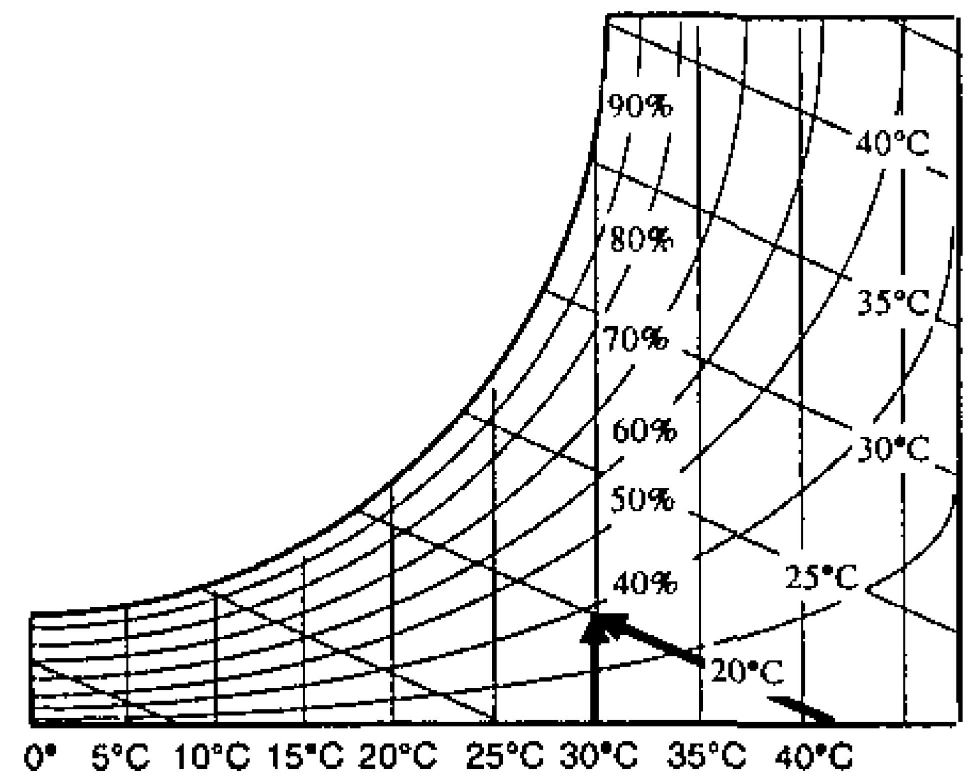


These lines represent the specific volume (volume of air in m^3 kg^{-1} of air — used to calculate mass of air in greenhouse)

The psychrometric chart can be used in the greenhouse for many purposes.

CALCULATING RELATIVE HUMIDITY (RH)

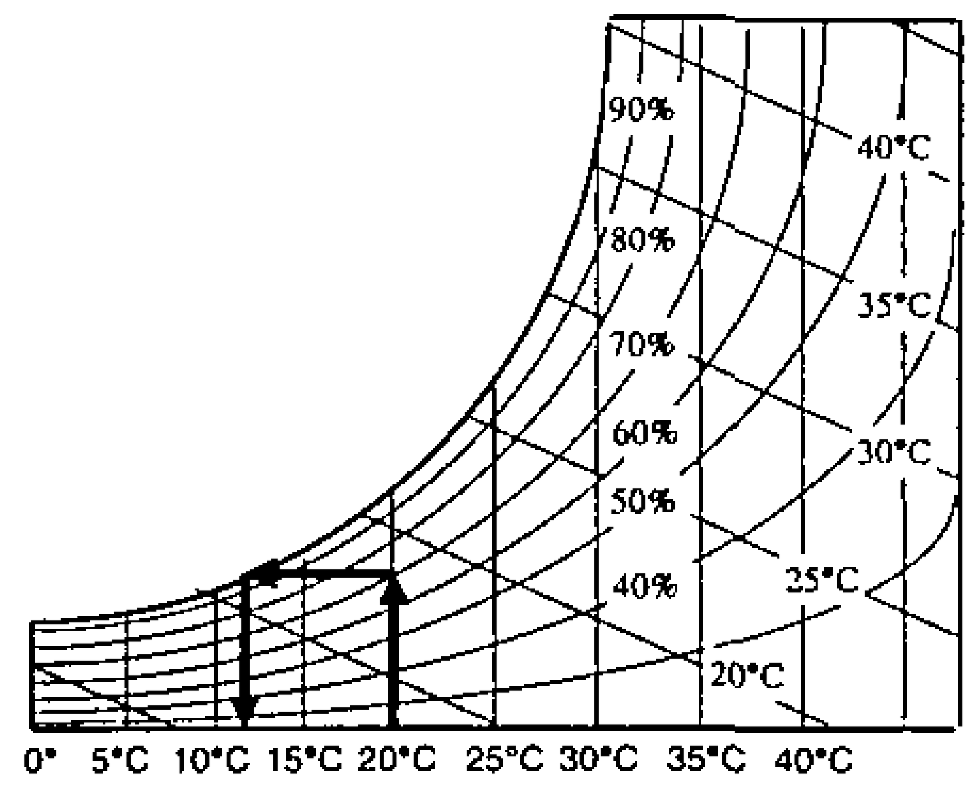
The grower can purchase several types of hand-held RH meters, but if one is not available, a fairly accurate measurement can be taken by taking the temperature in the greenhouse (dry bulb) and then taking the wet bulb temperature. To do this, set up a thermometer with a wet shoelace over the mercury reservoir, with the other end of the shoelace dipped into a small container of water. A small fan should be set up, blowing air onto the shoelace. The wet bulb thermometer should always read lower than the dry bulb thermometer.



If the dry bulb temperature is 30C and the wet bulb temperature is 20C, find the point where the vertical dry bulb temp line intersects with the wet bulb temp line. The nearest curved relative humidity line will indicate the relative humidity in the greenhouse. In this case, the indicated relative humidity is just under 40%.

CALCULATING DEWPOINT TEMPERATURE

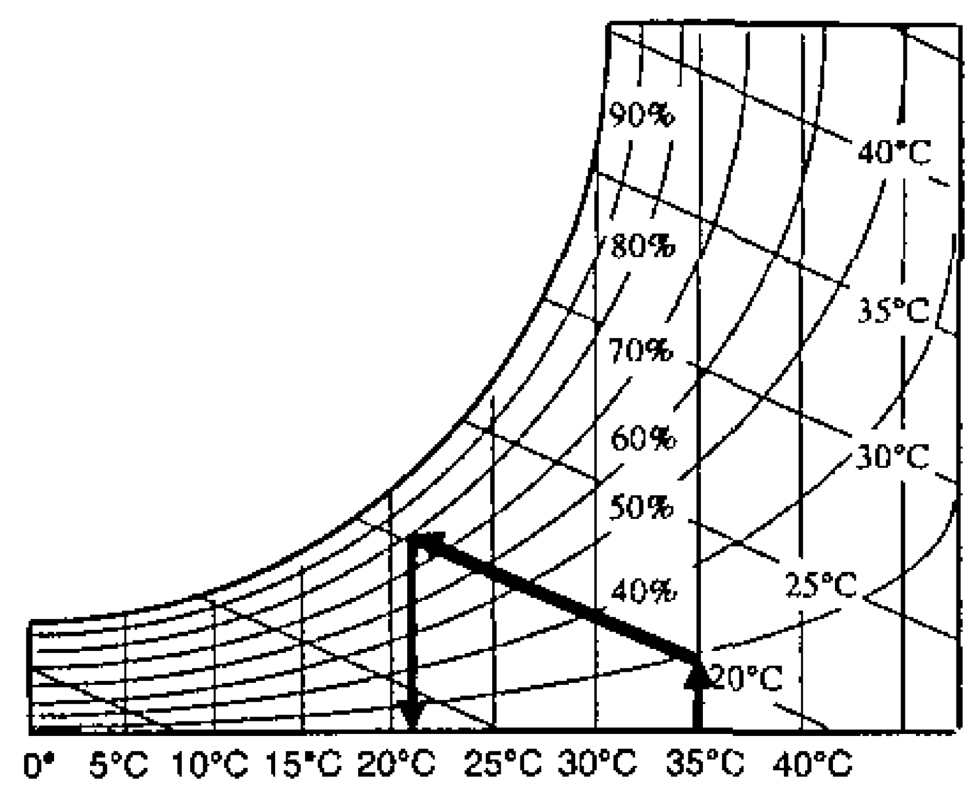
Given a starting temperature and humidity, it is possible to find out at what temperature the air will become saturated (100% relative humidity). This is called the dewpoint temperature and it is a greenhouse condition to be avoided.



If the air temperature is 20C and at 70% RH, go to that point on the chart and draw a horizontal line to the 100% saturation line. From there, draw another line directly down and this is the dewpoint temperature.

CALCULATING COOLING SYSTEMS

It is also possible to calculate the effect of cooling the greenhouse by adding water vapour to the air.

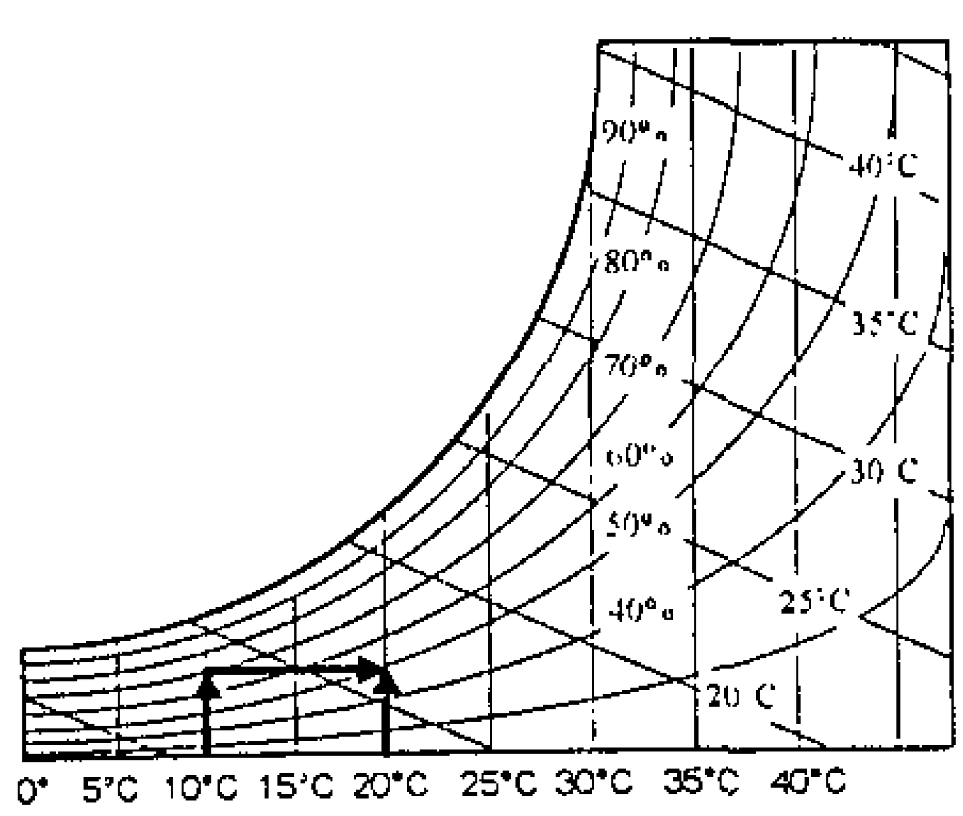


If the starting conditions are 35C at 20% RH and the aim is to cool the greenhouse as much as possible without exceeding 80% RH, draw a line from that starting position, parallel to the wet bulb lines until it intersects the 80% RH curve. Draw another line down from there to indicate the temperature that the greenhouse would then be. In this case it is about 21C — a 14C drop in temperature.

From the same chart, it is also possible to determine how much water would be required to cause that drop in temperature so that a fogging system could be designed to perform the task.

CALCULATING HEATING SYSTEMS

Using the psychrometric chart it is also possible to calculate the effect on humidity of heating the greenhouse air. Heater size can also be calculated.



If the greenhouse starts at 10C and 70% relative humidity and the greenhouse is to be heated to 20C, to find the final relative humidity, draw a line from 10C at 70% RH, horizontally until it hits the 20C vertical line. The nearest curved relative humidity line indicates that the humidity drops to 50%.

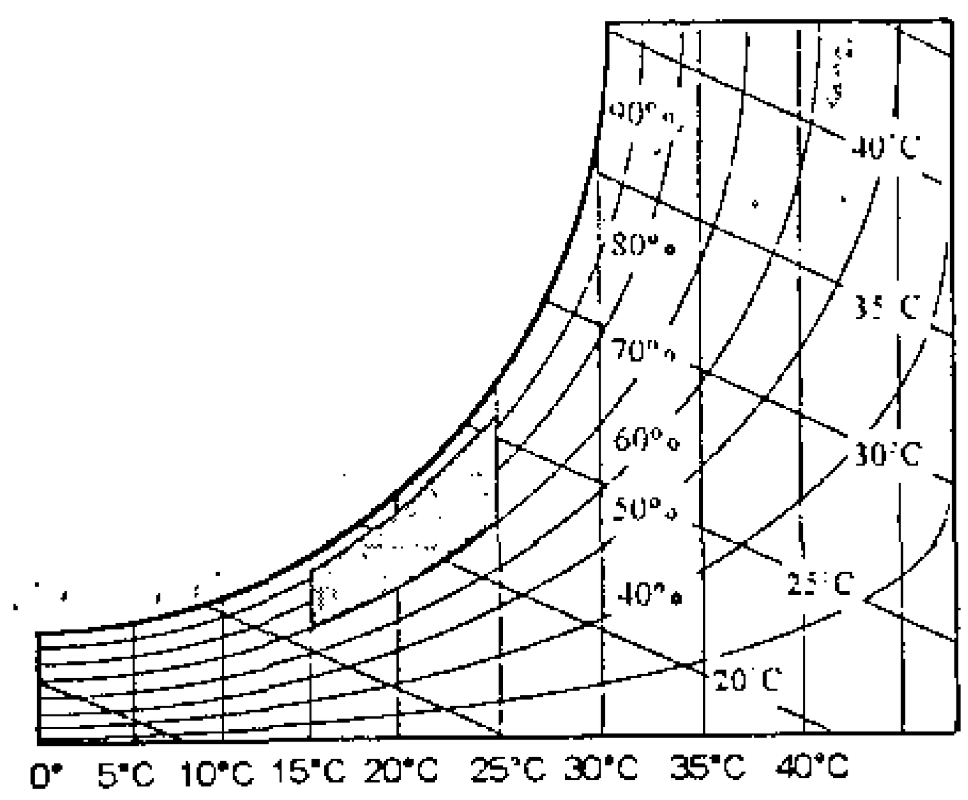
The heater size can be calculated by the change in enthalpy, but the calculations are too complex for the purpose of this paper.

The calculation of refrigerative cooling (air conditioning) can also be done, but with the horizontal line moving from right to left instead of left to right.

NOTE: These representations of psychrometric charts are not to scale.

SUMMARY

One of the most important aspects of successful propagation is maintaining a low-stress environment for the cuttings or young seedlings. For many crops there is a very small 'window' of temperature and humidity ranges, as depicted in the chart — between 15 to 25C and between 70% to 95% relative humidity.



Keeping the greenhouse environment within that window can be very difficult and requires good equipment and good management.

I hope that this paper helps with the implementation of both.

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Oak Seedling Propagation in Plug Containers

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I have had a long-term interest in the development of techniques for propagating plantation tree species in containers. A factor commonly mentioned as a reason why shallow containers are unsuitable for tree seedling propagation is that tree seedlings produce a long tap root shortly after germination. Pruning this tap root is commonly considered to be detrimental to the plant.

As is obvious from the many millions of containerised plantation tree species propagated in shallow containers every year, pruning the tap root of these species has no obvious detrimental effect on either the root system or the overall health of the plants. However, oaks and other species with similar nut-type seeds are commonly considered difficult to propagate or totally unsuited to container propagation.

Fresh acorns of English and Turkey oaks (*Quercus robur* and *Q. cerris*) were collected and sown immediately into a peat substrate in Lannen Plantek 64F cell containers with side slots for air root-pruning. The cells of these containers are 46 mm × 46 mm × 73 mm. The acorns were placed flat, diagonally across the top of the cells. Seeds were deliberately not pregerminated because of potential root defects caused by this practice (Whitcomb, 1988). Normal air root-pruning at the base of the cells was achieved by suspending the trays on a metal bench to allow free air movement below the cells. Water was applied as required.

Six months from sowing, the seedlings were healthy and thriving. Inspection of the base of the cells showed some of the roots had curled slightly around the cross piece at the bottom of the cell. All pruned roots had a thickened callus at the pruned end. The seedlings were not easily extracted without disrupting the root plug as the roots had not yet fully colonised the plug volume. Exposing the roots showed that lateral roots had begun branching from the primary root and no root defects were noted. The very thick radicle emerging from the acorn had been successfully air-pruned.

Nine months after sowing, the seedlings were easily extracted from the cells without disrupting the root plugs (Fig. 1). Exposing the roots showed a nicely consolidated root plug made up of many lateral roots, both primary and higher order, with no apparent distortion of the root system. The callus at the pruned tip of the radicle had disappeared, or was easily rubbed off.

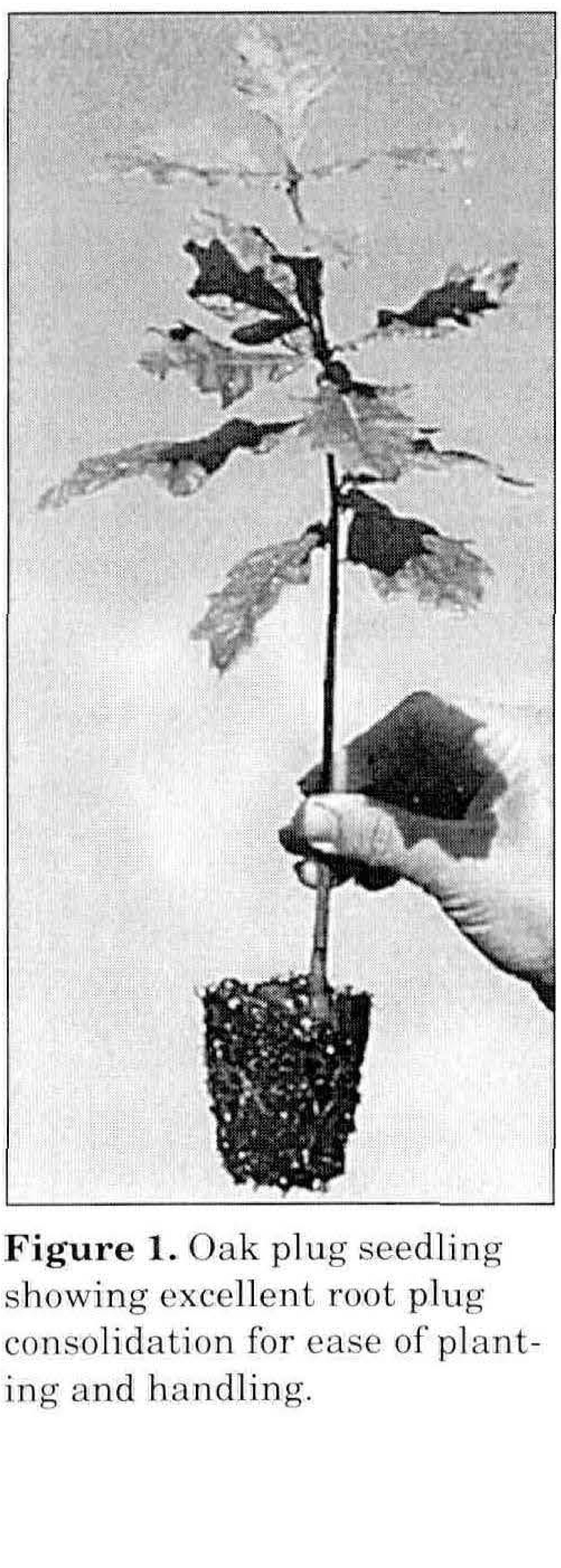

Figure 1. Oak plug seedling showing excellent root plug consolidation for ease of planting and handling.

Some seedlings were plugged out into larger containers where they continued to grow the following spring, showing no adverse effects of their early germination treatment. Investigation of these roots after a further summer's growth showed no root distortion and good lateral root extension from the root plug at all levels.

This experience demonstrated to me that oaks could be easily propagated in a plug tray. There are a number of distinct benefits to germinating oaks under controlled nursery conditions in plug containers (Krautman, 1995). The plug method is more likely to be used as an early stage of propagation rather than for producing field-ready plants. Research conducted elsewhere tends to emphasise the need for large-sized transplants of oak species for survival and early field growth (Zaczek et al., 1995; Burgess et al., 1996).

Why does this form of root-pruning work? Possibly it is because of a physiological change induced in the root tip before the air-pruning occurs. Physical pruning would not allow any physiological conditioning of the root system prior to pruning. The development of a carrot-shaped tap root with essentially no laterals appears to be linked to physical removal of the tap-root apex close to the cotyledons. I have seen this occurring in many species, including various *Pinus* and *Eucalyptus* species after pricking out.

The key to successful oak plug propagation appears to be to sow only fresh seed, ensure early pruning of the tap root by gentle means, and continue this root pruning for a few months after germination to ensure formation of a fibrous root plug consisting of a tap root and many laterals. Gentle pruning of roots means a gradual process, not the sudden removal of large parts of the root system. Fertilisation during this plug phase of growth is not necessary as the seed reserves are adequate for normal shoot growth.

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Horticulture Training for the Nursery Industry

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The Horticulture Industry Training Organisation was set up in 1992 and as a leader in the Skill NZ strategy was part of a group of four, ironically named, early harvest Industry Training Organisations. Our ITO represents all sectors of Horticulture, including production sectors like fruit, nursery, and vegetable; but also service sectors like amenity and landscape. The nursery sector has been represented on the ITO from the outset (and still is) by the current President of the Nursery and Garden Industry Association, Mark Dean. I mention this because it is important to realise that the ITO is a nonprofit incorporated society owned and operated by the horticulture industry through sector organisations such as NGIA.

To date our ITO has built training numbers to 760 apprentices in 10 sectors and we are aiming for 850 people in our mixed on- and off-job training programmes by the end of this year (1997).

Three Hundred unit standards, Ten National Certificates, and a National Diploma of Horticulture have been established by the ITO on the NZ Qualifications Authority National Qualifications Framework for horticulture learners. More recently 20 credit traineeship taster programmes have been introduced for employers and employees alike.

The ITO has also trained in excess of 600 industry people in occupational safety and health compliance procedures through our one day "Health and Safety in Horticulture" programme.

All our workplace assessors undertake a thorough training programme with the ITO before they can assess apprentices for competency credits in horticulture unit standards.

The Horticulture ITO is seen by the relevant government agencies as a leader among the 52 industry training organisations that have been established and we have certainly made more rapid progress than most. The competency-based training reforms which the NZ Qualifications Authority and ITOs have been implementing over the last 4 to 5 years are not without the usual detractors and I am sure some of you will have heard from this vocal minority who are always present in times of substantial change. Regardless of this negativity, which often arises from vested interests, the programme is succeeding in many industries. In horticulture this ITO is expanding and in August will introduce a new programme for the forest nursery industry.

Before I finish I would like to leave you with two things to consider:

Firstly, New Zealand's competitive advantage will increasingly depend on the human resources it has and the quality and flexibility of the training programmes that those people have access to. The Skill NZ programme now has over 35,000 people across the majority of our industries in structured training programmes, the highest number of apprentices and industry trainees in formalised training ever in this country's history.

That is a major turn around from the situation which existed with less than 12,000 people in training at the end of the 1980s.

The second thought I will leave you with is this:

Employers sometimes say to me about becoming involved in the training programme. "What if I go to the time and expense of training someone and they leave?" My reply is always. "What if you don't train them and they stay?"

Containerized Forestry Seedling Production from a Historical Perspective

Stellan Karlsson
Forest Nursery Specialist, BCC AB/Arbos, Sweden

The following is a subjective report based on discussions and meetings with nurserymen and researchers around the world, scientific reports and my own experiences.

The North American Indians were probably among the first container growers in the world. They used small fish as containers which they threaded on a rope and hung between two trees. They put a seed in the throat, germinated it and let the seedling grow as long as nutrients and moisture were available in the "container".

Containerized nursery production systems have evolved during the past 50 years from simple tar paper pots used in the 1930s, plastic bags used in the 1950s, to the wide variety of rigid-walled containers in use today. In the beginning the containers were placed on the ground and very poor growing media was used, often topsoils or mixes with very low air-filled porosity. This resulted in a lot of problems with pathogenic fungi causing damping off and root dieback. It also resulted in very poor field performance with low survival and bad establishment.

Dividing up the "container growing history" in 15-year periods can look like the following:

1950 - 1965

A period of trial and error with quite low success according to field performance. The containers were mainly made of different types of paper during this time.

1965 - 1980

The breakthrough for containerized production came during the mid 1960s when countries like Canada, Sweden, and Finland received the system. Paper pots, hard plastic multi and single pots, and in the beginning of the 1970s even styrofoam trays were used in large-scale forest seedling production. The outer dimension of the trays differed depending on whether the seedlings would be shipped directly in the tray or extracted in the nursery and shipped in paper boxes. Characteristic to all these tray models were small drainage holes in the bottom and no ribs on the inside walls. This design of course, with todays knowledge, caused problems with root spiralling. It also caused continued problems with root diseases even if the growing media were improved and peat-based substrates used. Some nurseries alleviated this problem by using frames or table systems for the trays. This step also made air pruning in the bottom of the container possible. Fertilizing regimes were not developed during this period and inappropriate bareroot regimes were adopted which caused prob-

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This led to the next "historical" period.

1980 - 1995

The characteristics for the new models were guiding ribs and increased drainage area in the bottom. The most commonly used material for trays was hard plastic (multi and single pots) and styrofoam trays. The use of paper pots decreased during this period. Several countries around the world received the container system for large-scale, forest-seedling production and in some countries even programs for cutting propagation were developed. It was also a time when results from biological research were applied and programs for fertilization, spraying, storage, and night-length regulation were formed. Chemical root-pruning, like copper-treated trays, became very popular in Canada and the U.S.A. and are still today the most used systems in both countries. The first trays with open sides were developed during this time but they were designed for mechanical root-pruning. The criticism and fear of root deformations continued loudly and resulted in the first scientific reports. These reports were based on results from the first generation trays and showed reduced stability in container-grown trees planted in high altitude and cold soil plantations. In the beginning of the 1990s the development of new tray models increased and resulted in air-pruning containers with vertical slits for stimulation of lateral pruning.

1995 - 2010

Containerized seedling production increases around the world and new countries are adopting the concept, which also means new scientists with fresh ideas will be involved in the development. Air-pruning trays have probably come to stay if the problem with root bridging can be handled in a proper way. This new container system needs good air circulation otherwise it has to be mechanically pruned which is a costly operation. Whether continued use of chemicals for root pruning will be acceptable in the future is a question for politicians. Environmental movements are growing strong today all over the world and politicians have to take this into consideration when making decisions. A good example is the case of the Spotted Owl on the American West Coast. Environmental considerations also advocate hard plastic containers which can be used in production for several years and then recycled in a new moulding process. An interesting alternative in the future could be compressed peat or woodfibre containers if the costs for this system could be kept low.

Finally, I would like to end this presentation with a warning. After 20 years in the seedling growing business there is still one point which concerns me and that is the tendency, all over the world, to grow the container seedlings to the size of a bare-root seedling in a density which is at least five times higher. We must remember that container seedlings are fresh goods and actually need a "best before date".

If we continue to grow the seedlings too long in the container without respect for the seasonal root growth periods, we will surely deform roots irrespective of what kind of container system we are using, in the same manner as the bound feet of upper class women of many Chinese dynasties.

A Review of Factors Influencing Container-media Temperatures

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INTRODUCTION

Temperature is the main environmental factor determining the release period of encapsulated controlled-release fertilisers (CRFs). Therefore, an understanding of container media temperatures is important to the nursery grower. The aim of this work is to review the factors influencing container media temperature, its effect on plant growth, and to try to establish to what degree various parameters influence the relationship between air and container media temperature. Such an understanding will hopefully allow a more accurate prediction to be made as to container media temperatures based on air temperatures. The latter are more readily recorded and would consequently assist in the estimation of the longevity of CRFs.

FERTILISER RELEASE

Factors such as pH, microbial activity, and moisture levels in growing media have little affect on the rate of nutrient release from a given encapsulated CRF formulation (Sharma, 1979). Different formulations depend on variations in the capsule thickness to provide varying release rates (Rutten, 1980), so that the grower can produce containerised plants for specific periods. The nursery person uses the growing times provided by the manufacturers for each formulation and so a short-term crop may utilise a 3- to 4-month or 100-day material. This nutrient release period is based on a given temperature for each CRF formulation, e.g., 21C for Osmocote and Multicote, and 25C for Nutricote (Lamont et al., 1987; Anon, 1991). Additional information on release periods may be given for other temperatures, e.g., 8-9 month Osmocote will last 10 months at 16C (McPherson, 1994). A local knowledge of media temperatures is therefore important for making use of the advantages of CRFs and to assist in decisions such as when to apply a side dressing. Hicklenton and Cairns (1992) have voiced concern at the way Nutricote recommendations in the U.S.A. tend to be highly generalised and lack specific recommendations for woody ornamentals. Conover and Poole (1987) also point out that release curves developed by manufacturers of Osmocote tend to disregard plant and soil factors in their evaluations.

FACTORS INFLUENCING MEDIA TEMPERATURES

Maximum media temperatures in black polythene bags have been recorded at 49.5C in Auckland, New Zealand (Young and Hammett, 1980). Similarly daily media temperatures can be >40C for up to 6 h and 50C for up to 2 h in Southern U.S.A., and have been recorded as high as 57C adjacent to the container wall (Ingram, 1981; Martin and Ingram, 1988). These temperatures are not necessarily uniform within the pot and will tend to be highest on the east side in the morning and the west side after midday (Ingram et al., 1988). Martin and Ingram (1993) refined this further by showing that the highest temperatures at these two positions on the container walls also tend to be halfway down the profile, regardless of container height (20 to 50 cm) or volume (10 to 70 litres). High temperatures are most likely to occur in black containers where there is high solar radiation. Pot colours that are most similar to black, with its potential to absorb radiation, are most likely to promote the highest media temperature.

MEDIA TEMPERATURE EFFECTS

Of greatest interest here is the fact that high temperatures will influence nutrient release from CRFs. Worrall (1981) found that nutrient release rate from encapsulated fertilisers increases dramatically with temperatures exceeding 35C and concluded that this may occur with surface application. It has also been stated that nitrification can be inhibited resulting in high ammonium-to-nitrate ratios in media (Walden and Wright, 1995). Johnson and Ingram (1984) found that the nutrition of plants was changed at 40C and resulted in reduced K, Fe, and Zn tissue levels but increased N uptake.

Conover and Poole (1985) reported on the effect of full sun (in Florida) on media containing Osmocote having 21 or 32C release curves. Plants with these sources showed that none of the formulations were acceptable unless given 63% shade. In further work by these authors, they state that rapid release of nutrients and possible plant damage may not be as temperature dependent as suspected, and can be strongly influenced by plant size at time of application (Conover and Poole, 1987).

The important end result of high root temperatures is that plant growth will be suppressed as a result of direct as well as indirect temperature effects. Ingram et al. (1986), for example, found that a 40C root temperature regime reduced root growth and increased the shoot-to-root ratio in different species. Keever and Cobb (1984) studied the effect of two pot colours and types of mulch placed on the ground. They found that plants in black pots with a white mulch developed the greatest winter foliage discolouration and leaf abscission and that wide pot spacings (30 cm) were also detrimental.

Much research has shown that root and often shoot growth of container-grown plants subjected to high root zone temperatures is reduced. Spiers (1995) working with two species of blueberry showed that all plants demonstrated a negative linear response to these high temperatures. He found that root and shoot growth were best at 16C and that the two species responded favourably to cultural practices that lower soil temperatures during the summer. Blueberries, like many other plants, have fine shallow roots and there are probably many other plant species that are especially sensitive to high media temperatures. Ingram et al. (1988) conclude that heat injury to roots may result in visual symptoms of water stress, nutrient deficiencies, or lack of vigour. The causal agent of these observed symptoms may primarily be heat stress. These workers showed that the symptoms can be quite strongly influenced by container spacing and that plants at 30-cm centered spacings put on new growth 2 to 3 weeks later than others at closer spacings.

In summary, media temperatures can be influenced by many factors which alter the amount of solar radiation absorbed. Surface covering, container orientation, volume, colour, spacing, and pattern of placement are examples of these. Temperatures in turn will influence nutrient release from CRFs as well as the direct and indirect influences on plant growth. Martin and Ingram (1992) state that the primary environmental factors causing changes in media temperature patterns are solar radiation, wind, temperature, and absolute air humidity. They went on to develop a computer model to simulate the thermal environment in a container. Other factors involved are the differing thermal properties of media and the influence of media water levels (Parikh et al., 1979).

RECORDINGS AT LINCOLN UNIVERSITY

Three studies were carried out to examine media temperature levels in containers. In each study the probes were inserted into the centre of the media of pots with the measuring tip 85 mm below the surface. Air temperature was measured at 1.8 m in an aspirated radiation shield. Temperatures were recorded at 5-min intervals.

Study 1. Media (peat and perlite [1 : 1, v/v]) temperatures of pots containing *Schlumbergera* plants in 2.5-litre (175 mm diameter) brown plastic pots on a 1-m high bench, in a fibreglass greenhouse, were recorded. The mean readings for three media probes, and air temperatures, plus the total hourly solar radiation recorded at a nearby weather station, are shown in Fig. 1. This demonstrated a lag period between media and air temperatures. Another notable aspect was that the air temperatures overnight were 2 to 3C higher than the media figures. This was thought to be due to temperature stratification in the greenhouse at different heights. The air temperatures were recorded at 0.8 m higher than the pot probes. There was on this late winter day quite low solar radiation. This in part was due to the somewhat opaque nature of the fibreglass cladding of the greenhouse. When the sun rose to its highest at noon it caused a peak in the air temperature and a more rounded rise in media temperature which followed. Air and media temperatures also showed a subsequent fall after the solar radiation had declined.

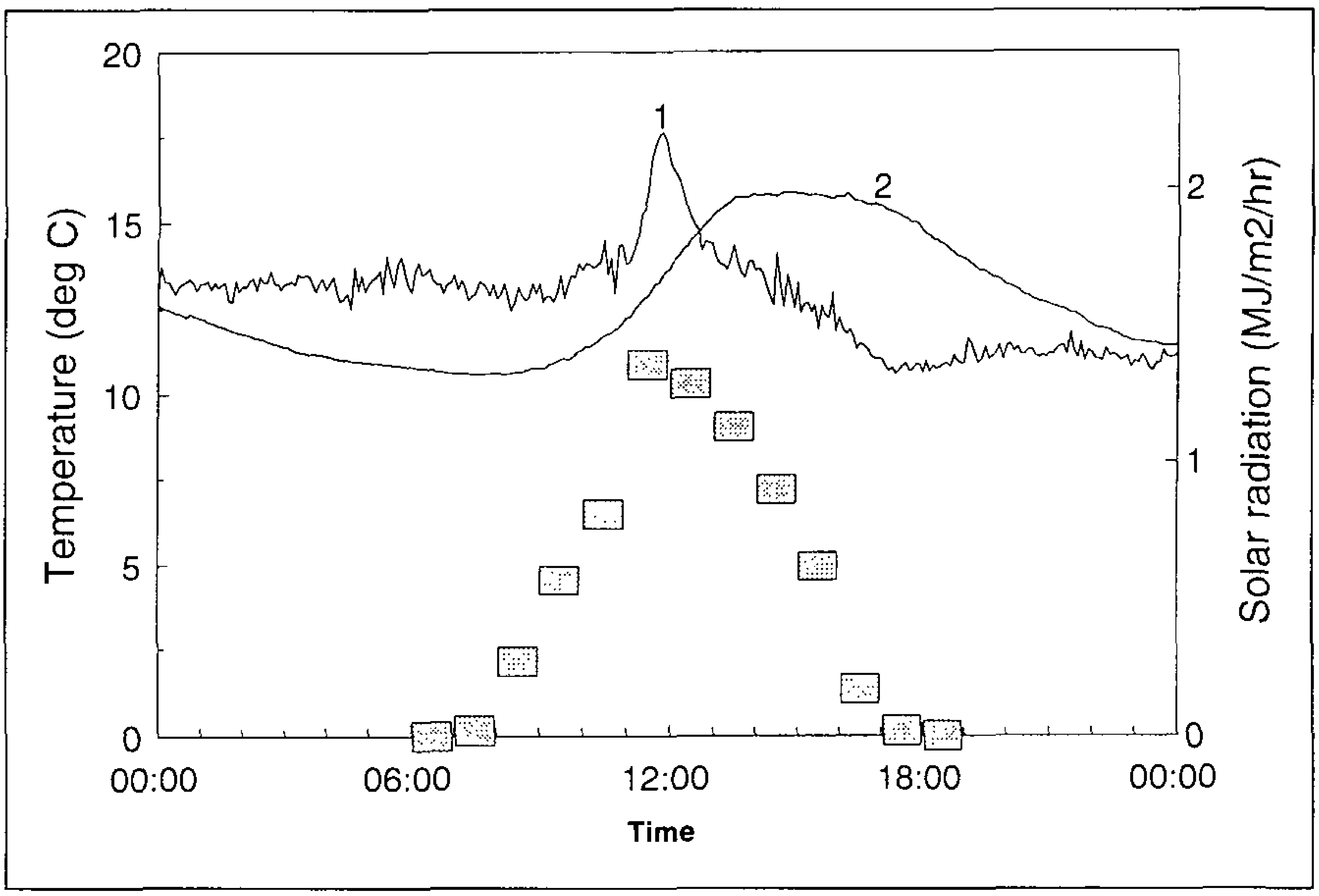

Figure 1. Air temperature (1) and mean media temperatures (2) in a greenhouse and solar radiation (shaded) on 14 August.

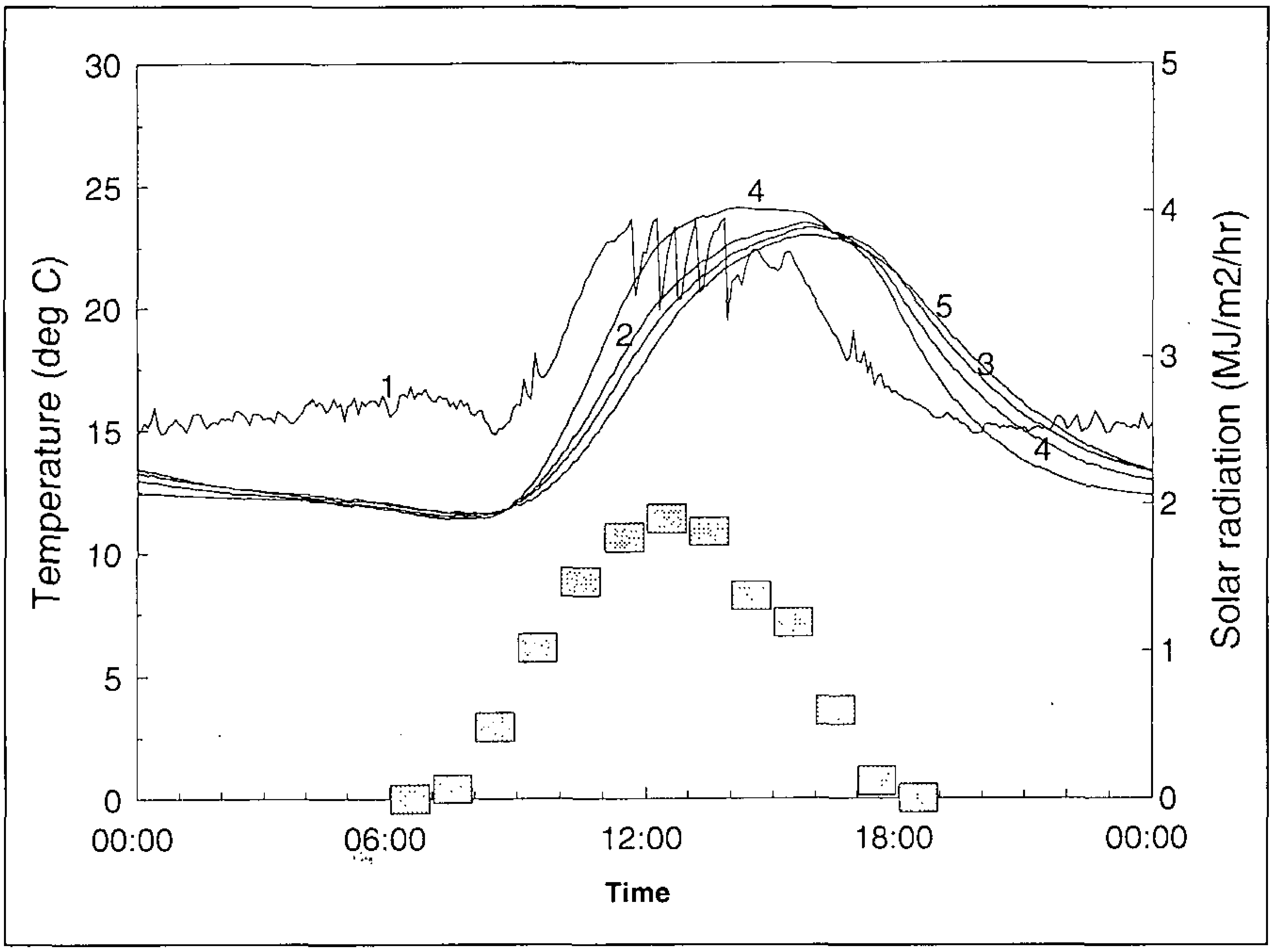

Figure 2. Air temperature (1), and media temperatures (2) bark and sand [4 : 1, v/v], 1.5 litre, 100%WHC; (3) peat and perlite [1 : 1, v/v] 1.5 litre, 100% WHC; (4) peat and perlite [1 : 1, v/v] 1.5 litre, 50% WHC; (5) peat and perlite [1 : 1, v/v] 5 litre, 50% WHC in a greenhouse and solar radiation (shaded) on 19 August.

Study 2. Probes were inserted into five plastic pots as stated in Study 1. In this case the difference was that they contained no plants and had different media, colours, moisture levels, and pot sizes.

Figure 2 depicts the influence of different media, moisture levels, and pot sizes in a greenhouse environment. The influence of the lifting-ridge ventilation system is shown quite dramatically when the air temperature reached a maximum of close to 24C. There was a sudden drop in temperature with cool air replacing hot air. The peat and perlite (1 : 1, v/v) medium heated up most rapidly, especially when at 50% water holding capacity (WHC). The other three treatments appeared similar; namely a larger pot (5 litre instead of 1.5 litre) containing the same medium, bark and sand (b/s) (4 : 1, v/v), and peat and perlite at 100% WHC were all slower to warm up and slower to cool down than the 50% WHC peat and perlite (p/p) (1 : 1, v/v).

The mean figures for the seven days (24-h periods) starting midnight of 16 August were:

Medium	WHC	Pot Volume (litre)	Pot Colour	Temperature (C)
air	-	-	-	17.6
b/s	100%	1.5	black	16.2
p/p	100%	1.5	black	16.3
p/p	50%	5.0	black	16.3
p/p	50%	1.5	black	16.3
p/p	50%	1.5	brown	16.2

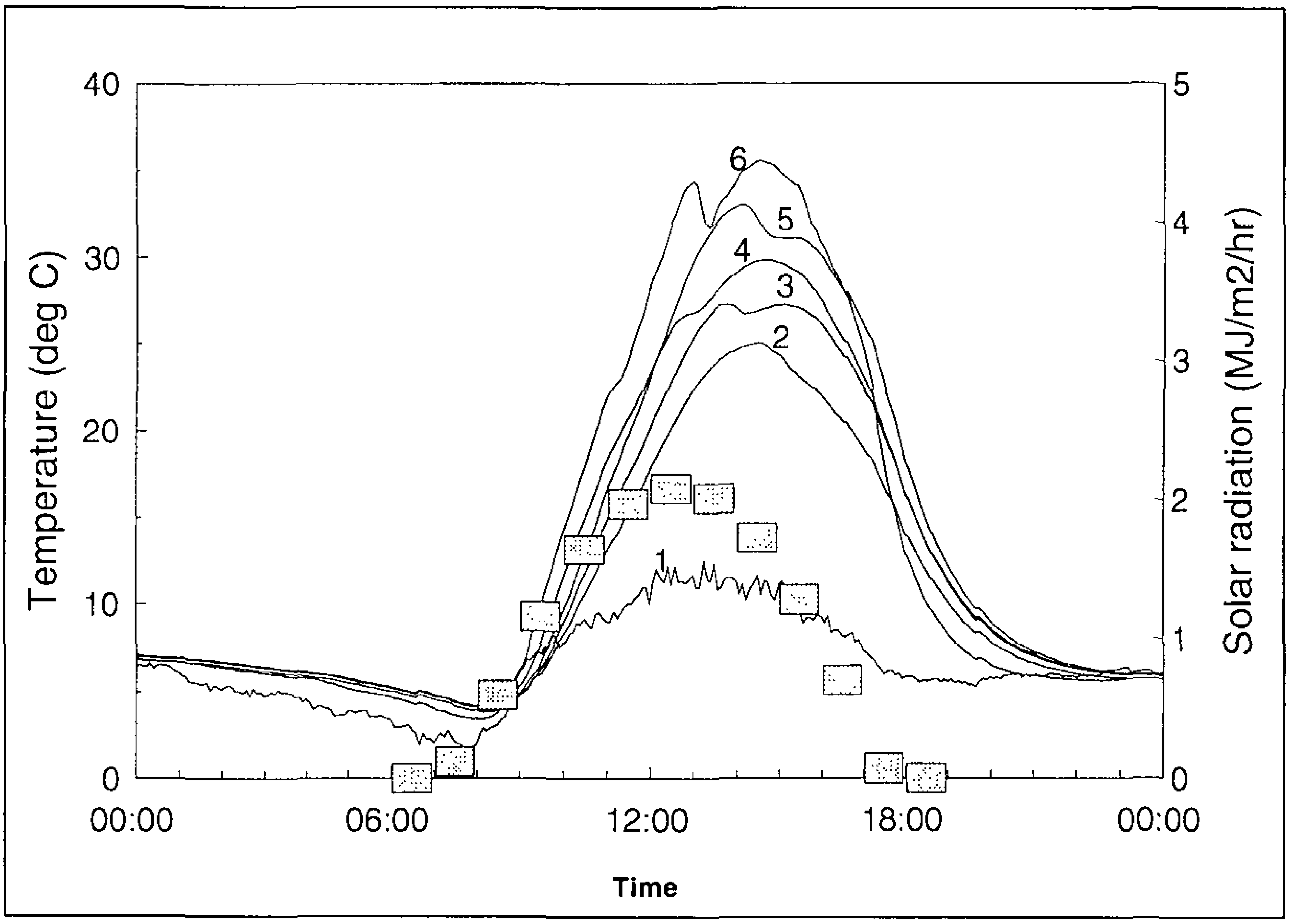

Figure 3. Air temperature (1) and media temperatures in different coloured pots (2) light blue 2.5 litre; (3) brown 2.5 litre; (4) green 2.5 litre; (5) black 2.5 litre; (6) black 1.5 litre outside, and solar radiation (shaded) on 26 August.

The means over these seven days were very similar for all of the pots showing that although some pots increased in temperature more rapidly than others, this was compensated for by faster cooling. The air temperature mean was 1.4C above the media but this may be accounted for by temperature stratification within the greenhouse as discussed earlier.

Study 3. Five pots were again used but they were placed outside on the north end of the greenhouse. They were all 2.5-litre (except for one 1.5-litre black pot) plastic pots and different colours (as shown in Fig. 3). The pots all contained peat and perlite (1:1, v/v) at 50% WHC and were placed 10 cm apart, running east to west, on a 1-m high bench. An additional pot was placed at both ends of the line to act as a "guard pot". The air temperature was measured at 1.8 m.

Figure 3 shows that colour can have quite a major affect on media temperatures. During the day the 1.5-litre black pot heated up most rapidly followed by the 2.5-litre black pot. Media in the dark green, brown (terracotta), and finally the light blue pots reached their maximum temperatures between 2 and 3 PM on this winter day (26 August). The maximum for the small black pot was 10C higher than that of the light blue pot. A dip in the readings towards the peak of the curves is thought to be a small pole which would have given temporary shading. It is also noteworthy that outside in the sun the media temperatures rose between 12.5 and 22.5C above the air temperature. Hourly solar radiation figures have also been plotted on the graph and they confirm the importance of the sun's radiation in heating the pots and media.

The mean temperatures recorded over the 4 days from midnight August 23 were:

Pot colour	Volume (litres)	Temp. (C)
Light blue	2.5	10.9
Green	2.5	12.5
Brown	2.5	11.7
Black	2.5	12.7
Black	1.5	12.6
Air		8.1

Media temperatures for pots outside were much higher than the air temperatures and it was found that colour had a great influence with black pots having the highest mean temperatures.

DISCUSSION AND CONCLUSIONS

In the greenhouse the recorded mean media temperatures were very similar to the air temperature. It appeared that the nature of the media (ingredients and WHC) and pots (volume and colour) had only a small effect on the media temperatures. The greenhouse had a moderating effect on the media temperatures because of the relatively low light levels (approximately 50% of solar light transmittance) experienced. It can therefore be concluded that where solar radiation is low, for example, because of the opaque nature of a cladding material or the application of heavy shading, it is probable that the greenhouse air temperature will give a close indication of media temperatures.

Under these circumstances the media and pot characteristics will have little effect. This would be particularly so when natural solar radiation is lower from late autumn to early spring. From this it would appear that under these conditions recorded air temperatures should give an indication as to the likely nutrient release period of an encapsulated CRF.

In the outside area there were much greater extremes and in fact the air temperature mean was 2.8 to 4.6C lower than the various pot colours. This difference is accentuated by the clear exposure of the pots to solar radiation and compounded further by pot colours which absorb heat to varying degrees. This would be maximised in mid summer in sunny locations and tropical climates or perhaps in an unshaded greenhouse with clear cladding.

The observations carried out at Lincoln University confirm that there can be quite large variations in temperature between pots. Solar radiation is the major factor inducing high media temperatures and it was demonstrated that this influence can even occur in late winter in Canterbury. This is especially likely to occur with black pots. Conversely any form of shading, close spacing, and the use of light coloured pots, all tend to minimise these problems and benefit the plants, as suggested by other workers. The recordings at Lincoln University have shown that greenhouse temperatures, under low solar transmittance, can provide a useful guideline but under high solar radiation, air temperature will probably not help in assessing the media temperature and consequently the nutrient-release periods of encapsulated CRFs. Similar studies repeated in summer would help clarify these conclusions.

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Conservation and Recovery of *Cheesemania* 'Chalk Range' an Endangered New Zealand Brassicaceous Plant

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INTRODUCTION

The Marlborough chalk cress *Cheesemania* 'Chalk Range' is a critically endangered New Zealand plant (Cameron et al., 1995). It is a small herb (10 to 15 cm tall, with inflorescences up to 25 cm) and the surviving plants were found on mostly south-facing montane bluffs. The leaves form a single rosette on a large root which extends above the ground giving the plant the appearance of a small palm tree (Anon, 1992). The plant is a monocarpic perennial. It is highly palatable and introduced browsing animals such as goats, possums, sheep, and hares were thought to have eaten the plant to extinction by the 1970s (Anon, 1992).

However, in 1992, 45 chalk cress plants were found clinging to steep bluffs on private land in the Chalk Range in Eastern Marlborough by Department of Conservation staff (Anon, 1992). In March 1992, at the Forest Research Institute (FRI) Rotorua, New Zealand, a propagation programme was initiated, with the aim of testing the viability of field-collected seed and of establishing protocols for in vitro multiplication of plants of diverse genotypes. Subsequently the propagation programme included an investigation into cryopreservation of in-vitro-grown plants and long-term storage of seed.

The importance of cryopreservation of endangered species is that it facilitates the long-term preservation of plants which may produce seed erratically, have threatened natural habitats, and which might have genetic value for crop improvement. Long-term cryopreservation has the potential to preserve a wide range of genotypes for genetic evaluation and intercrossing while using a minimum of space and cost.

MATERIALS AND METHODS

Propagation. Seed capsules were collected from three plants and some of them were sterilised in 270 mg litre^{-1} mercuric chloride with surfactant followed by two rinses in sterile water. Seeds (38) were placed on plant nutrient medium in petri dishes and incubated with a 16-h light (24C), 8-h dark (18C) photoperiod. After 20 weeks seeds were assessed for germination. Plantlets from germinated seeds were transferred to a Murashige and Skoog medium (MS) (Murashige and Skoog, 1962), containing 2 mg litre^{-1} Merck activated charcoal, in 600-ml jars. At 4-weekly intervals, plants were cut into 10-mm nodal segments and placed in fresh medium. Nodal segments with roots were transferred to potting mix in the glasshouse.

Cryopreservation. A cryopreservation experiment was carried out using a vitrification solution designated PVS2 (Sakai et al., 1990; 1991a; 1991b; Yamada et al.,1991). A small number of in-vitro-grown shoots were cut into 3- to 5-mm nodal segments and pretreated for 2 days at 4C on preconditioning media (a modified Quoirin and Lepoivre medium, Horgan, 1987) containing 50 g litre^{-1} glucose or 73 g litre^{-1} sorbitol (0.4 M), with or without 5% dimethylsulphoxide (DMSO). There were 2 to 7 nodal segments per treatment. Following preconditioning, PVS2 was added to nodal segments contained in 2-ml cryopreservation vials. These were cooled in a Nalgene™ Cryo 1C Freezing Container held in a -80C freezer for 1.5 h *prior to immersion in liquid nitrogen (-196C), control segments were removed after* 1.5 h cooling. After 1 week of storage in liquid nitrogen (LN) tissue was thawed rapidly (2 min in a 40C water bath) and PVS2 rinsed from segments with a high osmoticum sucrose solution (340 g litre^{-1}). Nodal segments were placed on MS medium and returned to standard growing conditions. Segments were assessed for growth 4 weeks after thawing.

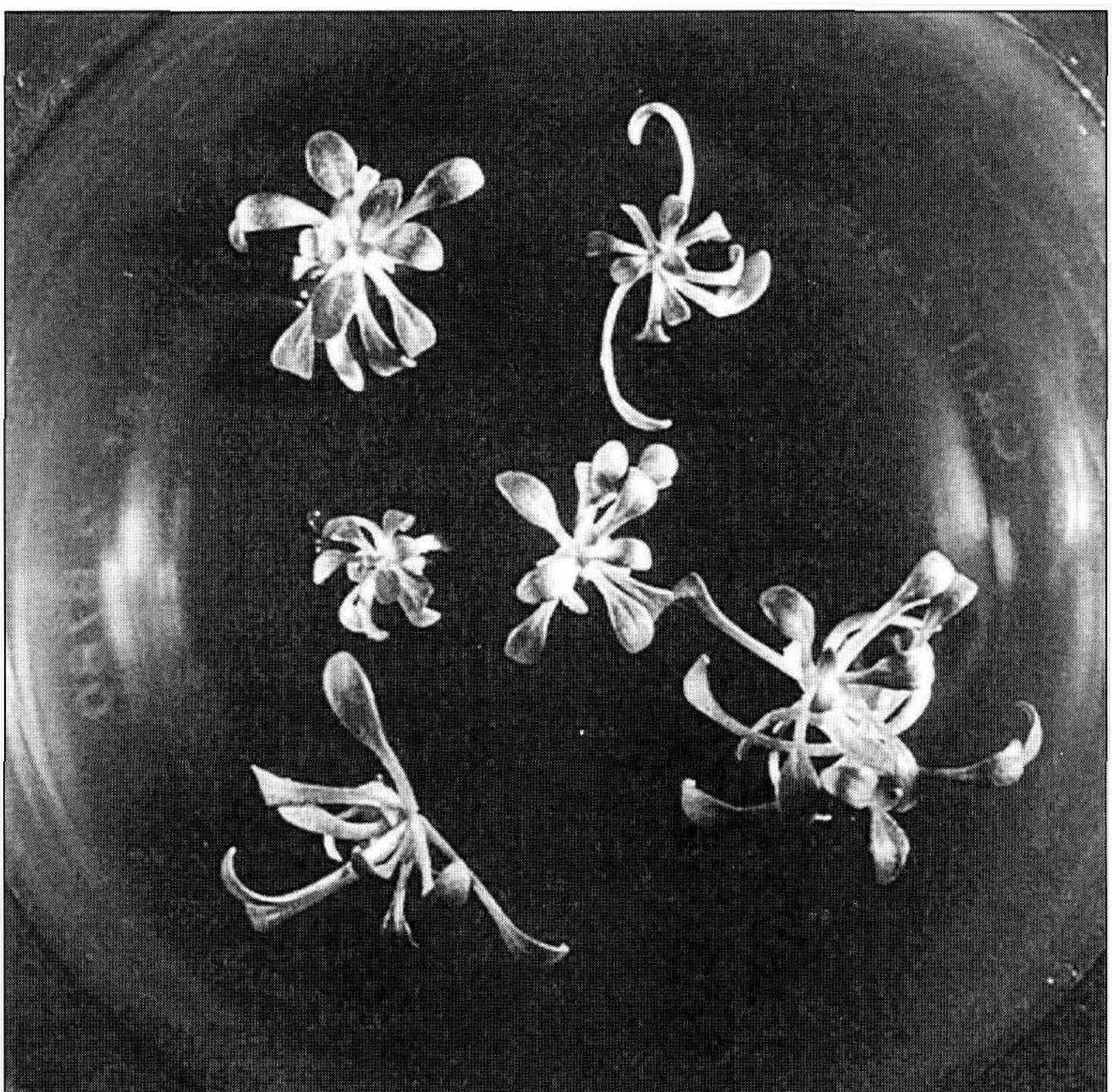

Figure 1. Vigorous shoot cultures of *Cheesemania* 'Chalk Range' on Murashige and Skoog medium.

Seeds which were not sterilised in the initial 1992 germination experiment were stored at 4C. In 1996, these seeds were surface sterilised, placed on medium and assessed for germination at 20 weeks (total of 326 seeds).

RESULTS AND DISCUSSION

Propagation. Chalk cress plants were successfully propagated using the techniques described. The multiplication factor was high with a four-fold amplification per nodal segment possible at each 4-weekly transfer. No contamination was observed at any stage during the in-vitro culture of *Cheesemania* 'Chalk Range'. After 20 weeks 81% of the fresh seed had germinated and shoot cultures established from these were vigorous and subcultured well (Fig. 1). Nodal segments spontaneously produced roots and these plants were transferred to the glasshouse. However, some problems were experienced with both damping-off fungi and white cabbage butterfly and none of the plants survived to produce seed. These problems could be overcome by spraying with fungicide and establishing plants in the glasshouse in winter so that they would be hardened and less palatable to the white cabbage butterfly.

CRYOPRESERVATION

Table 1. Percentage of *Cheesemania* 'Chalk Range' nodal segments showing axillary meristem development 3 to 4 weeks after storage in liquid nitrogen.

Preconditioning Media	(Control) Preculture + PVS2	Preculture + PVS2 + LN
50 g litre^{-1} glucose	100 (2)*	0(7)
50 g litre^{-1} glucose + 5% DMSO	50 (2)	33(6)
73 g litre^{-1} sorbitol	50 (2)	0(6)
73 g litre^{-1} sorbitol + 5% DMSO	50 (2)	17(6)

* Number of nodal segments/treatment

Plants of the chalk cress were successfully regenerated from cryopreserved tissue. Cryopreservation preculture treatments that included 5% DMSO gave up to 33% survival following immersion and storage in liquid nitrogen (Table 1). No survival was observed in nodal segments precultured without 5% DMSO (treatments 1 and 3, Table 1). Dead tissue remained bleached in appearance and green shoots elongated from meristems at the base of the leaf axils (Fig. 2). Other researchers have also observed the beneficial effects of 5% DMSO in preculture media with angiosperm in-vitro-grown axillary or shoot-tip meristems (Kartha et al., 1979 and 1980; Fukai et al., 1991; Touchell et al., 1992).

It was noticeable that seed viability was reduced on storage at 4C and after 4 years the germination had reduced from 81% to 43% after 20 weeks in germination conditions. The storage of seeds thus seems an unlikely long-term conservation practice.

Cryopreservation has been used with other endangered species with variable success. The Australian plant *Grevillea scapigera* was thought extinct until 1989

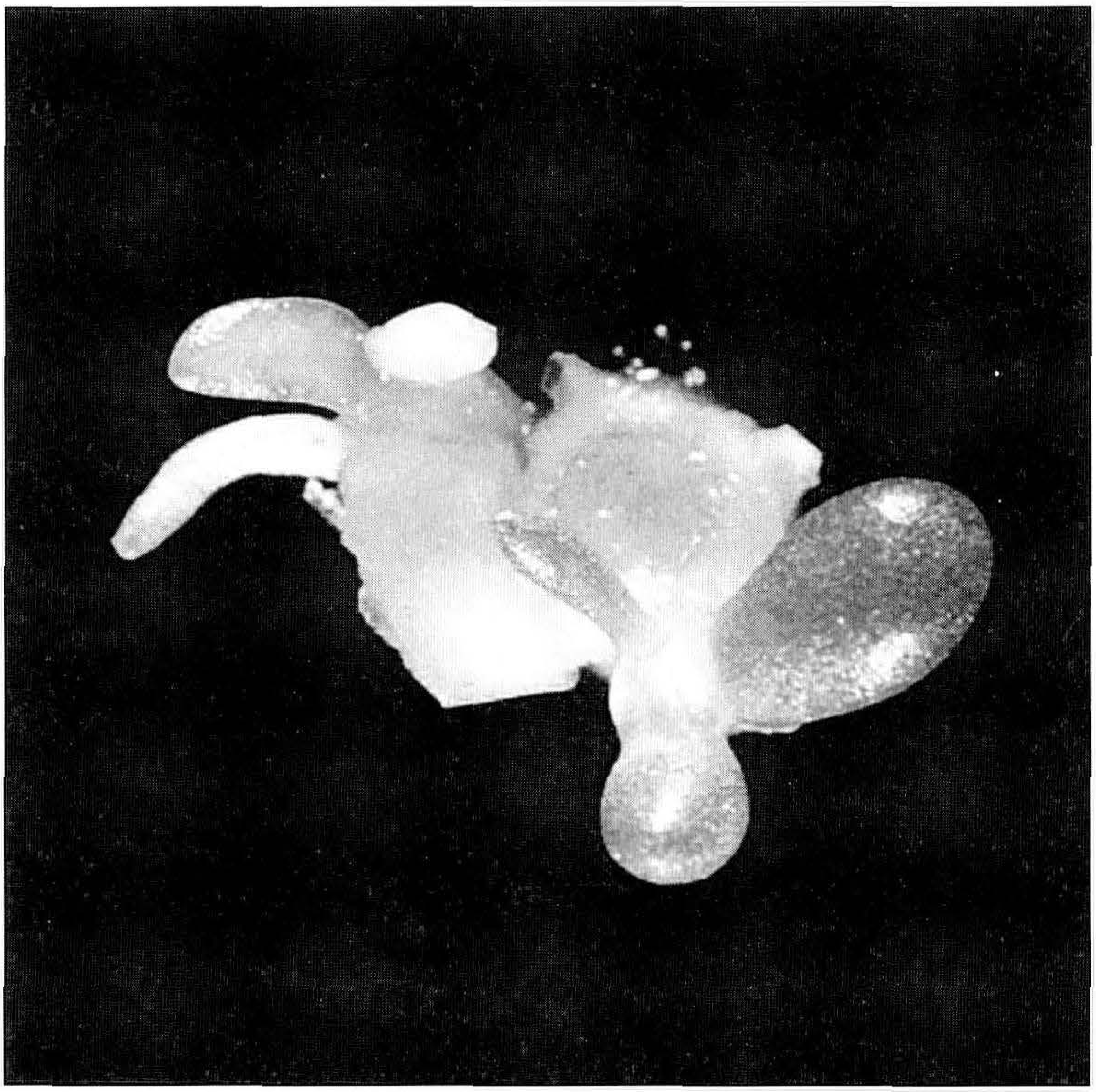

Figure 2. *Cheesemania* 'Chalk Range' development following cryopreservation (4 weeks following thawing).

when six plants were found and an in vitro propagation programme was established. Chrysanthemum [*Dendranthema* ×*grandiflorum* (syn. *Chrysanthemum* ×*morifolium*)] related species are also seriously endangered in Japan. Shoot tips of both these species were precultured with media containing 5% DMSO (Fukai et al., 1991; Touchell et al., 1992). Up to a 100% of the *D.* ×*grandiflorum* and related species produced plants and 20% of the *G. scapigera*. Long-term preservation of in-vitro-grown *Cheesemania* can thus be justified for all the reasons of erratic seed production, threatened habitat, possible importance to crop improvement programmes, and economy in terms of space and duration of storage required.

CONCLUSIONS

These results are encouraging for the long-term survival prospects of the critically endangered New Zealand *Cheesemania* 'Chalk Range'. Over 125 genotypes and more than 400 plants are now growing in vitro. Plants have been grown in the glasshouse for up to 2 months. Improved glasshouse techniques should allow such explants to grow to maturity. Successful plant regeneration from cryopreserved meristems has been demonstrated. Such storage will provide an economic method of holding in-vitro-grown *Cheesemania*.

Acknowledgments. Phil Clerke, Shannel Courtney and Cathy Jones of the New Zealand Department of Conservation are thanked for their enthusiastic support of the project.

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African Trees and Plants at Gardens of the World

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Perhaps it is because I was raised in Kenya, perhaps it is because I was born at 8300 ft or 2500 m above sea level, that I am putting so much extra effort into the African Area of "Gardens of the World", a 6 acre ($2\frac{1}{2}$ ha), challenge for the rest of my life.

The climate at 2500 m on the equator is similar in many ways to the climate here in Nelson.The temperature range is roughly the same, and there are about the same amount of wet and dry times, with a similar rainfall.

The main difference is the length of days, which is constant at 12 h all the year round at the equator.

I have had no trouble growing trees which grow naturally at or above this altitude. Some of these are:

Hagenia abyssinica. A large, spreading, frost-hardy, evergreen tree which mulches itself with its own old leaves. It prefers a reasonably moist situation and is very fast growing with large compound leaves. My grandmother had one in her garden in Kenya. I can remember a Christmas when there were 80 of us sitting down to lunch at a long table, 40 people on each side, under this one tree. It was a truly magnificent, wonderful specimen. The dried female flower heads are used as a powerful remedy for intestinal worms, while an infusion of the bark will cure diarrhoea.

***Afrocarpus gracilior* (syn. *Podocarpus gracilior*).** A graceful, slower growing evergreen tree with attractive pale green new growth and eventually good useful timber.

***Olea europaea* ssp. *africana* (syn. *O. africana*).** (African olive). An evergreen tree with dark narrow leaves and a habit of growing in all directions. Eventually it produces dense wood which is useful for making ornamental furniture, and excellent for carving. I have made some very attractive table lamps. The bark, leaves, and roots are used in traditional medicine. The fruit is small and of no commercial value.

Juniperus procera. The East African cedar is a conifer which is used for timber, and is often grown in plantations as pines are here. It has very attractive red heartwood. I believe this is a tree which could have commercial value in New Zealand.

***Dombeya torrida* (syn. *D. goetzenii*).** This is an evergreen forest tree which grows to 15 m usually in wet highland forests. The light brown wood was used in Kenya as a general purpose timber. It has large leaves and attractive umbels of white flowers with red centres. It is an attractive tree to have in a garden, as are the other shrub dombeyas which are grown here.

I am also growing some trees which are definitely marginal for our climate in Brightwater where we do get frosts. You will see quite a few trees with frost protection around them at Gardens of the World. I have even put a 25-watt electric bulb beneath some which I have on a thermostat, so that when the temperature drops the small heat source improves the chances of the trees surviving while young. It would be better to grow them in frost-free areas.

Some examples are:

Vitex keniensis. A handsome deciduous forest tree which grows to 20 m with a clear straight trunk. It is similar to the puriri (*V. lucens*) though with a paler green leaf. It produces a valuable timber and has edible fruit. It is also valuable as an ornamental tree or can be used for windbreaks.

Polyscias fulva. The parasol tree, is a tall forest tree which grows to 25 m. Again it has a straight, slender trunk with a high crown which makes it look like an umbrella. It is a very decorative tree, fast growing, with very attractive large compound leaves.

***Allophylus cobbe* (syn. *A. abyssinicus*).** This is another useful timber tree which grows in high mountain forests. It is an attractive, poplar-shaped tree with glossy leaves. As yet I have no more information on it, but I believe it will grow well here.

Croton megalocarpus. This is another forest tree which grows to 35 m. It spreads high above the forest canopy usually with a flattish crown and horizontal layers of branches. It is fast growing in good soils with conspicuous yellow flowers. The seeds and nuts contain oils and proteins and are eaten by birds. If you need a purgative take some of the oil.

I have all these trees available at the nursery as well as small quantities of other trees and shrubs both from East Africa and Southern Africa.

A few examples are :

Celtis africana. Stinkwood, so called as the wood smells when freshly cut. It is a deciduous, hardy tree.

Khaya nyasica. The African mahogany. A very attractive evergreen timber tree with brilliant red new growth.

Markhamia lutea. An upright evergreen flowering tree with bright yellow trumpet-shaped flowers and long thin seed pods which grow up to $^{3}/_{4}$ m, a most attractive ornamental tree for a frost free area.

Echinacea — The Big Chill?

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INTRODUCTION

World demand for the medicinal properties of *Echinacea* has raised its profile above that of simply an attractive American wildflower.

Echinacea, or purple coneflower, as it is commonly known, is a genus of herbaceous perennials native to the prairies of central North America. Of the nine species, *E. purpurea* and *E. angustifolia* are the two that have been actively commercialised and upon which this report will focus.

Echinacea belongs to the daisy family Asteraceae. They produce a cluster of leaves from a short (20 to 30 mm) rhizome. *Echinacea angustifolia* has a vertical taproot whereas *E. purpurea* has fibrous roots. *Echinacea angustifolia* has narrow, entire leaves covered in stiff bristly hairs while *E. purpurea* has larger, rounded leaves that are coarsely toothed.

Single flower heads are produced at the end of simple or branched stems. The spiny raised receptacle or "cone" in the centre of the flower is a characteristic of the genus. The ray flowers of *E. purpurea* and *E. angustifolia* are an attractive pink colour and the "petals" sometimes reflex downwards.

USES

The main use of *E. purpurea* and *E. angustifolia* is medicinally as a stimulant of the immune system. Hobbs (1994) notes that of all the indigenous medicines introduced by Native Americans, *Echinacea* may be one of the most important.

Studies on the effects of *Echinacea*, mostly published in Germany, have established that *Echinacea* improves nonspecific immunity and stimulates new tissue growth. It is regarded as effective in treating certain viral and bacterial infections, healing wounds, and controlling inflammations (Foster, 1991).

Herbalists commonly believe that quality *Echinacea* products should contain at least one part of, or a combination of, the roots, leaves, and flowers of *E. purpurea* or this plus the roots of *E. angustifolia* (Hobbs, 1994). Preparations are available as liquid extracts, dried or powdered extracts in capsules and tablets, or fresh juice preparations of *E. purpurea* tops stabilised with ethanol.

In addition to medicinal uses, *E. purpurea* is also popular as an ornamental garden plant and several cultivars have been selected, e.g. 'White Swan' a white-flowered cultivar and 'The King' with crimson rays.

The resurgence in popularity in the United States of using native wildflowers in landscape plantings, and interest in prairie preservation, has stimulated research on the germination and cultivation of *Echinacea* species.

MARKET DEMAND

The largest market for herbal medicines using *Echinacea* is in Europe, where in 1990 phytomedicine counter sales were US$2.4 billion. Sales in Germany made up 65% of this trade (Douglas and Parmenter, 1993). The popularity of *Echinacea* preparations is increasing worldwide and it is possibly the most popular herb in the United States (Hobbs, 1994).

Hobbs (1994) comments that due to the harvesting pressure on dwindling wild supplies of *Echinacea*, the focus is shifting to organically grown commercially cultivated supplies of *Echinacea*.

ECHINACEA RESEARCH

Research trials of *Echinacea* by The New Zealand Institute for Crop & Food Research Ltd, began in 1988. Examples of this research includes trials on germination, field production, and chemical analysis of root product. Two species in particular, *E. angustifolia* and *E. purpurea*, have received most attention and these have been the subject of production trials at several sites around New Zealand (Parmenter et al., 1992).

The following is a summary of one aspect of that research — a trial to investigate the chilling requirement of commercial *Echinacea* seed. Full details of that trial are published in the N. Z. J. Crop and Hort. Sci. 1996. 24:109-114.

ECHINACEA — THE BIG CHILL?

Poor germination of commercial *E. angustifolia* seed and conflicting evidence in the literature about the benefits of a period of cold-moist treatment (stratification) of *Echinacea* seed indicated the need for an examination of methods of reducing seed dormancy in *Echinacea*.

Foster (1991) has reviewed some of the information available on stratification requirements in *Echinacea*, including studies by Hemmerly (1976) and Ottoson (1978), which appear to indicate the need for long periods (up to 10 to 15 weeks) in cold, moist conditions to produce maximum germination of *E. purpurea* and *E. angustifolia*. Other studies indicate germination improvements after much shorter periods of stratification. For example, maximum germination rates have been reached after 8 weeks of stratification for *E. angustifolia* (Baskin et al., 1992) and after only 4 weeks of stratification at 5C for *E. purpurea* (Bratcher et al., 1993). In this latter study the increase in germination over controls was only from 89% to 99%. Wartidiningsih et al. (1994) recently showed that stratification improved germination in five out of six commercial *E. purpurea* seed lots, with the greatest improvement occurring at 10C for 10 days. In the five lots that responded to stratification, the mean improvement in germination was from 45% to 80%. One study has shown no benefit to *E. angustifolia* or *E. purpurea* of chilling at 0C for 1 or 2 months (Smith-Jochum and Albrecht, 1987). In the same study, *E. pallida* germination was improved from 15% to 65% after 1 month of chilling.

Removal or cutting of the seed coat may improve germination. Foster (1991) quotes studies which suggest that trimming the seed coat may have some effect on the dormancy of nonstratified seed, either by allowing more rapid hydration of the seed or leaching of germination inhibitors. When the seed coat of *E. angustifolia* was removed, germination was improved from 13% to 92% (Sorenson and Holden, 1974).

METHOD

Experiment 1. Seed of *E. angustifolia* and *E. purpurea* was sown in Sept 1992 in cell trays filled with a steam-sterilised seed-raising mix of peat and sand (8.5 : 1.5, v/v). In each tray, five replicates of 10 cells of each species were sown, each cell containing a single seed. Half of the *E. angustifolia* seed in each replicate was left whole, whereas the other half had the pappus trimmed from the distal end of the seed coat with a scalpel, exposing, but not cutting, the seed. Trimmed and untrimmed seeds were randomly assigned to cells within each of the five replicates.

A total of 10 trays were sown. Given evidence that germination of *Echinacea* is enhanced by light (Foster, 1991), seed was pressed horizontally into the surface of the mix without being buried.

Each tray was watered and allowed to drain before being placed in a plastic bag to retain moisture. All but one of these trays were placed in a dark coolstore (3-5C). A single tray was placed immediately in a glasshouse, without a plastic bag covering it. Every 1 or 2 weeks thereafter, a further tray was removed from the coolstore and placed in the glasshouse. Trays in the glasshouse were watered lightly each day to keep the seed moist. Glasshouse temperatures were regulated and ranged between 10C at night (8 h) and 20C during the day.

Each week for 4 weeks after placement in the glasshouse, the number of seeds that had germinated (cotyledons visible) in each tray were counted. The last tray was removed from the coolstore 11 weeks after the first.

The effect of storage time on percentage germination and the time to maximum percentage germination was determined for each species, as well as the effect of seed coat trimming on *E. angustifolia*.

Experiment 2. Experiment 2 was similar to Experiment 1, except that *E. purpurea* was not tested. Both experiments began on the same day in mid September 1992.

In each of 10 seed trays, five replicates of 10 seeds of *E. angustifolia* were sown with half the seeds trimmed and each seed pressed horizontally into the surface of each cell. The trays were watered. One tray was immediately placed in a glasshouse and the rest were covered in plastic and placed in a dark coolstore (0 to 1C). Trays were removed from the coolstore at 2 weekly intervals, with the last tray removed 18 weeks after the first. Weekly assessments of the number of germinated seeds continued for 4 weeks after removal from the coolstore. In this experiment, glasshouse temperatures were unregulated, but maximum and minimum temperatures were recorded. Maximum and minimum temperatures averaged 24 and 6C for October, 26 and 10C for November and 27 and 11C for December. Because of the warmer conditions in Experiment 2, trays were sometimes watered twice each day.

RESULTS

Maximum Germination Percentage. *Echinacea purpurea* appeared to have no stratification requirement, with a maximum germination rate of 84% averaged over all stratification periods (Fig. 1A). *Echinacea angustifolia*, in contrast, showed a marked improvement in germination percentage once stratification periods exceeded

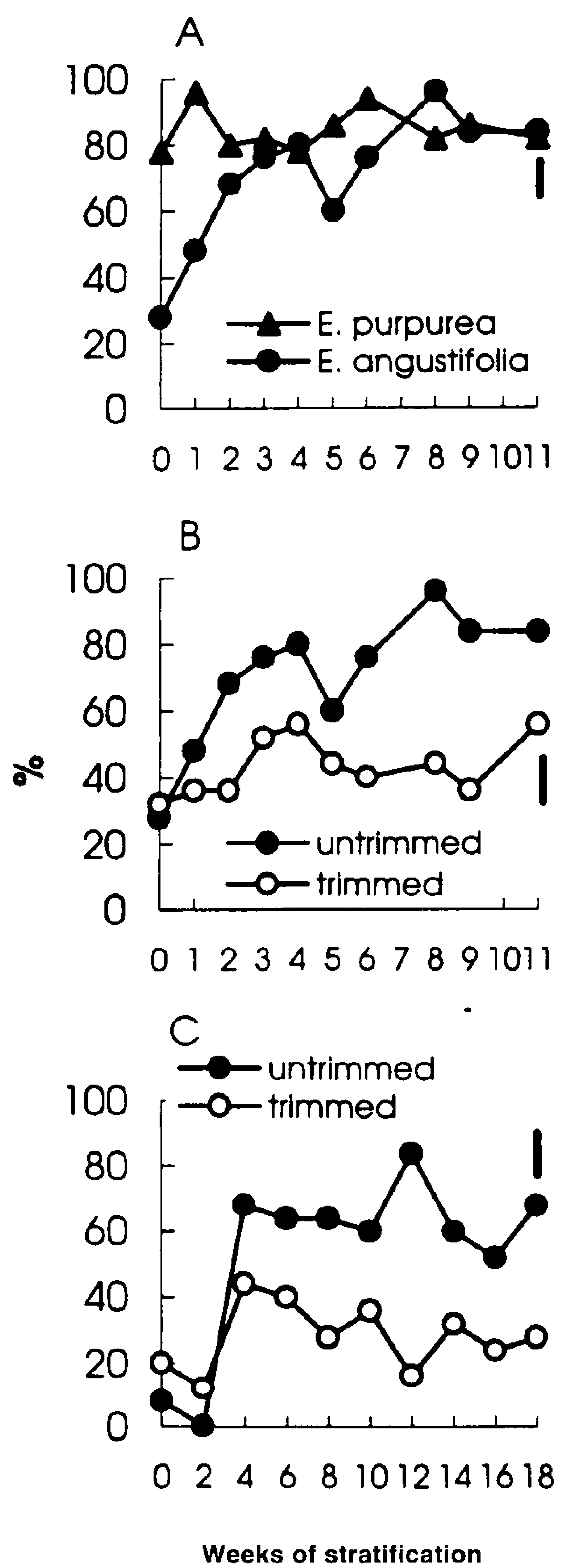

Fig. 1. Effect of stratification at 3 to 5C (Experiment 1) or 0 to 1C (Experiment 2) for periods ranging from 0 to 18 weeks on the maximum germination percentage of *Echinacea.* **A,** Comparison of *E. purpurea* and *E. angustifolia* in Experiment 1; **B,** Comparison of trimmed and untrimmed seed of *E. angustifolia* in Experiment 1; and **C,** Comparison of trimmed and untrimmed seed of *E. angustifolia* in Experiment 2.

2 weeks, from an average of 48% germination to 80% in Experiment 1 (Fig. 1B) and from 10 to 48% in Experiment 2 (Fig. 1C).

Trimming the seed coat approximately halved the maximum germination percentage in *E. angustifolia* seed stratified for more than 2 weeks from a mean of 80% to 47% in Experiment 1 (Fig. 1B) and from c. 65% to 31% in Experiment 2 (Fig. 1C). However, in nonstratified seed (0 weeks stratification), there was no significant difference in the germination percentage of trimmed and untrimmed seed — 32% trimmed compared to 28% untrimmed in Experiment 1 (Fig. 1B) and 20% trimmed compared with 8% untrimmed in Experiment 2 (Fig. 1C).

Maximum germination rates of untrimmed *E. angustifolia* seed were greater in Experiment 1 than in Experiment 2 (80% to 100% compared with 60% to 70%) (Fig. 1B,C).

Time to Maximum Germination. The time taken to reach maximum germination decreased as the length of the stratification period increased. The time taken decreased by 1.02 days per week of stratification for the species comparison in Experiment 1 (Fig. 2A), by 0.76 days per week of stratification for the trimming comparison in Experiment 1 (Fig. 2B), and by 0.73 days per week of stratification for the trimming treatment comparison in Experiment 2 (Fig. 2C). No significant evidence was found that *E. purpurea* and *E. angustifolia* differed in time to maximum germination after the same length of stratification. However, untrimmed seed took longer than trimmed seed to reach maximum germination, by 1.7 days per week of stratification.

DISCUSSION

Echinacea angustifolia required only 2 to 3 weeks of stratification to raise germination rates to maximum levels of around 80% or more, close to the best germination rates reported elsewhere for this species. This is a relatively short period of stratification compared with outdoor winter chilling which has been shown to be effective in breaking dormancy, or the longer periods of time (8 to 16 weeks) apparently required to reach maximum germination in some other experiments. However, other recent results also indicate high germination of this species after 2-weeks stratification, although only in combination with other treatments such as ethylene and light (Feghahati and Reese, 1994).

The lack of response of *E. purpurea* to stratification confirms the results of Smith-Jochum and Albrecht (1987), who had germination rates of 70% to 80% with or without stratification. Wartidiningsih and Geneve (1994) also found two of six seed sources had germination rates of 80% to 90% without stratification, indicating little dormancy. Bratcher et al. (1993) did show an apparent improvement in germination as a result of stratification, although nonstratified seed still had a high (89%) germination rate. Wartidiningsih et al. (1994) showed a clear improvement in germination as a result of stratification in five out of six seed lots. However, seed primed in salt solutions or polyethylene glycol, without chilling, showed a similar improvement in germination rates. Samfield et al. (1991) also improved germination rates from 60% to 90% without chilling by priming seed, although distilled water was as effective as salt solutions.

These results indicated that chilling is not a prerequisite for good germination of *E. purpurea*. Where initial tests of germination percentage of *E. purpurea* indicate that some improvement in germination appears necessary, priming for 3 to 9 days

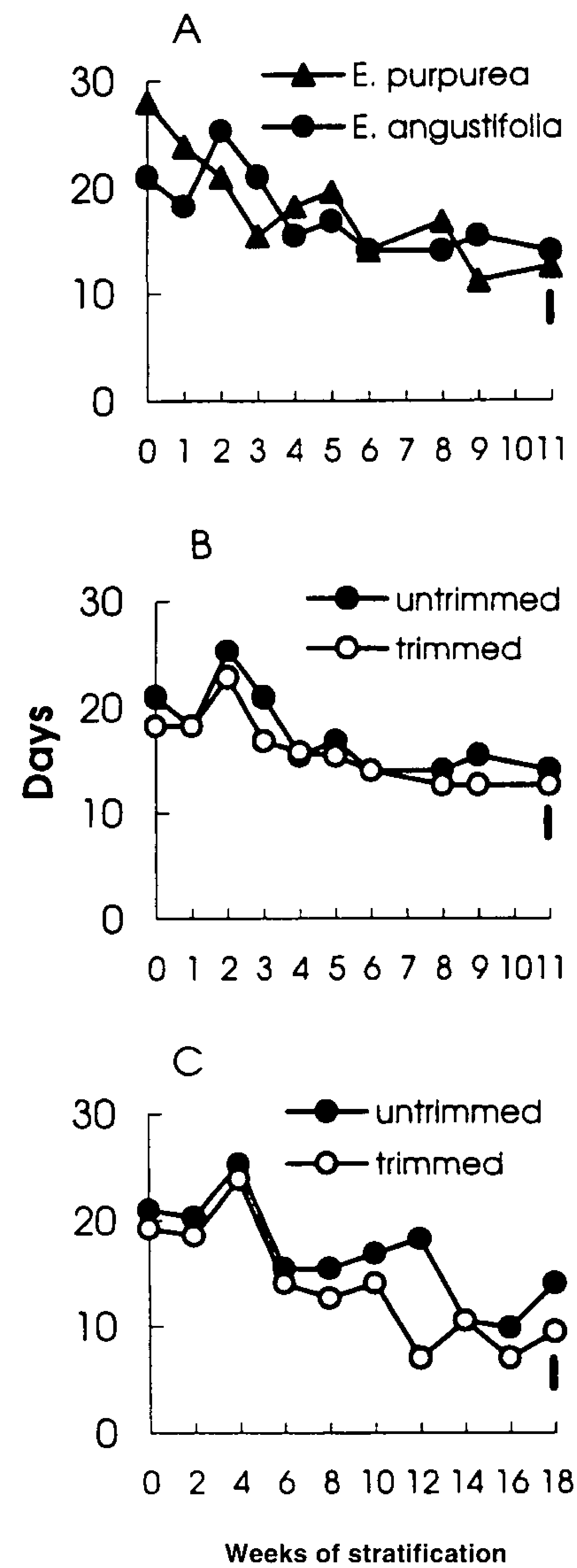

Fig. 2. Effect of stratification at 3 to 5C (Experiment 1) or 0 to 1C (Experiment 2) for periods ranging from 0 to 18 weeks on the time taken (in days after removal from the chiller) for *Echinacea* to reach maximum germination percentage. **A,** Comparison of *E. purpurea* and *E. angustifolia* in Experiment 1; **B,** Comparison of trimmed and untrimmed seed of *E. angustifolia* in Experiment 1; and **C,** Comparison of trimmed and untrimmed seed of *E. angustifolia* in Experiment 2. Vertical bars are SEDs.

in aerated distilled water (Samfield et al., 1991) is likely to be as effective as 10 to 20 days of moist chilling.

Echinacea purpurea and *E. angustifolia* had similar maximum germination percentages in Experiment 1, but *E. angustifolia* germination percentage in Experiment 2 was lower. The 3 to 4C cooler stratification temperature in Experiment 2 may have been a factor. There is some evidence that stratification of *E. purpurea* is more effective at 10C than at 5C (Wartidiningsih et al., 1994). Perhaps a more likely cause of the poorer germination in Experiment 2 is the hotter, and possibly drier conditions in the glasshouse. Even though watered twice daily, the soil surface, and the seeds pressed into it, are likely to have experienced considerable drying and heating on some days. High incubation temperatures (35C day/20C night) following stratification have been shown to reduce germination percentage in *E. angustifolia* (Baskin et al., 1992). Although air temperatures in Experiment 2 were not typically as high as 35C, soil surface temperatures are quite likely to have been so. In environments where high soil temperatures are likely, the benefits of exposing seed to light may be outweighed by the reduction in germination caused by drying, making shallow burial a better sowing method.

The reduction in percentage germination of *E. angustifolia* caused by trimming the seed coat was unexpected. Damage to the seed does not seem a likely explanation for this effect as the seed coat was trimmed carefully and any seed trimmed in the process was not used. That the reduction only occurred in seed stratified for more than 2 weeks appears to confirm this. Seeds were not treated with fungicide before stratification, so seed death as a result of fungal infection is a possible explanation, although the absence of progressive reduction in germination with increasing stratification period appears to make this unlikely. In a recent study scarification did not increase germination and the authors concluded that germination of *E. angustifolia* is probably not inhibited by physical limitations to imbibition imposed by the seed coat or by water soluble inhibitors carried in the seedcoat (Feghahati and Reese, 1994).

SUMMARY

Stratification did not improve maximum germination percentages of *E. purpurea*, but did improve the maximum germination of *E. angustifolia* when applied for more than 2 weeks. The time taken to reach maximum germination was reduced for both species as the stratification period was increased. Trimming the seed coat of *E. angustifolia* had no significant effect on nonstratified seed, but halved the maximum germination of seed stratified for more than 2 weeks.

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Goldenseal (*Hydrastis canadensis*): An Introduction to this North American Medicinal Herb

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INTRODUCTION

Goldenseal (*Hydrastis canadensis* L.) is a highly valued North American medicinal herb belonging to the family Ranunculaceae. It is a small herbaceous perennial found in Northwestern United States and Canada, from Ontario in the North, to North Carolina in the South. Common names include yellow root, orange root, Indian dye, and yellow puccoon. Its main active ingredients are the alkaloids, hydrastine and berberine, and it is used among other things as a muscle stimulant, stomach strengthener, antihaemorrhagic, and laxative. Goldenseal also has some antibacterial activity. Collecting goldenseal from the wild resulted in its near extinction in its native habitat, however, as a result of intensive cultivation it has become more common. In New Zealand goldenseal is currently being evaluated as a new crop (Douglas, 1988).

DESCRIPTION

Goldenseal is a native to the open woodland areas of Northeastern North America. The plant overwinters as a rhizome with leaves emerging early in spring. The stems grow to about 30 cm and generally have two large, slightly hairy leaves. Plants grown at Ruakura in the Waikato flower in mid-spring. A small white flower develops on an extension of the main stem above the oldest leaf. The flower develops into a green berry, which later turns bright red when the seeds are ripe. After the fruit has ripened the leaves start to senesce although they often do not completely die until the first frosts. As the plant develops, the central part of the rhizome eventually dies leaving the remaining parts of the root to grow as independent plants.

HISTORY

The use of goldenseal was widespread amongst the north-eastern American Indians before Europeans arrived. They used formulations of the root to treat local inflammations, debility, dyspepsia, whooping cough, diarrhoea, liver trouble, fever, sour stomach, flatulence, pneumonia, and to improve the appetite (Foster, 1991). Other reports indicate that goldenseal was also used to promote healing of open wounds and, when mixed with bear grease, as an insect repellent (Hobbs, 1990), while Tyler (1993) reports it was used by the Cherokee Indians for treating skin disease and sore eyes. Early pioneers chewed the root to treat a sore mouth and used it as an infusion and treat liver and stomach ailments (Krochmal and Krochmal, 1984). By 1747 goldenseal had become commercialised and in 1860 was entered into the United States Pharmacopoeia (Hardacre, 1974). As a result of low supplies and high prices during the 1903 and 1904 season the first attempts at cultivation were made. Demand until then had been met entirely by harvesting wild populations. The price paid for goldenseal increased gradually until 1933 when an oversupply caused a price collapse. The next high point for goldenseal collectors and growers was the

Second World War with root selling for US\$16 kg^{-1}. The high demand for antibiotics at this time resulted in a strong demand for herbal remedies. Returns for roots peaked in 1946 at nearly US\$18 kg^{-1} then dropped to a low of US\$5 kg^{-1} in 1950. In 1996 the price for dry goldenseal root was US\$77 kg^{-1} while dried leaves and petioles sold for US\$16.50 kg^{-1} (Louttit, pers. comm.). The revitalized interest in herbal medicine makes it likely that demand for goldenseal root will remain firm. However as a minor crop it is likely that price fluctuations will continue as growers over or under supply in response to changing prices (Foster, 1991).

PHARMACOLOGY

Although all parts of the plant are used for medicinal purposes the rhizome is the most valued component because it contains the highest concentration of active ingredients including 2% to 4% hydrastine and 2% to 3% berberine (Genest and Hughes, 1969). Other active ingredients include hydrastinine and canadine. The pharmacological action of goldenseal is thought to be mainly due to hydrastine and to a lesser extent berberine. Hydrastine is known to constrict blood vessels and lower blood pressure. It has been used in the treatment of gastric inflammation, but higher doses can cause exaggerated reflexes and convulsions. Hydrastinine, on the other hand, causes an increase in blood pressure and stimulates many kinds of involuntary muscles. Berberine acts as a stomach strengthener and anti-haemorrhagic, while canadine has been shown to stimulate the uterus in rabbits and guinea pigs (Genest and Hughes, 1969). Goldenseal is not commonly mentioned in modern pharmacological literature but is still used for its antibacterial properties and its false reputation as a masking agent for drug concentrations in urine (Foster, 1989; Hobbs, 1990; Tyler, 1996).

PROPAGATION

Goldenseal can be propagated by seed, division of the rhizome, or by root cuttings. Division is the most commonly used method (Van Fleet, 1916). Propagation by seed is also popular although the seed reportedly requires 3 months of stratification before it will germinate (Foster, 1984).

At Ruakura whole plants have been lifted throughout the winter when all top growth had died down and the rhizome and roots broken up and lined out into a variety of potting mixes. Although considerable numbers of plants have been produced results have been inconsistent with many of the rhizome segments and root cuttings not producing shoots.

The most successful means of propagation has to date been by collecting suckers from parent plants growing in the field. Suckers are detached from the parent plant in spring when they are about 10 to 15 cm tall and transplanted directly into production beds. By leaving as much soil on the roots as possible and transplanting the plants quickly, transplant shock is kept to a minimum. Overhead watering has not been required provided cuttings are transplanted early enough in the spring to allow roots to develop before the heat of summer. Poor transplanting technique will result in the plants "sulking" until the following spring or plant death. Beds are often mulched with untreated pine (*Pinus radiata*) sawdust for moisture conservation and weed control, soon after planting. Using this method we get a 95% emergence in the spring following transplanting.

Research at Ruakura evaluating strategies for germinating goldenseal seed is currently underway.

PRODUCTION

Goldenseal prefers a rich, friable, well-drained soil. Foster (1984) reports that adding leaf mould and phosphate promotes growth while Davis (1996) recommends a pH of 5.5 to 6.0 and little or no fertiliser. In New Zealand, excellent growth has been achieved on the free draining sandy loam ash soils found in the Waikato and Rotorua areas. In North America, goldenseal is planted out 20 cm apart in rows spaced 25 to 30 cm in either late autumn after crop harvest or in spring. Goldenseal requires shade to grow well with 75% shade commonly recommended (Sievers, 1948). Shade can be provided by wooden lath, shade cloth, or by growing the crop under a forest canopy. If propagating by division, harvesting should be possible after three or four years while seed-propagated plants may require an extra year. Goldenseal requires similar conditions to ginseng (*Panax quinquefolium*) for good growth (Foster, 1987) with some ginseng growers including goldenseal in their crop rotation after ginseng. After harvesting in late autumn, roots are washed and air-dried until brittle. After five years of growth goldenseal will yield 1 to 2.5 t ha^{-1} dried root. Plants grown for five years in the Waikato yielded on average a dried weight of 29.5 g of rhizome, 28.8 g of root and 31.5 g of leaves and petioles.

PROSPECTS FOR NEW ZEALAND

Goldenseal is reported to be one of the top-selling herbs in the American health food industry (Brevoort, 1995) with a large number of modern day uses (Duke, 1985). It can bring good prices, and if dried properly, has a long shelf life. Our research in the Waikato indicates that it is relatively easy to grow intensively under shade cloth with no major pest or disease problems. Research in the Rotorua area indicates goldenseal will also grow well under New Zealand's large exotic pine (*Pinus radiata*) plantations although growth is slower. Provided the demand and price remain high, early indications are that goldenseal has some potential as an export crop for New Zealand. It will, however, be several years before there is sufficient product available in New Zealand for test marketing to confirm this market potential.

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Germination Experiments on Seeds of Some New Zealand Lowland Forest Species

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INTRODUCTION

Nurserymen know a lot about germinating the seeds of native species, but have not often recorded their knowledge. Other professionals with an interest in the subject have published some information, but there is still only a limited amount of detailed information in print on how to get seeds of plants of our native flora to germinate. A recent review of literature on seed germination relevant to New Zealand native plants (Fountain and Outred 1991) covered only 38 articles and 113 species.

About 10 years ago I decided to study seed biology of plants in South Island native forests. My aim was to improve our understanding of this vital phase in the forest regeneration process. Since 1989 I have published articles on seed germination, seed crops, dispersal, and seed predation in New Zealand Natural Sciences, Canterbury Botanical Society Journal, and New Zealand Journal of Botany.

Here I want to outline the methodology I use and some results of simple experiments on seeds collected fresh, from wild plants, in South Island locations, when fruit are ripe (summer, autumn) and placed in sets of conditions like those that they could experience in nature. Much can be learned from such studies — some of it may be useful to plant propagators.

METHODS

As fruit ripens dry capsules open, releasing seeds, and fleshy berries and drupes are eaten by birds. The seeds fall to the ground — they may be exposed on the surface, buried in litter, or deeper in the soil. They may remain moist, or dry out for short, or long periods. My experiments are aimed at simulating these varied conditions.

I place my seeds into the experiments — conducted in an unheated, partly shaded glasshouse — after simple pre-treatments. One treatment in fruit (Table 1) mimics the situation where whole fruit fall from the parent. For all other treatments the fruit tissues are removed and the cleaned seeds are soaked in tap water for about 24 h and sorted to exclude any that are damaged or empty, before being placed in the experimental conditions. Tap water is used for all the tests.

The conditions of the remaining five treatments — standard, dark, soil, dry, and buried — are noted in Table 1. Standard is a baseline for comparison of results of all other treatments, as the best results are usually achieved in it. The numbers of replicate samples of 25 seeds are small; even so the full range of tests requires at least 300 seeds and these numbers are sometimes hard to achieve. The consistency of results between replicates seems to justify the use of small samples; in a sense every seed constitutes a unit sample.

Table 1. The conditions of the treatments.

	Treatments	No. of replicates of 25 seeds
1	In fruit — left in fruit tissues. For all other tests fruit tissues are removed (not completely possible for drupes, achenes).	1 or 2
2	Standard — kept wet, on filter paper, in petri dishes in maximum available daylight.	4
3	Dark — same conditions, but kept in black plastic bags.Checked at about monthly intervals in darkroom under photographic safelight.	2
4	Soil — in small grooves in pasteurized potting soil in small plastic meat dishes, kept continually moist.	2
5	Dry — kept dry over winter (3-4 months), then put in conditions as for standard treatment.	2
6	Buried — buried 5 cm below soil surface in a plastic drain pipe cylinder 30 cm high. If seedlings do not appear seeds are unearthed after 1.5 years (approx.) and placed in conditions as for soil treatment.	1 or 2

Physiological programming of seeds begins while they are on their parent and continues up to the time they germinate, through responses of the living seeds to environmental cues (temperature changes, light quantity or quality, gas concentrations, moisture conditions). Whatever treatments we give, seeds are likely to modify their behaviour. This is the rationale for working with seeds taken straight from ripe fruit on their parents (or freshly fallen fruit picked from the ground in the case of tall trees like *Prumnopitys taxifolia*, matai, or *Laurelia novae-zelandiae*, pukatea). The same rationale applies to the use of experimental treatments resembling the conditions which the dispersed seeds could experience in nature. The only exception that I have employed is testing sets of hard-coated seeds such as those of *Sophora microphylla*, kowhai, *Calystegia tuguriorum*, panahe, *Dodonaea viscosa*, ake ake; or seeds with hard endocarp around them such as *Myoporum laetum*, ngaio, or *Elaeocarpus dentatus*, hinau, after cutting through the tough enclosing tissues.

The experiments are monitored about weekly, and watered as needed. Glasshouse maximum temperatures can rise to 34C in summer, but are mainly in the range 15 to 25C. Minimum temperatures descend to -4C in winter, but are mainly in the range 5 to 10C. Germinated seeds are removed and planted out in soil.

RESULTS

So far I have worked on about 90 species. I will discuss a few examples, to illustrate salient points (see Table 2).

In-fruit. In this treatment there is almost invariably nil or poor germination (for fleshy fruited species and some dry fruited species).

Standard. Best results are achieved in this treatment — usually 90% to 100% germination. Many species germinate, some quickly, some slowly, in summer, autumn or winter [e.g., *Griselinia*, *Kunzea*, *Coprosma*, and *Melicytus* (Table 2)]. This means that their seeds are not primarily dormant (cf. Bewley and Black,1982; Burrows, 1994). Other species exhibit different kinds of behaviour, in relation to the seasons. *Aristotelia serrata* seeds from some locations germinate relatively quickly in autumn, except for a small proportion which overwinter and germinate in the following spring. *Hoheria* seeds germinate over a short period in early spring. *Myrsine australis* seeds are slow to start and complete germination. Like those of *Hoheria* and the few late-germinating *Aristotelia* seeds they appear to require some cold treatment (i.e., exhibit primary dormancy). In some species, e.g., *Urtica ferox*, onga onga, the biochemical blocking which characterizes truly dormant seeds may need several cold winters to overcome it.

Other species have delayed germination for other reasons. *Hedycarya* appears to have immature embryos, which require a long period of time before they are ready to become activated. *Pseudowintera colorata*, horopito, seeds are like this too. Cold treatment does not seem to speed up the process. *Dodonaea* seeds, like those of *Sophora microphylla* or *Calystegia tuguriorum*, have very hard coats, resistant to microbial disintegration. The germination of their seeds, in natural conditions, only takes place when the coat is finally breached. In *Dodonaea* it can take 2 years or more and in *Calystegia* more than 5 years, before all seeds from a cohort germinate. Another cause of delay is the requirement, in *Rhopalostylis*, for relatively high temperatures, before the seeds germinate.

Dark. Seeds of nearly all species germinate in the dark but the process is slower than in the standard conditions. Exceptions are *Schefflera digitata*, (pate) *Weinmannia racemosa*, (kamahi), and *Coriaria sarmentosa*, (tutu) which fail to germinate.

Soil. There is usually poorer germination success than in the standard. The cause of this is unclear, but microbes and fungus gnats may be at least partly responsible. Trials of some more inert media are needed to test these ideas.

Dry. Seeds of some species (e.g., *Hedycarya*, *Rhopalostylis*, *Pennantia*) fail completely if dried for 3 to 4 months. Others (e.g., *Griselinia*, *Ripogonum*) are killed by 1 or 2 weeks. Dry seeds of several species (e.g., *Coprosma robusta*, *Aristotelia*, *Hoheria*) lose much viability, while others (e.g., *Kunzea*, *Melicytus*, *Fuchsia excorticata*, *Myrsine australis*) are relatively unimpaired, and germinate well when moistened.

Buried. There are three main patterns of response to this treatment (at a reasonably extreme depth to ensure that the gaseous environment is isolated from direct atmospheric influence).

a) Seeds of some species germinate underground but lack the energy to get shoots to the surface and seedlings die underground. To succeed they need to be buried more shallowly (according to their maximum potential hypocotyl length). It is interesting that species such as *Griselinia* and *Kunzea* appear to have no means of preventing themselves from germinating when in this inappropriate situation.

b) Others germinate underground and send shoots to the surface. This applies to relatively large-seeded species such as *Rhopalostylis*,

Table 2. Germination results for five treatments with seeds collected in summer and autumn.

Species	Standard			Dark	
	Period before germination (weeks)	Germination period (weeks)	Success (%)	Comments	Success (%)
Griselinia littoralis broadleaf	1	5	92	Slower than standard	96
Melicytus ramiflorus mahoe	1.5	4	99	Similar to standard	96
Kunzea ericoides kanuka	3.5	11	100	Slower than standard	86
Coprosma robusta karamu	2.5	9.5	90	Slower than standard	60
Aristotelia serrata wineberry	2.5	10 (a few seeds delayed until spring)	96	Similar to standard	86
Hedycarya arborea pigeonwood	4.5	13	100	Slower than standard	92
Dodonaea viscosa ake ake	9	59	98	Similar to standard	24
Hoheria angustifolia narrow-leaved ribbonwood	11	5	93	Slower than standard	88
Myrsine australis mapou	16	41	100	Slower than standard	42
Rhopalostylis sapida nikau	43	9	95	Slower than standard	84

Soil		Dry		Buried	
Comments	Success (%)	Comments	Success (%)	Comments	Success (%)
Slower than standard	72	Seeds die within 1-2 weeks of being dried	0	All germinate underground and die	0
Slower than standard	84	Germinate in 8 weeks	98	All seeds go dormant; many germinate when brought into light in second year	52
Slower than standard	76	Germinate in 4 weeks	92	All germinate underground and die	0
Slower than standard	92	Germinate in 12.5 weeks		Germinate underground and send shoots to surface over 2 years	80
Slower than standard	84	Germinate in 18 weeks	76	Most germinate underground and die; some go dormant and germinate when brought into light in second year	28
Slower than standard	98	Seeds die when dried	0	Germinate underground and send shoots to surface over 2 years	76
Slower than standard	76	Not done	-	Germinate underground and send shoots to surface over 2 years	80
Slower than standard	84	Germinate in 6 weeks	16	All germinate underground and die	0
Faster than standard	54	Germinate in 26 weeks	100	Germinate underground and send shoots to surface in first year	68
Slower than standard	28	Seeds die when dried	0	Germinate underground and send shoots to surface over 2 years	92

Corynocarpus, and *Beilschmiedia tawa*, and also to some relatively smaller-seeded species such as *Coprosma robusta*, *Dodonaea*, and *Myrsine australis*. The *Myrsine* actually germinates faster in the buried treatment than in the standard.

c) Others go dormant and remain so until they are brought into the light, where they germinate, usually with reduced percentage success. Among them are *Melicytus*, *Aristotelia*, *Macropiper excelsum*, and *Solanum laciniatum*. The secondary dormancy that is induced by burial means that these species could all form seed banks of more than 1 year's duration. Even for the species that send shoots to the surface from 5 cm depth some seeds must be dormant, because their seeds germinate over a period of 2 years. Dormancy may be induced by a CO_2, or ethylene-rich atmosphere.

CONCLUSIONS

I will not discuss the results at much more length; their significance will be evident, generally, to nursery people. It is as well to note, however, that the results are usually from one or two provenances of seeds from South Island locations. Seeds from Auckland or other localities may behave differently, to some extent. Also, in my earlier experiments (published briefly in the Canterbury Botanical Society Journal Vol. 27, 1993 and Vol. 29, 1995, and in more detail in the New Zealand Journal of Botany Vol. 33, 1995 and Vol. 34, 1996) I had not done the dry and burial experiments. Furthermore, some results from the earlier dark experiments are suspect, because the petri dishes were wrapped in aluminium foil, which eventually may have let in some light through small holes. I have repeated dark experiments for most of the species tested earlier, with light excluded by thick, black polythene. These are the results outlined here. In late 1996 in the New Zealand Journal of Botany Vol. 34, and in future accounts, the dry, burial, and new method for the dark treatment are reported.

Summing up some useful tips for anyone wanting to work with seeds of native forest species:

Best results are obtained with fresh seeds. It is wise to take fruit from plants that are fruiting heavily.

Fruit tissues must be removed. This applies to both fleshy and dry tissues and, after the seeds are cleaned, I soak them in tap water for 24 h. I have not yet found a simple way to remove the mucilage from *Pittosporum* seeds. Bacteria and fungi do this eventually, usually without harming the seeds.

Seeds of many species germinate well without cold treatment (unlike many Northern Hemisphere species). However, nursery people may wish to store seeds over winter and it is sensible practice to do this with the seeds kept moist, in a refrigerator. Chilling may cause seeds to become dormant, but little is known about this for New Zealand species.

Seeds of some species must be kept moist all the time. Others can be kept dry for a few months. Seeds of some species respond very well if buried about 2 cm (or more). I would recommend this for large-seeded species like *Corynocarpus* and *Beilschmiedia*, but it also works for other species, as noted in Table 2.

I am writing a booklet on this work and hope it will be ready towards the end of 1997.

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Zantedeschia aethiopica

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Zantedeschia aethiopica is not a calla. This is a common misinterpretation by many in New Zealand. It does belong to the *Zantedeschia* genus, the leaf is similar, but there are many differences. Some of those differences I will endeavour to explain in this presentation. Firstly though let us look at some of the known taxa of *Z. aethiopica*.

We have the arum — which is the white bloom — it has various forms including winter and summer flowering.

In New Zealand we have the better known 'Childsiana', which is also white and also comes in various forms but this has been mainly induced by treatment with hormones and or containerising, creating a bonsai effect.

We also have the 'Green Goddess'. This is a well known cultivar in New Zealand.

If we look at the callas, we have numerous cultivars. The big thing that needs to be remembered is that all of the callas are deciduous. They have a specific growing season and require a dormancy. This is probably one of the essential differences. *Zantedeschia aethiopica* on the other hand, does not necessarily require any dormancy.

A few calla species are *Z. rhemannii*, *Z. angustiloba* (syn. *pentlandii*), *Z.* "odoutorata", and a number of cultivars. In New Zealand these have been hybridised very successfully to produce a multitude of colours.

Callas grow from tubers and they require, as already mentioned, a dormant period. They are extremely prone to *Erwinia*. They have, in general, a 6-week flowering period and they are not very tolerant of wet conditions.

Zantedeschia aethiopica is evergreen and it has, depending upon climatic conditions, a long flowering period of 3 to 6 months. They grow from a rhizome, are strongly resistant to *Erwinia* under most circumstances, enjoy wet conditions, and are a lot more forgiving. The only comparative disadvantage is the lack of a range of cultivars.

Zantedeschia aethiopica is left in the ground for long periods and is not dug on a regular basis. In fact they are better left in a position where they are growing well for 5 to 7 years until they become overcrowded, and only at this stage should they be lifted.

I have already touched on some of the known taxa of the *Z. aethiopica*. There are others that are little known and are comparatively new, such as the pink-throated form, which we call 'Marshmallow'. 'Marshmallow' has a beautiful pink colouring and this colouring is enhanced if the flower itself is set slightly above eye level in a vase. It is interesting to note that shading can influence the degree of colouring. This can be brought about by artificial shade or the greater leaf canopy as the plant matures in the 2nd or 3rd year and the emerging bud is shaded from the direct sunlight prior to its emergence. If it is then picked just shortly after it emerges and allowed to open inside, frequently this pink colouring will be throughout the whole flower.

Of the other potential culitvars that are still to be released onto the market, we have one that we call 'Green Tip', which at this stage is still being bulked up. Application has been made for plant variety rights (PVR) and it would be under patent pending. Unfortunately it will be a year or two before this cultivar is available. Its main distinguishing feature is the fact that it is only the top of the petal that is green and this tends to stand up. It is actually a hybrid between the white arum and 'Green Goddess' and it has taken time and effort to stabilise. The effort has gone on for somewhere near to 15 years to achieve this, and it is quite an exciting product that will be on the market shortly.

Another new cultivar is called 'Red Invador'. This too falls into the category of patent pending, but at the date of this presentation it would be doubtful if there were more than 20 plants available. 'Red Invador' is distinguished by its red spadix. This red spadix against the white is very, very striking.

Zantedeschia aethiopica, in my opinion, has a lot of exciting possibilities down line and have been much neglected. The problem of bringing more colour and more variation to them could be quite a challenge for breeders in the future. I am of the opinion that it will not cross or hybridise with the callas. Having made that statement I have got to admit that the pink-throated arum, some many years ago, was available at Kew Gardens in England, having been supplied by people from South Africa. The powers that be at Kew simply put this down to a hybridisation between *Z. aethiopica* and *Z. rehmannii*. I personally would challenge this. We have sourced this form back to a specific area in South Africa, where it was known some 20 years ago and all efforts by breeders have failed to create a hybrid between the *Z. aethiopica* and the common calla.

I said *Z. aethiopica* has some exciting possibilities. Again I would mention that it is a reluctant hybridiser and it does not respond readily to tissue culture. In fact tissue culture, I understand from most of those that operate in this area, is totally uneconomical.

To its credit, though, let me state that it is a wonderful cut flower with a very long vase life. It is a wonderful garden plant and also a wonderful container plant. We already have quite a number and range of cultivars that can be used for all these purposes.

Zantedeschia aethiopica has a vase life of 4 to 6 weeks providing it is picked at the right stage. It has a container life of 2 to 3 years and as a garden plant it has a life span that I would hesitate to measure, but would suggest 5 to 10 years in one area, possibly more depending upon the conditions. As a commercial cut flower it should be left in the ground for 5 years and more without digging. It is interesting to note that the flowering ability increases as the plant grows older and as it multiplies under the ground. It is not uncommon to pick 50 flowers from a single plant in Year 3.

It thrives on a high soil moisture content. It is also a lover of soils with high organic content, and high nutrients. It prefers some shading, to what degree we have yet to learn. If, for example, we look at the 'Green Goddess' in New Zealand it will grow with very little shading. In the case of 'Marshmallow' the degree of shading can definitely influence the colouring. It needs to be remembered here that while high light enhances the colouring, direct sunlight appears to reduce it.

Ideal conditions then are one of sensible husbandry, of supplying high organic matter and a good nutrient balance. High moisture content, observation of the performance of the plant, and a little experimentation will enable one to find what makes this plant produce both the best colour and the highest number of blooms.

It is interesting to note that 'Red Invador' and 'Green Tip' are the only new types for a number of years. White arums have quite a number of different forms that have not been exploited. These include different flowering periods, different petal textures which would travel differently, and different sizes. 'Marshmallow', which nearly became extinct at one stage, is now becoming available to the public. 'Green Goddess' is well known throughout New Zealand and let us hope there are many other new cultivars to come onto the market to keep the excitement of *Z. aethiopica* in the forefront of the marketplace.

An Overview of the South African Seedling Nursery Industry

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The concept of a seedling nursery industry only began in South Africa with the introduction of containerised seedling propagation methods and the development of large, specialised nurseries dedicated to servicing the market for vegetable seedlings. These specialised seedling nurseries really only developed from 1975 with the introduction of the Speedling system using the Todd Planter Flat (Todd, 1981). This was of particular interest for producing cabbage seedlings, but very quickly found another market in plantation tree seedlings (Barrett, 1980).

Some 2.2 billion seedlings are grown annually in South African nurseries (Nelson, 1991). The major vegetable seedling crops are cabbages, tomatoes and lettuce. Multi-seeded onions are also popular in some areas.

A particularly interesting aspect of these nurseries, apart from their sole purpose being to propagate containerised seedlings, was the strong cross-cultural influences when the same nursery propagated a wide range of seedlings. The very earliest nurseries very frequently grew vegetable and tobacco seedlings at a time when tobacco field extension staff knew only the highly developed bareroot nursery technique and its requirements. In spite of the well researched bareroot system for tobacco seedlings, the containerised nursery system rapidly became the dominant system.

The system was quickly adapted for containerised forestry seedlings. Within a mere 5 years of the first reports on containerised forestry seedlings, about 50% of the total forest seedling requirement was being produced in the Speedling system and incorporating copper lateral root pruning (Donald, 1986). About 240 million forestry seedlings are grown annually (Donald, 1991). Initially seedlings were grown almost exclusively by private nurseries. Increasingly, the forest companies have taken back control of tree propagation, in particular wanting to retain direct control over their genetic material. This means clonal forestry, either from cuttings or tissue culture. The forestry companies introduced a container based on Scandinavian designs. Two variants are now common, one based on a tube system as used in Brazilian clonal eucalypt nurseries (Unigro tubes), the other based on a Swedish tray (SAPPI tray). Neither of these tray types incorporates a lateral root pruning concept, only pruning at the bottom drainage hole. Coincidentally, these forestry companies are reporting tree instability problems thought to be associated with nursery management of plants in these containers.

The Seedling Growers' Association of Southern Africa (SGASA) has been a unifying focus for seedling nurseries. From small beginnings as an informal meeting of Speedling users, the Association now represents the bulk of the industry in South Africa. The focus has always been on research to resolve propagation problems or to develop new market opportunities. While some nurseries have remained within their chosen market sector, the Association represents all nurseries propagating containerised transplants. Membership is entirely voluntary — the membership fee being a sliding scale in proportion to the size of the nursery.

Bedding plants and other ornamentals are produced by some of the more generalised nurseries. The emphasis on small runs of each variety and regular deliveries to many outlets makes this a difficult market to service compared to vegetable or forestry seedling markets. The use of plug technology has meant that many of the techniques common in general seedling nurseries are also used in bedding plant nurseries. However, reliance on broadcast sowing and pricking out into punnets is also common.

Other nursery crops are being grown. Sugarcane has received considerable attention. This has the potential to become a major nursery crop, with the growing techniques from single nodes quite successful. Viral infections common to sugarcane are generally eliminated by hot water treatment of the seed cane material. Unfortunately, this treatment also seriously reduces the ability of single nodes to sprout.

Lawn and pasture grasses are a steady crop in some nurseries. Some pasture types are only propagated from runners and plug methods are very efficient. Lawn grass plugs represent an alternative to seed or direct sticking of cuttings, or instant lawn methods. Sweet potato (kumara) and tea cuttings are some of the less common crops grown successfully.

Nurseries are quite labour intensive. The two activities most likely to be automated are seed sowing and watering. Even in large nurseries, certain seed lots will still be hand sown. The expectation of accuracy from seed-sowing machinery is considerably lower than in New Zealand nurseries. Seed-sowing machines are generally used for the easier and longer runs of crops, particularly cabbage seedlings.

Watering is generally either by moving irrigation booms or fixed sprinklers. The degree of automation varies enormously. Fertigation is a very common practice.

Tray filling is commonly done by hand, and even where a filler is used, this is generally a simple hopper system with staff required to complete the filling process.

Nurseries can have 200 or so staff, although changes in labour laws are forcing a review of labour productivity. Some nurseries have shed a third of their staff through fairly simple productivity improvements such as introducing trolleys for moving plants into or out of the nursery, increasing use of simple conveyor systems in the head house, and a more in-line approach to filling and sowing functions.

The South African seedling nursery industry is unusual in the sense that so many seedlings are produced in specialised seedling nurseries and not simply in nurseries as extensions to vegetable farming or plantation forestry activities. This has resulted in a good cross flow of information and techniques not common in countries where the nurseries are more strongly associated with their client industries. In addition, the formation of the SGASA and its continued emphasis on research activities has maintained a common focus for the industry.

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Progress with Green Tea and Cultivated Sphagnum Moss Production

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At the I.P.P.S. Conference in Auckland 1988 (Vol. 38) I shared with you the methods developed for propagating over a million green tea cuttings at the time of establishing an industry here in New Zealand. Then I spoke in Christchurch (Vol. 45) about developments towards propagation of sphagnum moss as a cultivated crop in an artificial environment.

Because these things occurred here in the Nelson region I was asked to bring the Society up to date with developments and report on progress.

GREEN TEA

Green tea has the potential to be a broadacre crop for parts of New Zealand. The plant grows well and trial results showed it would yield satisfactorily. The cultivar Yabukita was planted on 95 ha by 21 farmers on soils ranging from the light fertile soils of the Motueka Valley and Plains, to the heavier soils of the Moutere.

A tea factory was imported and assembled in Motueka and became operational. Tea was produced and exported through the early 1990s and up to the 1996/97 season. The overall cost of equipment for harvesting and processing exceeded $1.25 million and the total investment probably in excess of $5 million.

On most fields the plants grew satisfactorily and the first harvest was made in October 1991, but things were not plain sailing. Serious frosts in November 1994 and 1995 ruined a large percentage of the higher valued first cut, putting the Cooperative behind their yield predictions and creating major problems for growers cash flow, and an early frost in February 1995 ruined most of the second crop that season. Today there are nine remaining farmers with approximately 25 ha being harvested. Some farmers were told by Japanese advisors that their land was unsatisfactory and left the industry. Certainly *Camellia sinensis* for tea production has fairly specific requirements with drainage and organic matter being important. The plants have a high requirement for nitrogen and this was being applied either as solid fertiliser or through trickle irrigation. The harvestable part of the plant is approximately 90% water and consequently is very vulnerable to frost and even chill factor from cold winds following precipitation can cause damage. High light levels also played an adverse effect on leaf quality turning the young shoots a lemon green. This was easily remedied by applying shadecloth over the rows for a few days prior to harvest. In as little as 96 h the leaves greened up, but this introduced another expense factor and an engineering problem in lifting and relaying the kilometres of cloth needed.

The cooperative began trading under the new name of Southern Cross Tea Cooperative in early 1997 and currently changes to its financial structure are also occurring.

More recently the extraction of antioxidants from tea has been investigated. Antioxidants are biologically active components found in fruits, vegetables, and tea and may have a role in cancer prevention. Over 150 nutritional studies have shown that people who eat adequate fresh fruit and vegetables have the best protection against cancers. The presence of these in green tea may account for lower cancer levels in nations consuming high quantities of green tea.

Though the Motueka venture has not reached its full potential, I firmly believe that New Zealand could be a successful green tea producer and exporter, if climate, soils, cultivars, and management are all suitable. Some parts of the North Island may be better suited than in the top of the South Island, despite its history of tobacco which required frost-free conditions for growth.

SPHAGNUM MOSS

My paper in 1995 was on a growth chamber experiment where we looked at the effects collecting location, light levels, and growth from three types of propagules had on growth of two species of sphagnum. Two years on from there we are looking at using the information gained from those experiments to grow moss on a pilot commercial scale in a totally artificial environment. Traditionally, sphagnum has been a horticultural commodity for lining baskets, germinating seed, etc. Other uses include medical ones for relief of pressure sores, absorption from open wounds and in sanitary products. The moss growing system we are developing is for these latter uses, and we expect this and the economics of growing will dictate a higher price for the product. All of these involve the naturally large moisture-holding capacity of sphagnum.

By growing in an artificial environment, grading to remove debris found in the wild is eliminated and our experience suggests the moss will not have the familiar brown banding layers of swamp moss and will in fact dry almost pure white thus eliminating chemical bleaching. Two growing systems are being investigated this year. Firstly in a twin-skinned Durophane covered tunnel house and secondly in an artificial pond situation.

1)Tunnel House Production. Removable wooden racks 1 m 5 1 m covered with tightly stretched knitted Ultraswind covers are the basic growing structure. These racks slide into a multitiered frame with a misting nozzle above the moss at each level. Moisture is controlled by a swing arm misting unit with a gauze leaf activating a mercury switch connected to 12v DC water pumps, of the type used on tractor-mounted spray booms. These are operated from a deep cycle battery, solar panel and through a battery charger connected to the mains as a back up to ensure no drying out. The racks are surrounded by Ultraswind to provide shade and reduce direct light and evaporation and a cover of the same material covers the outside greenhouse durophane. Racks on one half of the growing frame were initially seeded with a thin layer of sphagnum fines to provide a more natural moist growing medium, on the other, moss is just seeded onto the ultraswind. No differences are apparent between growth on the two substrates after 4½ months. During the period January to mid April 1997 the greenhouse double doors at each end of the house were open for ventilation. In mid April they were closed and a small electric fan heater was placed in the tunnel and set to keep the night temperature just above freezing (3C). Closing the doors increased the overall humidity of the house considerably.

Growth from January set up time to mid March (7 weeks) was approximately 5 cm. At this time half of the moss on each frame was trimmed and a plastic grid placed on top of the cut surface, so that exact growth can be measured in future.

In previous greenhouse experiments cooler winter temperatures stopped growth, the moss became overwet and often discoloured. It is hoped that by maintaining temperatures above freezing, growth will continue over the low light, cold period. So far this whole system looks promising.

2)Artificial Swamp Production. Here wooden frames were set up and prepared to level. Each of the four ponds were lined with heavy grade black plastic and divided into four smaller beds each 1 m square. A pipe between each of these four beds maintained a constant water level in each. A series of drain holes in each pond enable water level to be raised or lowered as required by plugging holes to suit. They also enable excess water to drain automatically during rainfall. The water level in each pond is maintained constant through a header pool with a ballcock much the same as for maintaining the levels in a capillary bed. Above the ponds are spiral jet nozzles operated again by a swinging arm mist propagation unit controller and mercury switch to a solenoid valve, to allow for simulating rainfall. The moss surface never dries out. Each pond holds 24 plastic nursery hygiene propagation trays in four beds of six trays. *Sphagnum cristatum* was collected from two sources, Burnbrae (172° 15E, 42° 2 S altitude 400 m) and Tophouse (172° 55E,42° 40 S altitude approx 700 m), near Lake Rotoiti, and trays filled to be level with the tops. These were then set into the ponds. Growth for the first three months was similar to that in the tunnels when trimming was done. Trimmings were placed in further hygiene trays to continue growth

Individual beds were either shaded in one of two methods or not shaded. Water pH and nutrient levels are being monitored as are water temperatures. Temperature of the moss surface is being collected constantly using thermocouples connected to a data logger in both systems. Several beds within the ponds have been kept free of moss and one observation of interest is the distinct lack of algal growth in the presence of moss.

In 1995/96 season a moss trial grown in 25 cm 5 13 cm berryfruit trays in a greenhouse responded positively to small amounts of nutrient. In future the pH and the nutrient levels in this experiment will be adjusted and the growth responses measured.

SOME EXAMPLES OF CHEMICAL LEVELS

	Tap water	Burnbrae	2 weeks in pond
pH	6.6	4.6	7.7
Acidity	8.8	43	1.8
Nitrate N	0.24	0.04	0.09
Total P	0.0	2.5	0.0
Tannins	0.0	82	0.0
Hardness gm^3			
CaC_3	24	7	27
Potassium	0.88	3.3	1.1
Zinc	0.06	0.46	0.03

In future moss for medical use may be produced economically in greenhouses or artificial ponds.

The Genus *Skimmia* and its Production at Hadlow College

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INTRODUCTION

Skimmia is the most important ornamental genus of hardy, woody plants in the citrus family (Rutaceae) and ranks highly amongst woody evergreen shrubs for park and garden culture. Only one species, *S. japonica* and its subspecies *reevesiana,* are of commercial ornamental horticultural significance. The three other species (*S. arborescens, S. laureola,* and *S. anquetilia*) are mainly of botanical interest, although the hybrid *S.* ×*confusa* (*S. anquetilia* × *S. japonica*) is of distinct horticultural merit.

Skimmias are fairly slow growing, of compact habit, tolerant of most soil types, and do best in partial shade. Male clones are grown for their flowers. The terminal panicles, usually creamy white, sometimes tinged with pink, are often fragrant. Female and bisexual clones usually have smaller flowers but are followed by clusters of brightly coloured red fruits which persist throughout the autumn and winter months.

PROPAGATION BY CUTTINGS

Source of Cutting Material. At Hadlow we have found it preferable to select semiripe wood cuttings from container-grown stock. The quality of cutting material from field-grown stock plants, particularly once the plants are a few years old is not as good.

Timing. Currently at Hadlow, propagation takes place around Weeks 39 or 40, fitting in with the propagation of other evergreen shrubs. Skimmia is not a difficult plant to root and as long as the wood is reasonably firm they can be propagated at almost any time of the year, in our experience.

Selection and Preparation of Cuttings. We select material with firm wood, not too thin, and without flower buds. Cuttings are prepared by removing leaves to retain three to four in the terminal cluster. These may be reduced in size if fairly large. The stem should be 6 to 8 cm long and a 1.5-cm slice wound is made at the base of the stem.

Hormone Treatment. We have used 0.8% IBA in talc with good results.

Rooting Medium and Container. Our propagation mix consists of: 1 bale fine grade moss peat; 2 bags fine grade pine bark; and 2 bales shredded rockwool. Thorough mixing, together with wetting, is required to ensure the rockwool is broken down and evenly incorporated. Quickpot 77 cell trays are used and careful filling is required to ensure media is evenly firmed into each cell.

Propagation Facilities and Aftercare. After watering in, the cell trays are placed on a wet sand base heated by hot water pipes to maintain a basal temperature of 20C. A low polythene tent is constructed using a hoop framework which means the polythene is around 10 cm above the cuttings. Rooting takes 6 to 8 weeks and by Weeks 49 to 50 the plants are weaned from the polythene and overwintered in a frost-free greenhouse.

PROPAGATION BY SEED

At Hadlow we propagate the bisexual *Skimmia japonica* ssp. *reevesiana* from seed. It comes true except for the occasional seedling which is all male — in my experience the proportion of these is less than half of 1%. This is probably caused by a mutation rather than crossing with *S. japonica* ssp. *japonica* as the characteristics of the seedlings are completely *S. reevesiana* except for flower size. Named male clones which have undoubtedly arisen this way are 'Bronze Knight', 'Fata Morgana', and 'Ruby King'.

Source of Seed. The ideal source of seed is to have a few specimen plants in 10-litre containers that can be isolated from other skimmias at flowering time, possibly in a glasshouse or tunnel being used for an entirely different crop, to avoid cross pollination with other forms of skimmia.

Collection and Processing. As soon as the fruits become fully ripe they can be collected, under protection this would be around Weeks 40 to 42. The fruits are then pulped down and the quite large seeds (there are up to four per fruit but usually two or three if the plant has a good crop) are fairly easily separated by flotation. The seeds are spread out on newspaper to surface dry which, in an airy building, will only take 1 or 2 h.

Treatment and Sowing. Skimmia seed just requires a cold period to ensure germination. Seed is sown in conventional seed trays (150 seeds per tray). The medium is peat, fine grade bark, and perlite (2 : 1 : 1, by volume). The trays are filled to the brim and the medium then pressed down by 1 cm. After sowing, the seeds are lightly pressed into the medium and then covered with a layer of 5-mm crushed grit to the brim of the tray. The trays are then stood down in a cold glasshouse to expose the seed to a natural cold period over the ensuing winter.

PRODUCTION OF 9-CM POT LINER

From Cuttings. Rooted cuttings are potted off in Weeks 11 to 12 and stood down using carrying trays in a cold glasshouse. After the first flush of growth has hardened up, normally Weeks 25 to 26, the shoots are pruned back to leave stumps of between 3 and 4 cm. The wood must be quite firm when you do this, otherwise die back can occur in shoots. After pruning, a fungicide spray of Octave (prochloraz) is applied to help reduce fungal infection. This pruning back will encourage more shoots from low down, ensuring a good bushy liner.

From Seedlings. As soon as germination takes place, usually Weeks 11 to 12, seedlings are pricked off into 9-cm containers and stood down as for the cuttings. Care must be taken not to give them the same watering regime as the cuttings. Once established and growing you will need to pinch out the tips around Weeks 15 to 16 to encourage side shoots.

PRODUCTION OF 2- AND 3-LITRE PLANTS

The following winter, in Weeks 2 to 10 depending on scheduling, 9-cm liners of most cultivars are potted into 3-litre containers — use 2 litres for the slower growing sorts. They are placed pot thick under Dutch light glass. After the first flush of growth has hardened up, usually Weeks 22 to 24, they are moved out into shade tunnels and stood down with adequate spacing.

The most important pest problems are vine weevil, carnation tortrix moth, and two-spotted spider mite, which need to be dealt with appropriately. Weed control is with Ronstar 2G granules at potting, followed up with Flexidor spray later on. Growing under shade is vital to maintain good leaf colour.

COMMERCIAL POTENTIAL

The male clones, especially the cultivar 'Rubella', are grown in large quantities already and they flower well in 3-litre containers at a good time of year for retail sales. They make good tub and patio plants for partial shade.

There is much more scope with the female clones but it takes another season on the nursery to produce plants in fruit. This is relatively easy to achieve by potting on into 5-litre containers for another season but the extra costs then mean it is becoming an expensive plant for the customer. An accelerated glasshouse production programme could produce berrying in the second season.

CULTIVARS WORTH PRODUCING

Skimmia ×***confusa*** **'Kew Green'**, male form, with large fragrant creamy coloured flowers;

Skimmia 5confusa **'Isabella'**, female form, not too free with berrying, but excellent foliage even in the open.

Skimmia japonica **'Fragrant Cloud'**, superb male clone, with fragrant white flowers;

Skimmia japonica **'Emerald King'**, a new male selection from Boskoop research station, light green in bud;

Skimmia japonica **'Red Dragon'**, the largest flowers I have seen on a female clone followed by well displayed fruits;

Skimmia japonica **'Rubella'**, the standard red-budded male clone;

Skimmia japonica **'Scarlet Dwarf'**, good compact female clone displaying its fruits well;

Skimmia japonica **Rogersii Group 'Snow Dwarf'**, good compact male clone, low-growing repens type;

Skimmia japonica **'Stoneham Red'**, this I think is the best red-budded male clone;

Skimmia japonica **'Tansley Gem'**, perhaps the best compact low-growing female clone;

Skimmia japonica **'Wakehurst White'**, more vigorous than some white-fruited female clones, looks good at Christmas time;

Skimmia japonica **'Bronze Knight'**, usually classified under *japonica* ssp. *japonica* but to me looks like a male form of *reevesiana*, good grower with bronze tints in the flower buds;

Skimmia japonica **'Ruby King'**, a large-flowered red-budded male clone of ssp. *reevesiana*;

Skimmia japonica **ssp. *reevesiana* 'Chilan Choice'**, makes quite a large bush, dark bronzy foliage with large red fruits;

Skimmia japonica **ssp. *reevesiana* 'Robert Fortune'**, the original introduction of *reevesiana* grown on the continent as a fruiting pot plant, seems to lack vigour nowadays, possibly because of selection for heavy fruiting. Plants at Wakehurst Place, growing outside, however seem to have more vigour.

Opportunities for Breeding Woody Ornamentals, With Particular Reference to *Sambucus*

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With a few important exceptions, little systematic plant breeding has been undertaken in woody ornamentals. A research programme at HRI - East Malling is focused on the breeding and genetics of ornamental trees and shrubs and good progress has been made with elderberry, *Sambucus* spp. With *S. nigra*, various crosses have been made among the cultivars 'Aurea', 'Guincho Purple', 'Laciniata', 'Fastigiata', and 'Pulverulenta', and subsequent generations have been raised. Yellow leaf and purple leaf were identified as dominant characters, while laciniate leaf, fastigiate habit, and variegated leaf are recessive. Trials have begun on several selections containing two or more of these characters. Propagation for commercial release of the most promising cultivar is under way. With *S. racemosa*, a second generation cross has been raised from 'Sutherland' × 'Tenuifolia'. This segregates for leaf colour, leaf shape, and vigour, and trials of several promising selections have begun.

INTRODUCTION

In many woody ornamentals, little systematic genetic improvement work has been undertaken. Rose, camellia, and rhododendron are obvious exceptions, but in most genera the diversity available to the gardener depends on observant botanists and horticulturists selecting interesting variants from the wild or from open-pollinated seedling progenies. The plant breeder, by careful choice of parents, controlled crossing and selection of promising seedlings, can take this existing variation and put it into new, commercially-useful combinations.

There are several stages to the plant breeding process, both before and after the actual act of cross pollination. First, the objectives of the breeding programme need to be defined. These depend on the subject but, in general terms, compact habit is often desirable for modern, small gardens, and novelty is important because it helps to stimulate demand to a greater extent than minor improvements of existing cultivars.

Once the objectives have been set, likely parents which have the potential to transmit the desired characteristics can be chosen. Works such as those by Bean (1970-1988) or Krussmann (1984-1986) are invaluable guides. For tracking down the plant material of the desired species and cultivars, the RHS Plant Finder (Lord, 1997) and the National Plant Collections organised by the National Council for the Conservation of Plants & Gardens (NCCPG, 1997) are extremely useful.

Controlled crosses involve several processes including emasculation, pollen extraction, and the checking of pollen viability. After the cross has been made, the resulting seeds may need stratification or other presowing treatments to optimise seed germination. Inferior seedlings must be discarded and promising ones selected. Then the promising selections are trialled to determine whether they are worth releasing, or whether they can be used as parents to raise a further generation of seedlings.

Genetic research enables the breeder to understand the mechanism of inheritance of important traits and so predict with greater accuracy the outcome of subsequent generations.

HRI-East Malling has received funding from the Horticultural Development Council and the Ministry of Agriculture, Fisheries & Food to work on the breeding and genetics of woody ornamentals. Much of this work is with elderberry, *Sambucus* species. Work has been undertaken on two different species and the brief account that follows represents an update on work described by Tobutt (1992).

BREEDING NEW CULTIVARS OF *SAMBUCUS NIGRA*

Sambucus nigra is the black-berried elderberry native to Britain. The wild form is attractive enough in flower or fruit and is tolerated in hedgerows, but otherwise it is decidedly drab. Over the years, botanists and gardeners have selected and propagated more attractive forms or cultivars that have arisen as sports or chance seedlings. At East Malling, crosses have been made using the following such cultivars in different combinations: *S. nigra* 'Aurea' (yellow leaves), 'Guincho Purple' (purple leaves), 'Pulverulenta' (variegated leaves), 'Laciniata' (laciniate foliage), and 'Fastigiata' (erect growth habit). The aim was to recombine these ornamental features into novel combinations by intercrossing.

Techniques. The crossing technique was tricky with *Sambucus* because the flowers are so small. To prevent self-pollination, the young flowers on the female parent were emasculated with forceps, before the pollen was shed. The flower clusters of the male parent were then dusted over the prepared flowers on the female. The flowers were covered with a bag to exclude insects and, later, to protect the ripening berries from birds. The resulting seed was sown in autumn in proprietary seed-raising medium, ripened in the warm for 1 month and then stratified at 4C for 3 months before germinating in early spring.

Results. When 'Aurea' was crossed with 'Guincho Purple', the seedlings segregated for yellow, purple, yellow and purple, or green leaves indicating that yellow leaf and purple leaf are both dominant characters. The yellow-purple combination often appeared as an eye-catching tawny or amber, especially on young shoots.

When 'Laciniata' was crossed with 'Aurea' and with 'Guincho Purple', the first generation segregated for yellow versus green leaf or for purple versus green leaf, respectively, but all seedlings had normal-shaped leaves, suggesting that the laciniate leaf character is recessive. To re-express the laciniate leaf, we intercrossed a yellow and purple seedling; the second generation expressed all eight combinations of yellow, purple, tawny, or green leaf colour and laciniate or normal leaf shape. Examples of yellow laciniate, purple laciniate, tawny laciniate, and tawny normal have been selected, propagated and planted in trial.

When 'Guincho Purple' was crossed with 'Fastigiata' the first generation segregated for leaf colour but all seedlings had normal growth habit, suggesting that fastigiate habit is recessive. A second generation was raised by intercrossing two purple seedlings. The resulting offspring segregated for green seedlings versus purple seedlings, some of which were exceptionally dark and presumably homozygous, and for normal seedlings versus fastigiate seedlings. A few interesting low-growing types appeared too.

Some of the fastigiate purple seedlings and some of the exceptionally dark seedlings of normal habit were propagated and planted in trial. Selection 528-180, one of the exceptionally dark purple seedlings, has pinkish flowers and appears to be sufficiently novel and garden-worthy that the HDC and HRI have decided to release it, probably under the name 'Black Beauty'. It is currently being bulked up by propagation from softwood cuttings.

Another cross was between 'Laciniata' and 'Pulverulenta'. As all the first generation of seedlings appeared normal, we intercrossed two seedlings. The second generation progeny segregated for laciniate versus normal, and also for variegated versus green, indicating that variegation is a recessive character. Some of the laciniate variegated seedlings were planted in trial, but their ornamental merit is debatable.

There is certainly further scope for breeding between these cultivars of *S. nigra*. For example, a fastigiate type with laciniate, tawny, variegated foliage should be achievable, though not necessarily desirable. In addition, within *S. nigra* there are other potentially interesting characters that have not yet been explored in breeding work at East Malling, such as weeping habit from *S. nigra* 'Pendula', thread-like foliage from 'Linearis', and dwarf habit from 'Pygmaea'.

BREEDING NEW CULTIVARS OF *SAMBUCUS RACEMOSA*

Sambucus racemosa is the red-berried elder, native to mainland Europe. In the work described here, only two cultivars have been used as parents, 'Sutherland' (yellow cut-leaved) and 'Tenuifolia' (dwarf with green, highly dissected leaves).

Results. Crosses between 'Sutherland' and 'Tenuifolia' produced seedlings that segregated for green versus yellow but with cut leaves rather than dissected leaves. With the aim of re-expressing the dissected character, two yellow seedlings were intercrossed; the second generation gave various combinations of green, yellow, or very pale yellow, with cut or dissected shape and normal or dwarf vigour.

These seedlings were grown in the field for about 5 years. Several are promising and have been propagated for trial. They include dwarf, cut-leaved forms in green and in yellow, and dissected, yellow slow-growing forms.

CONCLUSION

The natural variation that occurs in *Sambucus* has been exploited by conventional breeding, to produce a range of selections worth considering for commercialisation. The success of this approach justifies a similar approach being taken in comparable genera.

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Trends and New Plants in the Cut Foliage Industry

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INTRODUCTION

This paper describes the approach of a cut-foliage project in Ireland called Forest Produce, based in County Kerry and producing foliage for supermarkets in the U.K. and mainland Europe.

MARKET TRENDS

In the 1970s floristry was using long-stemmed bouquets of around 70 cm — mainly carnations and chrysanthemums. Foliage was used in very small quantities, and amounted to just 3% of the total turnover in flowers. By the 1980s the stem length of single-colour bouquets had decreased to between 60 to 65 cm. The amount of foliage used per bouquet increased to about 12% because more foliage lines were available in this particular stem length range. In the current decade stem lengths used in bouquets have decreased further to about 55 cm for supermarkets and between 45 to 50 cm for florists. The amount of foliage used has increased still further, driven particularly by increased consumer awareness of nature and a desire for natural-looking floristry.

MEETING MARKET NEEDS

Detailed research is needed before a particular item can be grown for the floristry industry. Species and cultivars with potential as foliage products have to be manipulated to meet the needs of the producer and the market.

For example, growing methods can affect what you grow and the way it looks; or a change in the market could give an old product a new impetus. Adding on other items such as labels or bigger pots can change market perceptions of an otherwise unchanged plant. Establishing the production of plants for cut foliage means thinking 3 years ahead, which makes good market research essential.

NEW PLANTS AND GROWING METHODS TO MEET CURRENT MARKET TRENDS

Criteria for Foliage Production. When searching for new species or cultivars to produce foliage for floristry, bear in mind that the crop should meet the following criteria:

- Foliage stems should be straight, and 55 to 75 cm in length.
- The bulk of the volume of the foliage should be in the top (the plastic sleeves used by florists have to be filled with as few stems as possible). A pyramid shape will not fill a bouquet in the top. However, shape can be manipulated by cultivation.
- Large quantities must be available during specific periods of the year, e.g., for Easter, Mothers' Day, etc.
- You must be able to price the crop in line with market expectations while providing a return for the grower. Pricing is related to how well the foliage fills the bouquet. You can obtain a higher price per stem for species or cultivars that fill a bouquet with fewer stems.

Crops Being Investigated by Forest Produce:

***Cotinus* 'Sandor'.** A yellow-leafed cultivar, which can be used as a garden plant as well as for cut foliage. It has a good vase life, the right shape, and a long harvesting period.

***Ilex aquifolium* 'Myrtifolia'.** Exclusive cultivar, right shape and length. Low productivity but can command high prices for the Christmas market.

***Olearia macrodonta*.** The leaf shape makes this a perfect replacement for *Ilex*, which is very tough and damages other flowers when mixed in a bouquet. This plant is soft and will not damage flowers. Right stem length and shape.

***Olearia stellulata*.** It grows in the wrong pyramid shape but by pinching the top at the right time of year, the topside branches grow an extra 10 cm to produce more volume in the top. Good vase life, very high productivity, good colour.

***Ozothamnus rosmarinifolius* 'Silver Jubilee'.** Has a poor shape but can be improved by pinching. Long harvesting period, from October to May, and very attractive in bud. Good productivity but frost sensitive.

***Physocarpus opulifolius* 'Diabolo'.** A patented cultivar which can be used for cut foliage. It has red foliage and straight stems of the right length, but could do with more volume in the top. One could pinch back to obtain a spray in late autumn. The season is a bit short, leaves fall during autumn.

***Pittosporum*.** This has been used for some years as an exclusive foliage item. Only available in low quantities, mainly from France and Italy. Stem length rarely meets expectation, therefore, sold per bunch or by weight. The bouquet industry would like to use more pittosporum but development is needed to produce green, variegated, and red foliage on 55 cm stems with bushier tops.

***Prunus laurocerasus* 'Etna'.** A garden plant which can be used for cut foliage. It has a natural upside-down pyramid shape, glossy leaves, and a long production period.

***Sophora* 'Little Baby'.** Market research shows a great demand for this item. The difficulty is stem length if grown outside. Production per square metre is only moderate but it could make a good crop producing low quantities for exclusive markets. It has the right shape and very good vase life.

***Viburnum tinus* 'Spirit'.** This can be used in flower for garden planting, as a pot plant, as a cut flower, and in berry as cut foliage.

FUTURE TRENDS

In the future, the following criteria are likely to drive the development of new cut foliage lines:

- The search for higher quantities available over a longer period of the year.
- A desire to market via exclusive deals over a specific period, for a particular supermarket or wholesale outlet.
- Changes to shape, length, and colour specifications.
- Price.

If we compare the U.K. with mainland Europe we see an enormous gap in attitude towards the market. In the U.K. there is no daily auction system, so buyers are forced to plan ahead. They have to rely on producers. New lines tend to be instigated by the breeder, while in Holland they are instigated by demand at the auction. In the U.K. breeders and propagators have to plan in conjunction with foliage producers and the floristry trade to ensure success. In other words there have to be very close links between breeders, propagators, and the trade. This trend is much more advanced in the U.K. than in other countries.

Review of Techniques used at Angers to Increase Genetic Diversity

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This paper surveys various techniques to develop and select new woody ornamental cultivars. Mutagenic treatments have proved valuable in modification of characteristics such as plant habit, flower colour, earliness of flowering, or to modify chromosome number in species such as *Forsythia, Weigela, Malus, Lonicera, Clematis, Hydrangea,* and *Pelargonium* [*P.* ×*hortorum* and *P. peltatum* (syn. *P.* ×*hederaefolium*)]. Intra- or inter-specific hybridization is preferred if existing genetic diversity is broad enough and plant biology makes it possible. Combinations of these techniques have also been successfully used in *Forsythia* and *Weigela.* Genetic transformation has been developed using *Agrobacterium tumefaciens* as a vector to introduce disease resistance in *Pelargonium* and to change flower colour of *Pelargonium* and *Forsythia.*

INTRODUCTION

Whatever the plant species may be, a breeding scheme always starts with a full description of breeding objectives and the gathering of a good collection of appropriate species and cultivars; this allows us to estimate existing and available genetic diversity.

Crosses are made within the collection to create new populations of seedlings from which individuals not expressing desired traits will be weeded out. Selection is based on criteria such as frost resistance, disease resistance, plant habit, flower colour, etc. We aim to select from a population with wide genetic diversity; this diversity has to be targeted to genes which can contribute to achieve our stated breeding objectives.

To incorporate the desired genes, breeders benefit from a range of tools from conventional hybridization to the advanced genetic transformation through mutagenesis. Any selected genotype should be capable of being the mother plant of a new cultivar reproduced by cuttings or grafting.

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EXISTING GENETIC RESOURCES

The existing genetic resources or genetic "raw materials" for breeding programmes consist of species and selected cultivars kept in botanical or horticultural collections; or of plants found in their natural habitat. Working collections are established to detect the most valuable genotypes almost immediately usable by growers or to be used latter on in a breeding program. For example, we have tested members of the Rosaceae against fire blight (*Erwinia amylovora*) in this way. Pretty good resistance has been found in several *Crataegus* and *Sorbus* species (e.g., *C. canadensis, C. delosii, S.* ×*arnoldiana*, and *S. decora*) which are now under evaluation for their ornamental qualities and possible use.

Natural genetic resources have long been exploited, but it is still possible to use them to broaden the genetic variability of cultivated plants because often only a small sample of the natural gene pool has been used to provide the stock of all plants in cultivation. New fire-blight-resistant genotypes of *Sorbus* have been introduced from natural sources in Yunnan (China), for example. Natural sources can also be used to introduce species which are scarcely known or even unknown in cultivation. We have been trialling collections of *Leptospermum, Coprosma,* and *Corokia*, introduced in 1987 from the coldest parts of the South Island New Zealand to select for frost resistance. Many have survived winter temperatures down to -12C. During the winter of 1996-97 temperatures reached -15C at ground level so we were able to select the hardiest individuals to provide clones for use in areas were these species are not usually considered hardy (Cadic and Harris, 1997; Decourtye and Harris, 1992; Decourtye et al, 1991; Lecomte and Cadic, 1993; Paulin et al, 1993)

HYBRIDIZATION

Controlled hybridization is the oldest but still the most common breeding tool. Crossing two complementary parents will produce a population of seedlings, which is a random sample of all possible combinations of the parental genes. The breeder then selects seedlings to retain the most desirable combinations. The limitations are that it must be biologically possible to cross the parents containing the desired genes, and the genes must be present in the working collection.

Hybridization has been used to obtain cultivars of *Pyracantha* resistant to scab (*Spilocaea pyracanthae*) and fire blight (*Erwinia amylovora*). The technique is also being used as part of the breeding program on *Pelargonium* ×*hortorum* and *P. peltatum* (syn. *P.* ×*hederaefolium*). Events linked to floral biology may interfere with breeding scheme. For example, in *Cotoneaster*, several polyploid species are also apomicts (producing seed "vegetatively" so that progenies are absolutely identical to the mother parent).

Ornamental horticulture has long made use of hybridization between different species. However, some species are so genetically distinct that interspecific crosses are not readily achieved. With *Berberis*, a solution has been to increase the number of combinations between red deciduous species and evergreen ones. Interspecific hybrids had green deciduous leaves and it was necessary to get a second generation by selfing those whose fertility had not been altered. In shrubby *Lonicera*, the number of possible crosses to combine early flowering as found in *L. fragrantissima* with the red-purple flower colour of *L. tatarica* 'Arnold's Red' is small. All crosses made by using fresh or preserved pollen failed but recent observations have shown that this is because of a failure of embryo development rather than of fertilisation. We are developing "embryo rescue" techniques whereby the embryo can be removed from the seed and grown in vitro, to circumvent this difficulty (Cadic, 1987; 1992).

MUTAGENESIS AND POLYPLOIDY

Mutagenic treatments are developed to modify permanently the genetic constitution of a given genotype — in other words to produce mutant strains. This is achieved by using chemicals such as EMS or physical agents such as X-rays and gamma rays. With vegetatively propagated species treatments can be applied to meristems and mutants (sports) have to be selected from corresponding growing shoots. The hundreds of cells of a treated meristem are randomly affected by the applied treatment and the sprouting new shoot is usually a chimera (i.e., a mixture of two or more genetically distinct tissues). In this situation it is difficult to identify the mutant parts, to protect them from strong competition by non mutant cells and to regenerate and select homogeneous plants.

In-vitro culture, however, allows mutagenic treatments to be combined with regeneration from callus, internodes, or leaves. Here regeneration starts from one or a very few cells so mutants are more easily detected and selected. In vitro culture has allowed this research station to undertake gamma ray treatments in nearby Angers hospital. Mutagenic treatments have to be made on the best existing cultivars and are commonly used to induce slight modifications, for instance in the length of internodes (*Forsythia, Lonicera*), precocity of flowering (*Forsythia*), flower colour (*Weigela*), and leaf variegation.

Inducing polyploidy (multiple sets of chromosomes) is a special mutagenic treatment. For example, chemicals such as colchicine have been used to double chromosome numbers. Cultivated types of *Pelargonium* and their wild relatives have 18 chromosomes in their nonsexual cells but colchicine can induce tetraploidy (36 chromosomes per cell). Such treatments are used to increase the variability allowing crosses between more distantly related species.

A tetraploid *P. quinquelobatum* has been successfully crossed with tetraploid cultivars of *P. ×hortorum*. Several triploid *Weigela* cultivars have been selected by using first in vitro culture and colchicine to get tetraploid forms then by crossing tetraploid with normal cultivars. The resulting triploid cultivars do not produce seeds and do not need to be pruned each year. Such cultivars have an advantage in amenity planting schemes (Cadic et al., 1980; Cambecedes et al., 1992; Duron and Decourtye, 1977).

GENETIC TRANSFORMATION

Genetic transformation consists of the introduction of a specific gene into cells which are then induced to regenerate full plants. Modified strains of *Agrobacterium tumefaciens*, the bacterium responsible for crown-gall disease, are used to transfer genes. More recently particle guns have been developed to transform monocot species which are not susceptible to *Agrobacterium*. This technique, in theory, allows transfer of any gene from any living organism irrespective of sexual or evolutionary barriers.

Transformation can only be carried out on plants which can be regenerated in vitro from calluses, internodes, or leaf-blade explants. You also have to know exactly where to find the gene you wish to transfer, you must be able to clone it and you must have been able to research its mode of expression. Laboratories which are developing genetic transformation need to master all the tools of molecular biology and they have to follow rules enacted by ethic committees and by specialised commissions.

At Angers, our first work on genetic transformation was on *Forsythia* in 1991 and on *Pelargonium* in 1993, involving flower colour and disease resistance. The very popular red flowering ivy pelargonium 'Roi des Balcons' is completely sterile and thus cannot be hybridized. It looks possible to block the biosynthetic pathway which produces anthocyanin pigment so that a white flowering cultivar could be produced.

Pelargonium cultivars used as pot plants or bedding plants are rather susceptible to a bacterium (*Xanthomonas campestris* pv. *pelargonii*) and to several viruses including the pelargonium flower break virus (PFBV) and the pelargonium leaf curl virus (PLCV). Resistance has not been found among known cultivars. Cecropin, a protein produced by an insect, has proved effective against the bacterium and can be introduced into pelargoniums.

We are also experimenting with genes from rat and yeast which can be introduced into pelargoniums to give resistance to viruses. (Robichon et al, 1995; Rosati et al, 1996)

CONCLUSION

Horticultural enterprise depends to a large extent on developing new crops. Hybridization remains one of the commonest ways to produce new cultivars from crossing parental lines with desirable traits. Vegetatively propagated woody plants have a juvenile period from 2 to 5 years and, with exception of a small number of species such as rose, rhododendron, and lilac, few have been systematically bred and selected so that a noticeable progress will be seen after just one or two selection cycles.

Mutagenic treatments are successful for vegetatively propagated ornamentals because resulting mutants can be cloned readily. The technique is ideal in cases where genetic variability is lacking and when only a slight modification of a good cultivar is required. Results are in part a matter of chance since treated cells are randomly affected by the applied treatment. More or less sophisticated strategies can be developed to increase the probability of detecting variants and recovering them as solid mutants. About half the number of cultivars issuing from Angers has been produced using mutagenic treatments. Among the so-called biotechnologies, only genetic transformation has been used in the Angers breeding program and, so far, no new cultivar has been produced. However, this technique is promising. Limitations might come from gene availability, gene patenting, consumer resistance, and costs.

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New Plants at Andre Briant Nurseries

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INTRODUCTION

Andre Briant Jeunes Plants is a specialist propagator of hardy ornamental nursery stock liners. The present owner, André Briant (I.P.P.S. GB&I Region President in 1993) purchased the business from his father's company in 1963 when it was a general ornamental nursery. Briant felt there was a market for a specialist propagator and transformed the general nursery into a liner producer selling to growers. Some 15 years ago, Briant met Didier Mathis, a passionate plantsman, and together they decided to make new plants a feature of the range offered by Briant. Mathis took on the role of finding new plants for Briant Nursery. The nursery currently propagates and grows approximately 10 million young plants each year (pot liners, bareroots, and plugs) which are sold throughout Europe (50% in France and 50% exported). Twelve percent of its turnover is represented by new cultivars, protected by breeders' rights. This paper describes how the nursery brings new plants to the market.

FROM THE BREEDER TO THE GARDENER

Definition of a New Plant. A new plant can be a real new selection or an old cultivar forgotten or never grown in large quantity, such as *Syringa microphylla* 'Superba'. A novelty can be a major new range of plants or a small improvement.

Source of New Plants. André Briant Nursery tends not to breed its own new lines although there are exceptions such as Weigela 'Olympiade' (registered name Briant Rubidor). More often, new plants come from public research such as that undertaken at the INRA Station in Angers, or commercial breeders or plantsmen, and amateurs. Often colleagues and other nurserymen with a good eye for spotting a more upright or more compact plant in a crop of seedlings bring them to the attention of the nursery. Workers on the nursery are also on the look-out for something which could appear different in the crop or in the stock plants.

Trials. Time is made available to test plants in propagation, containers, and open field. This varies depending on the type of plant, shrub or tree, and whether it is totally new or whether there is experience from growers in other countries. Trials in the open field are particularly advantageous as the plant has room to grow and show its real potential, perhaps after several years. When we need to test plants in different conditions (climate, soil, etc.), we work with colleagues or customers. Participants in the SAPHO group, which partly funds the research to trial-launch these cultivars on the market, test INRA cultivars.

Selection of Varieties for Marketing. The commercial team regularly visits the trial sites but it is not easy to motivate salesmen at the trial stage. The final selection decision is taken by André Briant and by the commercial manager and the production manager and is based on our knowledge of the market. Selections are made once a year.

Getting New Plants into Production. We aim to rapidly grow sufficient quantities as soon as possible, using tissue culture if necessary to bulk up numbers if the amount of stock material is small.

Market Launch. We have three methods:

Direct Launching. This is our classical method, using the catalogue with a good picture, posters, colour labels, press releases to horticulture magazines, competitions at trade shows, exhibitions to customers in our garden.

Organized Launching. Recently, we have tried to launch some new plants exclusively through selected nurseries who sell to the garden centre, landscape, or mail order market before the grower market. It will be included in our general wholesale catalogue 2 or 3 years later. The selected growers agree to grow minimum quantities and the promotion is more concentrated. Selected growers have more motivation to sell the plants and the technique can be used both for protected and unprotected cultivars.

Use of Specialized Launching Company. In 1990, André Briant founded, with two partners (Meilland and Flamand), a specialized company for launching new plants, called Selection New Plant. The system is based on a worldwide agent network which organises licencing and promotion.

The company is still young but has already launched two woody plants: *Robinia pseudoacacia* 'Lace Lady' (registered as Twisty Baby) and *Berberis thunbergii* 'Bogozam' (registered as Bonanza Gold). Two more are due soon and we will be monitoring the efficiency of the operation over the next few years for the right balance between costs and results.

CONCLUSION

Launching new plants is undertaken on a strategic basis and is part of the culture at Andre Briant Jeunes Plants. Several methods have been tried during the past 15 years and the nursery is still looking for the best balance between costs and results.

The Development of Australian Plants for Foods and Flavourings

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THE BUSHFOOD INDUSTRY

In recent years a small, but growing, industry has developed in Australia based around "Bushtucker" or "Bushfood" plants. There are currently up to 30 or more Australian plants being used for a range of products, from fresh and dried plant parts to plant essences and flavourings. The development of this industry has been influenced by a number of factors including adventurous chefs using the plant products in the first place; community concerns over "clean" and environmentally friendly foods; the new tastes and flavours available; and the unique Australian nature of the product (assisted in part by "The Bushtucker Man" television series). A recent report identified 14 of the most commonly used plant species and provided some financial estimates for intensive cultivation of these species (RIRDC, 1997).

There is certainly demand for the plant products. In 1995-96 the total sales value through the food processing part of the industry was AUS$4.5 million (Econsult, 1996), while the total sales of bushfood products in 1996 were over AUS$14 million (The Age, 13 Jan. 1997).

BUSHFOOD PLANT SPECIES

Many bushfood plants have not had extensive horticultural cultivation and exposure, except through native plant enthusiasts. The plant origins are diverse and include many common vegetation communities across the continent, including tropical rainforest, coastal heathland, open woodland, and semi-arid habitats. Aboriginal use of different food plants was extensive. In Victoria up to 140 different plant species have been identified as food resources by local aboriginal peoples (Gott, 1993), demonstrating the enormous potential that exists for further development.

A good example of a bushfood plant and perhaps the most widely planted species at present is the quandong or native peach (*Santalum acuminatum*). It is found throughout the semi-arid zones of the Australian continent. Being a partial root parasite, it would seem an unlikely species for horticultural exploitation. However the orange-red fruit has a sweet outer layer (and oily, edible kernal) which was prized by aboriginal people and later by early Australian settlers. The fruit is mainly used as a dried product and in a processed form, although there is also demand for fresh fruit. The development of cultivars through the Commonwealth Science and Industry Research Organisation (CSIRO) and Sunraysia Nurseries, together with improved propagation methods (Smith, 1994), has led to an increase in quandong plantings. The Australian Quandong Industry Association has estimated that between 40,000 and 50,000 trees have now been planted in Australia, with the vast majority planted in the last 4 years (RIRDC, 1997).

A recent survey of growers identifies the main plant species currently being cultivated in Southern Australia (Table 1).

Table 1. Main bushfood plant species cultivated by Southern Bushfood Association (SBA) growers (SBA newsletter and survey results, 1997).

Tubers, rhizomes, and allies
Arthropodium milleflorum, mountain vanilla lily
Microseris lanceolata, murnong or yam daisy
Triglochin procera, water ribbons
Typha domingensis, cumbungi

Fruits and seeds
Acacia spp, wattleseed
Acronychia imperforata, lemon aspen
Austromyrtus dulcis, midyim berry
Billardiera scandens, appleberry
Dianella revoluta (syn. *D. longifolia*), pale flax lily
Eremocitrus glauca and *Microcitrus* spp., wild limes
Kunzea pomifera, muntries
Nitraria billardieri, nitre or dillon bush
Podocarpus elatus, illawarra plum
Sambucus gaudichaudiana, native elderberries
Solanum spp., kangaroo apples
Syzygium leuhmannii, riberry

Herbs and foliage
Apium prostratum, sea parsley
Backhousia citriodora, lemon-scented myrtle
Correa alba, white correa
Drimys lanceolata (syn. *Tasmannia lanceolata*), mountain pepper
Mentha australis, native mint
Prostanthera spp., mintbush
Tetragonia tetragonioides, warrigul spinach or greens

CULTIVATION OF BUSHFOOD PLANTS

The types of plant products finding their way into the marketplace include both wild-harvested materials and increasing amounts of cultivated plant materials. The amount of bushfood still being wild harvested is a concern, both from a plant conservation viewpoint and because of quality and continuity of supply. There is some cultivation information for bushfood species (ANPI, 1994; RIRDC, 1997), but it is still very generalised and lacks significant cultural information. What is needed is basic agronomic information for bushfood species, particularly the optimum environmental and cultural requirements for plant performance and harvest details. Postharvest information, especially treatments that will maximise product quality and uniformity, is also needed. Growers experiences with different crops are providing a means of assisting the exchange of information where so little exists.

Growers however are currently mostly small-scale and lack capital investment for their enterprises. Within the SBA, a recent survey of growers indicated that most operate mixed enterprises, the average size for production is 8 hectares, 30 species were under cultivation (reperesenting approximately 350 kg of product), and 19 species were being wild harvested (reperesenting approximately 300 kg of product) (SBA newsletter and survey results, 1997).

RESEARCH AND DEVELOPMENT

Current research and development activities in the Bushfoods industry is minimal.

Plant Propagation. There is little information in the public domain on suitable propagation methods for most bushfood species. Many plants are unavailable in nurseries, so uncertain origin of materials and difficulties in vegetative propagation are common. For most plants a clonal propagation method will need to be developed to assist with utilising improved forms of the plant (through breeding and selection). A recent paper on the propagation of bushfood plants (McCarthey, 1995) outlines some of the issues associated with the propagation of five different plant species/ groups. Results of cuttings trials undertaken at Burnley College, University of Melbourne, of three bushfood species showed that slowness to strike (more than 15 weeks) was a significant problem with two of the species trialled (*Acronychia oblongifolia* and *Kunzea pomifera*) despite a range of treatments applied. In the third, *Tasmannia lancolata* (mountain pepper), however, 70% of the cuttings rooted after 7 weeks with 3000 ppm IBA application. Clearly more propagation research would be useful for those in the nursery industry.

CSIRO is undertaking a number of different research projects associated with bushfood plants. This ranges from entomology to soil management projects (Boland, 1997).

Plant Improvement. Activities have included *Santalum acuminatum* (quandong) and more recently *Eremocitrus glauca* and *Microcitrus* sp. (wild lime). Australian Native Produce Industries (whose Red Ochre Grill restaurants have been utilising Bushfood ingredients for years) have also been involved in the development of improved plant selections. They currently have seven protected cultivars of bushfood plants for sale through their nursery in South Australia.

Food Processing and Toxological Research. This has been very limited to date. A detailed paper on the chemical constituents and potential toxicities of bushfood plants (Plantchem, 1996) provided a useful background to the main issues associated with plant usage. Research undertaken by the University of Tasmania with *Drimys lanceolata* (syn. *Tasmannia lanceolata*) (mountain pepper) has looked at essential oil production and is now leading to the establishment of clonal plantations of mountain pepper throughout the state.

THE FUTURE FOR BUSHFOODS

Apart from greater research and development into bushfood production, there are other challenges facing the bushfoods industry. The problems of supply and demand need to be carefully considered. While there is demand for many products, some estimates of industry growth may be extravagent and there are already forecasts of overplanting with some species (RIRDC, 1997). Increasing demand for products will be essential for plant producers.

The grouping of a national alliance of regional grower-based groups (Australian Bushfoods Federation) is also crucial to the development of the industry. This group consists, at present, of the Australian Rainforest Bushfood Industry Association

(ARBIA), Southern Bushfood Network, and the Queensland Bushfood Cooperative society. The federation, as it evolves, will be in a position to look at national issues facing the industry (particularly the development of a new research and development plan) and hopefully act as a catalyst for increasing and disseminating information on the horticultural production of bushfood plants.

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Selecting and Breeding of New Plants at the Boskoop Research Station for Nursery Stock

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INTRODUCTION

Plant breeding has been undertaken at the Dutch Research Station for Nursery Stock in Boskoop since the 1940s, resulting in several popular cultivars such as *Buddleja* 'Pink Delight', *Cytisus* 'Boskoop Ruby', *Pieris japonica* 'Debutante' and 'Cupido', *Agastache* 'Blue Fortune', and *Lonicera* 'Honey Baby'. In 1990 the Dutch government withdrew finance for plant breeding research but nurserymen undertook to financing the selection of new crops in certain categories, through their commodity board.

In 1992, 5-year programmes started on four categories of plants:

1) Showy container plants for the impulse market;
2) Herbaceous perennials for low-maintenance amenity plantings;
3) Small trees for private gardens;
4) Woody ground cover plants for amenity plantings.

These four categories of plants cover 75% of all the species grown in nurseries.

Defining the Perfect Plant

Plant hunters or nurserymen find new species, new seedlings or sports, and trial them to see what they might be suitable for. A breeder starts with a specification of an ideal cultivar for a specific purpose and then aims to reproduce it as closely as possible through breeding and selection. Our work combined both approaches. We had specifications for the sorts of crops we wanted and set out to find them either by selection from species not currently in commerce or by breeding better strains of currently commercial plants.

The list of criteria the plants have to meet (Table 1 shows criteria for the most demanding of our four categories, as an example) is drawn up from information from literature, growers, salespeople, auctions, market research, etc. Because the demands change, these lists have to be kept up to date continuously.

CHOOSING THE PLANT MATERIAL

Selection from Species not Currently in Commercial Cultivation. Most of the new species in our trials came from botanical garden seed-exchange schemes and were selected from literature descriptions (if available). Winter hardiness was an important criterion, so we mainly ordered seeds originating in areas with a climate roughly similar to the Netherlands (USDA Zones 3 to 7). We were most successful in getting new winter hardy plants from the U.S.A. and Canada, the Far East (China, Nepal, Korea, Japan), Eastern Europe, North Asia, and the Mediterranean.

Table 1. Breeding and selection criteria for showy container plants.

Attractive leaves, flowers or fruits, borne for a long period — especially if attractive during a market "gap".
Resistance to diseases and pests.
Reliable winter hardiness.
Versatility (e.g. can also be used as a houseplant).
Easy maintenance by consumer.
Meets market trends — currently fragrance, hot flower colours, attractiveness to butterflies.
Absence of bad smells, skin irritants or toxic chemicals.
Grows well in a standard container size, uses standard potting mixture and fertiliser.
Compact habit needing no chemical inhibitors; the size and shape is easy to transport.
Easy to propagate consistently and uniformly.
Crop can be scheduled using temperature or day length.
Production does not require complex cultivation (grafting, cutting back, grading) or work during the busy periods of the year.
Work can be mechanised.

When checking seed lists for new plant genera to try out, without any specific plant in mind, some plant families were especially promising. These families had a large number of winter hardy genera that contained ornamental perennials or woody plants. These were the Apiaceae (Umbelliferae), Asteraceae (Compositae), Brassicaceae (Cruciferae), Fabaceae (Leguminosae), Lamiaceae (Labiatae), Liliaceae, Poaceae (Graminae), and Scrophulariaceae. In some smaller families, almost all the genera were attractive and winter hardy. These included the Berberidaceae, Caprifoliaceae, Cupressaceae, Dipsacaceae, Ericaceae, Oleaceae, Onagraceae, Plumbaginaceae, Primulaceae, Ranunculaceae, Rosaceae, and Saxifragaceae.

Selection of Commercially Available Species with Potential for Improvement by Breeding. One of the things we were interested in was to improve the disease resistance of showy container plants. To find the best crops for us to work on, we asked the Aalsmeer flower auction (an important sales outlet for these products in the Netherlands) for their top 100 nursery products. We ignored all the products on which commercial companies were working on a large scale (*Rosa, Rhododendron, Hydrangea, Chrysanthemum, Clematis,* and heathers), and products that only specialists breed well (conifers, grasses, alpines). This left about 60 different lines. From these we chose crops known to have major disease problems, or ones whose compactness or flowering could be improved.

SELECTION AND BREEDING

Selection from Species not Currently in Commercial Cultivation. Seeds were sown in a warm or cold greenhouse, depending on germination requirements. From the species that germinated a maximum of 40 seedlings were pricked out and hardened off. These were planted out in our experimental garden for between 1 to

3 years, to determine habit, winter hardiness, and susceptibility to pests and diseases. Although the tallest species were protected from wind no frost protection or pesticides were used; weeds were removed by hand.

We selected potentially showy, compact plants and these were divided and put in containers in a convertible-roof greenhouse. They were tested for ornamental value, while techniques for propagation and cultivation were devised. If there were differences between the seedlings we selected the best among them, and these were propagated.

A committee of nurserymen will then evaluate the plants and the best will be released. We will apply for plant breeder's rights where applicable and appropriate.

Perennials and shrubs for amenity plantings were not tested in containers but were tested at different locations on different soil types. We also looked at amenity planting densities and at how well the plants suppressed weeds and, where appropriate, recovered after mowing. The small trees for private gardens are not mature yet, but we have tried to propagate them. Some were grafted on different rootstocks to test their compatibility and we have trialled propagation by seed and cuttings.

Improving Commercially Available Species. We first obtained mother plants, which as a group possessed all the properties we wanted. Then we made test crosses, to determine the best way to remove anthers, hand-pollinate, keep insects out, and harvest the seeds. This also gave us information about which combinations of parents were possible. In the following years we made crosses between desirable parents. The seeds from these crosses were sown and the seedlings were selected in the field, as described above.

RESULTS

Seed accessions numbering 1250 from about 750 different species were obtained from botanical garden seed lists. From the plants we tested more than half have been rejected already because of: insufficient winter hardiness, not perennial or woody enough, too little improvement over similar plants already in commerce, low ornamental value, susceptibility to disease, weak stems, or invasiveness.

We expect that about 40 new species and cultivars can be released in the next few years. Most of them are new to the trade, some are known but rare in commerce. Plants currently looking promising include:

Showy Container Plants for the Impulse Market.

New plants. *Amsonia, Rhexia, Physochlaina,* and *Zizia.* Selections and cultivation trials currently under way.

Improved Plants.

Pieris japonica. A selection with upright, red-budded inflorescences.

Ligustrum. We had a large collection of *Ligustrum* species available, so we harvested free-pollinated seeds from interesting mother plants. We selected a compact but fast-growing type that can be used for low hedges and topiary.

Cytisus. We had a selection of *Cytisus* with a low and broad habit. This type is interesting to grow in containers because it doesn't have to be cut back as hard as the usual upright cultivars to keep it compact. We are trying to produce a complete colour range of this type by crossing.

Hypericum. Species with berries have become very popular in the last few years, in gardens, parks, containers, and for cutting branches for mixed bouquets. However, all the existing cultivars are susceptible to rust. By crossing cultivars with wild plants, we are trying to produce rust-resistant plants.

Herbaceous Perennials for Low-Maintenance Amenity Plantings.
New Plants.
Coluria. This Chinese relative of the strawberry has white flowers in May. The ornamental value is modest, but the leaf rosette seems dense enough to control weeds.
Silphium. Selections of these high plants with yellow flowers are very sturdy.

Improved Plants.
Solidago. We selected and crossed several species which are mildew resistant and have strong stems.

Small Trees for Private Gardens.
New Plants.
Sorbus. We tested several new compact shrubs from China with white or pink berries. They can be grown on rootstocks, from cuttings, or from seed.

Woody Ground Cover Plants For Amenity Plantings.
New Plants and Selections.
Aronia. We are comparing several well-known and new cultivars for their suitability for parks etc. A new cultivar from Sweden, 'Hugin', seems interesting because of its compactness.

Useful Characteristics for Breeding in *Heuchera, Pulmonaria,* and *Tiarella*

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INTRODUCTION

There are a good number of garden-worthy genera in which very few cultivars have been bred or selected. This paper focuses on the author's work on breeding and selecting new cultivars of *Heuchera, Pulmonaria,* and *Tiarella*. Gardeners regard a number of species within these taxa as "nice woodlanders". I wanted to go beyond this and began collecting as many species as possible to enrich the genetic "palette". These were crossed in a range of combinations and hybrids analyzed to the following criteria:

- Is the new strain sufficiently different from current offerings (i.e.: are differences obvious to an observer standing 3 m away)?
- Does the leaf or flower excite customer interest?
- Is hybrid vigor evident?
- Does it have a wide climactic range? (determined from Pan-American trials)
- Is it capable of propagation in tissue culture to fulfill consumer demand?

Between three and ten selections would generally be made from each 1000 seedlings. Visitors to the nursery were polled for their favorites. The selected plants were trialled in different climatic zones over a 3-year period, and if successful were moved into full production.

HEUCHERA

Coral bells are often thought of as drab little plants with tiny but bright flowers but breeding has resulted in an explosion of stunning new foliage and flower forms. Numerous seedlings have been drawn from, to present plants that are superior in foliage, flower production, and hardiness. Handsome plants have been chosen bearing satiny silver or purple leaves measuring 25 cm across. Others include breakthrough forms showing ruffled foliage and flowerscapes to a meter tall, yielding superior cut flowers and new rock garden plants.

Listed below are the plants I have used in my breeding program, together with the positive and negative points of each.

***Heuchera americana*:** The backbone of my breeding program because of its incredible shade tolerance, tall flower spikes, repeat blooming, evergreen leathery foliage, metallic highlights, mildew resistance, insect resistance, cold and heat/ humidity tolerance, and attractive seasonal variability.

***Heuchera parviflora*:** Drought resistant, sun tolerant, and good dwarf forms but has poor flower structure and dislikes lowlands and humidity.

***Heuchera micrantha*:** Ruffled leaves, good rhizomatous forms, huge flower spikes, and vigorous.

***Heuchera villosa*:** Good purple and discolor forms but has thin leaves and burns in sun.

***Heuchera cylindrica* and *H. pruhoniciana* hybrids:** Nice foliage, good dwarf forms, some mottled leaves, large flower size, and has long stiff stems that florists love but also suffers from mildew problems and poor flower color.

***Heuchera sanguinea*:** Colorful flowers, mottled foliage, and extended flowering period but suffers from mildew and, in areas of high heat and humidity, from poor growth.

***Heuchera richardsonii*:** Tremendous hardiness to -15C, flowers small, but colored.

Through hybridizing, different "blends" of genes have yielded a plethora of new forms combining characteristics from *H. villosa, H. americana, H. sanguinea,* and *H. micrantha.*

TIARELLA

In American woodlands, *Tiarella* taxa are low understory plants, some rhizomatous, others clumping. The breeding goal was to improve leaf, flower, and "in-pot" presentation — an element which some breeders overlook. It has been our experience that vigorously running cultivars "fly" off the edges of the pots and are easily damaged in transit and at the nursery. We are selecting clumping forms for a better "show". Available species for breeding show the following characteristics:

***Tiarella cordifolia*:** Good running habit, good fragrance, large short, if wispy, flowers; and large leaves.

***Tiarella wherryi*:** Nice clumping habit, some foliar and flower coloration but mildew-prone and smaller leaves and flowers.

***Tiarella trifoliata* ssp. *laciniata*:** Attractive, extremely dissected foliage with potential for introducing new leaf forms into other species but small wispy flowers and lack of vigor.

PULMONARIA

Natives of shady woods and scrublands from Siberia to Italy, *Pulmonaria* taxa are often the harbingers of spring. The flower colors range from salmon (*Pulmonaria rubra* 'Redstart') through raspberry (*Pulmonaria* 'Berries and Cream') to sky blue (*Pulmonaria* 'Roy Davidson'). An outstanding characteristic of most *Pulmonaria* is the fact that the flowers turn totally different shades as they age — pinks may fade to blues, wines to reds, or the reverse. Some, like *Pulmonaria* 'Sissinghurst White' and the coral *P. rubra* 'Bowle's Red' hold their color for the whole flowering period.

The other exciting aspect of *Pulmonaria* is foliage. Background colors may vary from apple green through olive to an almost black-emerald. Brilliant silver spotting may run from lightly dusted to solid silver (*Pulmonaria* 'Excalibur' U.S. Patent 8958). Foliage shape is another variable. Leaves can be lanceolate, such as *Pulmonaria* 'Bertram Anderson', to oval, as in *Pulmonaria angustifolia* ssp. *azurea*. The latter plant is one of the dwarves of the genus, rarely reaching 20 cm high. Plants like *Pulmonaria mollis* 'Samobor' can top out at 75 cm tall! One characteristic that I have bred into my plants is that of ruffled edges. This is seen in *Pulmonaria* 'Berries and Cream' and *Pulmonaria* 'Silver Streamers', an extremely wavy form that I hope to patent in 1997.

I have used the following species for their positive traits:

***Pulmonaria mollis*:** Showy violet flowers, bronze new growth in spring, heavily veined foliage, huge upright leaves but mildew-prone and poor foliage color.

Pulmonaria saccharata: Showy, oft-changing colors, some good silver forms but long petioles tend to cause leaves to catch the wind more easily and self-destruct and the plants are susceptible to mildew.

***Pulmonaria longifolia*:** Beautiful cobalt blues, lovely lance-shaped, well spotted foliage but some susceptibility to mildew, and the flowers are small, with very awkward flower stalks between flowering time and foliage production.

***Pulmonaria rubra*:** Very early and floriferous with large flowers in salmon and coral tones and good mildew resistance but leaves do not age as well as other species.

***Pulmonaria vallarsae*:** Extremely long blooming with short petioles and excellent mildew resistance. The plants have good substance and silvering with excellent vigor. The short pedicels show the flowers better while shorter petioles hold the leaves closer to the center.

Maximising Output from a Propagation Unit

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INTRODUCTION

Output can be maximised by making a system as efficient as possible, especially by analysing and planning the various processes in order to achieve the greatest possible efficiency in production. Greater efficiency is the key to greater profitability although too many growers still believe profit comes from screwing the supplier on price (Coutts, 1997). Growers will also need to improve their labour efficiency, by as much as 10% year on year (Rowe, 1997), because labour costs won't come down, more labour is likely to be used as you expand, and there are few other areas left to improve.

In terms of direct costs labour can account for between 25% and 60% of net sales and is therefore the single biggest cost.

PHYSICAL FACTORS INFLUENCING OUTPUT

The major physical factors are:

- People — their abilities, speed and motivation;
- Handling systems;
- Ergonomics;
- Batch volumes — as these increase, down-time decreases;
- Facilities — as capital investment increases management time for the crop and percentage losses should decrease;
- Type of crop grown, e.g., rooted cuttings or direct struck crops.

The people who are actually doing the work, taking the cuttings, for example, should be responsible for monitoring these points and producing the monitoring information required by management.

FINANCIAL FACTORS INFLUENCING OUTPUT

The key here is to compare all costs against a common base-line, for example (pounds or dollars) per square metre, remembering that so-called variable costs turn out generally to be fixed and fixed costs are variable. The aim is to reduce costs, increase output, and decrease losses. This is demonstrated well by an example from nursery stock adviser, Will George (pers. comm.) (Table 1).

Costings, work rates, etc. are often treated with suspicion by the staff in the propagation unit as a divisive management tool to get people to work harder. It has to be made clear that it is purely an aid to make the business run more profitably, which should benefit everyone.

Key parameters worth looking at are:

- Labour usage and efficiency is probably the most variable factor, so for budgeting purposes look at gross margin/1000 h. This is then translated into cuttings per hour or per labour unit.
- Gross margin per square metre.
- Net sales per 1000 h (do you have a target?).
- Number of square metres per 1000 h of labour.
- Return on capital.

Table 1. Comparison of effect of increases in yield or price on profitability.

	Initial position	Increase price 5%	Increase yield 5%
No. of plants produced	1000		
Cost	£1.40 each		
Selling price	£2.00 each	£2.10	£2.00
Yield	85%	85%	90%
Sales value	£1700	£1785	£1800
Cost of production	£1400	£1400	£1400
Margin	£300	£385	£400
Increased profit		28%	33%

Gross profit margin can be maintained by:

- Controlling variable costs.
- Maintaining production costs of facilities and overheads in ratio to sales.
- Setting pricing to maintain the margin by allowing for discounts and wastage before negotiations on price.
- Ensuring, where competition is less intense, that prices do not come under pressure.

The industry does not have available sufficient information about pricing. Countrywide realistic costings are needed to help nurseries achieve prices based on unit costings which in turn would generate a better margin and "profit". It is difficult to understand how 9-cm liners of *Buddleia, Escallonia, Euonymous, Lavender, Lavatera, Penstemon,* and *Pernettya* can all be found priced with only a 1% to 2% difference when they have such vastly different production costs. When these plants are sold on, 8 to 10 months later, as the final product there are price differences between the species of around 25%.

CONCLUSION

Nursery operators must monitor costs in order to maximise output from propagation units. It doesn't matter what is monitored as long as monitoring is regular — the discipline of doing this will have many benefits for your propagation unit.

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Comparison of Japanese Maple Production in United Kingdom, France, and Italy

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INTRODUCTION

This Mary Helliar Travel Scholarship was undertaken to study the production of *Acer palmatum* in France and Italy and to see if any of the methods used there could be used to improve the quality of Japanese maples produced and retailed in the United Kingdom. To compare production methods I visited three recommended producers: Filli Gillardelli, 20041 Agrate Brianza, near Milan, Italy; Maymou Nurseries, 64100 Bayonne, near Biarritz, France; and Liss Forest Nursery, Greatham, Hampshire, U.K. Both Gilardelli and Maymou produce their plants in open ground and I was particularly interested in the part played by soil and climate in their production method and their effect on the quality of the resulting plants.

ORIGIN AND CLIMATIC PREFERENCES OF JAPANESE MAPLES

The Latin *Acer* means "sharp", perhaps a reference to the hardness of maple wood, which was used by the Romans for their spear shafts. There are more than 100 species in the genus but this report looks at the commercial production of only two of them, *A. japonicum* and *A. palmatum* (three if, as does Hilliers Manual, one classifies *A. shirasawanum* as a separate species) which are, together with their numerous cultivars, referred to as Japanese maples.

These species originate from East Asia, central China, Korea, and Japan. They prefer a temperate climate and a moist but well-drained loam soil. The leaves are delicate and susceptible to damage by water stress caused either by excessive sun or cold wind, both of which will scorch the leaves of some cultivars. Both Gilardelli and Maymou nurseries are located in areas of high rainfall and relatively mild winters (minimum temperatures no colder than -2 to -5C) where field-grown plants are not subjected to the fatal combination of cold and damp. The availability of water is important to make the most of the two or three flushes of growth, which these plants will make each year.

At present most imports of Japanese maple to the U.K. come from other E.C. countries, mainly from Holland. Some plants are thought to come from Japan, where the plant quality is excellent, via Holland. New Zealand, where plants are field budded, produces good quality plants, but transport costs are high and the plants suffer a setback from the 6-month change in seasons.

JAPANESE MAPLE PRODUCTION AT FILLI GILARDELLI

The nursery consists of five sites with a surface area of 80 ha on flat land to the west of Milan. The soil is a slightly clay loam with a pH of between 6.5 and 7. The area receives on average between 1000 mm and 1500 mm of rain each year. The minimum temperature is between -2 and -5C.

[1]Mary Helliar Travel Scholarship recipient 1996

A system of field grafting perfected by Giordano Gilardelli, one of the current owners, enabled the firm to move from relatively small scale to very large-scale production of Japanese maples and it currently has about 1 million plants in production. As well as Japanese maples it grows conifers, trees, shrubs, and climbers with a tendency to produce mature specimens for the landscape and amenity market. The nursery produces its own seeds for growing rootstocks and has many plants for sale which are up to 40 years old.

Gilardelli grows more than 100 cultivars of Japanese maples, but production is concentrated on about 40. None of the cultivars are propagated from cuttings. For the rootstocks, seeds are sown under protection and seedlings are either grafted in the pot when they are 2 years old, and then planted out in the field; or they are planted out and grafted using whip and tongue grafts when they are 5 or 6 years old. The 2-year-old grafts were of a side cleft type, which the propagator described as being a variation on a "maiorchina" graft. Grafting is done between June and September, and they expect 90% to 95% graft take although this is reduced considerably if the summer is hot. The main pests are two-spotted spider mite (*Tetranychus urticae*) and vine weevil (*Otiorhynchus sulcatus*).

The pricing structure for plants is based on their size and the number of times they have been transplanted. They find that transplanting increases plant development and leads to a more uniform product. Their marketing strategy emphasizes the quality of their plants and the exclusivity of some of their own selected cultivars, including a selection of *A. palmatum* Dissectum Atropurpureum Group which they call 'Pink Filigree' and a selection called *A. palmatum* 'Orange Dream'.

JAPANESE MAPLE PRODUCTION AT MAYMOU NURSERIES

The nursery is situated in wooded hills just above Bayonne. The vegetation in the area is noticeably lush, especially in contrast to the flat countryside to the north around Bordeaux. As in Milan, the rainfall averages between 1000 mm and 1500 mm per year, and the minimum temperature between -2 and -5C. The soil tends to be acidic because of the high rainfall. Monsieur Maymou's grandfather started the business and there are many large *A. palmatum*, up to 12 m tall, edging parts of the nursery. Japanese maples are the main crop but there are many other trees and shrubs, all field grown. All the Japanese maple rootstocks are grown from seeds collected on the nursery and sown in trays immediately after collection in November or early December. About 2 months after germination, when the roots are well developed, the seedlings are pricked out into clay pots with loam-based compost. At the beginning of September these are plunged into a cold frame under shade — although some seedlings are at this stage lined out in the field.

The potted seedlings are grafted in August of the following year using a side veneer graft. Once the grafts take, the understock is headed back a bit — an operation repeated about a month later if necessary. Once growing, plants are not pruned as a natural shape is preferred. Lined-out plants are top worked at a height of about 1.3 m. The graft used here is a development of a shield graft: a scion about 10 cm long is taken with the branch collar. A "T" cut is made in the rootstock stem, the scion is then slid into position and tied.

In the field no fertilizer is applied and rainfall usually supplies sufficient irrigation here. The surrounding forests also increase humidity and offset the effects of any drying winds. There was no leaf scorch to be seen and M. Maymou said that he had never had any problem with dieback.

Verticillium wilt has been a problem in some areas of the nursery, and these have been set aside. He sells his field-grown plants bare rooted in winter.

JAPANESE MAPLE PRODUCTION AT LISS FOREST NURSERY

The nursery is situated north of Petersfield in Hampshire, southern England and produces ornamental trees and shrubs, with a particularly wide range of Japanese maple as well as *Ceanothus, Clematis,* and *Hebe*. Slightly more than half of the 32 listed Japanese maple cultivars are produced by grafting the remainder from cuttings.

Cuttings. Cuttings are taken in May and take 6 weeks to root. They must be potted on by July, otherwise they are left in their trays and are potted the next year. If they are potted after July they will not have time to harden off. Nodal tip cuttings, normally with 2 nodes, are made from the base of the wood working upwards. When the wood towards the tip loses its stiffness or resistance it is not used as it tends to rot off. The cuttings are then dipped in a hormone powder containing 0.3% w/w indolebutyric acid (e.g., Seradix 2) and stuck in a peat and grit mix containing 10% bark. They are then given 18C basal heat with mist. The rooted cuttings are potted from 9-cm to 12-cm pots with a compost of peat, bark, grit, and loam (11 : 3 : 1 : 1, by volume). The loam is added to absorb any excess fertiliser.

Grafting. Grafting is done using side veneer grafts in June and July on understocks between 1 and 3 years old and matching understock and scion wood of the same size. Scionwood varies from one to three nodes long depending on the availability of material. Sealing the summer grafts with wax is unnecessary but the grafted plants are kept humid under polythene covers. It is important to check watering regularly at this stage to maintain humidity. Once the grafts have taken they are gradually aired about 4 weeks after grafting and they will be fully aired 2 weeks after that. The top of the understock is removed early in the spring of the following year, although some growers remove it in September or October. Potted on plants are then stood on an Efford sand bed in an unheated polythene tunnel and irrigated from the bed from the end of May onwards. The plants are pruned between growth flushes to produce a bushier plant.

CONCLUSION

The requirement of Japanese maples for plenty of water and warm, humid conditions was met by high natural rainfall at the Italian and French nurseries; however, in southern England such conditions can successfully be replicated using polythene tunnels and Efford sand beds and such techniques can produce plants of similar quality in pots.

The field growing system is, however, more suited to the production of larger plants than are currently generally sold in the U.K. market. French and Italian buyers do, however, seem prepared to pay for large specimens while U.K. buyers want as much growth as cheaply as possible.

The Italian market seemed to prefer a neatly dome shaped plant while the French wanted a more natural-looking unpruned plant.

From catalogues it is only possible to make approximate comparisons of the wholesale price of plants, which varied between 58.1 DM for plants at 80 to 100 cm from Gilardelli, to 20 DM for plants at 40 to 60 cm from Liss Forest.

Acknowledgements. Finally I would like to acknowledge the assistance of those at the I.P.P.S, Renzo Limonta at Gilardelli, M. Maymou at Maymou, and Peter Catt and Judy Medhurst at Liss Forest Nursery. I would also particularly like to thank those members of the I.P.P.S. who so generously contribute towards the Mary Helliar Travel Scholarship.

Notes on the Propagation and Cultivation of *Romneya coulteri*

Karen Hawkridge
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INTRODUCTION

Romneya coulteri is native to the Santa Ana Mountains, southeast of Los Angeles, California, where it is said to be abundant. The Irish botanist Dr. Thomas Coulter discovered it in 1833. The generic name commemorates the Irish astronomer Dr. F. Romney Robinson, a friend of Dr. Coulter.

Romneya coulteri was not introduced to the British Isles until 1875, when seeds were received by E. G. Henderson and Co. and by Thompson of Ipswich. The first recorded flowering took place in Ireland where a small plant at the Glasnevin Botanic Garden opened one bud in the autumn of 1876, having been planted in the March of the same year. The following year it flowered abundantly after reaching 1.8 m in height.

PROPAGATION

Although most commonly propagated by root cuttings, *R. coulteri* is very easy to germinate from seed which can be stored for many years without losing its viability. The essential ingredient is petrol to break the seed coat. Wrap the seed in muslin and soak in the petrol for 10 to 15 min before washing thoroughly in soapy water several times. Remember petrol is highly flammable or explosive so take great care. Use a container holding the minimum amount of petrol necessary and keep it well away from sparks or other sources of combustion — remember that petrol vapour can spread over some distance. Wear protective gloves and avoid having petrol come into prolonged contact with your skin.

Mix the seed in vermiculite for easy sowing then sow quite thickly and cover with sharp sand. Place the seed trays outside for the autumn and winter but keep a close eye on them, as germination can start as early as November/December, although it does not usually occur until February. As soon as you see signs of germination, put the trays into a frost-free glasshouse and prick out as soon as germination has occurred. Germination will be rather uneven but pricking out must be done before the second pair of leaves appears because the seedlings do not react well to disturbance, even at this stage. You will get several flushes of germination over 3 to 4 months.

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Placing the seed trays on a heated floor once the first flush of germination has started will bring forward the remaining seeds, although make sure you have the staff and ample space to cope with this — sometimes this can be a problem during February. We have found that although *R. coulteri* does need winter stratification, a wet winter will cause problems with root rot when germination begins. Placing a Dutch light over the trays is beneficial.

CULTIVATION

Romneya coulteri may be relatively easy to propagate but its cultivation is another matter.

Compost. The essential point is that the compost should be well drained and while pH is not of great importance, extremes should be avoided. *Romneya coulteri* is a hungry feeder but high levels of fertiliser should be avoided in the early stages to avoid a build up of salts that could lead to root scorch.

Feeding. *Romneya coulteri* does soon run out of steam, however, when this happens, top dressing is preferable to liquid feeding to avoid foliar scorch.

Pots. Deep "rose pots" are ideal for *R. coulteri* because it is quite deep rooting.

Beds. At Fromefield we have found capillary beds to be the best solution, although gravel standing areas work well too. Use of dark-coloured standing-out textiles such as Mypex is not recommended because they absorb too much heat at the root zone.

Pruning. At Fromefield we pinch the plants when young to promote a bushier growth habit.

Watering. *Romneya coulteri* requires plenty of water through the growing season, which is best applied in the morning or evening.

PEST AND DISEASE

Romneya coulteri is fairly pest resistant. Keep an eye out for slugs and caterpillars, along with red spider mite (two-spotted mite) and whitefly. A regular drench with Nemolt will control sciarid fly larvae. Drench regularly with Rovral or Repulse against *Botrytis* along with Octave to minimise the risk of stem rots.

ENVIRONMENT

As with any plant one is considering growing for the first time, clues about how to grow *R. coulteri* successfully come from studying and copying its natural environment.

Growing in the mountain ranges of southern California, *R. coulteri* encounters hot dry conditions with low daytime humidity and plenty of air movement. These areas are however subject to nighttime fog so a degree or two of humidity is not a real problem. Don't be fooled into thinking they need to be kept on the dry side. They will quickly perish if not kept moist.

Once planted out, *R. coulteri*'s deep searching roots will soon find their way to moisture and, if happy, after a few seasons will turn into more of an attractive weed than a notoriously difficult plant to propagate and cultivate — and you'll wonder what all the fuss was about.

Developments in Biological Control for Nursery Stock

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INTRODUCTION

Biological control has been used commercially on protected edible crops for more than 25 years in most Northern European countries. Many pests are similar for most horticultural crops, whether grown outside or under protection. Nursery stock plants however, are subject to some additional pest organisms not usually associated with edible crop production. These include vine weevil, many aphid and caterpillar species, plus transient minor pests such as psylids, gall midges, etc.

The basic technology behind biological control is independent of the crop, so the lessons learned in one branch of horticulture can usually be modified to suit another. For non-edibles, programmes which integrate biological and chemical controls, are more usual because of the wider range of selective pesticides available. The U.K. is fortunate that any pesticide approved for use on an edible crop can automatically be used on a non-edible crop grown under similar conditions. An example is the recently approved Luxan Dichlorvos 600 and Dichlorvos Aerosol 15 which only carry label approval for thrip control on protected cucumber. However both products can also be used as a rapid knockdown of many adult pest organisms on any non-edible crop. However, as with all ornamental off-label uses, the liability for phytotoxic damage on crops, other than protected cucumber, falls to the grower.

Integrated pest management (IPM) is a method of harmonising several control strategies. Principally biological and cultural control methods are used for the major pests: aphids, spider mites, thrips, vine weevil, and whitefly. Cultural control includes the use of sticky traps for flying insects and covered floors to help prevent spread of soil borne diseases and weeds. Certain chemicals may also be integrated with biological agents to control diseases and other pests. The pesticides mentioned in the text are known to have negligible effects on beneficial organisms and can therefore be used in an IPM programme. Most other pesticides are harmful to beneficial organisms — for example synthetic pyrethroids such as bifenthrin, cypermethrin, and deltamethrin are broad-spectrum insecticides capable of killing most insects and are active for several weeks.

You can use an IPM strategy for most crops grown under protection for several months of the growing season. This paper will concentrate on the two pest organisms for which recent developments have occurred: aphids (the development of new species of parasites) and vine weevil (the development of new control strategies).

APHIDS

Aphids feed on plant sap causing leaf yellowing and distortion, they also excrete a sugary honeydew onto leaves on which sooty moulds develop. These moulds reduce the photosynthetic area, thereby reducing crop growth. Aphids can also transmit several plant viruses. Several species of aphid may be found on protected crops. *Myzus persicae* (the peach-potato aphid) is extremely common and variable in colour, ranging from shades of pink and yellow to grey-green. Other species include *Aphis gossypii* (the melon or cotton aphid), which is usually found on cucumbers, chrysanthemum, and other ornamentals. Recently several other aphid species have become more prominent and invariably more difficult to control. These include *Aulacorthum circumflexum* (the mottled arum aphid), *A. solani* (the potato aphid), *Brachycaudes helichrysi* (the leaf-curling plum aphid), and *Macrosiphum euphorbiae* (the glasshouse potato aphid). Biological control using parasites, predators, and pathogens is now well established.

Parasitic Wasps. *Aphidius colemani* can be purchased as a mix of adults and "mummies" (the papery bodies of dead aphids in which the wasp has pupated). Adult parasites lay single eggs in up to 150 individual aphids, the egg hatches into a larva, which eats the internal body tissues. When the parasite pupates inside the aphid body it forms the characteristic papery mummy which remains stuck to the leaf. The complete life cycle (adult to adult) takes around 3 weeks. Parasite mummies are well protected from most pesticides allowing short-persistence and selective chemicals to be safely integrated. Aphid parasites tend to be fairly specific against the aphids they will attack. *Aphidius colemani* is mainly active against *Aphis gossypii, Myzus persicae* and several cereal aphids. This has forced the development of other aphid parasites, most of which are equally specific but to different aphids.

Aphidius ervi attacks the pea aphid (*Acyrthosiphon pisum*) as its principle host, along with several cereal aphids. However, within a biological programme we use it against *Myzus euphorbiae, M. persicae*, and *Aulacorthum solani*. Perhaps the most useful second-line aphid parasite is *Aphelinus abdominalis*. This parasite can be used to control *M. euphorbiae, M. persicae* (plus other *Myzus* species), *A. solani*, and others. Trials, by Novartis BCM, have shown that, at 20C, each female is capable of parasitising 200 aphids, over a period of between 15 and 27 days. Fecundity is low during the first few days of adult life, but by day four has risen. Daily fecundity rates are between 10 and 15 eggs per female per day after this, and do not decline with age. In addition, host feeding kills approximately two young aphids per day. A black mummy forms 7 days after parasitism at 20C. The adult parasitoid emerges from this mummy 14 days later. At 25C the daily average fecundity drops slightly to 11 eggs per female per day, but the total number of aphids parasitised continues to increase. Mortality of aphids as a result of host feeding rises to approximately three per day.

Aphid Midge. The aphid midge, *Aphidoletes aphidimyza*, will attack almost all species of aphids. They are distributed around the crop as cocoons from which the nocturnal adult fly emerges. Adults lay between 100 to 200 small orange/red eggs close to aphid colonies, these hatch after 3 to 4 days and the larvae attack the nearest aphid, injecting a paralysing toxin. Larvae hide beneath the aphids, where they suck out the body fluids. After 4 to 5 days of feeding, the orange-coloured larva will have killed between 5 and 50 aphids and be 2.5 to 3 mm long. At this stage the larvae drop from the leaf and produce a cocoon in which they pupate. If the predators receive less than 15.5 h of light per day they may enter diapause — a form of hibernation. However under longer periods of light adults will emerge after about 10 days.

Green Lacewing and Other Parasites. Each green lacewing (*Chrysoperla carnea*) larva will kill more than 200 aphids and they can control several other pest organisms. Recent research has developed an artificial diet, which should result in a dramatic price reduction enabling further widespread availability of this predator. Other noncommercially available aphid predators include hoverflies and ladybirds, both of which can consume 300 aphids per developing larva. These often enter biologically controlled crops and provide additional, free, pest control.

Pathogenic Fungi. The insect pathogenic fungus *Verticillium lecanii* can control several aphid species, western flower thrips, and whitefly on a range of crops. The pathogen has strict environmental requirements, including a temperature of 15 to 25C and relative humidity of 95% or higher. Such humidity levels are rarely met in greenhouses using modern growing techniques. However, during spring, autumn and occasionally during muggy summer weather these conditions can be obtained and excellent control achieved. Propagation units however, by design, will provide high humidity and warmth, which will encourage the fungus to germinate and protect the crop against insect attack.

As *V. lecanii* is a fungus, great care must be taken with any fungicides used against plant disease. No fungicide should be tank mixed with *V. lecanii* and at least 3 days (longer is better) should elapse between applying *V. lecanii* and any fungicide. The following fungicides are known to be relatively safe to this biocontrol: bupirimate, iprodione, fenarimol, and triforine. Other pesticides may also be integrated but their full toxicity to *V. lecanii* has not been fully evaluated so a small-scale trial should be made before use on a commercial crop.

VINE WEEVIL

This pest evokes more emotion from growers than most other organisms mainly because it is hidden from view for most of its life cycle. Damage, in the form of leaf notching, occurs overnight when the adults feed, while plants can collapse because of larvae feeding on roots. Both adults and larvae can ring young shrubs at ground level, killing the plants. Adult weevils are all female (males are very rare) and can live for more than 1 year and produce about 1000 eggs each. These hatch into small C-shaped white larvae with brown heads, which feed on plant roots. Larvae develop into pupae, which form a small cell in the compost where they overwinter to emerge in the spring as soft bodied, white adults. These adults soon harden their skins and turn black, hiding during the day under leaf material to emerge at night and feed.

Biological Control. Biological control of larvae is possible using insect parasitic nematodes. The most commonly used and efficient ones being *Steinernema carpocapsae* and *Heterorhabditis megidis*. Nematodes are minute eelworms, which swim in a film of water surrounding soil or compost particles. Thus dry composts can reduce their mobility and eventually kill them, water-logged compost can drown them and gritty mediums allow them to be flushed through. The majority of peat or coir growing media are perfectly suitable for nematode use and good results are achieved.

Compost-Applied Pesticides. Although not biological, compost-applied pesticides such as Suscon Green are fully compatible with these biological control agents. When the granules are evenly incorporated into compost before potting they give a full 2 years of control in liners or small pots. ADAS trails have shown that the level of control can be reduced in composts containing more than 20% bark or wood-fibre-based materials. With these composts a rate of 1 kg of Suscon Green m^{-3} is necessary for acceptable weevil control. Suscon Green has also been evaluated for use in cutting modules with good results and cuttings have recently been added to the label approval. Efficacy is good with large modules but becomes more variable in module sizes below 75 ml. This is probably because it is not always possible to get sufficient granules into these very small volumes of compost, even with good mixing. Margaret Scott evaluated phytotoxicity at HRI Efford with little damage being recorded.

A recently approved addition to the soil-incorporated control agents is imidacloprid. This active ingredient has a persistence of about 1 year and is systemic through the plant. This gives activity against whitefly and aphids plus some other sucking insects but not against thrips or spidermites. Being systemic the product is also harmful to many beneficials, including *Aphidius, Aphidoletes, Chrysoperla, Encarsia,* and *Orius* (Novartis BCM data). Its lengthy persistence also allows insect pests to be exposed to sublethal doses as the product breaks down — giving rise to the potential for resistance problems.

Other Chemical Controls. The Agricultural Development and Advisory Service (ADAS) has conducted many trials against vine weevil under the guidance of Dr. John Buxton. These have included the development of an adult weevil attractant based on an aggregation pheromone and plant leaf extracts and the results are eagerly anticipated. Pesticide spray programmes, against adults, have shown that malathion and the pyrethroid insecticides, especially Talstar, are good contact insecticides (night sprays being most effective). The pyrethroids also have a strong repellent activity which reduces feeding by up to 14 days after application. Unfortunately these chemicals are very broad-spectrum insecticides which will kill beneficial organisms for several weeks after application.

PESTICIDE INTEGRATION

All producers of biological control agents produce tables showing how each agent is affected by different crop protection chemicals. In general most fungicides are safe to natural enemies (except for the fungus *V. lecanii*, as noted above). The following insecticides are relatively harmless, although some will kill everything they hit but persist for only a short period of time: Pirimor, Hostaquick (persistence of 4 to 5 days), Torq, Nemolt, Applaud, Nico Soap (persistence of 1 to 2 days), and Savona (persistence of 1 day).

The use of IPM reduces potentially harmful exposure to pesticides and will slow the development of resistance, and ultimately extend the useful life of the few pesticides we have available.

New Approaches to Optimising Environments for Rooting Cuttings

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INTRODUCTION

Achieving high rates of success in rooting leafy cuttings is strongly dependent on the provision of a suitable environment. Improving existing propagation environment technology offers the prospect of bringing new plants to the market by enabling nurseries to propagate cuttings that are currently considered too difficult. There are two obstacles to such progress: the difficulty of identifying the optimum conditions for a particular plant, and the difficulty of describing that environment in a way that others can reproduce reliably in their own facilities. This paper outlines new approaches to overcoming both of these obstacles.

THE BASIC REQUIREMENTS

Detached from the root system that previously supplied it with water, the cutting's most important requirement is for protection from water stress. As the capacity for water uptake through the cut base is small, the emphasis must be on providing an aerial environment which restricts potential transpiration, i.e. the rate at which cuttings with fully open stomata would lose water (Harrison-Murray et al., 1992). Three components of the aerial environment largely determine potential transpiration: humidity, light, and leaf wetting.

Raising the humidity decreases transpiration by reducing the difference in the concentration of water vapour between air inside the leaf and that outside it. If the leaf surface is kept wet then, as the water evaporates, it absorbs energy (the latent heat of evaporation) that would otherwise be available to drive evaporation from inside the leaf (i.e., transpiration).

Light stimulates transpiration because only a small proportion of the light energy absorbed by the leaf is used for photosynthesis, the remaining energy is available to drive evaporation. One result is that transpiration continues even when the relative humidity of the air around the leaves is 100%. But light is essential for photosynthesis and most leafy cuttings must photosynthesise to obtain enough energy to survive and root. Therefore an important part of optimising the environment for cuttings is the striking of an appropriate balance between light, which stimulates transpiration, and the combination of wetting and humidity, which suppresses it.

CONTROLLED PROPAGATION ENVIRONMENTS

Much previous research, using conventional propagation facilities, has demonstrated the practical benefits of using different propagation systems such as polythene tents, mist, and fog and has elucidated the individual benefits of leaf wetting, elevated humidity and shading on the water status and rooting of cuttings (e.g., Grange and Loach, 1983; Harrison-Murray et al., 1988). However, the conditions in such facilities change constantly, making it difficult to define the environments precisely and impossible to reproduce them exactly. As a result, there is still much to be learned about the response of cuttings to their environment, particularly concerning the interactions between different factors.

To avoid these limitations, novel controlled-environment facilities were developed at HRI - East Malling. The novel facilities consist of three walk-in polythene chambers erected inside a large controlled-temperature room, with wetting and humidification provided by carefully positioned Sonicore fog nozzles and light from high pressure sodium lamps. These controlled propagation environments (CPEs) combine reproducibility with the ability to achieve the wet and humid conditions needed for cuttings.

They include a chamber known as the "gradient CPE" or G-CPE in which separate gradients of wetting and light have been established at right angles to each other, creating a matrix of 54 different combinations of light and wetting. The levels of light and wetting cover the range of daily average values likely to be encountered in shaded propagation houses in the U.K. The relative humidity is close to 100% throughout.

ENVIRONMENTAL FINGERPRINTS

With so many different environmental combinations, the numbers of cuttings that can be placed in each is usually only four. Therefore, it is necessary to look for trends in responses to the gradients rather than at the results from individual locations. Three dimensional line graphs have been found to be the most effective way of displaying these trends (see examples in Fig. 1). These 3-D graphs are referred to as "environmental fingerprints".

Figure 1 shows how a fingerprint provides an effective summary of the response of a particular plant to a range of environments and demonstrates the scale of differences between species. The fingerprint for *Cotinus coggygria* 'Royal Purple' shows that it rooted well where heavy wetting was combined with moderate to high light but failed completely at similar light levels with little or no wetting, whereas *Cryptomeria japonica* 'Elegans Compacta' showed the opposite response. However, neither subject rooted well at the lowest light levels tested, irrespective of the amount of wetting.

In work funded by U.K. growers through the Horticultural Development Council, this approach has been extended to a wide range of additional plant subjects. These studies have served to improve production of a number of troublesome subjects and to test the value of morphological characters (e.g., hairy leaves) as indicators of the environmental conditions likely to favour rooting in particular species.

RELATING RESULTS TO CONVENTIONAL FACILITIES

Responses observed in the gradient CPE have paralleled results from conventional facilities, encouraging confidence in the practical value of environmental fingerprints. For example, subjects with fingerprints similar to that for *Cotinus coggygria* can be expected to root well in a wet-fog or enclosed-mist system, whereas a simple polythene tent system would not be adequate. Further work is required to determine whether it is possible to translate more precisely the optima identified in the G-CPE to the fluctuating conditions of conventional propagation systems. The light factor is straightforward but wetting is more difficult, especially as it cannot be considered in isolation from humidity because both contribute to the suppression of transpiration.

A promising approach utilises a novel sensor developed at HRI - East Malling. This

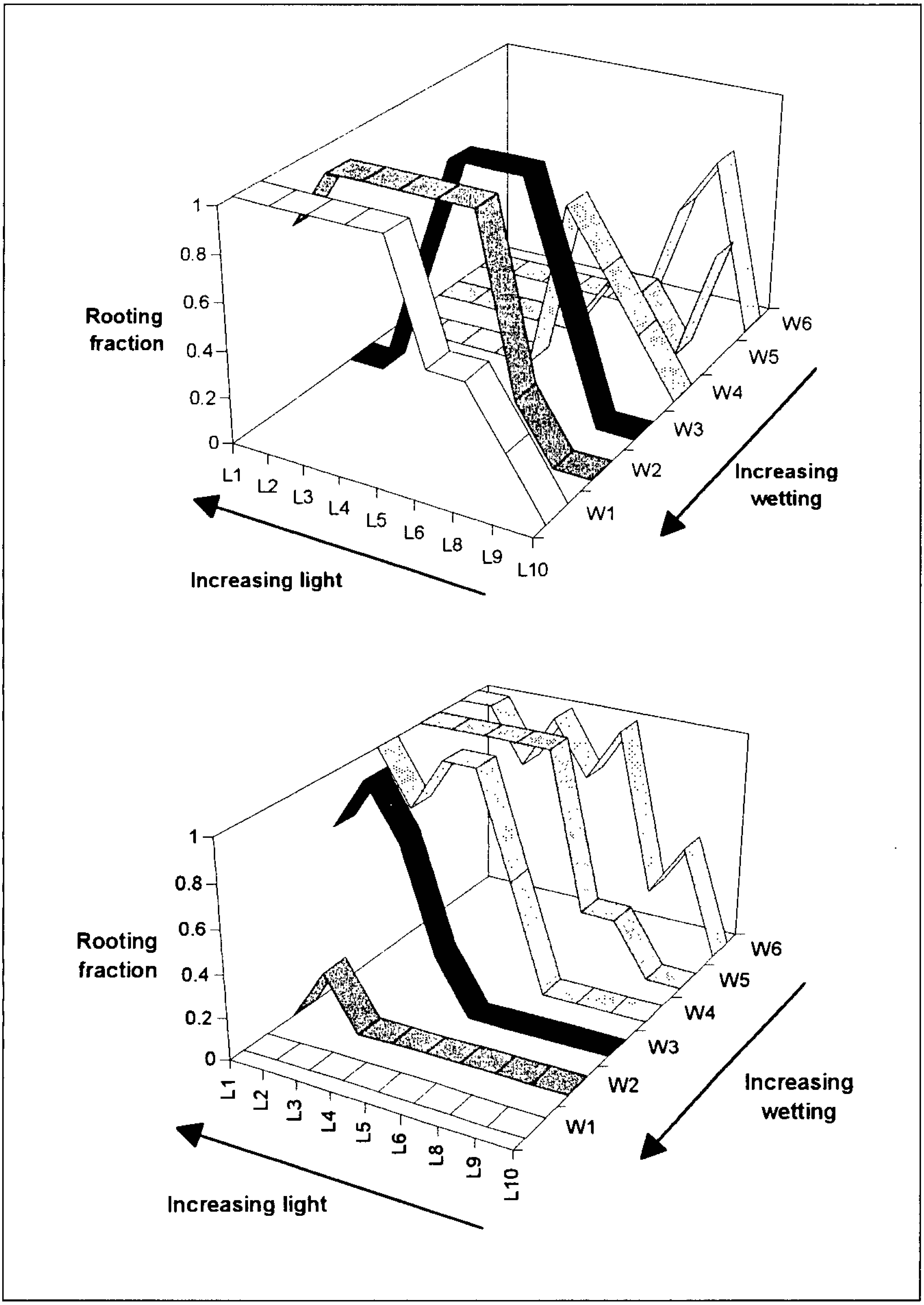

Figure 1. "Environmental fingerprints" for *Cotinus coggygria* 'Royal Purple' (upper) and *Cryptomeria japonica* 'Elegans Compacta' (lower). Light levels (photosynthetic photon flux density) increased from 10 to 213 µmol m^{-2} s^{-1} between L10 and L1, while wetting increased from 0 to 400 µm h^{-1} between W6 and W1 (over the 12-h light period).

"evapo-sensor" is sensitive to the combined effects of wetting, humidity, light, temperature and wind on potential transpiration. Using this instrument, separate measurements of light would be less critical because the effect of light on transpiration would be taken into account already. Opportunities for the commercial production and marketing of this evapo-sensor are being evaluated.

PHYSIOLOGICAL STUDIES

The reproducibility of the controlled propagation environments is a great advantage for studies into the physiological processes underlying rooting responses. To date these studies have focused mainly on water relations and photosynthesis, processes intimately connected to the balance of light and moisture. Gas exchange measurements are used to monitor changes in stomatal conductance, photosynthesis, and respiration in contrasting environments, together with measurements of leaf water status and the accumulation and distribution of dry matter.

One objective of these studies is to understand why species differ so much in their tolerance of different environments. For example, when *C. coggygria* 'Royal Purple' was compared with *Weigela* 'Florida Variegata' — a subject which can tolerate conditions in all parts of the gradient CPE — we found that the main reason for weigela's wide tolerance was the high sensitivity of its stomata to leaf water deficit, probably combined with inherently faster rooting.

A second objective is to understand the involvement of the carbon balance in

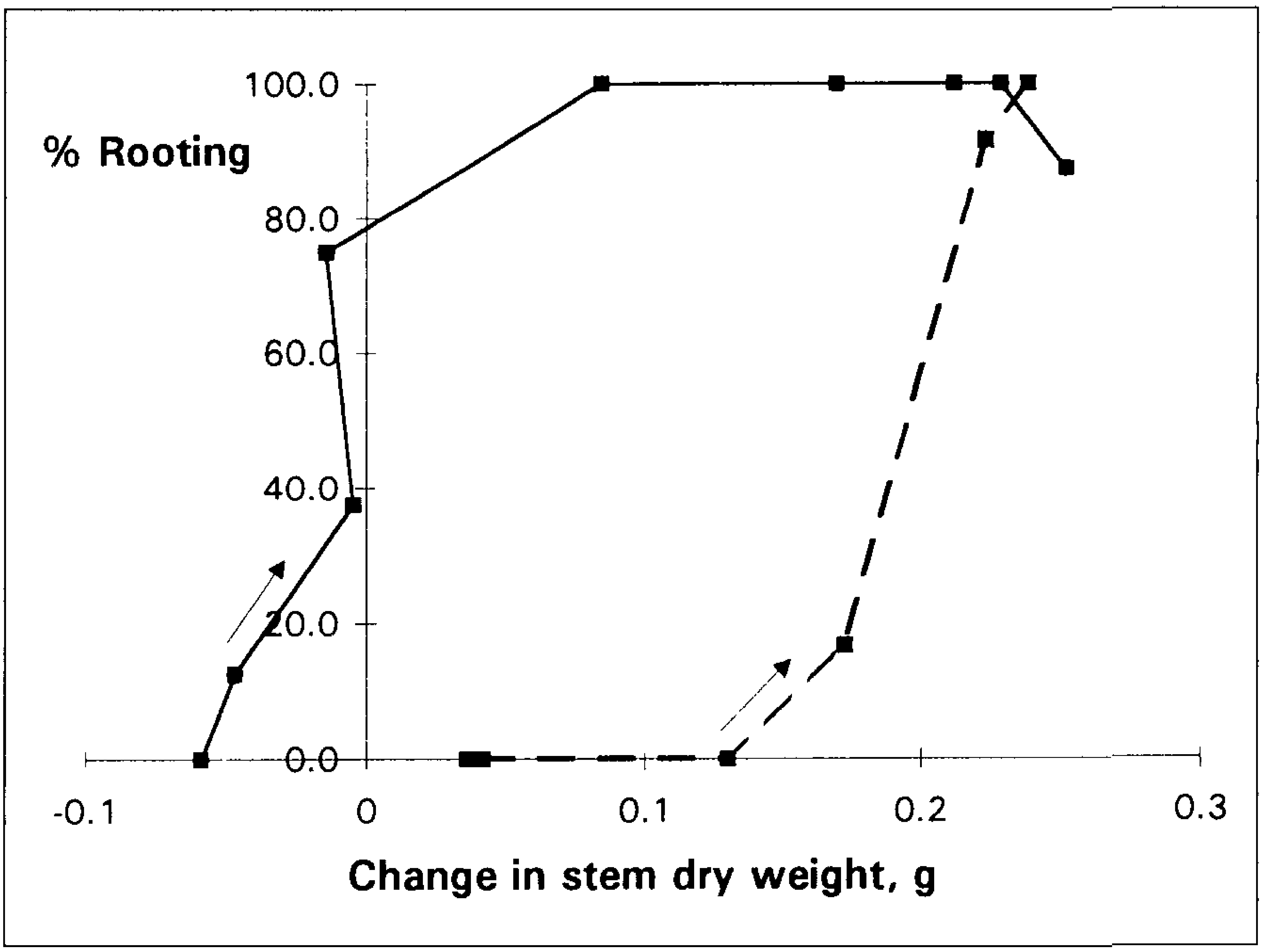

Figure 2. Two different relationships between rooting percentage and the change in stem dry weight of *Cotinus coggygria* 'Royal Purple' cuttings observed in the G-CPE. The data relate to cuttings at different light levels in the heavily wetted zone (solid line) and different wetting levels in the high light zone (broken line). Arrows indicate increasing light and wetting respectively.

rooting responses. For example, stomatal closure conserves water but it also restricts the uptake of CO_2 for photosynthesis and might thus be responsible for some of the inhibition of rooting caused by water stress. The restriction of photosynthesis could starve the cuttings of the source of carbon they need to produce roots.

For example, rooting of *C. coggygria* 'Royal Purple' declined both at the wet end of the gradient-CPE when light levels were low and at high light levels when wetting was reduced. Weight measurements indicated that the accumulation of dry matter by the cuttings was central to the response to light but not the response to water deficit. When high wetting was coupled with low light the reduction in rooting coincided with a loss in dry matter as starving plants began to draw on carbohydrate reserves just to survive. But this was not so at high light levels as wetting was reduced (Fig. 2). Even where cuttings wilted severely and stomata closed almost completely, they continued to accumulate dry matter, albeit at a much reduced rate. Similar results were obtained in experiments with *Syringa vulgaris* 'Madame Lemoine', which also showed that the response of cuttings to environment can be altered by stockplant treatments such as etiolation (Howard and Harrison-Murray, 1995).

FUTURE DEVELOPMENTS

The Gradient Controlled Propagation Environment is a flexible facility and in future could be modified readily to extend the range of conditions or to examine another factor altogether, such as base heating. Interest has also been expressed in the commercial application of the CPE concept, both for more consistent rooting of high value difficult-to-root plants and to remove a major seasonal constraint on production.

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Walnut Graft-Union Callused by Heating Cable

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Trials were performed using electric heating cable instead of hot-pipe callusing to maintain walnut grafts at the recommended 25 to 27C for callusing. Hot-callus pipe and hot-callus cable gave similar results. Best results were obtained when cable was used on in-situ-grafted walnut seedlings. Under nursery conditions graft take was 70%. At the end of the growing season plants had achieved a grade-out similar to 1-year-old grafted plants.

INTRODUCTION

Sitton (1931) showed that for callusing the graft-union in walnut (*Juglans regia*) it is necessary to maintain a temperature around the union of 25 to 27C for about 4 weeks. Lagerstedt (1981) among others later developed the hot callusing pipe (HCP) as a piece of propagation equipment for grafting a range of difficult-to-graft species.

Hot callusing pipe is capable of increasing the graft-take of several plant species (Dunn, 1995) and is known to be successful on walnut (Avanzato and Tamponi, 1987). However, even using this technique, walnut plants do not achieve the minimum height of 1.2 m required by the commercial nurseries (Moraldi and Lanzi, 1993). The poor growth that appears when the plants are bench grafted (Lantos, 1995; Stanisavljevic and Mitrovic, 1997), may be a result of the transplanting shock. To simplify the hot callusing technique and to stimulate the growth of the grafted plants several comparative experiments were conducted using electric-heating cable instead of hot-water pipes to provide the temperature lift.

Initially, the HCP technique was simplified by just wrapping a heating cable around the graft union. Several trials using this technique were performed. Results were similar from both pipe and cable but in each case there was poor growth after callusing. To overcome the problem of transplant shock, an insulated low voltage cable, covered by Velcro tape and connected to a thermostatically controlled central heating panel, was arranged and used on in-situ-grafted walnut seedlings. Under nursery conditions the graft take was about 70% and at the end of the growing season the plants achieved a sale standard height, and stem diameter comparable to 1-year-old plants grafted by HCP.

MATERIALS AND METHODS

Randomized block trials were designed in different places and years. One-year-old walnut seedlings were cleft grafted and the graft union was wrapped with aluminium foil and heated at 27C for 4 weeks. The hot-callus-cable system was a 45-volt heating cable, a sensor to monitor the temperature of the graft union, and a thermostat. For HCP the procedure described by Lagerstedt (1981) was used. Graft take percentage (after 4 weeks of callusing), stem height, and diameter (recorded at end of vegetative season) were submitted to statistical analysis.

Comparison of Cable and Pipe for Bench Grafted Transplanted Plants. The efficacy of the hot callus cable was compared with HCP at the Fruit Tree Research

Institute of Rome. 'Hartley' and 'Sorrento' cultivars were bench grafted in March 1987 and 1988, respectively, and placed horizontally on the hot pipe or heating cable heating the graft union only. To maintain the humidity, the plants were covered with polythene and the scions exposed to environmental conditions.

Hot Callus Cable Used for Bench-Grafted Plants Left in Situ. In Italy the experiment was carried out at the Fruit Tree Research Institute of Rome. One hundred seedlings were bench grafted, callused by hot callus cable during April 1989, and left in the grafting site to complete the growing season. Equal numbers of seedlings were grafted with cultivars 'Sorrento' or 'Del Carril'; the graft union was either wrapped with wet cloth or left unwrapped.

Another trial was conducted in India in February 1996 in Jammu, at the Horticultural Department of the Jammu and Kashmir Government, funded by the UN Food and Agriculture Organisation. For efficient and quick handling of the heating system, the cable was inserted into a waterproof cloth tube stitched onto Velcro fastening tape. Seedlings were grafted with a local cultivar, 'Rajouri', by an inexperienced budder and then left in the grafting site for the full growing season.

Hot Callus Cable Used in the Field. This trial, funded by the FAO, was conducted in March 1994 at the Seed and Plant Improvement Institute of Karaj. The experiment was designed to compare the effect of wet cloth and heat from pipe or cable around the graft union. Seedlings were grafted in situ with local clone, K144, and the graft-union heated by electric cable. Another group of seedlings were bench grafted, callused for 4 weeks by a HCP system, and transplanted. Heating was applied either immediately or 48 h after grafting in both methods.

RESULTS

Bench Grafted, Transplanted Plants. The percentage of success in HCP treatment was slightly but not significantly higher than with hot-callus cable. With the hot pipe, a graft-take of 82% in 1986 and 62% in 1987 was obtained against a graft-take with cable of 78% and 58%, respectively (Table 1). After transplanting, the plants achieved an average height of 35 cm at the end of vegetative season.

Table 1. Graft-take (%) of hot callus pipe vs. hot callus cable.

Year	Cultivar	HCP[x]	HCC[x]	Control
1986	Hartley	82 a[y]	78 a	< than 1 b
1987	Sorrento	62 a	58 a	< than 1 b

[x] Hot callus pipe = HCP, hot callus cable = HCC
[y] Means within a row followed by the same letter are not significantly different (P=0.05, Student-Newman-Keuls test); 40 seedlings per treatment.

Bench Grafted Plants Left in Situ. In Rome a positive graft-take response was observed for the hot callus-cable treatment in different genotypes ('Sorrento', 69% and 'Del Carril', 77%), with an increase of 9% when the graft union was wrapped with wet cloth. The grafted plants achieved a maximum height of 66 cm during the growing season.

In Jammu the results were influenced by the subtropical climate with day temperatures between 15 and 27C and night temperature not below 10C. In the control, 40% graft-take was observed but was significantly different from the 70% obtained with hot callus cable. The grafted plants achieved a height of 55 cm in 4 months and at the end of the vegetative season, height and thickness were above the required standards (Table 2).

Table 2. Graft-take and height (cm) of grafted plants in Jammu.

Treatment	Success (%)	Height after 4 months	8 months
With hot callus cable	70 a	55 a	135 a
Without callus cable	40 b	8 b	105 b

Column means with similar letter do not differ significantly (P=0.05, Student-Newman-Keuls test); 45 seedlings per treatment.

Hot Callus Cable Used in the Field. The results of graft-take using hot callus cable with or without wet cloth were similar to those with HCP when the heat treatment was immediate (Table 3). The only exception being for plant height at the end of the growing season where hot callus cables in situ resulted in a height seven times greater. Graft-take increased when wet cloth was used and decreased when heating was delayed. With hot callus cable plant height was not influenced by the cloth or by delayed heating. The 3-months-old grafted plants obtained by hot callus cable treatment were comparable to 15-months-old, hot-callus-pipe-treated plants (Table 4).

Table 3. Graft-take and plant height.

	HCP[x] immediate		HCC[x] immediate		HCC delayed	
Parameter	-WC	+WC	-WC	+WC	-WC	+WC
Graft-take (%)	55 a[y]	74 b	53 a	70 b	38 a	55 b
Height (cm)	20 a	20 a	130 a	140 a	130 a	150 a

[x] Hot callus pipe = HCP, hot callus cable = HCC

[y] Results in the same row with similar letter do not differ significantly (P=0.05, Student-Newman-Keuls test); 100 seedlings per treatment.

Table 4. Size of the plants callused by hot callus cable and hot callus pipe.

Parameter	3 months old (from hot cable)	15 months old (from hot pipe)
Trunk diameter (cm)	1.02 a	1.03 a
Trunk height (cm)	1.36 a	1.00 b
Trunk volume (cc)	66.79 a	49.97 b

Row means with similar letter do not differ significantly (P=0.05, Student-Newman-Keuls test).

DISCUSSION

The experiences with the electric cable method of hot callusing tried under different geographical and agroclimatic conditions show the potential of this technique in fast production of grafted walnut plants. The main aim of using electric cable was to simplify the hot callusing method and evaluate its efficiency in in-situ-grafted seedlings. The results did not show any significant difference between pipe and cable treatments in terms of graft-take and growth.

When the seedlings were bench grafted, callused by electric cable, and left in situ, scion development was enhanced and within a few months plants achieved marketable height.

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The European Launch of Debutante® Dahlias

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INTRODUCTION

The selection, propagation, production, and marketing of any new plant is a long process. This paper will not cover every detail of the process but will highlight some of the key points and expand them.

Debutante® Dahlias (Debutante® Dahlias is a Registered Trade Mark) is a new range of genetically dwarf, true double-flowered dahlias raised in New Zealand by Dr. Keith Hammett. They are classed as Miniature Decorative by the National Dahlia Society. In New Zealand they are known and raised under the name Baby Dahls. Dr. Hammett first began to collect, raise, and hybridise dahlias in the mid 1960s. He emigrated to New Zealand in 1967 where he worked as a plant pathologist for the New Zealand Department of Scientific and Industrial Research. In 1973 Dr. Hammett acquired a 10-acre property which he has since developed as a plant breeding operation actively working with a wide range of material including *Lathyrus, Dahlia, Dianthus, Petunia, Clivia, Polyanthus, Chrysanthemum,* and *Helianthus.*

The history of Dr. Hammett's dahlia breeding work underlines its quality and depth:

- Bred top level exhibition cultivars, winning top trial ground and show bench awards worldwide;
- Developed and introduced dark-leafed strains of dahlia;
- Developed the "Showpiece Hybrid", "Baby" series, and "Silk Symphony" seed strains;
- Continuing selection of the Debutante® Dahlias (Baby Dahl) and Faerie Dahl series since 1983;
- Currently looking to introduce dark foliage to Debutante® Dahlias and to extend existing colour range.

Amongst many awards, Dr. Hammett has received Gold and Silver Medals from the American, British, and New Zealand Dahlia Societies. *Dahlia* 'Elizabeth Hammett', perhaps his best-known cultivar, has won more awards than any other of its type in the past decade.

MARKETING

A marketing company, Quality Ornamentals, was formed in 1994 by four nurseries with a core product of bedding plants — at the time of formation it was not intended to market other plants such as dahlias. Once we had agreed to market these plants in the U.K. all we knew was that we had 10 good, new, unique cultivars in our hands with a name — Baby Dahl — that didn't quite seem to fit. We could see the horticultural and commercial advantages of these plants and needed to turn them into a success. The exercise was to become a steep and rapid learning curve. The following have proved to be key development areas for Quality Ornamentals along the way. Those with more experience in this field could argue that some points are unnecessary; however, for those with less experience of introducing new plants, this route has not let us down yet.

Trialing and Bulking Up. It is essential to be convinced of the quality and performance of the plant in the countries in which it is to be produced and sold. Early in 1995 we were able to obtain small trial quantities of the new dahlias. By Summer 1995 we had built up small stocks of the first cultivars and had an appreciation of how they would perform under U.K. conditions, both in pots and the garden. These early trials showed us when we might expect to market stock and the potential sales period. As bedding plant growers it was a real bonus for us to discover a product with the potential to grow, flower, and sell through the summer months. After flowering through the late summer and into autumn the stock was allowed to go dormant to test overwintering and tuber formation.

Convinced of the dahlias' potential, and needing to begin large scale trials and to bulkup stock rapidly, micropropagated plants were obtained from New Zealand in January 1996 to begin bulking up mother stock. From these stocks we were able to produce the first commercial crops in 1997. The availability of micropropagated stock probably saved us two seasons bulking up and considerably eased the movement of plants between New Zealand and the U.K.

In parallel to trialing and bulking up, one should be working on the legal aspects of agreements with the breeder and the protection you need for your cultivars (see sections on Protecting Your Interests, below).

Image Building. Now is also the time to decide on plant names, photography, labels, posters, a launch date, and the target market or markets. Aim to chose a generic name which describes the plants and gives them a sophistication — we hope people will eventually talk of Debutantes rather than dahlias in the same way as trailing petunias have all become referred to as Surfinias. The cultivar names need to be short, catchy, and easy to use. If anticipating a European market they should be widely acceptable. If possible the cultivar names should reflect the marketing theme.

Professional point-of-sale materials are vital to garden centre sales — they are expected by the customer. The first essential for label production is good quality photography and this is another job which should be undertaken by a professional — without good photography it is difficult to produce good point-of-sale material. Clear photography will also be required for Plant Breeders Rights applications. Point-of-sale material should be consistent with the plants, stand out from the crowd, and get the message over quickly and concisely. The back of the label gives plenty of room for information so keep the front free for first class pictures showing how the plant performs and what it will do in the consumer's garden. Once the concept has been decided on this will best be developed by the label company or promotion company one chooses to work with.

The Market Launch. Finally we come to the launch itself. With a new plant there a great opportunities for free publicity so be ready to take full advantage. Here are a few of the items to consider:

- Most trade shows provide a media list — so be sure to use it;
- Prepare a press release, with photographs, and mail to all on the media list — this subsequently gave us contacts in the States and Canada;
- If possible send samples to the TV gardening personalities;
- Invite customers to your stand to see the new introduction;
- Enter the new product for awards.

PROTECTING YOUR INTERESTS

In the modern world it is not enough to have a new plant. Ideas, concepts, and intellectual property have to be protected and to this end there are at least three, probably four, essential steps to be taken: a test and talk agreement; a marketing agreement; plant breeders rights, and trademark protection.

Test And Talk Agreement. A Test and Talk Agreement is between the breeder and the potential producer/marketer. This document — probably no more than one page long — sets out the terms under which trials take place. It will acknowledge the original breeder as the owner of the stock, set out the type of testing which is allowed (simply growing on or possibly propagation), state the tester's right to be growing stock, and the conditions under which the trials might be terminated. The test and talk agreement generally favours the breeder quite heavily as the purpose is to protect his/her interest in the stock while the tester assesses the commercial potential.

Marketing Agreement. The marketing agreement is a much more extensive document which has three functions: to protect the financial and intellectual interests of the breeder; to clearly define who is responsible for what; and to act as a point of reference in the event of dispute or misunderstanding.

The marketing agreement should also define, to the satisfaction of all concerned, the following:

- ***Intellectual property***, to define who is the owner of the stock;
- ***Territory***, the area in which the seller is permitted to operate;
- ***Management of intellectual property rights***, giving the seller the right to organise the sales and production within the agreed territory;
- ***Royalty***, the definition of the royalty to be paid on sales and production, the amount to be paid either as a percentage or amount per plant, when the royalty is to be paid, and what costs may be deducted from the royalty by the seller;
- ***Appointment of sub-licensees***, if appropriate this grants the seller permission to sub-licence other growers from whom the seller is responsible for collecting royalty;
- ***Marketing and promotion***, will describe who, usually the seller, is responsible for the design, production, and purchase of marketing materials;
- ***Liaison***, outlines the information and frequency of reporting the seller must supply to the breeder;
- ***Terms***, defines the time of the agreement and the conditions under which it would normally be renewed;
- ***Termination***, details the events that would cause early termination and what action would be taken in such an event;
- ***Law***, states the country under which law the agreement is written;
- ***Arbitration***, provides for disputes to be resolved by the International Association of Arbitrators.

This may sound somewhat daunting, however there are a number of professionals working in our industry who have a wealth of experience and advice in this field and it is well worthwhile making the investment in this advice. In addition, once the agreement is signed it can be put it in a drawer and forgotten about — you will only ever have to read it again when it comes up for renewal.

Plant Breeders Rights. It is, from our experience, essential to obtain the assistance of someone with experience in this field because of the complex legal issues involved.

In the U.K., plant breeders rights is available for U.K. only or E.U. Rights. There are three key reasons for using the newer E.U. Rights:

- Although the cost is higher per application, it covers 16 countries/ states therefore reducing the cost per country/state;
- Protection is clearly given throughout the European Union;
- One year's prior commercialisation is allowed before making the first offer for sale.

Trade Mark Protection. There is some debate about the value of a trademark on plant names. My company holds two registered trademarks — Growing Gardens® (which is a design) and Debutante Dahlias® . It is our belief that we are investing money in these plants and the names associated with them. Therefore, it is in our best interests to protect both the plant variety itself and the name.

THE EUROPEAN MARKET

Debutante Dahlias® were first sold in the U.K. in July 1997. The first continental sales are (at time of writing) planned for September of the same year. This is not so much a launch as a test market. By putting in place each of the points already discussed one is ready to sell into Europe. Two avenues are available to nurserymen: the export of saleable stock to the garden centre market and young plants to licensed growers.

Local market knowledge is essential so if you do not have the ability to travel extensively in Europe, it may well be better to licence selected growers in each country which will give the most controlled and profitable approach. Through the export of young plant material one can increase volume production and directly control (if necessary) the quantities in the market.

CONCLUSION

Ensure your business retains proper, legal control of the plant. Be flexible in your approach to Europe and take heed of local advice while at the same time ensure your own interests are protected. Always ask "how will this step help me to produce more stock?" We are nurserymen not royalty collectors! Finally, the market opportunities are tremendous, so take them.

Planning For Successful Plant Promotion

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INTRODUCTION

In the last 6 years there has been a dramatic increase in the number of large-scale co-ordinated plant promotions and these now account for 40% of Farplants' total sales. As the retail market becomes increasingly competitive garden centre buyers, who are already spoiled for choice, will become much more selective. Inferior promotions will quickly fall by the wayside but those which have been well planned will stand the test of time. As garden centre groups and multiples continue to expand, so too will the demands on their suppliers. Therefore, those growers who do not gear up to supply top quality, well-marketed plants in real volume and on time, will get left out in the cold.

DECIDING WHAT TO PROMOTE

Plants don't have to be new to make successful promotions. Indeed most of Farplants' best sellers are traditional popular subjects such as lupins and hollyhocks. Our success at promotions has been a result of combining fashionable old favourites that the market is hungry for with good new or little known cultivars.

In the future however, first-class new cultivars will become more important to our increasingly competitive market and only first-class ones will stand any chance of long-term success. It is not the case that there is a fortune to be made from every new discovery.

When deciding whether or not to proceed with a new plant, you must ask the following questions:

- Is this genus trendy and on the increase like *Nemesia,* or is it already over-done like *Penstemon*?
- Can it be sold in bud and flower to increase the chance of impulse sales?
- Does it have a long period of interest?
- Can it be presented in an appealing way in a pot? Alstroemerias look superb in the garden but tend to shoot unevenly as young plants on the nursery.
- Is this species fairly easy to grow in volume?

THE IMPORTANCE OF THOROUGH TRIALLING

The recent hunger for new cultivars has sometimes resulted in trialling being less thorough than it should have been. Initial trialling establishes the potential of a new cultivar but volume commercial trialling must follow. We would usually grow 1000 to 2000 of a cultivar but if we are testing several different composts or propagation windows then trial numbers may run into many thousands. Be absolutely confident so that when you play the real numbers game it doesn't end in disaster. A full year of commercial trialling could save a lot of money.

As larger buying groups demand greater volumes within narrower delivery windows, the pressure on crop timing will intensify further. With increasingly unpredictable weather patterns, growers may have to invest in such innovations as removable walk-in cloches for new crops. When Walberton Nursery launched the new *Spiraea japonica* 'Magic Carpet', these cloches enabled despatch of 30,000 plants in a 7-day window.

It is also vital to conduct garden performance trialling in parallel with the nursery trials on secure sites in other parts of the country.

AVOID MARKET PEAKS

Sixty percent of Farplants' turnover happens during a 10-week spring period when up to 35 lorryloads a day leave our distribution centre. So if a new plant can be sold at other times of the year this has to be an advantage, even at the expense of some volume. In June and July 1996 we sold 50,000 *Oenothera* 'Siskiyou'.

GET THE PRODUCTION TARGET RIGHT

Think very carefully before you set production targets for new plants. Never be tempted to go mad just because it roots like a weed. Also resist any pressure from the breeder to grow thousands more of their wonderful new cultivar than you know you can realistically sell. After all, any wastage will be yours to swallow. At Farplants we first decide how many plants should be in a collection (i.e., 12 trays of 8 1-litre pots). Then we calculate how many outlets are likely to buy this promotion, to include independent garden centres, garden centre groups, and multiples, if applicable. For the major promotions we may grow an extra 30% for top-ups so that larger retailers can run the promotion for a few weeks.

THE IMPORTANCE OF GOOD PHOTOGRAPHY

Good quality photography is another vital ingredient in the success of a plant promotion but the general standard of many pictures published is appalling. Printers are now equipped with all the latest technology but they cannot print miracles from inferior transparencies.

A few slides should be taken early on in the trialling of new plants. This will at least give designers some sort of reference should you wish to make an early start at working-up point of sale promotional designs. Too much horticultural printing is done from 35 mm snapshots taken by the breeder or nurseryman. If you want good printing results then you must commission medium format transparencies taken by a professional photographer. As a guide we would expect to pay a photographer up to £300 to achieve what we want for a particular subject.

Plants must be set aside in good time. They should be well spaced and, in the case of tall items like hollyhocks, supported. Small blemishes tend to become accentuated on film, so the flowers must be in perfect condition when photographed.

The correct choice of background is essential, but it seems that few people in the trade have realised this yet. We regularly take plants to Highdown Gardens at Worthing where there is a good choice of backgrounds, not to mention shelter from the wind. I am certain that if the public view pictures of plants in a proper garden setting then they are more likely to subconsciously think "yes that would look good at home" and make that all important purchase.

Be careful, too, that the background contrasts with the plant. If you photograph small flowers and foliage like *Saxifrage* 'Silver Cushion', don't set them against gravel like we did. Put them in front of bold-leaved plants like blue-leaved hostas or purple cordylines.

Make sure that you get plenty of shots taken and preferably from more that one angle. Then you will always be able to offer your publicity contacts a choice. Over the past 6 years we have added more than 2000 slides at a cost of about £8000 to our library. This is now housed in a £700 fire-proof safe. Do be sure to brief the photographer about the shape of picture you want, whether it be horizontal, square, or upright. It is no good having a super square transparency to fit a long oblong picture window in the label.

CHOOSING A GOOD NAME

We all know the importance of choosing the right name for a new plant. It can make the difference between success or failure. Short, simple names that don't have to relate to a plant's flower colour or foliage, can be most effective. When Pershore College held a naming competition for their variegated *Ceanothus*, of the 400 suggestions received, only 30 or so avoided the word blue. We chose 'Zanzibar' as it had a tropical feel about it and, being a single word would fit well into our point-of-sale designs. It had also, to the best of our knowledge, not been used before.

EFFECTIVE, POINT OF SALE DESIGN

Your new plant may be good but you have to get this message across to the public. As around 80% of all plant purchases are on impulse, then those designs which catch the eye will win the day. With *S. japonica* 'Magic Carpet' we all knew it was a great cultivar. However, the *Spiraea* market was already crowded so we decided to omit the genus name completely and turn it into a fun purchase. Many retailers reported it as their best selling promotion this spring. We sold 130,000 in 7 weeks and left the market still hungry. So don't be afraid to dispense with convention when you face design decisions.

If you can't bring yourself to be this radical then at least make the design bold and simple and allow as big an area as possible for the picture. Make the bullet points of information short and to the point. They are only there to reassure the customer. Once the sale is made then the plant label will do the rest.

GET THE LABELLING RIGHT

Bespoke labelling has come a long way since *Scabious* 'Butterfly Blue' was launched 12 years ago. However, many growers still resent paying a little extra for exclusivity and settle for cheaper off-the-shelf labelling. Product differentiation will become even more vital in the increasingly competitive market. One sure way of making your new plant stand out is with effective bespoke labelling.

This was the thinking behind the labels for Farplants' "Tasty Patio Herb" labels. As competition in the herb market increased from small family-run nurseries, the only way Farplants could survive was to make our product look different. Mike Tristram, our herb grower, came up with the idea of showing a cartoon French chef on the label. I was always opposed to labels without photographs but as herbs are, on the whole, fairly unphotogenic, I knew the chef idea would be a winner. Garden centres that changed over to this presentation reported an increase in sales of up to 25%.

When commissioning bespoke labels be sure to temper your designer's artistic flair with practical application. Make sure labels are easy to insert, with no sharp corners which could annoy nursery staff or put the public off buying them. Don't hide the retail price like we did on our first version of the 'Magic Carpet' label. Don't give gardeners an excuse not to buy. The back of a label is important too. Provide as full a description as space will allow but don't make the type too small.

MAKING THE MOST OF PUBLIC RELATIONS

Horticulture is beginning to realise the significant role that publicity can play in a plant's success. I recently attended a public relations training day which was specifically aimed at our sector and was horrified to discover there were only five other people present.

With increasing competition we will need to create demand from the consumer, but this is no easy thing. I believe that branding is still not truly relevant unless backed by significant financial investment which, I don't believe, our margins will allow. Pride of Place tried hard for several years, but the message never really got home to the consumer. Instead we have to invest time and effort targeting the media in the hope that we can influence consumer demand.

At Farplants we have a four-pronged attack. Firstly, we regularly contact all the main garden writers — but make sure you do this well in advance. Once new promotions are launched to the trade in September, we mail to about 40 writers, enclosing a copy of the new promotions catalogue. This allows plenty of lead time before publication of spring issues of magazines. The Horticultural Trades Association has published a very useful list of garden writers which is well worth the cost.

Exposure at shows such as Chelsea can create enormous demand especially if timed with delivery into garden centres. For those like us who have no retail identity, try linking up with one of the specialist nurseries who regularly win medals. We have found this to be a very beneficial symbiotic relationship.

Another angle is to offer new plants to garden writers for trialling in advance of your release date. This can be difficult to administer, but will enable writers to write from their own personal experiences.

Of course, we must not forget the trade press who usually come at the top of most growers' publicity hit-list. However, as a former retailer, I have a feeling that many planteria managers rarely get to see current editions of the trade press. Still, it is a valuable way of letting the competition know what you are up to.

TRADE LAUNCH

Most leading nurseries launch their promotions in September at the GLEE retail exhibition or at the Four Oaks nursery trades exhibition. It is essential to have a good quality brochure for the launch so that the sales team can focus effectively and efficiently at securing next year's business. Start work on point-of-sale designs in plenty of time so you can feature everything in this brochure. Think ahead so that you have the right photographs to show. We take pictures up to a year in advance of publishing to achieve what we want. Spend as much as you can on the printing. Our brochure costs several thousand pounds but after all, it does represent more than £3 million turnover.

COSTS OF EFFECTIVE PROMOTION

Here are a couple of examples to illustrate just how much it costs to get a Farplants promotion off the ground:

	Single-cultivar promotion 20,000 plants	Four-cultivar promotion 100,000 plants
Photography	£100	£350
Label origination	£50	£200
Brochure cost @ £400 per page	£130	£200
P.O.S. design (existing house style)	£90	£250
P.O.S. artwork and origination	£100	£480
Chromalin colour proof (full size)	FOC	£70
P.O.S. printing	£270	£1155
Exhibition costs	£100	£ 250
Label printing	£1000	£5000
Total	£1840	£7955
Per plant	9.2p each	7.95p each

Lessons from the Development and Launch of Cut Flower Chrysanthemums

B.J. Machin
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HISTORICAL BACKGROUND

Between the two World Wars, the introduction of new cut flower cultivars was relatively simple, although grossly inefficient. Breeders had very small nurseries and existed by selling seedlings outright to leading commercial growers and by selling cuttings to amateur growers. The flower growers who bought these seedlings would discover that only a small percentage of them fulfilled the requirements of the commercial market and it took time to find the best cultivation techniques and to gain the confidence of the markets. However, once successful, most of the other growers would produce them and good cultivars (such as *Dendranthema* 'Mayford Perfection', 'Friendly Rival', and 'American Beauty') tended to last for years.

HOW YEAR-ROUND CHRYSANTHEMUMS WERE INTRODUCED

The situation changed radically with the arrival of the year-round crop into England in 1955, which involved single-stem production. Suddenly, thousands of vegetative cuttings were required each week, so the modern chrysanthemum propagator was born. I worked for Framptons where I planted the first year-round crop in Europe. The first lesson we learned was not to take the markets for granted. The market representatives thought that the first specially-bred American spray cultivars we sent them were English disbuds which had not been disbudded. Rock-bottom prices resulted! Lesson one, therefore, is to define your product and agree its specifications with the markets.

The next problems were production ones. To begin with, the American cultivars we were using only grew well in reasonable light conditions and quality was poor from January to March. Indeed, we struggled to cover the high fuel costs for January to April production. Having been employed as a propagator and developer of the year-round system, I soon found myself also in the role of breeder and made my first crosses in 1963.

I was aware that I had four sections of the industry to deal with and another lesson rapidly learned was that a new cultivar had to satisfy each one of them to be successful. These are, of course, the propagator, the grower, the salesman, and the consumer.

The propagator needed cultivars whose stock plants produced large numbers of uniform cuttings capable of travelling up to 2000 miles in cold store and to be tolerant of chemicals for pest and disease control. Flower growers needed dependable, easy-to-grow cultivars, with no peculiar growing requirements. Salesmen needed good travelling and vase-life as well as a very presentable bunch of flowers. The consumer demanded beautiful flowers in a wide range of colours and forms which lasted for weeks

Because of the slow growth of the American cultivars in winter, we could only produce three crops per year and this was not sufficient to sustain the industry in competition with natural season chrysanthemums and other cut flower crops. The first general aim was to increase both the quality and speed of production, but to do this specific objectives had to be addressed.

Low-Light Tolerance. This was an obvious requirement since we needed to reduce the 20 weeks or so it took to grow naturally flowering Christmas cultivars from January to March. I released 'Snowdon' in 1968 which is still in production. Winter production time was reduced to 16 weeks.

Good Neighbourliness. This may seem extraordinary, but it is a fact that within some cultivars in a close-planted population (60 per m sq.), large plants will tolerate small plants and allow them to develop. Bad neighbour types were discarded.

Good Vase Life. This not only avoids wilting due to failure to take up water, but cultivars are only selected when leaves remain green whilst flowers remain fresh. Now, a new cultivar must tolerate 6 days of cold storage after cutting dry, and a lorry journey of 1,000+ miles and more than 14 days of vase-life is required after this, but we aim at 21 to 28 days.

Low Temperature Tolerance. The year 1974 was terrible for cut flower chrysanthemum growers. The oil crisis in Iran caused the price of oil to quadruple in 12 months and the industry was in extreme difficulty. Framptons reduced its breeding programme to save money, so I left to breed low-temperature tolerant cultivars at Perifleur Ltd. Now, of course, low-temperature tolerance is of little importance in North Europe because growers can afford to use temperatures of 18 or 19C at night in winter using low-priced fuel and thermal screens. I am, however, very glad to have low temperature tolerance in my cultivars, because this enables them to be grown under plastic in places like Israel and Colombia, where artificial heating is not used and temperatures can fall at night to 0C.

Stem Weight. The next goal which I became very much aware of was that the Dutch required a 70-cm stem to weigh 60 g in order to be sold as first grade. In winter, 70% of the crop is expected to be 60 g plus, with a crop time of 14 to 15 weeks. In summer, 95% should be 60 g plus, with a 9- to 10-week schedule. The Japanese use chrysanthemums more than any nation, but they require beautiful flowers on graceful but strong stems, with small dark leaves. Weight is not a top priority for that market. On the other hand, Americans require good doubles and singles, but they must be large and have long (20 cm) pedicels. In Holland, a wide range of types are grown with the emphasis on singles and anemones, but with the ever-present requirement of stem weight.

For large, production-efficient nurseries in Holland, the breeder has other headaches. For instance, the leaves should be green to the base of the stem, even in midbed. The plant should be easy to pull out of the ground at harvesting (i.e., a small but efficient root system) and the leaves should not be too brittle and fall off when the stem is grasped roughly for pulling out.

Uniformity. This is one of the most difficult objectives to breed for, but is more and more necessary. Modern harvest machines need to harvest the whole crop in one go in summer and growers tolerate only two cuts in winter. This means a close observation of stock plants which produce uniform, easy-to-take cuttings, in places as far apart as Costa Rica, South Africa, and Kenya. A new cultivar now needs speed, weight, and uniformity and, of course, the requirements already mentioned.

LAUNCHING NEW CULTIVARS

The objectives of breeding have largely been covered but this is usually only half the story. It is perhaps easier to produce a new cultivar than to get it into commerce.

I am fortunate in that I work on a large nursery and new cultivars are easily compared with the current mainline cultivars. Southern Glasshouse Produce Ltd. is also a propagator, so that promising lines can be bulked-up rapidly, according to the requirements of the industry.

The breeder can have two basic approaches, one being relatively simple but with limited rewards and the second being more speculative but with potentially greater rewards. The first is to introduce better cultivars for existing programmes so that growers have no new growing conditions to meet. However, the second option offers real progress when a new cultivar can be grown on a shorter schedule so that increased production is possible. This usually involves some changes to husbandry techniques and the new and potentially better cultivar might fail if grown in existing programmes which do not suit it. In this case, the breeder must persuade a top grower into production, often on a large scale so that the specific programming can be used. The breeder may have to travel, perhaps to Holland, to give advice as the crop progresses, so that the new cultivar has a good chance of making an impact on the auction. If the new cultivar is pink and, unluckily, competes with a surplus of pink cultivars in any particular week, the price on the auction will not reflect the true value of the cultivar. Much hard work to recover the situation then needs to be done.

FUTURE WORK

There is much more breeding and development work to do in the next few years to ensure the prosperity of the year-round chrysanthemum industry.

I have long been interested in the direct short-day planting system. This involves the rooting of cuttings in a nutrified container and planting directly into a short-day regime in the flowering house. The trick is to have sufficient leaves developed in the plant in the propagation house so that, with good growing conditions, internodes will lengthen sufficiently to give a crop height of 75 to 80 cm in the flowering house, with sufficiently heavy stems.

In 1973, when I produced a thesis on the technique, only the nutrified peat block part of the system was successful, because of the 60 g per stem requirement which had recently been introduced and the consequent need for some long days in the flowering area. However, I can now release cultivars which will produce 60 g, 70 cm stems planted direct into short days. This reduces summer crops to 8 weeks and winter crops to 11 weeks and radically changes the economics of production. From three crops per year in 1967 we are now in easy reach of five crops per year.

CONCLUSION

The breeder must be aware of both production and consumer requirements in all major chrysanthemum production areas in the world. He must be able to influence sales by demonstration and by providing production information and must be prepared to travel to do so. This is much easier if he is involved with a substantial firm with world-wide interests. It is a long way from the small independent breeder of 60 years ago. The stakes are high, because a good new cultivar will soon sell in many millions per year. Because the cost of the breeding programme is also high, there are relatively few breeders of year-round chrysanthemums.

The main lesson I have learned is that one must find out what is required before one makes a cross. Then one must select and trial the seedlings to meet modern specifications without personal preference. From the very short list emerging, the industry must finally choose the cultivars to keep it viable.

Intellectual Property Rights for Plant Raisers

Peter Hillier
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INTRODUCTION

This paper will look at different forms of intellectual property, that is patents, designs, copyright, and trade marks. Particular attention will be given to trade marks, contrasting this form of protection with variety rights and varietal names. The information contained in this paper is based on U.K. practice, although customs and laws in other countries and states are much the same.

Patents relate to inventions, that is the way things work, as opposed to how they look. The typical cartoon showing a line of people queuing outside the Patent Office with contraptions they have invented is apocryphal but incorrect. The Patent Office only deals with written documents (though sometimes machinery is demonstrated to an examiner in order to persuade him or her of the merits of a particular invention). To gain a valid patent an invention has to be novel and non-obvious.

Generally you must file a patent before you disclose your invention to the public anywhere in the world. Patents have a maximum term in the U.K. of 20 years, after the expiry of which the invention is free for everyone to use.

Designs and Copyright, which are closely allied, relate to the appearance of "art works". The artistic content need not be high. The way something works is irrelevant to design and copyright protection. Copyright can vest in films, drawings, books, true art works, mass-produced articles of "pleasing" shape and, of particular relevance to industry (including the nursery industry), plans, and diagrams.

DIFFERENT FORMS OF INTELLECTUAL PROPERTY

There are three forms of intellectual property which plant raisers need to consider: copyright, design right, and registered design.

Copyright and Design Right. These two forms of intellectual property are automatic in that as soon as you make an original sketch (not copied from any other work) you have copyright and/or design right. When you make a sketch, for example of a new shape of plant container or box for carrying such plant containers, or a new watering can, copyright subsists in such a sketch.

You should sign and date your sketch and all original sketches should be retained in a safe place. Because this form of intellectual property is automatic you have to prepared to travel to do so. This is much easier if he is involved with a substantial firm with world-wide interests. It is a long way from the small independent breeder of 60 years ago. The stakes are high, because a good new cultivar will soon sell in many millions per year. Because the cost of the breeding programme is also high, there are relatively few breeders of year-round chrysanthemums.

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You should sign and date your sketch and all original sketches should be retained in a safe place. Because this form of intellectual property is automatic you have to be in a position to demonstrate that you own the copyright as this may be required if a court case arises. One way is to take a copy of your sketch and post it to yourself by registered mail and, when the packet arrives, do not open it but store it for future use. You can then, if necessary, open the officially dated packet in Court.

Copyright and Design right have finite fixed terms varying from 10 to 15 years for design right, up to the length of the author's life plus 70 years for author's copyright. Other fixed length terms apply to related rights such as those relating to performers, phonograms, films, and broadcasts.

One U.K. exception is the copyright in the book *Peter Pan* which is without limit, proceeds going to Great Ormond Street Children's Hospital.

In copyright and design right, appearance is everything. If you paraphrase a written article in which copyright resides and thus convey the same information using different words, copyright will not be infringed.

Trade Marks. These are different from many points of view. Firstly, they are renewable *ad infinitum*. U.K. registered trade mark No.1 is still in force having been registered at the end of the last century. It is, incidentally, a Bass beer label. Secondly, although trade marks are assignable property they are, in essence, attached to the goodwill of a business. Their *raison d'etre* is to form a link between goods or services to which they are attached or associated and the owner of the trade mark who is normally, but not always, the manufacturer of the goods or provider of the services.

For example, having purchased Kodak film and found it to be of good quality I may select Kodak film in the future expecting consistent quality from the same source. Or, having had my clothes cleaned at Sketchley Cleaners I may choose another branch of Sketchley and expect to receive the same standard of service.

Trade marks are of two general kinds, house marks and product marks. Either can relate to goods or services. For example the trade mark "Boots" is a house mark. One finds many products at Boots stores which are both "own brand" goods and other manufacturers goods. Boots also functions as a product mark on their own brand goods.

For service, "Sketchley" is a house mark, whereas "Sketchley Gold Service" would function as a product mark.

The most important point about trade marks is that they must be distinctive of the goods or services for which they are to be registered. Some marks, especially logos, are distinctive *per se*. An example is the Lloyds Bank Black Horse or the mark "Gales Force 8" registered by brewers George Gale & Company Limited for one of its beers. Other marks become distinctive by long use. An example is "Draper" for tools. Draper is a fairly common surname and thus not distinctive per se but it has been used for many years by Draper Tools Limited and has become distinctive for their tools. Under our new Trade Marks Act a trade mark may consist not only of a word or logo but of a smell or a sound. For example a recently registered trade mark is "The smell of bitter beer applied to the flights of darts". The "Classic FM" radio station and "Direct Line Insurance" jingles are also trade marks.

Trade marks can be registered for goods or services or both. However, because a trade mark must be distinctive it must not constitute the name of the goods or services for which it is to be used. One could not therefore expect to register the word "paint" for paint. That would not be a trade mark. It might however, be registered for other goods of which it is not descriptive, for example laser lightshow equipment might be given the trade mark "Light Paint".

Moreover, everyone must be free to use the word for the goods. Slightly more subtly one could not register "Green" for green paint, nor probably for paint of any other colour since the mark would be wholly descriptive of green paint and deceptive when used on any other colour.

THE RELATIONSHIP BETWEEN INTELLECTUAL PROPERTY AND PLANT BREEDERS RIGHTS

Plant breeders rights are similar to patents in that they relate to a particular product — in this case a plant variety — just as a patent relates to a particular invention. *Both have a restricted term of protection.*

Plant variety names, of their very nature, cannot be trade marks. One chooses a plant variety name to define and label a particular kind of goods i.e. plants of a particular variety. This is almost like the inventor of the first ever paint choosing to call it paint, and so defining its name for the future. It is the name of the goods. The name is exactly co-terminous with the variety and vice versa. In choosing a plant variety name one has in fact chosen the name of the goods in much the same way as an inventor may once have chosen to name his invention a vacuum cleaner. Moreover, the name will stay with the variety and, when any variety or breeders rights have expired the name will still be the name of the goods, irrespective of the origin of the particular plants sold.

Thus vacuum cleaners are still being made but a trade mark is the common way to associate products with manufacturers. One may, therefore, look for a Dyson vacuum cleaner or a Miele or a Hoover one. The mutual exclusivity of trade marks and varietal names is recognised by UPOV, the international agreement on plant variety rights. In all member states of UPOV it is prohibited to register, as trade marks, varietal names of plant varieties that appear in the common catalogue of varieties of agricultural plant species. Therefore, to try to prolong a plant variety registration in this way would be inappropriate and artificial.

There have been few relevant cases in the United Kingdom but the leading one is Wheatcroft Brothers Limited's trade marks (71 RPC 43). Wheatcroft registered as trade marks names for roses which were already registered under the variety names. The trade mark registrations were expunged as lacking distinctiveness for the goods.

The System of Plant Variety Rights in the European Union

Sergio Semon
Community Plant Variety Office, P.O Box 2141, 49021 Angers Cedex 02, France

Plant breeders' rights are a form of intellectual property rights. In the past 2 years protection has been available throughout the European Union by a single application to the Community Plant Variety Office. Applications can be made for varieties of all botanical genera and species as long as the variety is new, distinct, uniform, and stable, and an acceptable denomination is proposed. Since its inception the Office has received more than 5400 applications from breeders all over the world, and granted in excess of 2250 titles. Within these, ornamental species make up more than 50% of applications, *Rosa* being the species most applied for; breeders from the Netherlands have submitted over twice as many applications as those from any other country.

INTRODUCTION

Plant breeders invest time, energy, finance, and facilities to develop a new variety and expect some reward in return. Plant breeders' rights protects the intellectual property which the new variety represents in the same way that a patent protects an invention. In addition, plant breeders' rights enables collection of a royalty payment, whereby the breeder controls the multiplication of his variety, and derives financial benefit from the selling of it.

Plant breeders' rights can be described as an offshoot of both patent law and copyrights (themselves branches of intellectual property), being a system which was established in the International Convention for the Protection of New Varieties of Plants on 2 Dec. 1961, ratified originally by five European countries, thereby providing an effective technical and legal framework through which plant varieties could be protected internationally. The Union pour la Protection des Obtentions Végétales (UPOV) is an intergovernmental organisation based in Geneva which is based on and oversees the Convention. The following 30 years saw many other countries from around the world sign up to the Convention. As a consequence of this and other advances in the industry, the Convention was revised by a 1991 Act to strengthen the scope of protection afforded to plant breeders, as well as to stave-off criticism from patent circles which described the system as inappropriate in the wake of biotechnology.

The regime of Community Plant Variety Rights (CPVR) established by the European Union (under its Council Regulation No 2100/94 of 1 Sept. 1994) was the first regime in the world to be adopted according to the UPOV 1991 Act. This system takes advantage of the fact that the Act of 1991 now allows appropriate intergovernmental organisations to accede to the Convention. By submitting just one application, these rights offer intellectual property protection for plant varieties covering simultaneously all 15 Member States. National protection systems may exist in parallel with the Community system, although it is not possible to protect a variety under both systems at once; Community rights take precedence, with any existing national right lying dormant. In order to implement the CPVR regulations, a Community Plant Variety Office (CPVO) was established on 27 April 1995, and is based in Angers, France.

HOW COMMUNITY PLANT VARIETY RIGHTS (CPV RIGHTS) WORKS

Varieties of all botanical genera and species, including hybrids between genera or species, may form the object of CPV Rights. To date, more than 5400 applications covering 316 different species have been received from 28 countries at the CPV Office (Tables 1 and 2), the Netherlands making its presence felt particularly in the ornamentals sector, where many family-run, small-scale, firms have been attracted to seek protection under the new CPV Rights system. The applicant must be the person/company which bred or discovered the variety, or his/her successor in title; if applicants are not based within the European Union, then they need to appoint a representative within this territory to act on their behalf.

Table 1. Applications for Community Plant Variety Rights (April 1995 – July 1997).

Applications	Number	%
Ornamentals	2868	53.1
Agricultural crops	1497	27.7
Vegetables	684	12.7
Fruit	344	6.3
Miscellaneous species	9	0.2
Total	5402	100.0

Table 2. Applications listed by main countries of origin (April 1995 – July 1997).

Country	Number
Netherlands	1853
Germany	867
France	856
United States of America	399
Denmark	382
United Kingdom	379
Italy	116
Belgium	111
Sweden	80
Spain	76
Australia	44
Switzerland	43
New Zealand	23
Japan	22

A grant of rights may only be given for a variety if it is new, and is distinct, uniform, stable (abbreviated to DUS), and if an acceptable variety name is given.

Novelty. A variety is considered to be new if it has not been sold or otherwise disposed of by, or with the agreement of, the owner either within the European Union, earlier than 1 year before the date of application; or outside the European Union, earlier than 4 years before that date (6 years in the case of trees and vines).

Certain types of disposal are not deemed to be disposals for the purposes of novelty, for example: to official bodies, or to others in the context of a legal relationship, solely for production, reproduction, multiplication, conditioning or storage, provided there is no further disposal and the owner retains the exclusive right of disposal; between companies in the same ownership; disposal of material resulting from research and development work without revealing the identity of the variety involved; and disposals resulting from the display of the variety at an officially recognised exhibition.

Distinctness. The variety must be clearly distinguishable in the expression of its characteristics from any other variety in common knowledge at the date of application.

Uniformity. The variety must be sufficiently uniform in the relevant characteristics.

Stability. The expression of these characteristics must remain unchanged after repeated propagation of the variety.

Denomination. To serve as its identity card, every applicant for CPV Rights must propose a variety name in relation to the variety he/she is seeking to protect. If the name proposed is not acceptable (e.g., if the name is already being used or if the name could cause offence), the CPV Office will reject it and require the applicant to propose an acceptable alternative.

TESTING AND GRANTING OF RIGHTS

In order to verify the uniqueness of the candidate variety, a DUS technical examination is carried out by a designated testing authority within the European Union in field or glasshouse trials for one or more seasons. This examination may be supplemented by laboratory tests. For fruit and ornamentals centralised testing is normally carried out for a particular species within the Community, e.g., chrysanthemums at NIAB (UK), geraniums at the Bundessortenamt (Germany), carnations at the CPRO-DLO (Netherlands), thereby building up expertise and a reference collection next to which the relevant plant material will be judged. The main fruit and ornamental species tested are shown in Table 3.

Once a variety has passed its DUS test, a technical report and description of its characteristics is issued. Provided there are no impediments, a title of rights is granted soon afterwards by the CPV Office. Rights in an individual variety remain in force for 25 years (or 30 years for trees and vines). More than 2250 CPV Rights have already been issued.

Table 3. CPV Rights applications for ornamental and fruit species (April 1995 – July 1997).

Species	Number of applications
Rosa L. - rose	553
Dendranthema ×grandiflorum Kitam - chrysanthemum	299
Pelargonium L'Hérit ex Ait - geranium	255
Dianthus L. - carnation	135
Gerbera Cass. - gerbera	133
Euphorbia pulcherrima Willd. Ex Klotzsch - poinsettia	113
Tulipa L. - tulip	112
Impatiens L. - busy lizzie	94
Prunus persica (L.) Batsch - peach, nectarine	80
Malus Mill. - apple	74
Petunia Juss. - petunia	74
Fragaria L. - strawberry	71
Alstroemeria L. - alstroemeria	70
Lilium L. - Lily	65
Osteospermum ecklonis (DC) Norl. - osteospermum	53
Gladiolus L. - gladioli	40
Kalanchoe Adans. - kalanchoe	39
Saintpaulia ionantha H. Wendl. - African violet	38
Begonia ×hiemalis - begonia	36
Dahlia Cav. - dahlia	34
Ficus benjamina L. - weeping fig	31

Once a variety is protected by CPV Rights the authorization of the owner is required for the following acts in respect of variety constituents or certain harvested material of the protected variety: production or multiplication; conditioning for the purpose of propagation; offering for sale; selling or other marketing; exporting from the Community; importing to the Community; and stocking for any of these activities. Nonetheless, these rights — unlike patents — do not extend to acts done privately and for "amateur" purposes, as well as those done for research and breeding purposes. If a new variety has been "essentially derived" from— i.e., has depended for its breeding on — a protected variety, then it may be protected by CPV Rights but cannot be exploited without authorisation from the breeder of the initial variety.

In order for the protected variety to reach as wide a commercial market as possible, the owner of the right may conclude licences with third parties for the exploitation of the variety. The holder of the CPV Rights can attach conditions and limitations to the licence, any breach of which, as well as of the rights themselves, will constitute a legal infringement, which can be taken before the courts.

The Importance of Labels in the Retail Plant Market

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Consumers are faced with a staggering array of products and services vying for their money. Sometimes they buy for a reason, sometimes on impulse. Your challenge, if you propagate plants for retail sale, is to ensure that when a consumer comes to make their buying decision, it is your plants that get bought rather than someone else's (or something else altogether).

Good labels helps producers to present plants so that they appeal to consumers, many of whom are thirsting for information and need to be convinced that the plant they're looking at is indeed one they should buy. A name label alone is simply not enough. Even a £10 camera comes with comprehensive instructions and advice for getting the best out of your purchase.

Labels can supply that reassurance with helpful care information, illustrating features, and benefits (such as flowers, fruits, or autumn colour not immediately obvious at the time of sale), and of course can include a brand, a guarantee, or an endorsement (such as the RHS Award of Garden Merit logo, if appropriate) to add further credence to the value of the purchase. Some plants have been linked to charitable donations, giving yet another reason for impulse purchase.

One major grower, who for a long time resisted moving into colour labelling, finally test-labelled some clematis. In the previous year the grower had sold 12,000 plants. The following year a staggering 200,000 plants were sold at twice the price.

But labelling is really just part of the story. For really effective promotion and impact at point-of-sale, growers need to consider a complete promotional package of coordinated bed labels, Correx boards, possibly leaflets, and perhaps even complete display systems.

Breeders, growers, and producers need to develop and support their plants with promotional support material — this should not be left to retailers. Some retailers will make magnificent displays, some will simply not get round to using supplied material, and some organised multiple retailers may demand material tailored to their own house style, but it is the grower that needs to manage how the displays should ideally be achieved, and provide the wherewithal to do it.

Some growers have been particularly successful at promoting their brand image, for example, Colin King and Kinder Garden Plants. From humble beginnings, a market leading position has been created by consistent and dedicated attention to integrated labelling, point of sale material, and retail display methods. The Kinder Garden butterfly is specifically looked for, each season, by satisfied consumers who come back for more.

Labels shouldn't be viewed as a commodity, a distress purchase, something a grower has to get at the last moment, just to get a name on the plant. They should be seen as part of the planned investment in building a brand, building a presentation, building a reputation for a plant or range of plants, that have doubtless required significant investment in other ways to bring them to the market in the first place.

Trends for Garden Centre Retail Promotion

Chris Primett
Malcolm Scott Consultants Ltd, 1 Loves Grove, Worcester WR1 3BU,

The garden centre market in the U.K. has been going through a tough time during the 1990s. The total value of the garden market fell by 5% from 1990 to 1994. However, within this overall picture plants were one of the few sectors to hold their value. In 1996 the U.K. garden market was worth £2.8 billion of which plants accounted for £950 million at retail prices.

After a period of rapid growth during the 1980s, garden centre retailers have been facing the challenge of a static market. The response has been a marked increase in the number of acquisitions and buy-outs and the development of initiatives such as loyalty cards by retailers aiming to retain or increase their market share.

The trend towards market segmentation (Table 1), which started 20 years ago, has resulted in three well-defined types of outlet for garden plants (Table 2). Together these are responsible for about two-thirds of the retail market as a whole.

Specialist retailers such as plant nurseries, which are driven by the range of plants they carry, have about 13% of the market. Independent garden centres are responsible for 24% of the total garden market. But while they have lost overall market share to the multiples, they have successfully increased sales of nursery stock when plant sales overall have shown no growth. The garden departments of do-it-yourself retail multiples, which are driven only by price, account for 28% of sales and are still showing strong growth in product lines such as growing media and fertilisers while their sales of plants have remained static or declined.

Most business development has been taking place in large garden centres which are re-inventing themselves as leisure destinations designed with education, fun, and entertainment in mind. These retailers are promoting garden inspiration, once people are inspired, the mechanics of selling are cheaper and easier.

The traditional garden centre faces increasing pressures from competitors both within and outside the garden market and retailers will increasingly have to decide which of the three types of outlet they should be specialising in as the market segments further. This in turn is likely to influence the way growers promote their plants within each of the three distinct types of retail plant sales outlet.

Table 1. Trends in the garden retail market.

Decade	Consumer trend	Market trend	Retail trend
1970s	Mass consumption, values, mass tastes	Commodity lead, product development	Supermarket approach, physical expansion
1980s	Growth of individualism	Market growth and segmentation	Specialist shops, planned layouts
1990s	Lifestyle consumption	Market share	Acquisitions, loyalty schemes
		Further differentiation price, product range or place	Specialists within a single unit entertainment

Table 2. Segmentation in garden plant retailing.

Predominantly pleasure driven environments
Historic gardens, independent garden centres, some garden centre chains

Predominantly price driven environments
DIY multiples, supermarkets and hypermarkets, some garden centre chains

Predominantly range driven environments
Nurseries, florist shops

Finding New Plants - Their Development and Production

Peter Catt
Liss Forest Nursery Limited, Petersfield Road, Greatham, Hampshire, GU33 6HA Great Britain

Having an interest in all plants, it's only natural to search out new ones. My nursery's reputation has been built on finding and introducing new plants both from home and abroad or reintroducing appealing plants largely out of cultivation.

Looking back over old catalogs, the first new plants I introduced to the U.K. were *Cornus florida* 'Barton White' and 'Sweetwater' and *Pieris* 'Brouwers Beauty'. These were all from the U.S.A.

At the same time I introduced the first plants of my own: *Potentilla fruticosa* 'Orangeade', an upright form with bright orange-red flowers and *P. fruticosa* 'Pretty Polly', a pink that holds its color in the sun better than most.

In 1984, I introduced *Spiraea japonica* 'Lisp', Golden Princess™ spirea, a chance seedling found in a local garden, but thought to be a cross between *S. japonica* 'Gold Flame' and *S. japonica* 'Little Princess'. This was shown at the Chelsea Flower Show by Blooms of Bressingham. This was the first plant I had protected by Plant Breeders Rights (PBR) that allow for a royalty to be paid on all cuttings rooted. Previously, any plants introduced had a basic label tag attached with the name of the plant, but we started producing color tags, bed labels, and posters to promote the plant and increase sales. This was the first plant we grew in excess of a few hundred.

The year 1986 was big for the nursery when again using Blooms of Bressingham to show the plant at Chelsea we introduced *Choisya ternata* 'Lich', Sundance™ choisya. It was shown on television on the morning of the show. This was an entirely new plant. *Choisya ternata*, Mexican orange blossom, has trifoliate, rich green leaves, is evergreen, and has sweetly scented white clusters of flowers. What I introduced was a form with bright yellow leaves. This plant is protected by PBR and I have a trademark on the name Sundance™ in Europe. We produced a wild-west style poster with the *Choisya* bursting through a wanted poster with the catchy phrase "Look out for Sundance". We started with 10,000 and every year more and more are grown by licensed growers in the U.K. and elsewhere.

We have introduced many plants since then including some I will show today like *Erica lusitanica* 'Sheffield Park'. This seedling from a famous garden in the South of England is much improved on its parent. The buds are red and the bells open a purer white.

We have been working closely with Briggs Nursery, Olympia, Washington, for a number of years and are now applying for European rights on their new *Daphne* ×*burkwoodii* 'Moonlight'. It is a truly amazing plant having white foliage with a thin edge of green. For a plant of such variegation it is quite a strong grower and will undoubtedly become very popular.

Another interesting daphne is *Daphne odora* 'Geisha Girl' given to me by a Japanese friend. Its most unusual green and cream variegated leaves make it an outstanding shrub.

An exciting new plant from Taylor's Nursery, Raleigh, North Carolina is *Abelia* ×*grandiflora* 'Sunrise' for which we are applying for E.U. protection. We are hoping through an agent to protect it also in many other countries. The abelias are popular hardy shrubs flowering mid through late summer, but with the clear yellow variegated leaves from spring to late summer before the yellow turns to flame red; it is a real winner.

Euonymus fortunei 'Harlequin' started life in Japan, went to the U.S.A., and we introduced it into the U.K. It is an attractive ground cover with white flecks on the green leaves.

Spiraea japonica 'Candle Light' has large soft-yellow leaves on a medium-sized shrub and is a perfect companion plant to *S. japonica* 'Fire Light', both of which I raised and introduced. The names enabled us to produce an attractive poster promoting the plants very well. While on the subject of spiraeas, I am cross pollinating *Spiraea japonica* 'Candle Light' and 'Fire Light' with *Spiraea japonica* var. *albiflora* to try to get white flowers on yellow or orange foliage.

Cistus 'Golden Treasure' was found at New Place Nurseries, Pulborough, Sussex, and introduced this year by John Hedger. It is a medium-sized shrub of upright habit. Sage-green leaves with an irregular margin of golden yellow becoming more prominent in late summer. The flowers are bright pink.

Clerodendrum trichotomum is not what could be called a good selling name, though in my opinion, it is a fine plant with its large felt-like leaves, scented white flowers and beautiful violet-blue berries. We have now introduced an excellent form we have called 'Carnival'. The leaves are big and variegated with creamy yellow and white.

My first selection of *Caryopteris* ×*clandonensis* I've called 'First Choice'. With an upright habit, flowers are large, deep-blue and it starts to flower earlier and carries on for longer than most.

I have introduced three lavateras of my own: 'Ice Cool' (white), 'Candy Floss' (pink), and 'Burgundy Wine' (light purple). *Lavatera* 'Candy Floss' and 'Burgundy Wine' were recently awarded an Award of Garden Merit after trials at the R.H.S. Gardens.

On a trip to Belgium I bought some *Cornus kousa* cultivars not knowing their names. One that has shown up well this summer is *Cornus kousa* 'Bultinck's Beauty' with its white-splashed foliage. It will be popular in the U.K. for summer sales.

Vitis coignettii 'Claret Cloak' is a selection from a batch of seedlings on a local nursery. The young leaves are the color of a good claret wine. It is a healthy grower, putting on several feet of growth each year and the autumn fall colors are beautiful. This plant has U.K. PBR.

Lastly, I would like to mention *Nyssa sylvatica* 'Wisley Bonfire'. This particular tree has been growing in the R.H.S. Gardens for as long as I can remember. Every year the autumn colors are superb. Now it has been named and I am the first to offer it for sale.

Plants for Our Future: Collecting Plants Around the World

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I have been interested in plant searches since the late 1950s. I traveled mainly in Asia then to Australia and Tasmania for close to 7 years before I finally settled in Canada.

Putting my life as a bum behind, it was a little while later in the late 1970s when I got the bug again to look for plants and over the years collected plants in many areas in South America, East Africa, several times in China, Taiwan, Korea, Japan, and lately in Laos.

I am a nurseryman, not a scientist; therefore, I look at plants more for their ornamental and medicinal value than for their scientific classification or other application.

Since I began traveling I have witnessed the mass destruction of flora throughout the world by deforestation and other means. We have lost countless plant species and countless other forms of life. We have lost many opportunities to gain knowledge. We have greatly impoverished our planet and are continuing to do so at an enormous rate.

One of the main purposes of Piroche Plants Inc., started in 1987, is to introduce species of potential ornamental or medicinal valve that are on the verge of extinction.

A joint venture was set in Nanjing, China, in cooperation with the Nanjing Botanical Garden in 1993 to search for new or endangered species, to propagate and to do the first evaluation before proceeding with continuing research and commercialization here at Piroche Plants, Canada.

We have in the last few years introduced many plants worldwide. The pleasure of being able to smell the fragrance for the first time of *Styrax odoratissimus*, makes all this very worthwhile.

These slides will show you a glimpse of the diversity of the Laos flora, most of which remains unclassified. The literature used in Laos is "Noms Verniculaires de Plantes en Usage au Laos" by Jules Vidal, published in 1959. A rare book but still covering only a fraction of the flora of Laos. So much now remains to be done. Laos has only two botanists; therefore, a long road lies ahead to compile substantially the flora of this beautiful country which may be one of the richest in the world.

One interesting note, the botanists or foresters in Laos are able to identify plants by taste alone while walking in the jungle. One of the reasons given is that in the jungle, the vines and tree canopies are generally so difficult to see that tasting the plant is more reliable than by other observations; no decisions are reached without having a bite!

Selection of Deciduous Tree Magnolias

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INTRODUCTION

Magnolias are often called aristocrats among landscape plants. This is because of their lovely, large flowers and glossy leaves. The number of available hybrids has exploded in recent years. My talk will focus on selection in two specific areas of deciduous magnolias, what I call the "tree magnolias" and the "yellow flowering" magnolias.

BACKGROUND

I am a third generation nursery owner/operator. My grandfather came to Canada in 1924 with a young family and a dream to start a nursery someday. In 1937 he started what is now Reimer's Nurseries growing fruit trees and roses. My father has also been passionate about plants all of his life. As long as I can remember Dad has been discussing and bringing in all types of plants for evaluation and trial growing purposes and consequently he has had a terrific influence on my career. We are not plant breeders but as growers we select plants that perform in desirable ways.

Our selection process is really quite simple. We observe our plants for the purpose of marketing. I'm borrowing from J.C. Raulston and Kim Tripp's book *The Year in Trees* wherein four criteria are listed as factors in commercial success:

- Propagation efficiency — if it's not relatively easy to do forget it.
- Growing efficiency — if it produces heavy losses or culls easily or doesn't grow relatively fast — forget it.
- The plant must be a tough survivor, able to survive both busy retailers and unknowledgeable gardeners.
- The plant must be a new form of familiar plants or be colorfully showy enough to make the impulse sale during that hectic 5-week sales period when 70% of all plant sales occur.

Furthermore it helps the sales process enormously for the plant to have a marketable name. For instance compare the name *Magnolia* ×*wieseneri* 'Aashild Kalleberg' with *M.* 'Goldstar' or *M.* 'Yellow Bird'. In order for widespread commercial success, a plant must have a good balance of these production and utilization factors. My role in the selection process is to evaluate all of our magnolias in this way.

PROPAGATION

We use *M. sieboldii*, *M. denudata*, *M. kobus*, or *M. stellata* as seedling understocks. These provide a fairly good root system for transplanting later on and reasonable hardiness. Using a modified chip bud we grow our magnolias in the open field in much the same manner as a fruit tree.

REASONS FOR SELECTING

Over the last 10 to 15 years the arborists in our cities and those who have a concern about urban horticulture have voiced concerns about monoculture in our urban plantings. The Dutch elm disease that wiped out the elms in many cities in North America is often cited as an example of what not to do. Presently, there are still legions of ash, maples of all kinds, flowering plums, pears, and cherries planted in our cities. Many of these taxa have served us well. But there is still a concern that perhaps a new disease or pest may someday denude significant portions of our urban forest. The city of Vancouver has drawn up limits of 20% of one genus and 10% of one species as target planting maximums in an effort to prevent a future decline in our urban forest.

This concern along with the desire to do something different served as a catalyst for us to look at magnolias as trees. We sold *M. kobus* to some of the local cities in the 1970s and 1980s. These seemed to stand up fairly well in the urban environment.

THE IDEAL TREE

Perhaps the ideal street tree is one that grows extremely rapidly to about 20 ft, whereupon it will cease growing so as not to tangle with overhead wires or underground sewers. It will flower profusely over a long period of time yet not shed any flowers, or fruit, and will provide great shade during the hot months yet not drop any leaves for people to rake in fall. It will withstand all manner of human and environmental abuse in an urban setting such as pollution, pests, diseases, and teenagers. I jest to prove a point. There is no ideal street tree. Magnolias come fairly close in my opinion, especially cultivars such as 'Wada's Memory', 'Vulcan', 'Galaxy', 'Spectrum', and 'Caerhays Belle', and the species *M. kobus*. I'd like to look at each of these briefly.

Tree Magnolia Selections.

***Magnolia* ×*kewensis* 'Wada's Memory'.** This cultivar was received in a batch of *M. kobus* seedlings at the University of Washington Arboretum in Seattle. The flowers are white and drooping. I am not thrilled about the flower but I love the foliage and especially the form of the tree. J.C. Raulston recommended using 'Wada's' Memory for commercial plantings as a street tree.

***Magnolia* 'Galaxy' and 'Spectrum'.** I list these cultivars together because of similar parentage (*M. lilliiflora* 'Nigra' × *M. sprengeri* 'Diva'). 'Galaxy' is a single-stemmed, upright tree with a pyramidal or columnar shape. It has purple-pink buds that fade somewhat after opening. 'Spectrum' is more broadly oval than 'Galaxy' producing larger darker yet sparser flowers than 'Galaxy'. 'Galaxy' is somewhat hardier than 'Spectrum'. It is listed as a Zone 5 to 8 plant. Generally, from what I understand the flowers escape the late spring frosts along the eastern seaboard.

***Magnolia* 'Vulcan'.** I have grown to love this cultivar even though I've been disappointed with the flowering characteristics. A few years ago all the magnolia lovers were talking about this new red flowering cultivar. In fact it even rated a picture and write-up in the American Nurseryman magazine 5 years ago. I have only seen pink/purple color in this cultivar, but after talking with Dorothy Callaway who wrote *The World of Magnolias*, I suspect that one has to be further south to get the true color. But what intrigues me is the upright columnar growth habit probably attaining a mature height of 20 to 25 ft and the lovely dark green foliage.

***Magnolia* 'Caerhays Belle'.** This relatively unknown cultivar is probably my favorite of the tree magnolias. It is stiff, upright, and branched with clear salmon-pink

9-in. blossoms, and thick textured foliage. It is already receiving some favorable reviews and I suspect many more.

Yellow Flowering Magnolias.

Two of the biggest problems with magnolias are its lack of hardiness and early flowering. In attempting to solve these problems hybridizers have used two of the hardier species: *M. acuminata* and *M. liliiflora*. From these crosses have come the bulk of the yellow flowering magnolias.

At present we have over 20 cultivars of yellow magnolias. We bring in new cultivars every year. This year we brought in 'Koban Dori' from Switzerland and other cultivars from the U.S. What we are looking for is some character that will make the plant stand out from other cultivars. Next we will look at several cultivars that are worthwhile in my opinion and some that we are still looking at:

'Golden Pond'. This cultivar is not particularly dark yellow in flower, but it came with the boast of a Zone 3 hardiness rating. The best way to tell is to sell some of these plants into Zone 3 and wait for a hard winter.

'Butterflies'. We've had this cultivar for a few years and are still waiting for it to flower. I've seen the pictures and read the reports. It is to be a precocious dark yellow that should be hardy to Zone 4. It's hard for me to recommend it until I've seen it flower myself.

'Goldstar'. A cream-colored star magnolia with reddish leaves. It has attractive qualities, but I can't decide whether to grow it as a bush or a tree. It flowers about 4 weeks after *M. stellata* and thus should avoid the late spring frosts.

'Hattie Carthan'. A stocky plant producing yellow flowers with a touch of magenta at the base. It has good possibilities.

'Large Yellow'. Last year we watched with growing excitement as this cultivar produced 30-plus flower buds as a 2-year-old plant. It survived the winter frosts with ease. However as we watched the flowers open during an exceptionally wet year we were disappointed because the rain seemed to cause the flower petals to fall off before they were fully open.

'Elizabeth'. Evamaria Sperber of the Brooklyn Botanical Gardens crossed *M. acuminata* with *M. denudata* producing this exceptional precocious cultivar. This was one of the first yellow-flowering magnolias to become available and although it is only cream-colored yellow and despite all the new cultivars now available, this is still one of the finest. It flowers as a 2-year-old plant and has lovely large flowers and leaves. It has some of the *M. denudata* floppiness as a young plant but deserves a significant place in the yellow-magnolia field.

'Yellow Bird'. The offspring of *M. liliiflora* and *M. acuminata* are called *M.* ×*brooklynensis*. These plants are generally hardier than *M. liliiflora*. The flowers appear at the same time as the leaves and continue for about 2 to 3 weeks. The flowers are a good yellow with a bit of greenish tinge at the base and are held upright on the branches. Although some prefer to see the flowers without the leaves, 'Yellow Bird' is one that flowers heavily as a young plant at the right time of year. In my opinion, this is probably the best of the yellows.

Future Selections.

By way of comparison, the development of magnolias is likely where rhododendrons were 30 years ago. The focus is on developing cultivars that are hardier, withstand the early frosts, flower after the danger of frost has passed, or have a longer flowering period. We are just starting to get the 2nd and 3rd generation hybrids now.

For example, through a technique called "induced polyploidy" whereby the chromosomes are doubled, tripled, or quadrupled, the characteristics of a known plant are changed somewhat. The leaves and flower petals are thicker resulting in more frost resistance and later flowering than regular diploid forms of the same species or cultivar.

In order to select the better cultivars we need to continue to use the criteria described above.

SUMMARY

Magnolias have tremendous landscape potential. New colors with hardier, more dependable flowering cultivars will excite us for years to come. We can also look toward new uses for magnolias as street and boulevard trees. I look forward to evaluating and selecting the better cultivars as they come along. No doubt my "top ten" list will change.

Hardy New Plants for Northern Gardens

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INTRODUCTION

It is a privilege to speak to you today about developing new plants for northern gardens. My talk today will cover plants hardy in Zone 4 and colder regions. Since so much of the stock grown in the Pacific Northwest and British Columbia is shipped to colder eastern zones it is important that you propagate hardy cultivars on hardy rootstocks. For over 30 years I have worked with these northern plant materials and those experiences have given me an appreciation for plant breeders who have made dramatic strides over the past 30 years. For example, there were only one or two large shade tree cultivars available for colder zones when I entered the field. Clonal propagation was very limited outside of flowering crabapples and possibly a few elms. Today there are 20 to 30 available shade trees for Zones 2 and 3. Now if we hear a complaint it is that we have too many cultivars for the limited market available.

As a plant breeder and nurserymen you first need to know that if you introduce an inordinate number of new plants, growers will simply back off until the selection is narrowed down. Could I suggest that coral bells and spireas are two crops in which breeders have named more plants than industry will accept?

Secondly, we need to give relative weighting to various factors that limit plants. Far too often flower color is rated most important and disease resistance less important. May I suggest that we give the following rank of importance to adaptation including: hardiness (highest), disease resistance, insect resistance, ease of propagation, foliage distinctiveness, flower distinctiveness (lowest)? We need to remember some plants that do not perform well in container production do well in the landscape and vice versa. Since all nursery plants generally end up in the landscape the performance in this location is paramount. For I.P.P.S. members the ultimate test is that an efficient propagation method can be developed. Overriding all these factors are such basic criteria as a hardy rootstock for a hardy cultivar. It makes little sense to breed a flowering crabapple for Zone 2 and then graft it onto a Zone 6 'Golden Delicious' seedling and ship it back to Zone 2.

Thirdly, every nursery grower and propagator should be on the look-out for variation that could lead to new plants. Many of our new plants have been found in seedling populations and cutting beds.

Promotion of new plants should go hand in hand with a program of education and publicity (Table 1). I suggest that each new plant should be accompanied with the following: A proper description and photo showing the salient features of the plant. Prior to publicity there should be sufficient stock to meet demands of growers. Promotion to growers and propagators should precede public promotion. Far too often the opposite takes place and both the grower and public are left wondering why we can't coordinate new plant introduction.

New plant introductions have given the nursery industry a strong sales boost. The key word has been "color", usually in foliage, occasionally in twigs and flowers. A second key characteristic has been plant form either in grafted standards or dwarf stature. The importance of the above criteria will be detailed in the following illustrations of popular nursery plants.

Table 1. Promotion of new plants.

1) Promotion to Growers		
Photos, slides, CD images		
Fact sheets — descriptions		
Nursery magazines	New plant Issues	Advertisements
2) Promotion to garden centers		
Nursery wholesale catalogues		
Photos supplied		
Sample plants distributed		
Trade shows		
3) Promotion to the Public		
Merits of new plants — characteristic uses in landscape		
Advertisements in gardening magazines and promotion with garden writers support		

1) Dwarf, Colored Foliage. 'Gold Mound', 'Goldflame', 'Flaming Mound', and a host of other dwarf gold-leaved spireas have taken up to 10% of the shrub market demand.

Gold ninebarks such as 'Dart's Gold' outsell green ninebarks 50 to 1 in our region. The silver foliage plants such as *Cornus alba* 'Argento-Marginata have been a strong seller and I predict the new dwarf Ivory Halo™ dogwood will have a strong market position for the next decade.

Other examples include the dwarf 'Minuet' and 'Tango' weigelas which are becoming more popular. Purple-leaved sandcherry, developed over 75 years ago has never been more popular than it is today even though it shows some degree of winter kill in northern zones.

2) Top-grafted Pea Shrubs. The success of the top-grafted pea shrubs has been beyond anything I could have imagined. Two cultivars from the prairies continue to become more popular. 'Walker Weeping', a fine-leaved hybrid of *Lorbergi caragana* and the regular weeping *L. caragana* continue to become more popular. Globe caragana from Dr. F.L. Skinner's work of over 50 years ago has made a comeback as a grafted standard.

3) Hardy Roses. Hardy roses with recurrent bloom such as the Parkland roses from Morden and the Ottawa Explorer roses have defined a new standard for own-rooted hardy roses. Now the effort will go into disease resistance and an expanded range of flower colors.

4) Shade Trees. Those trees including the 'Patmore' ash from Manitoba, the 'Fallgold' black ash, and the introduced Manchurian ash have been the basis for a new class of quality shade trees. New flowering trees such as 'Ivory Silk' tree lilac and flowering crabapples have given northern areas valuable new plants.

SPECIFIC PLANT GROUPS

Fraxinus. Ashes remain the most important shade trees in Zone 4 and colder zones. The cultivar picture is not totally clear, but these are my perceptions. 'Patmore' ash, introduced over 20 years ago, continues to be the #1 ash in North America. It has glossy green foliage, seedless habit, and straight trunks with pleasing branching. 'Summit ash' (Minnesota) and 'Prairie Spire' from North Dakota both do well. 'Bergeson' ash has very rapid growth that may cause poor branching and very wide spacing between limbs. 'Fallgold' ash has given growers another species and added a tree with distinct foliage and fall color. Manchurian ash from Asia is one of the most unique ashes we grow and the 'Mancana' seedless form is certainly a marked improvement over the species. Hybrids between black ash and 'Mancana' are just now becoming known. This cross made in 1969 shows the time it can take to develop a new tree. 'Northern Treasure' and 'Northern Gem', from this cross, will make a major impact as shade trees. Finally, a word about white ash, *F. americana,* which has not been considered hardy in northern zones. A population of seedlings grown from northern Minnesota and Ontario sources gave one seedling with extreme hardiness and dark green foliage. We have introduced this as 'Northern Blaze', an improved form compared to the 'Autumn Blaze' introduced from Morden in 1982.

Acer. Even though sugar maple is the national emblem for Canada there are no named cultivars for northern zones. From a group of selected trees we have identified one promising selection. Now we are seeking an acceptable propagation procedure that will retain maximum hardiness.

Tilia. Linden introductions from Manchuria have given the basis for two new distinctive lindens. 'Harvest Gold' is a Mongolian linden type with exfoliating bark, small leaflets, upright oval crown and superb fall color. 'Golden Cascade' is a related plant more akin to little leaf linden. It has a cascading crown excellent fall color and disease-free foliage.

Ulmus. Most of us have lived to see the decline of the splendid elms which had been the predominant boulevard tree in all northern zones. I have been interested for over 30 years in a disease-tolerant tree from Asia that has withstood cold winters down to -42C. The Asiatic elm, *U. japonica* has a form approaching American elm. A colleague of mine has introduced the new 'Discovery' elm which reproduces well in tissue culture. This elm is resistant to aphids and produces very little seed, so it should become popular.

Populus. While not an important plant to residential areas, poplars remain a choice for large lots and shelterbelts. Swedish columnar aspen (*Populus tremula* 'Erecta') has become a popular tree particularly in Alberta. 'Tower', a silver-leaved form, propagates more readily and grows somewhat faster.

NEW SHRUBS, FRUITS, AND PERENNIALS

'Blizzard' mock orange, a native *Philadelphus lewisii,* has clear white flowers and prolific bloom even when sheared. Zone 2 hardiness sets this plant apart from other mock oranges. Introduced by John Wallace of Beaverlodge Nursery, it was named by the Morden Research Station.

'Miniglobe' honeysuckle, is an excellent dwarf, green-foliaged plant and an improvement over the older cultivars.

Potentilla fruticosa cultivars (shrubby potentillas) continue to be an important summer-flowering shrub for northern gardens. Research at the University of Manitoba has resulted in several new forms and colors. The double-flowered 'Yellow Bird' and 'Snowbird' and the outstanding new pink semidouble flowered 'Pink Beauty' are noteworthy. The new low-growing plant form seen in 'Yellow Gem' from University of British Columbia Botanical Garden is a breakthrough in breeding as it makes the potentilla into an effective low groundcover. Watch for new potentilla cultivars that will extend this growth form with new flower colors.

Fall-bearing raspberries have been recently introduced from the Morden Research Center. These primocaine types make fall bearing a reality in Zones 3 and 4. 'Red River' and 'Double Delight' fruit about the end of August and give abundant yield. 'Double Delight' is more vigorous and upstanding with larger fruit.

Heuchera (coral bells). Although there have been many introductions recently, very few have been developed for northern zones. 'Northern Fire' and 'Ruby Mist' are two Zone 2 types with good green foliage and red flowers. 'Chocolate Ruffles' has performed fairly well in northern zones, but I have found many of the other foliage variants have been weaker plants.

Monarda (bee balm). New work from Morden has produced a dwarf form suitable for bedding plantings. 'Petite Delight' and 'Petite Wonder' deserve your attention.

Lilium (lilies). Recent work at the Morden Research Station is the basis for new colorful lily hybrids for northern zones. These hybrids between trumpet lilies and tender oriental lilies will be important for the northern plains states and Canada.

In conclusion, some major plant breeding opportunities remain and I will list a few:

1) Black-spot and mildew-resistant cultivars in roses are a pressing need.

2) Black knot resistance in purple leaf cherry such as 'Schubert' and 'Canada Red'.

3) Birch borer resistance in birch of several species.

These and many more problems will need new technologies to solve them. Ornamental plants do not have the value associated with crops such as wheat, canola, or potatoes. These economic crops are receiving genetic engineering attention and we now see Round-up-resistant canola, potatoes with insect resistance for potato beetle, and genetically engineered corn. Hopefully these procedures applied to major ornamental crops will solve the most important breeding problems. The future is bright and for the present we can grow the many fine new plants that are available.

"PLANT BREEDING AND SELECTION IN WESTERN CANADA" QUESTION-ANSWER PERIOD

HANNAH MATHERS: In the tree fruit area, rootstocks have been heavily studied. Do you think we have spent enough time studying rootstocks in ornamentals?

WILBERT RONALD: Rootstocks need to be a focus for future studies and more needs to be done. Problems, such as chlorosis resistance, need attention.

ANONYMOUS: Are you doing any work with summer-blooming magnolias?

PAUL REIMER: Most of our work has been done on the spring-flowering ones. However, we are doing some work with *Magnolia sieboldii*.

ANONYMOUS: What was the name of the silver dogwood?

WILBERT RONALD: 'Ivory Halo'. It is patented in the U.S. and registered through C.O.P.F. Plants in Canada and it's in Europe as well.

Collection, Propagation, and Use of Native Plants

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INTRODUCTION

Before we begin let us decide what we mean by native plants for the purpose of this presentation. By native plants we mean plants found growing naturally in a certain area. They include native perennials, shrubs, and trees. These are the plants present in that area before other plants were introduced, intentionally or unintentionally, from elsewhere. These native plants evolved in their natural habitat over time and they can be assumed to be the most optimum plants for the sites where they are found. Along with the plants evolving in their particular area other life forms have evolved with them, such as mammals, birds, and insects, as well as more primitive life forms, including fungi and soil organisms which, together with nonliving elements, form complex ecosystems.

Native plants have an important role to play in maintaining the diversity of ecosystems in the less disturbed outlying areas where forestry and agriculture dominate, as well as in the urban areas. In conclusion, we can say that native plants will always be an essential component of the landscape, both urban and nonurban, for reasons of biodiversity, as well for their aesthetic value.

PROPAGATIVE MATERIAL

Native plants have been used for habitat restoration and landscaping purposes in British Columbia for at least the past two decades. Initially the common propagation method was to collect plants in their natural habitat and replant them in the desired location. In some instances, e.g. ferns, the root systems would be divided, and the divisions potted up. This practice has led to the disappearance of a number of species from extensive areas. Some local species that come to mind are: deer fern, *Blechnum spicant;* evergreen huckleberry, *Vaccinium ovatum;* white fawn lily, *Erythronium oregonum;* and western trillium, *Trillium ovatum.*

For obvious reasons the collection of plants is unacceptable. As a result the collection of native plants has been replaced, to a large extent, by plant propagation, although a substantial number of plants, e.g., ferns and wetland species (for restoration purposes mainly) are still collected from the wild.

Two main methods of propagation are currently being used: (1) seed; and (2) vegetative propagation by way of cuttings. Additionally, tissue culture is used for some species, e.g. a selection of *V. ovatum* like 'Thunderbird'.

In the case of native ferns, these can be propagated from spores.

Whether seed or cuttings are used for propagation depends on:

- The destination of the resulting plant material,
- Which one of the two methods is the easiest.

As to the destination of the plant material a distinction between two markets can be made:

Ornamental and/or Landscape Market. Some of the users of native plants for this purpose attach a value to the uniformity, form, colour, or size of the product. As a result selections of several native plant species have been made, which are maintained by way of vegetative propagation. The University of British Columbia Botanical Garden has, through its plant introduction scheme, released a number of native plant selections. Some are: *Arctostaphylos uva-ursi* 'Vancouver Jade', *Ribes sanguineum* 'White Icicle', *V. ovatum* 'Thunderbird', and *Penstemon fruticosus* 'Purple Haze'.

Restoration or Rehabilitation Market. These users include mine sites, utility corridors, forestry sites, and wetlands. In this case, factors such as uniformity, size, etc. are not important; in fact plant selections are undesirable. The user will look for proper seed origin, i.e., geographic location, elevation, and biogeoclimatic zone in an effort to maintain the genetic variation of the species and the suitability of the new crop to the planting site.

VEGETATIVE PROPAGATION

In order to maintain a cultivar or selection, with its "improvements", cuttings are taken from plants of the desired selection either in the landscape or from (stock) plants in the nursery. This is also done for species not easily grown from seed. Some of these are: falsebox, *Paxistima myrsinites*; willows, *Salix* spp.; stonecrop, *Sedum* spp.; twinflower, *Linnaea borealis* var. *longiflora*; wild ginger, *Asarum caudatum*; strawberries, *Fragaria* spp.; and poplars and aspen, *Populus* spp.

In most cases softwood cuttings are taken, however, *Populus* spp. and *Salix* spp. are grown from hardwood cuttings. More research for the optimum timing when cuttings are to be to be taken needs to be done.

PROPAGATION FROM SEED

The majority of native plants are grown from seed. Seed is not easily available commercially, so seed has to be collected. As seed is not always produced reliably every year, it is a good idea to try to build a seed inventory large enough to cover at least a 2-year requirement.

Growers may collect their own seeds or they may use seed collectors. At Linnaea Nurseries Limited we collect seed crops that we can reach within 1 day; longer overnight trips are not economical. For this reason we contract out seed collections to contractors who cover other biogeoclimatic areas. This also allows us to obtain other species not available in our own collection area, and build up a seed inventory that includes the same species from different biogeoclimatic zones.

A successful seed collector:

- Knows the collection area well
- Has an inborn interest in plants growing in their natural environment
- Has a basic knowledge of seed and plant biology
- Is able to use field guides and identify plant species
- Has the time and ability to locate adequate seed crops, as well as to monitor seed development and maturity
- Knows when and how to collect seed, ship, and store it
- Properly records and labels any seed collected.

Types of seed the collector encounters:

- Seeds in fruits, containing from a single or several to many seeds, e.g., *Rosa* spp., *Amelanchier* spp., *Cornus* spp.,and *Vaccinium* spp.
- Dry seeds, e.g., in capsules containing a number of seeds like, *Menziesia ferruginea, Rhododendron* spp. or achenes, a dry fruit containing a single seed, e.g., the *Asteraceae,* in the case of conifers, seed in cones.

Seed maturity is an important factor, which strongly influences the seed germination rate. Immature seed has a low germination rate or does not germinate at all. On the other hand, if the collector waits too long, the seed will often fall off the plant or will be eaten by birds. In many cases the "collection window" occurs between the time when seeds reach the required maturity level for collection and when seeds are released and dispersed naturally. It can be as short as a couple of days. Crop monitoring, therefore, is essential.

SEED MATURITY

Seed maturity can be evaluated in different ways and varies with species. Many berries turn from hard and green fruits to soft and to a color indicating the stage of maturity, e.g., orange/red for rose hips, blue for *Mahonia* species, and orange for *Cornus canadensis*. In the case of dry seed, seed heads or capsules will turn from green to brown.

Whenever feasible, before collecting berries, cones, capsules, etc., the seed-containing structure should be opened, e.g., cut with a knife to check the presence and the number of seeds. If there is no seed present, or in the case of seed cones, if the seed count is very low, a seed collection may not be worthwhile.

Other criteria in judging seed maturity include:

- Seed color, usually brown if mature.
- Hardness of seed, milky or soft seeds are immature. Mature seed is hard; cannot be squeezed, indicating a low seed moisture content.
- Embryo development; a mature embryo fills at least 90% of the embryo cavity. This requires cutting the seed with a sharp knife or one-sided razor blade. The embryo is usually cream to yellow in color, while the seed storage tissue (megagametophyte) is white. An empty seed or a discolored seed (often with a "woody" brown seed interior) indicates seed is not viable.

Mature berries and dry seeds are collected by hand in pails or plastic bags. Tree seeds require different methods. Mature cones can be picked off trees or collected from squirrel caches. In some cases, e.g., *Thuja plicata, Alnus* spp., the collector can wait till seed is ready to be dispersed naturally, by shaking the branches and collecting the seed that drop on a tarp below the tree.

Berries, seeds, and cones in transit and temporary storage are to be kept cool, ideally, between 2 to 4C (35 to 39F).

SEED PROCESSING

Upon arrival at the processing location, seed has to be checked for weight, quality, maturity and, in the case of dry seeds, for moisture content. Most dry seeds benefit from additional drying on trays or racks in a dry, well ventilated space. Often an unused, dry spot in the greenhouse works well.

Berries should be processed as soon as possible. For most cases a simple food processor is adequate. Large commercial macerators and separators are available, but expensive (there are several European products costing in excess of CDN $10,000 each).

The berries are macerated (ground into a pulp), which takes from 25 sec to 5 min per batch. If processed for too short a time pulp is not removed adequately. If processed too long seed may be damaged. Stop the processor regularly to check. Experience will do the rest. The pulp and the seed are separated in water. A 20-liter (5-gal) pail works well. As a rule, the good, heavy (filled) seeds sink to the bottom, and the pulp and empty seeds are floated off. To prevent losing valuable seed, the water solution containing seeds and pulp is run through a strainer. Have several strainers with different mesh sizes at hand. Floating seeds must be checked (cut with a knife) regularly to ensure that not too many filled seeds are floated off with the pulp. The pulp has to be checked for the presence of seed and may have to be re-processed. Most of the debris can be floated off and seed purities of approximately 90% to 95% upon completion of processing are quite common.

After processing, the seed needs to be dried. This can be done on fine mesh wire or cloth screens, which are easy to construct. The same screens can be used to screen off most of the remaining debris from the dry seed. Screens with different mesh sizes will be required. Seed that is to be sown or stratified shortly after processing can be dried back to between 10% and 30% moisture content. Seed that will go into (long-term) storage must be below 10% moisture content. Either a dry stove or lots of experience will be needed to determine moisture content.

Store seed in air-tight containers, or 4 mil plastic bags at approximately 2C (35 to 36F). For long-term storage (2 to 10 years) ensure moisture content is below 8% for freezer storage at -5/10C (20/15F). Some (often nonhardy coastal) species do not store well at temperatures below freezing.

RECORDS

Records are an essential tool in quality and inventory control. Records are to include the following information: name (and address) of collector, botanical species name, collection location, collection date, seedlot number, weight of seed before processing, weight of seed after processing and drying, filled seed count, seed purity in percentage, number of seeds per dry weight unit (e.g., gram, ounce, etc.), yield of seed per weight or volume unit of collected seed before processing and storage location (e.g., box number, shelf number).

With this information you build up a database on collectors, collection areas, yield comparisons between collection years and locations, sowing rates, costing, invoicing, etc. A computer is a helpful tool for record keeping!

SEED STRATIFICATION

At Linnaea Nurseries two methods of stratification are used:

1) Natural stratification; mostly in propagation trays filled with peat moss or some other soil medium.
2) Artificial stratification; in cooler at approx. 2C (35 to 36F).

Where we have found no advantage in natural stratification we stratify seed in plastic bags in the cooler, e.g., *Arctostaphylos uva-ursi, C. canadensis, Amelanchier alnifolia,* and *Shepherdia canadensis.*

Standard Procedure. Seeds are soaked for 24 to 48 h in running water, drained, mix with moist peat moss, and store in plastic bag in cooler for the required duration for the species. Stratification development can be monitored by taking a seed sample (e.g., 25 seeds) out of the bag followed by a germination test during the final stages of the stratification period.

For natural stratification seed is sown in late summer or early fall for species requiring warm/cold stratification, e.g., *Mahonia* spp., *Acer* spp., and *Symphoricarpos albus*. Many species are sown in October and November. Many native perennials are sown in early spring.

Seed flats are either left outside without protection (woody species) or in the case of small-seeded species with thin seed coats and some perennials, in an unheated shelter house.

Seed scarification (e.g., using acid, crushing, grinding, etc.) is rarely used at Linnaea Nurseries.

Seed germination timing can be influenced somewhat by bringing seed flats into a heated greenhouse either earlier or later (e.g., between February and April). If in doubt whether stratification is satisfactory, carry out a germination test before moving seed flats into the warm greenhouse.

Stratified seed can be sown just before germination or seed can be allowed to germinate in seed flats and be transplanted into the desired container type.

Generally, growing media should be well drained, using fairly coarse peat moss in combination with perlite, pumice, and sometimes some sand. Being aware of the natural growing conditions of native plants is helpful in selecting the growing media and growing regime, i.e., water, fertilizer, and shade requirements.

Once the native plant seedling is established you will find that the growing requirements are similar to the non-native crops, and the same rule applies: the grower's footsteps are the best fertilizer.

USE OF NATIVE PLANTS

We have touched on some of the uses for native plants. One of the oldest uses, and often not thought of as such, is in growing seedlings for reforestation purposes. Almost all seedlings planted in logged areas are native conifer species. More recently, native shrub and nonwoody species are used for deactivation of logging roads, landings, etc., as well as slope stabilization, erosion control, streambed restoration, etc.

Public pressure has led to legislated measures and a general preparedness to repair the damage to the landscape from forestry, mining, gas pipelines, and urbanization. Although the methods used by some environmental groups may sometimes be questionable, it is largely thanks to their pressure that the public has become aware of environmental issues and a new environmental ethic has come about. This has led to an increased interest in end use of native plants which has provided new opportunities to the nursery industry. Furthermore, initiatives such as Greenways, Naturescape, and recently the establishment of the BCNPS, British Columbia Native Plant Society are reinforcing awareness and use of native plants in the (urban) landscape, including their use in the garden.

It is my belief that native plants have a continuing role to play in maintaining a healthy environment, and for that reason we at Linnaea Nurseries are prepared to identify and fill the needs created by this new reality.

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Growing Functional Nitrogen-Fixing Native Trees and Shrubs for Land Reclamation in British Columbia

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Native actinorhizal trees and shrubs have the ability to fix atmospheric nitrogen and improve soil nitrogen concentrations. This is of particular value for the reclamation of low nutrient mine wastes. Nursery studies were conducted to assess practical methods for inoculating *Alnus viridis* ssp. *sinuata*, *Elaeagnus commutata*, and *Shepherdia canadensis* seedlings with appropriate strains of *Frankia* bacteria. Results indicated that application of a liquid inoculum achieved good success. An additional application method using Mikro-Beads™ is also discussed.

INTRODUCTION

Revegetation of mine soils is often limited by coarse-textured materials with high coarse fragment content and low nutrient status. Application of fertilizer, either as an inorganic commercial product or as an organic waste product, is typically used to initiate a nutrient pool in the mine soil. Legume species such as clover or alfalfa which have rhizobial associations that fix atmospheric nitrogen are often seeded to improve the nitrogen content of the soils. These plants have value as forage for range cattle and other animals, but at some mine sites proposed land uses such as forestry or wildlife habitat require the establishment of woody species. In these instances the use of actinorhizal perennial woody trees and shrubs can fix atmospheric nitrogen and increase the soil nitrogen content. In addition to improving the soil nitrogen levels, actinorhizal plants ameliorate soil temperature and moisture conditions through the accumulation of organic matter resulting from leaf and root litter deposition and decomposition (Visser et al., 1991).

Various species of actinorhizal shrubs are grown in western Canada for use in mine land reclamation. These species include *Alnus rubra* (red alder), *Alnus viridis* ssp. *sinuata* (Sitka alder), *Ceanothus velutinus* (snowbrush), *Elaeagnus commutata* (wolf-willow), and *Shepherdia canadensis* (buffaloberry). While these plants have the capability for association with a bacterium (*Frankia* spp.) and the potential to form root nodules, this often does not occur in container-grown nursery stock. A survey conducted of seven nurseries located in Alberta and British Columbia indicated that *E. commutata* and *S. canadensis* seedlings did not become nodulated in their first year and that planting stock generally lacked nitrogen-fixing ability (Danielson and Visser, 1990). The conclusion of this survey supported our observation that container-grown nursery stock of *E. commutata* and *S. canadensis* were lacking *Frankia* nodulation. In monitoring programs conducted at various mine sites planted with these two species it was also our observation that the initial growth of these two species planted on reclaimed mine sites was poor. The soils at these mine sites, in addition to having low nutrient conditions, did not contain potential *Frankia* inoculum. Therefore, without a source of *Frankia* inoculum *Shepherdia* and *Elaeagnus* displayed similar growth to other non-actinorhizal, species planted on these sites. Occasionally, a number of years subsequent to planting, the actinorhizal species would begin to grow rapidly and could be shown to have become nodulated. This was particularly noticeable with *S. canadensis* where the leaf color would change to a dark green shade. This type of on-site nodulation must be due to inoculum from adjacent forest areas being transferred to the reclaimed site.

METHODS

It became apparent that for us to utilize these actinorhizal plants for their nitrogen-fixing abilities, it would be necessary to ensure that the seedlings were inoculated with the appropriate *Frankia* species before they were planted on the mine sites. We experimented with collecting nodules from plants growing in natural forest sites and applying a slurry of the ground nodules to our nursery stock. The results from these initial experiments had limited success. We then contacted Mikro-Tek, an Ontario company with experience in growing bacterial cultures of *Frankia* for the inoculation of *Alnus*. At that time they had not grown *Frankia* inoculum for either *Shepherdia* or *Elaeagnus*, but believed they could provide us with a suitable culture. We collected nodulated roots from *Shepherdia* and *Elaeagnus* and sent them in coolers to their lab where they processed the nodules and initiated the cultures. The growth of these *Frankia* species were much slower than Mikro-Tek had experienced with other *Frankia* cultures, but with adjustments to their media they were able to culture these bacteria. We also collected nodules from a northwestern *A. viridis* ssp. *sinuata* population and they also provided us with a suitable culture for this *Alnus* seed source.

We have applied *Frankia* to our seedlings using two methods: the bacterial culture can be directly watered onto the seedlings or it can be mixed into the soil media if the bacteria is encapsulated in peat moss beads called Mikro-Beads™. The first application technique is relatively simple, the inoculum can be hand watered onto the seedlings or can be introduced into the overhead watering system. To utilize an overhead watering system, it is important to remove any filters in the water system which could trap the bacteria. In the second application technique, it is important to mix the appropriate number of Mikro-Beads™ into the soil media to ensure that the bacteria are evenly distributed to each cavity and available to the young roots. The advantages of the Mikro-Beads™ method is the ability to store the product for a longer period over a wider range of temperature conditions. The liquid cultures are shipped in a growth media and must be shipped and stored in refrigerated conditions. The liquid cultures must be applied quickly after reaching the nursery; therefore, it is important to be able to predict when the seedlings will be available for inoculating. The *Frankia* bacteria infect the young growing roots and it is necessary to have the seedlings at the right stage of development when inoculating with the liquid culture. The timing is not as critical for the Mikro-Beads™ which can be incorporated into the top 2 or 3 cm of the soil media at the time of planting.

Most of our seedlings of *A. viridis* ssp. *sinuata*, *E. commutata*, and *S. canadensis* were inoculated in the spring of 1996 using the liquid inoculum method. Two hundred of each species were maintained as a control which did not receive inoculum. In 1997 most of the treated seedlings were treated with the Mikro-Beads™, but some were treated with the liquid inoculum and two hundred were maintained as an untreated control.

RESULTS

We assessed the results of the application of the *Frankia* inoculum on *S. canadensis*, *E. commutata*, and *A. viridis* ssp. *sinuata* in September 1996, approximately 5 months after the date of application. Samples were selected randomly from these populations and visually inspected. Of the *Frankia*-treated *Alnus* stock, 75% had nodules which were easily visible; however, 68% of the untreated control *Alnus* seedlings also had visible nodules. Since our nursery is located adjacent to a forest containing *A. rubra* it is likely that spores of *Frankia* naturally inoculate much of our *Alnus* stock. Nodules were not visible on any of the *Elaeagnus* or *Shepherdia* seedlings. A subsample of *Shepherdia* seedlings were shipped to Mikro-Tek where they were assessed. They gently washed the root systems to remove the soil and then observed the roots under a microscope at 20X magnification. All of the root systems were observed to have nodules and ranged from 4 to 10 nodules per plant. Most of the nodules were small, less than 2 mm in diameter, and only one had multiple lobes. All of the nodules were located at the bottom of the growing plug near the drainage opening.

DISCUSSION

The results from the inoculation of the 1997 crops are not yet available, but it is hoped that the use of the Mikro-Beads™ will be as effective in the establishment of *Frankia* populations as was the liquid inoculum used in 1996. While the liquid inoculum is easily applied, the shipping and storage of the material is limited by both temperature and time. Use of the Mikro-Beads™ is more practical for nursery management.

In a field trial conducted on oil sands tailings, Visser et. al. (1991) reported that both *Elaeagnus* and *Shepherdia* had greater height growth, and produced heavier shoots and roots when inoculated with soil containing *Frankia* than did the uninoculated controls. We intend to monitor the growth response of the actinorhizal shrubs grown in our nursery that have been planted in various mine reclamation projects. We expect that the successful inoculation of these species with appropriate *Frankia* species in the nursery will result in superior growth at the mine sites.

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Mycorrhizal Inoculation of California Native Plants in Containers

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At Tree of Life Nursery, we grow California native plants for ecological restoration, revegetation, and authentic early California landscaping. Our plants need to stand up to the rigors of the harsh, dry planting sites typical of southern California. More important than the rate of growth in the nursery are the sturdiness, vigor, health, and self-sustaining capabilities of the plants when they leave the nursery. For this reason, we began looking seriously at mycorrhizae approximately 12 years ago.

From our experience, the first step the nursery should take if interested in mycorrhizae is to seek the services of an expert in the field. We learned early that our expertise in propagation is completely different from the expertise required to produce healthy inoculum and maintain a program for making plants mycorrhizal. The expert at Tree of Life Nursery is Dr. Ted St. John, who has been on staff for about 10 years.

After experimenting with methods of inoculum production, we determined that a commercial product would only become popular if it were easy to handle in the field. Since endomycorrhizal fungi are host-obligate, we needed a growing medium for the host plant that would hold spores and hyphae, stay viable for a long time, and handle like a granular soil amendment. We found that calcined clay (similar to cat litter) met all our criteria. The commercial vesicular arbuscular (VA) inoculum produced by Tree of Life Nursery is labeled "VAM80" and is registered by the California Department of Food and Agriculture for use as a soil conditioner. Essentially, the inoculum is the screened, clay-based root ball of the production host plant.

We produce the fungus *Glomus intraradices*. This species occurs widely as a native in the soils of western North America and has proven itself adaptable to a wide range of climates and soils. We have in the past produced mixtures of fungal species native to the particular restoration site, but we find that almost all of our customers prefer the convenience and lower cost of our "generic" inoculum.

As we move into the fall planting season, the nursery continues to produce thousands of mycorrhizal container plants every week. Our routine production methods were not derived easily, but have required special accommodations in container mix, fertilization, and other details of the production schedule. Some of the most important details have been presented by Castellan and Molina (1990), St. John (1990, 1996), and St. John and Evans (1990).

Our inoculum has become a separate product and is in direct use in field restoration projects. The easily handled material appears to be changing the way habitat restoration is done in California. Many tons of the product were applied last year by both specialized machinery (a "land imprinter") and conventional agricultural and landscaping equipment.

To successfully establish a mycorrhizal program, the nursery must commit to a considerable modification of the standard routine, and must realize that the benefits are not to be realized by the nursery, but by the customer.

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"Collection and Use of Native Plants in the Landscape" Question-Answer Period

KATHY ECHOLS: Are you marketing the products you are currently using?

MIKE EVANS: Yes. It is labelled in California as a soil conditioner with the name VAM80.

LAINE MCLAUGHLIN: Do we have reason to think that this same fungus will work up here in the northwest or will we have to start from scratch?

MIKE EVANS: That's a good question; will it work here. Bob Linderman at Oregon State is one of the premiere researchers in the world and we've been in contact with him. We're working on some strains of *Glomus* that will tolerate acid soils, but *G. interadices* has not been very promising under acid conditions. It grows best in the pH 6.5 range and even slightly alkaline soils.

HANK BROKAW: I would like to know if you find different concentrations of the mycorrhizae with different depths in your 15-gal containers? If so, to what do you attribute that?

MIKE EVANS: Yes, we do find different concentrations. We discard the entire top (3 inches of medium) simply because there are not many roots there and that's where there would be any contamination from surrounding fields (weed seed, etc.). I think it relates directly to the quantity of roots in that part of the container and that's why we use SpinOut™ in an attempt to get a uniform distribution of roots throughout the whole container volume. The spores and hyphae, of course, attach themselves to the roots and prefer the cooler temperatures in the center of the container.

LIBBY DAVISON: Do you know anything about the temperature sensitivities of various VAM fungi?

MIKE EVANS: It's a good question. Inoculum laying out under the full sun for as little as a half-day will be damaged. However, within the container, as long as roots are surviving the fungus will be in good condition. We paint the containers white to minimize the build-up of heat in the soil medium.

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Don't Let the Well Run Dry: Water Conservation Practices for Container Nurseries

Richard Regan
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INTRODUCTION

Plant nurseries are looking for ways to help conserve water and solve environmental concerns regarding water quality and runoff. In addition, water costs are increasing and water use regulations are more restrictive. Managers must determine which irrigation systems and production methods best fit their nursery. First, consider the basic practices that have been shown to conserve water and reduce runoff (Kabashima, 1993). These practices are based on improved irrigation systems, irrigation scheduling, and using tail-water return systems. Secondary consideration should be given to plant water use, water application, and the plant environment. Usually, these methods are effective in conserving water only after implementing the previous practices.

IRRIGATION SYSTEMS

Selecting the best irrigation system to help conserve water is a difficult but essential task. Overhead irrigation is commonly used to produce container-grown plants and its popularity is based on practicality and economics. Sprinkler systems with low application rates tend to create less runoff. A major objective of sprinkler system design is to apply water uniformly. While drip systems have the potential to substantially reduce the amount of water applied and runoff, if improperly designed and/or managed, poor efficiency and poor plant growth will result. When several diverse species are located within the same irrigation zone, extra water must be applied to satisfy the needs of the high-water-use plant.

Sprinkler systems apply water in the form of a spray and can be used to modify the environment (cooling or frost protection). Impact sprinklers apply water to large areas at a wide range of rates. With fixed-head sprinklers, the diameter of coverage is smaller, thus their application rate is higher. Application rates of spinners are kept low by using a small nozzle size, a factor which can cause the nozzle to become plugged. The traveling boom system used in greenhouses are controlled electronically and the application rate ranges from very low (mist) to moderate.

Water distribution pattern efficiency is a measure of how uniformly water is applied to all the containers within an irrigated area. It can be estimated either on site using a can test or by computer software. Low distribution pattern efficiency means that a greater number of containers will be drier than the rest. To compensate for the dry ones, more water must be applied which causes other containers to be over-watered resulting in poor root systems, excessive nutrient leaching, and increased runoff. Distribution pattern efficiency is influenced by: (1) sprinkler spacing and type, (2) system hydraulics (pressure, friction loss), (3) wind speed and duration, and (4) plant canopy density and configuration.

Drip or trickle irrigation refers to the frequent application of water at very low rates. Larger container sizes are best suited for this type of irrigation system. It is so different from sprinkler irrigation that changes in weed management, fertilization, as well as irrigation are required. When compared to overhead sprinkler irrigation, drip irrigation can lower operating costs, reduce the potential for foliar disease, and allow fertilizer to be injected and applied as needed. Numerous types of microsprinklers are available which distribute water more uniformly over the surface of the container media. Recent developments include: improved pressure compensation, reliable flow control valves, and less tendency to clog.

Some of the overall operational problems with drip systems include: lead tubes becoming displaced, lateral lines interfering with cultural operations, and emitters plugging. The maintenance of drip systems is essential for success. Emitters should be checked and measured for correct flow and water pressure must be monitored. Water used for drip irrigation should at least be as clean as drinking water, preferably even cleaner. Several stages of filtration are often required depending on the types of contaminants in the irrigation water. If a filter does not back-flush effectively, its filtering ability is reduced.

IRRIGATION SCHEDULING

Irrigation scheduling can result in a 25% savings in water. The ideal way to schedule irrigations is to determine how much water the plants are using and then replenish it. This works best when only one plant cultivar is grown under a single irrigation zone. Frequent irrigations (pulse or daily) that minimizes medium water depletion is considered best for plant growth and irrigation efficiency (Beeson, 1994; Karam et al., 1993). Nursery managers are likely to use container weight measurement to determine percent water depletion. They lift the container and judge the amount of water left in the container by its weight. Moisture measuring technology has not advanced far enough to reliably assist container nurseries. Containers that are allowed to dry down below 40% medium water depletion are very difficult to wet resulting in plant stress. In dry containers, irrigation water tends to move along the sides of container with less chance of it being stored in the medium.

How much water to apply should be adjusted daily. A standard run time that delivers a specified amount of water is budgeted for the weather conditions (temperature, wind, relative humidity, and sunshine) the previous day. This standard irrigation is based on crop water use for the average evapotranspiration at that time of year. This can be done by a controller operated by a trained irrigation manager or by a computer. For example, if the standard amount of water to be applied is 0.4 inches, and yesterday was much cooler than normal, the irrigation budget for today might be 75% of the standard (0.3 inches). It is very important to evaluate how completely the available water is replenished following an irrigation.

TAIL-WATER RETURN

An important water conservation practice for container nurseries is tail-water collection. Water is reused by collecting runoff in a reservoir and pumping it back into the water supply. Tail-water return systems are expensive to install especially with existing nurseries. Usually, the return system does not disrupt regular production practices if it has been carefully engineered. Expect a water savings between 30% and 60%. Fertilizers, pesticides, and plant pathogens are dynamic factors which influence water quality and should be monitored frequently. Very little is known about effective treatment (filtration, aeration, chlorination, etc.) of nursery tail-water.

PLANT WATER USE

Grouping plants with similar water use under the same irrigation zone is a very difficult task for a production nursery. It might be more practical to avoid placing a new planting next to mature crops and only separate out plants with very high or very low water use rates. Water use of plants is strongly influenced by the climate and by production practices and crop characteristics (Regan, 1991). Daily weather conditions affect the amount of water a plant will use. Most temperate zone plants use more water on hot, dry, and windy days. Using crop water requirements to schedule irrigation for container-grown plants is not practical (Schuch and Burger, 1997).

Variation in plant water use exists within the major plant groups (conifer, deciduous, broadleaf evergreen) as well as between the groups (Burger et al., 1987). Generally, as plants get larger they require more water (Knox, 1989). During crop establishment water use is low and rather constant, but frequent irrigation may be necessary due to limited root expansion and soil water evaporation. As the crop develops it is influenced by the type of shoot growth and dormancy. Plants that grow continuously (free growth) tend to use more water than plants which have only one growth flush (fixed growth). Plant growth rate is another factor that affects water use with fast-growing species using more water (Roberts and Schnipke, 1987). Plant water use declines rapidly with the onset of dormancy and winter.

WATER APPLICATION

Most of the irrigation water applied through sprinklers is not stored in the container medium. Water application efficiency is the amount of water stored in the container medium after an irrigation compared to the total amount of water applied. Application efficiency is very low due to water falling outside of the containers and decreases further when the amount (depth) of water applied exceeds the medium storage capacity (leaching). Application efficiency in ornamental nurseries ranges between 15 to 25% (Beeson, 1991) and about 40% for traveling boom irrigated forest seedlings (Dumrose et al., 1991). The application efficiency is best when the plants are small and spaced can-tight and decreases dramatically when the spacing between containers increases. Water shedding and water holding by dense plant canopies can further reduce application efficiency. While it is not always practical, application efficiency can be improved by using larger containers and keeping them can-tight for as long as possible.

PLANT ENVIRONMENT

Modifying the growing environment is seldom used to help conserve irrigation water due in part to the expenses involved. The main objective is to lower the air temperatures of the growing area by using an overhead shade structure. Some nursery managers believe that crop water use can be reduced by as much as 40%. This could result in significant savings if irrigation was scheduled accordingly. One disadvantage to growing plants under shade, especially in the northern regions, is that reduced sunlight could limit plant growth and quality. Nursery managers interested in trying this conservation practice should consider using retractable or removable shade. A dense plant canopy cover will also help reduce the container medium temperatures, but this type of canopy could also decrease water application efficiency. In very windy areas, wind breaks could help reduce plant water use up to 10%.

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Water Recycling at Byland's Nurseries: An Extensive Water Catchment and Recycling System

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Twenty-five minutes is not a long time to talk about water recycling so I will endeavor to give you a brief overview as to what we have done at Bylands Nurseries to solve our water runoff problems. Byland's Nurseries is a diversified wholesale nursery located in British Columbia's Okanagan Valley. We are classified as a Zone 5 or 6 depending on location and proximity to Lake Okanagan which has a significant moderating influence on our climate. The climate is semi-desert with many years only receiving 12 to 15 inches of rainfall or snowfall equivalent. Like many nurseries we were a field grower that converted to container-grown plants to fulfill a demand from our customers, and like many growers we started growing container plants on a very small scale.

Container plants require large amounts of water when compared to field-grown plants and, of course, the disposal of this water can be a huge problem. On a hot summer day up to 1 inch of water is applied daily on our container plants. On our 40-acre home lot this is the equivalent of about 750,000 gal per day. One of the unique problems posed by the location of our nursery was there were no swamps, lakes, or streams into which irrigation water could drain. Our water comes from an irrigation district, not from adjacent bodies of water. This means we irrigate our plants with high-quality chlorinated water (potable), but it also means disposal was a challenge. When we started growing plants in containers the area covered with container stock was small enough to allow for the water to percolate away. As we added more area this became more difficult. Large ditches were constructed to allow for percolation and large quantities of water ran into adjacent vacant fields and orchards. Our water problems seemed to be in control until one day after a heavy rainfall, water escaped from our dwindling orchard and flooded nearby industrial buildings. We knew we had to contain our water and the only way possible was by recycling. The challenge, of course, was designing a closed system as we have no outlet for overflow. This problem was helped immensely by the fact we are in a semi-desert with low annual rainfall. Once we had made the decision we contacted several engineering firms for proposals and after discussing the issues with them the proposals were, to say the least, elaborate and some were insane. We then contacted the B.C. Ministry of Agriculture and talked to a drainage specialist by the name of Ted Van der Gulik. Many of his ideas plus some of our own gave us the confidence to proceed on our own with the assistance of a very competent local contractor. One of the most important things that was done in the planning phase was the drawing of a topographical site map of the area we wanted to reclaim water. Based on this map the locations of ditches, ponds, and catch basins were determined. This had to be done while working around existing structures and nursery beds and also keeping future expansion in mind. Construction began in the fall of 1991 and was completed in the spring of 1992 with the pond being the last part built. Without going into detail an elaborate system of drain pipes, screens, sumps, catch basins, ditches, underground pipes, and above ground channels was created weaving in and about existing buildings, greenhouses, and container beds. All water is picked up including that from parking lots. The water eventually finds its way back to the main recycling pond which contains one million gallons of water when full.

There, it is mixed with fresh water and reused. The main pond is constructed of blown concrete called gunnite. The water levels are controlled by a series of four floating balls. The lowest is a low level shut off to shut down the pumps should the water level drop too low. The second flight ball turns on the fresh water feed, the third flight ball shuts down the fresh water feed, and the fourth flight ball is a high alarm shut off that turns off the two sump pumps that feed the pond. This causes water to back up in the ditches until the pond is low enough for the pumps to turn on again to fill the pond. Although we recycle water from a 40-acre property we reuse the water only on 15 acres. The reason we do this is our home lot was comprised of six different lots acquired at six different times with a different irrigation system for each lot. We consequently have a different irrigation system for each lot. We felt it was too difficult and expensive to tie all the irrigation systems back into our recycling system. We also have chlorinated 100 psi water at our doorstep so it seemed ridiculous to repump it if not necessary. We made the decision to dump the water into our new pond and repump it as the entire field was designed for recycling from day one and it was the simplest system to construct and design.

Are we happy with our system? Completely. Although nothing is maintenance-free our system has proven to be trouble-free and easy to look after. Water quality is high and diseases have not been a concern. We were experiencing increased problems with *Phytophthora* in junipers, but by moving them away from the area using recycled water this problem has largely been solved. Our water has been tested for pesticide residues and nutrient levels and both test show very low levels. The worst problem we have had over the years has been algae growth. Fixed copper treatments proved very effective, but the addition of an aerator completely solved the problem while improving water quality. The only other significant change to our original recycling system has been replacement of the original pump with a Variable Frequency Drive Turbine. These pumps are extremely efficient in their use of power and are virtually trouble-free. They work very well where the water requirement of different zones is quite different. The area where recycled water is used has zones that use between 150 and 450 gpm.

We have now completed a second recycling system in a second field and it too is working trouble-free. It was also much easier to do because we planned to recycle the water from day one. What have we learned from our water recovery systems? First of all the higher water quality you start with the easier it is to reuse the water with simple systems. Don't build your storage reservoirs too small. Allow sufficient time for the water to aerate and settle. This also helps with disease suppression. Keep it simple, but don't get cheap when it comes to controls and pumps. Try to build traps to catch debris and sediment. Try to make these large enough to provide some settling time and also lengthen the time between cleaning. Pay attention to weather records so pipes, catch basins, etc. are large enough to handle freak rainstorms. Finally, have a plan for those floods that may occur in 100 years especially if you have a closed system like ours. Our new pond is designed to flood adjacent container beds. The pump house is built about 1 m higher than surrounding areas so the electrical equipment and pumps will not flood. I would encourage all nurseries that are not recycling their water to start planning now to prepare for the future. No matter where you are regulations concerning water consumption and runoff are bound to get more stringent.

Constructed Wetlands for Treatment of Nursery and Greenhouse Runoff

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Nutrients, copper, and biocides contained in runoff from nursery and greenhouse operations pose a risk to the receiving waters and groundwater drinking supplies. Due to the concentration of these compounds in the wastewater, nursery effluents can be classified as an agricultural waste and the direct disposal of these effluents to the environment is an offence under the federal Fisheries Act and the provincial Waste Management Act. Under correct circumstances, wetlands specifically designed and constructed for water treatment can offer a cost effective, low maintenance water treatment alternative to the nursery and greenhouse industries.

INTRODUCTION

The nursery industry in British Columbia is a growing agricultural sector serving a wide range of consumer requirements from seedlings for silvaculture prescriptions to bedding plants for apartment balconies. To optimize plant production fertilizers, biocides, and growth inhibitors (i.e., $Cu(OH)_2$) are utilized in various capacities. Nursery and greenhouse effluents are unique with respect to other well-characterized and studied wastewaters due to their high nutrient and low organic carbon concentrations. Of particular environmental concern is the nitrate, phosphate, and copper present in runoff from nursery and greenhouse operations and the potential for these compounds to impact the quality and safety of drinking water supplies, induce eutrophication of the receiving waters, and alter the structure and dynamics of aquatic ecosystems. Research conducted at nurseries utilizing controlled-release fertilizers and having leaching fractions near 30% have reported nitrate-N concentrations of 220 to 580 mg liter^{-1} present in the water (Huett, 1997; Yeager and Cashion, 1993). Huett (1997) reported 43% of the nitrogen and 18% of the phosphorus applied as controlled-release fertilizers to potted crops was lost to leaching under normal operating conditions in Australia. Locally, the average nitrate-N and orthophosphate concentrations in the overdrain from vegetable production greenhouses in B.C. is 223 mg liter^{-1} and 99 mg liter^{-1}, respectively (Prystay, 1997). Arnold et al.(1997) reported concentrations of copper between 0.07 and 0.11 mg liter^{-1} in leachate from a nursery utilizing copper-hydroxide-treated containers and suggested that concentrations of 0.5 mg liter^{-1} are possible.

In British Columbia, the regulatory agencies utilize two pieces of legislation, the Federal Fisheries Act and the Code of Agricultural Practice for Waste Management under the Provincial Waste Management Act, to control the discharge of agricultural wastewaters. Under section 36(3) of the Fisheries Act, it is an offence to deposit any deleterious substance into water frequented by fish, including water that may eventually enter water frequented by fish. Part 5, Section 11 and Section 13 of the

Provincial Code of Agricultural Practice for Waste Management states that agricultural waste must not be directly or indirectly discharged into a watercourse or groundwater. Due to the high nutrient content, the runoff from nurseries and greenhouses can be considered an agricultural waste and therefore should be treated prior to discharge.

The use of constructed wetlands for water treatment poses a unique opportunity to the nursery and greenhouse industries as periods of high wetland productivity roughly parallel the production season with the winter dormancy period for wetlands coinciding with winter shut-down and periods of low wastewater production. The beneficial aspects of using wetlands for wastewater treatment include: relatively low construction costs, low maintenance requirements, tolerance to variable hydrological and contaminant loading rates, and reliable wastewater treatment.

WETLAND DESIGN AND REMOVAL PROCESSES

A significant body of treatment wetland research has been published since 1979 assessing the use of wetlands to treat a wide range of wastewaters including municipal sewage, landfill leachate, acid mine drainage, urban stormwater and agricultural wastewaters. These studies have demonstrated constructed wetlands to be effective tools for nutrient management and suggested that they may be more cost-effective than other treatment alternatives (Haberl and Perfler, 1990; Johnston, 1991; Reed and Brown, 1995). During this period three major design strategies have developed: surface flow, subsurface flow, and vertical flow. Of these, surface flow wetlands are the recommended design for greenhouse and nursery operations based on the characteristics of the runoff and cost considerations (Prystay, 1997).

Pollutants entering a wetland system are eliminated through a combination of physical, chemical, and biological processes. With the exception of plant assimilation and the various adsorptive processes, the contaminant processing mechanisms in wetlands are very similar to the removal processes that occur in conventional wastewater treatment facilities. As these processes are naturally occurring in the wetland environment, treatment objectives similar to those established for traditional biological wastewater treatment facilities can theoretically be met at a relatively low developmental and operational cost. The chief drawback to the use of wetlands is related to the natural treatment processes which are inherently slower; longer residence times are required to meet treatment objectives and therefore constructed wetland facilities have large land requirements.

Wetland design is site specific and is dependant upon a number of factors including: volume of wastewater to be discharged; target pollutants to be removed; discharge guidelines; land area available; and, whether wildlife habitat is to be incorporated into the design. The removal of nitrogen, phosphorus, and copper from wastewater occur by very different mechanisms and these all must be promoted to achieve the treatment objective. Nitrate and ammonium nitrogen can be microbially transformed into nitrogen gas and be permanently removed from the nursery effluents under the correct environmental conditions by way of nitrification and denitrification. Phosphorus and copper, on the other hand, are conservative and must be removed by promoting plant uptake, adsorption to sediments and chemical precipitation.

NITROGEN REMOVAL MECHANISMS

Constructed wetlands have been utilized for the removal of nitrogen from wastewater streams with highly variable degrees of success. The predominant removal mechanism is the combined processes of nitrification and denitrification. The conversion of ammonia to nitrite, and nitrite to nitrate, by bacteria is collectively known as nitrification. The group of bacteria which carry out these reactions are generally called nitrifying bacteria or nitrifiers. Nitrification is a two step process, the oxidation of ammonia to nitrite by *Nitrosomonas europaea* and the oxidation of nitrite to nitrate by *Nitrobacter winogradski* (USEPA, 1993).

$$NH_4^+ + {}^3/_2\, O_2 + 6\, e^- \xrightarrow{(N.europae)} NO_2^- + H_2O + 2\, H^+$$

$$NO_2^- + 0.5\, O_2 \xrightarrow{(N.winogradki)} NO_3^-$$

$$NH_4^+ + 2\, O_2 \rightarrow NO_3^- + H_2O + 2\, H^+$$

Denitrification is loosely defined as the reduction of nitrate to a gaseous product, resulting in a loss of fixed nitrogen from the affected environment. The production of nitrogen gas by denitrification is depicted below and is mediated by a number of different microorganisms (Soderlund and Rosswall, 1982; Boyd, 1984).

$$6\,(CH_2O) + 4\, NO_3^- \rightarrow 6\, CO_2 + 2\, N_2 + 6\, H_2O$$

In wetland soils denitrification occurs in anaerobic regions of the litter and below the aerobic sediments. The rate of denitrification is dependant on the supply of NO_3^-, temperature, pH, redox potential, and available biodegradable organic carbon. While in natural systems nitrate is typically found in very low concentrations, many wastewaters have high nitrate concentrations. In these instances temperature and available organic carbon are the limiting factors for denitrification.

The final dominant mechanism for the removal of nitrogen from the wetland environment is the incorporation of nitrogen into plant tissues and eventually the sediments. Biomass analysis of natural and constructed wetlands have shown wetlands to produce approximately 1 ton of above-ground plant biomass annually (Vymazal, 1995). Of this, up to 30% does not decompose over one year and slowly contributes to the development of the sediments (Godshalk and Barko, 1985). Over long periods this accretion will result in the permanent loss of nitrogen from the biological cycle; however, on an annual basis, the amount removed by this route in extremely small when compared to the nitrification/denitrification cycle.

PHOSPHORUS REMOVAL MECHANISMS

Unlike nitrogen, phosphorus is a conservative nutrient and cannot be permanently removed from solution by conversion to a gaseous form. To remove phosphate from the aquatic environment, it must be adsorbed to sediment minerals, assimilated into plant tissues, or precipitated from solution. Retention of phosphate in natural wetland systems has been demonstrated to be directly related to the content of Fe and Al in the sediments (Richardson, 1985). Under acidic conditions PO_4 can be precipitated as insoluble Fe and Al-phosphates, while Ca-phosphate precipitate formation is the dominant removal transformation under neutral to alkaline conditions (Faulkner and

Richardson, 1989). Adsorption to oxides and hydroxides of Al and Fe are also potential removal mechanisms under acidic conditions (Huang, 1980).

The precipitation of phosphorus as calcium phosphate is the most promising method of phosphate removal. Laboratory studies with greenhouse effluents (95 mg liter^{-1} PO_4) demonstrated greater than 90% reductions in soluble phosphate from solution by increasing the pH from 6.5 to 8.0 (Prystay, unpublished data). One method of promoting phosphate precipitation in the presence of calcium, without the addition of a strong base to increase the pH, is to create an environment which will promote a dense algal population and subsequently a high rate of CO_2 uptake. Natural waters are buffered by dissolved inorganic carbon. The status of the CO_2-HCO_3^--CO_3^{2-} equilibrium, with respect to which species is dominant, is pH dependant. The equilibrium state of the buffering system depends on the concentration of hydrogen ion, amount of excess base, the partial pressure of carbon dioxide in the atmosphere, and temperature. When algal biomass growth in a pond is rapid, the uptake of CO_2 from solution by the biomass outstrips the rate it can be replaced and HCO_3^- and CO_3^{2-} are converted to CO_2 producing OH^- which raises the pH of the water (Zehnder 1982, Kadlec and Knight 1996). To promote optimal calcium phosphate precipitation, a pH between 7.5 and 9 will ensure all phosphate is present as dihydrogen phosphate and able to combine with the calcium in solution but not so basic as to promote calcium carbonate precipitation (above pH 9) which would reduce the availability of Ca^{2+} for further phosphate removal.

COPPER REDUCTION

Copper in water is extremely toxic to aquatic biota, even at concentrations as low as 2 μg liter^{-1}. Like phosphorus, copper is a conservative element and must be removed from solution by incorporation into the sediments. This can be effectively accomplished in wetlands due to a number of factors including: the ability of emergent macrophytes to assimilate high levels of copper; a high affinity for copper to bind to organic matter; and, the decreasing solubility of copper with increasing pH. In treatment wetlands planted with *Typha latifolia*, up to 200 mg copper has been assimilated per kilogram plant biomass (Reed et al., 1996). With increasing pH and organic matter the percentage of free ionic copper in solution can be reduced by up to 99%. Additionally, organically bound copper has been established to be nontoxic (CCME, 1995) and constructed wetlands designed with peat substrates have demonstrated up to 98% copper removal efficiencies (Sobolewski et al., 1995).

CONCLUSION

In light of the federal and provincial environmental protection legislation, the nursery and greenhouse owners must address the issue of water quality in the runoff from operations. Constructed wetland systems may offer an ideal wastewater treatment option. Research over the past 16 years has demonstrated constructed wetlands to be effective tools for nutrient management and indicates that they may be more cost-effective than other treatment alternatives. Further, periods of high wetland productivity roughly parallel the production season with the winter dormancy period coinciding with winter shut-down and periods of low wastewater production. By understanding the biogeochemical cycles of target wastewater constituents and the processes that occur within natural wetland systems, treatment wetlands can be designed to take advantage of specific natural processes which improve water quality.

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"Nursery Water Issues" Question-Answer Period

ROBERT APPLETON: I presume you're using gravel or sand in your construction. Would there be any benefit in adding a bark base to increase the amount of carbon?

WARD PRYSTAY: Yes. We chose to use the gravel as a control in the experiment. We didn't want to have either system influenced by the presence/absence of gravels or the presence/absence of an organic soil. Subsurface-flow wetlands have to be designed with an extremely porous medium to allow flow of accumulated debris or solids within the system. For low-carbon wastewaters like nursery or greenhouse effluents, having a organic soil would be beneficial.

BRUCE BRIGGS: It's been observed in the past that the waves of rippling water was more effective than recycling with a pump. Have you observed this?

JOHN BYLAND: No. We felt that using aerators or splashers was such an easy solution that could be done quickly.

JIM CONNER: I'm using secondary effluent water right now from a wetlands area. The wetlands, of course, are removing nitrogen and phosphorus which I want. My biggest problem with the effluent water is with sodium and boron causing leaf burn and scorch on my plants with overhead irrigation. Is there anything coming along that might remove those two elements?

WARD PRYSTAY: When you're dealing with the conservative elements like phosphorus, potassium or sodium, the only way to remove them from solution is to incorporate them into the sediments. Plant uptake for those is not that high; therefore, a chemical reaction is required to remove it. I haven't seen anything recently that's even addressed the issue you raised.

LYDIANE KYTE: You mentioned using a vinyl liner. What were you using before that?

JOHN BYLAND: The previous one was made from a product called gunnite, a specific formulation of concrete that can be blown and pumped very easily.

ANONYMOUS: What information was used to create the computer-generated image you showed us of water distribution from an irrigation system?

RICHARD REGAN: The Center for Irrigation Technology (Fresno, CA) has developed profiles for sprinklers. These profiles can be entered into a program to determine the influence of spacing, nozzle size, pressure, and height of nozzle above the crop. Many irrigation suppliers either have the software or subscribe to that software so they can provide those results for you.

Size-controlling Fruit-tree Rootstock Production: Methods Used at Traas Nursery

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Traas Nursery Ltd., 24355 48th Ave., Langley B.C. V2Z-2M4 Canada

INTRODUCTION

At Traas Nursery our primary product is dwarfing and semidwarfing fruit-tree rootstock. We currently raise 12 different cultivars of *Malus* for apple rootstock, *Prunus avium* F12/1 for cherry rootstock, *Cydonia* A (often called Quince A) for pear rootstock, and *Prunus insititia* Saint Julien A for plum and large stone fruit such as peaches and nectarines. The range of size control available in our *Malus* line varies from approximately 25% to 80% of standard. All our stock is vegetatively produced from clonal selections, either by mound-layering, stooling, or hardwood cuttings. No seedling stock is raised at all. The advantages of clonal production as opposed to seedling production is well known. Uniformity is critical when planning new orchards of high density plantings. With some plantings as high as 3500 trees to the acre, there is no place for trees that do not develop to a uniform size, particularly if they grow larger than anticipated. Our main markets are nurseries that custom-bud or graft for orchard renewal and/ or garden center sales and the actual orchardists who in some cases prefer to raise their own young trees.

Most of our early plant material came from European sources, primarily East Malling Research Station in England; well known for its work in developing and testing fruit tree rootstock. Stock was also obtained from Poland, The Netherlands, and Germany. Some of our more recent mother stock came from a tissue culture lab in B.C., as we are not set up to do our own tissue-culture work. Our findings were that in the initial years of production, the rootability of the tissue cultured stock seemed to be better than the same cultivars but of a non-tissue cultured origin.

Our annual production of understock fluctuates from 900,000 to 1.1 million trees. All trees are harvested annually. Of this number, approximately 20% are trees transplanted for a second year to develop a more abundant root system. After grading, stock is kept in cold storage at 33 to 36F and can be kept dormant for up to 6 months if necessary. There are similarities in production in all species, and where they are different it will be noted.

MALUS, PRUNUS AVIUM (CHERRY) AND *CYDONIA*

Once the parent stock has been obtained and planted, we allow them to grow for 1 year to establish a well anchored tree. Typically our plant spacing in the row is 20 to 25 cm (8 to 10 inches) apart, with row spacing being 1.25 m (50 inches). During the first year we maintain good growing conditions by timely weed control, pest management by regular spray program, and irrigation as necessary. Our weed control is all done mechanically, with hand weeding between plants in the row. The trees are layered the spring after planting. The method we use can best be described as a running braid down the length of the row. To accomplish this we remove approximately 1 to 1½ inches of the soil from between the trees in the row so as to lower the bed level. We then bend the tree horizontally and weave each adjacent tree with the next. These are secured horizontally by a wooden peg with a nail inserted.

As the stock starts to grow, we cultivate the beds every 7 to 10 days, weather permitting. The shoots being positively phototropic, grow vertically, regardless of initial placement of buds on the layered mother plants. Once the shoots reach 10 to 12 inches in length, we begin mounding on the 7 to 10 day cycle. In the early stages of mounding, care must be taken not to damage the shoots as they are quite herbaceous for the first 6 to 8 weeks. Damage can occur by breaking the shoot off at the base or by burying the shoot too deeply, effectively smothering the plant. Each time we mound up, we add approximately ½ to 1 inch of soil to the base of the shoots or the top of the existing mound. This is repeated until there is about 10 inches of soil above the mother plant. Not only does this process add rooting medium (soil in most cases), it also doubles as effective weed control since any germinating weeds do not get very large with the short interval cultivation. By the end of September it is no longer possible to add any more height to the mound as the angle is too steep and the soil rolls off. By the middle of October, most of the needed caliper has been attained but there can be too much top growth for ease of handling. Stock is therefore topped to an overall length of 28 to 30 inches. At times 12 to 18 inches can be removed. This is done by a modified corn chopper which returns the chips back to the field in small enough pieces so as not to interfere with later harvest or cultivation. As we grade the cherry rootstock by length over 3 ft this part of the preharvest operation is not done with our F12/1.

Our harvesting methods are also different between the *Prunus* and some of the *Malus*. As the cherries do not root as easily as some of the apple clones, they must be hand-harvested to ensure a good supply of well rooted plants. Since the roots have a tendency to develop quite low on the shoot, it is more advantageous to cut them with loppers rather than our mechanical harvester. This same method of harvesting also applies to those of apple that are not as rootable as others. Of the 12 cultivars that are produced at our nursery, the rootability percentages range from 40% to 50% for the poorest rooting to 90% to 95% for the best rooting. Unfortunately, not all the high-demand understock have high rooting percentages. The poor rooting of the stock most in demand is of great concern to us, as our harvest window during the winter can be restricted by weather, which in our area is usually in the form of rain. As most of our rows are between 400 and 450 ft in length, the time difference between mechanical harvesting (10 to 12 min per row) and hand harvesting (2.75 to 3.5 h per row) manifests itself the most in the amount of gradeable stock inside the warehouse when the wet periods do come. We have done some mounding with sawdust (hemlock/fir mix) in some of our heavier fields where the clay content is high. In the summer months when the fields are drier, it is difficult in these fields to break up the soil into a friable texture that will incorporate well around the developing shoots. It is essential that there is good soil-to-shoot contact for roots to develop. One of the benefits of using sawdust, that we had not expected, was that even when the soil-based fields were wet, and the clay-based fields without sawdust all but impassable, harvesting from sawdust-based fields could still continue as there was little or no mud.

During grading, the poorly rooted or rootless stock is discarded, unless there is a higher demand than 1-year production capability for that particular cultivar. In those cases they are rough-graded to size and dipped in 2500 ppm IBA for apples and smaller cherry stock. Cherry stock larger than 5/16-inch caliper are treated to an increased concentration of IBA (5000 ppm). In all cases the trees receive a 5-sec dip. We have found that this stock roots more readily than a hardwood cutting, as the base has already been etiolated during the first year's development on the stool bed. These "rootless" shoots in the case of *Malus* are stored horizontally in square piles with the bases facing out to enable us to water as necessary to prevent drying. This is done in a root cellar with a uniform temperature of approximately 45 to 50F. Humidity is also quite high although no readings have been taken with a hygrometer. The *Prunus* rootless stock is heeled in sawdust in a cooler with a heated floor as this method has been successful for us in the past.

Cydonia A had been grown by hardwood cuttings prior to 1992. We now produce these from a true stool bed. We switched from cuttings to stooled production purely by accident. The mother block had not had the cuttings removed in the fall of 1991 and as the shoots were already starting to flush before late cuttings could be taken, we felt we could not grow any quince that year. Being pressed for time, we cut the whole mother plant down to ground level. Shortly thereafter, the abundant new shoot development that manifested itself was too inviting to ignore. We mounded with sawdust and to our surprise found these new shoots were readily rootable. The quality of plants harvested were also better as the shank was straight as opposed to the former hardwood cutting method which usually had a dog-leg from the top of the cutting where the new growth started.

PRUNUS (PLUMS)

In the past we attempted to raise our plums from layer beds and found this to be impossible. Although there was excellent shoot development, none rooted. We have, therefore, grown all our plum rootstock from hardwood cuttings. Cuttings were taken in the fall (late October) and cut into 14 to 16 inches in length.

Our experience has shown that the base cutting always rooted the best with marked decrease in rooting with the second and third cutting from the base. Any growth over the third cut is discarded. All Saint Julien A cuttings are dipped for 5 sec in 5000 ppm IBA with the medium temperature maintained at 68 to 70F for 4 weeks. By taking the cuttings in late October we could capitalize on our available time before actual layer-bed harvesting commenced in early November. Sadly, this convenience has not been to our advantage. We have struggled with inconsistent stands of cuttings and have always done small experimentation each year to improve the production. This past season's experiments included different media types. In the past we have used damp sawdust (hemlock/fir mix). For our trials we used milled coconut husk (coir), coir/sawdust (1 : 1, v/v), coir/sand (1 : 1, v/v), sand/sawdust (1 : 1, v/v), sand, and sand/coir/sawdust (1 : 1 : 1, by volume). Results were varied but no one trial was remarkably different than any other. Another experiment involved timing. It is here that the most dramatic difference showed up. Having made most of our cuttings at the "normal" time of late October, we left some of the cutting bank untouched to provide a source for early spring cuttings. These later cuttings were taken and stuck on 1 March. Hormone treatment and bottom heat were identical to fall cuttings. The rooting was more spontaneous and after planting established much quicker with a more uniform stand. Both cutting times were planted within 2 days into the field. We will repeat this procedure in the coming year to determine if it is consistent year after year. We will undoubtedly reduce the number of fall cuttings considerably and concentrate on early spring. Although making cuttings in the spring may not be as convenient for us as in the fall, the extra effort will result in extra stock that establishes and grows better.

These are the methods we use for fruit tree rootstock production and they have served us well. We will continue to strive for increased production efficiencies both in numbers and labor in the future to continue to supply the understock necessary for the trees of the future.

Sanitation for Clean Liner Production

Bill Smith
Briggs Nursery, Inc., 4407 Henderson Blvd., Olympia, Washington 98504

HISTORY

Briggs Nursery produces 7 million plantlets from tissue culture on an annual basis. At any given time 2 to 4 million plants are either in rooting or in a production phase.

At Briggs Nursery plants are always being sold or moved and by utilizing facilities and personnel on a year-round basis the empty houses are continuously being refilled.

The threat or potential for diseases, weeds, liverwort, and/or mosses is always present. Some of the disease organisms that are a concern are: *Botrytis, Fusarium, Rhizoctonia, Cylindrocladium, Phytophthora, Theiophis*, powdery mildew, downy mildew, rusts, leaf spots, and mushrooms.

Where disease organisms originate, how they spread, and what causes flare-ups remains a mystery. The nursery has used consultants and research people to help pinpoint sources of contamination. Their recommendation is always the same: maintain cleanliness and use good water management.

WHY SANITATION IS IMPORTANT

Without good sanitation procedures disease problems are unavoidable. Sanitation needs to start at the beginning of the crop growing cycle and to be carried through to the end. Sanitation steps should be practiced on benches, flats, containers, soils, propagation areas, trailers, and all growing structures. All of the above, if not monitored for cleanliness, can cause the spread of disease and liverwort.

METHODS

All growing/propagation flats and pots should either be new or cleaned and sanitized thoroughly. Any soil particles left in flats or pots have the potential to harbor disease spores. At Briggs Nursery flats are reused only after being washed and sanitized. Pots are never reused because the possibility of leaving behind soil particles is too great.

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Sanitizing agents that have been used have chlorine as the base. Greenshield Saniquat, Zero Tolerance, and Clorox are examples. The use of disease-free growing media is important, especially in liner production where plantlets are either rooting or have very fine root systems.

At Briggs Nursery peat moss, perlite, pumice, and bark in different combinations, make up the rooting or growing media. All these products are either steamed or come from clean sources.

A biological fungus is added along with fertilizer to the raw ingredients and blended together to make the soil media. After blending, flats and pots are filled and transported to either propagation or liner transplant departments.

At each of these departments, floors, benches, and tools are cleaned daily with a sanitizing agent. All trailers used to transport flats of liners are hosed off between loads. Propagation benches are cleaned and sanitized between crops. All sprinklers and riser pipes are taken off and put into a sanitizing agent and scrubbed to eliminate algae and disease.

After the benches have been cleaned and risers and sprinklers put back, a sanitizing agent is applied and a copper spray is used.

Liner houses are treated the same as the propagation area except for the following differences. The houses are emptied of plant material and the skiffs (which are 1-inch wooden frames used to keep flats off the ground) are removed. The houses are swept and washed out before clean skiffs are put into place. The walls, floors, and skiffs in each house are sprayed with a sanitizing solution and then a copper spray is applied. The house is then closed, allowing heat to build up until the new cycle begins.

When the house is needed the doors are opened and plants are put into place. The growing of these plants begin with watering, nutrients, and maintenance.

Disease organisms, liverwort, and mosses thrive in similar conditions, i.e., high humidity, nutrients, and an open wound to spread and grow. A prevention program using biological, chemical, and other methods is established and practiced.

Constant monitoring for disease is very important at Briggs Nursery. All growing crops are walked and monitored on a weekly basis, or more frequently, and any problems are promptly handled. To discourage chemical resistance build-up by organisms and to be caring of the environment, we prefer to treat smaller areas than to do a spray of all growing areas.

Liverwort and mosses have become a real problem in the last 2 to 3 years. Many chemicals along with top dressing materials have been tried, but all seem to have phytotoxicity or other problems.

It is very important that insects like fungus gnats and shore flies are controlled both to stop the spread of disease and to protect new roots. To accomplish this, both biological and chemical means are employed. Predator mites are released monthly, plus weekly sprays are used.

CONCLUSION

Cleanliness and sanitization at Briggs Nursery is one of the most important aspects of growing healthy, saleable liners. Constant monitoring by observant growers and the responsible use of chemicals makes Briggs Nursery liners disease- and problem-free, while protecting the environment.

The ABCs of Propagating Herbaceous Perennials by Stem Cuttings, Root Cuttings, and Division

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Propagating herbaceous perennials is very similar to propagating woody plants. Methods such as cuttings and tissue culture are used and the same environmental factors influence propagation: temperature, photoperiod, light, and humidity. However, there are some important differences. For instance, while the perennial propagator uses some mist propagation, cuttings usually root faster, so are often placed in poly tents, covered with Remay, or simply syringed periodically. Probably the biggest differences in asexual propagation are: today, few herbaceous perennials are grafted, with the exception of tree peonies; herbaceous perennials require little or no rooting hormone; and many perennials are divided while very few woody plants are propagated by this method.

With experience, the perennial propagator becomes aware of some of the keys to successful propagation. This involves an intimate knowledge of each taxon, a daunting task with the thousands of different plants that a large nursery may grow. However, careful observation, attention to detail and timing are the first steps. In addition, the propagator must develop an extensive information network. This usually comes with time and a willingness to share information, adhering to the I.P.P.S. motto of sharing, since very little specific information about perennial propagation is written in books. With these rules in mind, let's examine some propagation methods as they apply to a few major crop areas.

STEM CUTTINGS

Many perennials can be readily rooted from cuttings, but taxon, methods, and rooting environment must be considered in order to achieve efficient results.

There are two types of cuttings taken from perennials: basal and stem. Both types can be harvested only during the growing season. Basal cuttings are short shoots with a few roots attached and are gathered in early spring from plants like *Geranium* or *Achillea*, or from plants that bloom early in the season where the presence of a flower bud inhibits rooting. In contrast, stem cuttings are harvested from plants like *Coreopsis*, *Veronica*, or *Physostegia* that have shorter internodes and bloom later in the season. Rooting of these is also inhibited by the presence of flower buds except that the vegetative growth phase is somewhat longer. Here though, the cutting season can be extended by shearing to produce new lateral shoots. In some situations, the cutting may root rapidly and develop a large root ball, but not survive winter storage. This has happened in *Coreopsis* if rapidly growing shoot tips are used and the base of the cutting may not contain a node. To overcome this situation, be sure at least one node, preferably two, are stuck into the medium to encourage the development of new shoots which, in turn, form roots.

Most propagators use no rooting hormone, but others will use weak concentrations of no more than about 3000 ppm, equivalent to a Hormodin #2. Cuttings can be stuck in a mist bench, but due to the herbaceous nature of the stems, more care must be taken, so cuttings are not overly misted causing disease to develop. Some cuttings do not really need mist. For instance, I have rooted *Sedum*, *Tricyrtis*, and *Physostegia* by using light shade and daily misting. In another example, many of the silver-leafed plants like *Artemisia and Stachys* must be stuck and rooted before the onset of hot weather. Otherwise, disease problems can severely reduce rooting results. In addition, many plants like *Artemisia* and *Scabiosa* respond to extended photoperiods. If you have greenhouse facilities, they can be brought into the greenhouse early, and placed under HID lights, forcing growth so cuttings are available before hot weather.

ROOT CUTTINGS

Some plants produce a type of growth where only leaves rise above soil level. Many of these can be efficiently propagated by root cuttings. As with all root cuttings, when successful, new shoots are initiated from the root tissue and grow, eventually rooting at the base of this new shoot. The new root system is then initiated at the base of these new shoots. Most oriental poppies (*Papaver orientale*) are produced by root cuttings. Poppies are usually a field-grown crop, but go dormant in late summer. When most of the foliage dies down in late August, plants are lifted, shaken free of soil, and placed in crates; no cool storage is necessary since they will be cut immediately. A few of the largest roots are removed from those with a sufficiently large root system and the rest of the plant is sold as a bare root division. The roots are cut into 1- to 1.5-inch segments and planted into cells, just deep enough so the proximal end of the root is under the medium surface. The cell flats are then placed into cold frames and watered lightly. Plants are kept on the dry side for the first week or so to allow the cut ends of the roots to cure before normal watering is resumed. By early October, new foliage should appear and the cell should be filled with roots. Fertilize once or twice, then harden the plants off for winter. The cells can remain in these frames where they should be covered with microfoam and white copolymer for winter protection.

While poppies are propagated at the end of summer, most other root-propagated crops are prepared during the winter season and some can be done in early spring. *Acanthus*, *Pulmonaria longifolia*, and some *Geranium* taxa like *G. cinereum* 'Ballerina' are normally done by lifting plants after they are fully dormant, but before the ground freezes. They can be put into cold storage until they are prepared. The root system is shaken free of soil (washing often helps) and remove the thickest root pieces available. *Acanthus* often forms buds on the roots that are visible at this time, so they can be removed and potted immediately. Otherwise, roots can be prepared in one of two ways. Pieces 2 to 3 inches long can be placed upright (proximal end up) in rows in flats of potting medium. Again, the medium should just cover the tops of the cut ends. The flats are then watered lightly and placed in a cool greenhouse at about 60F. In another method, the roots are washed, cut into 2- to 3-inch pieces, bundled, and placed proximal end up in 48 or 72-cell trays WITHOUT medium. The trays are placed in a shaded grafting case in a cool greenhouse and lightly syringed to prevent them from drying out. As buds form, the individual roots are removed and planted so the bud is just below the surface. Again, new roots will form at the base of the new shoot. Finally, plants like hybrid *Anemone* can be lifted from the field in the fall and placed into cold storage. Usually, shoots will form on roots during cold storage. At shipping time the new shoots can be removed and potted without substantially reducing the size of the root system to be shipped. I also do *Sanguisorba canadensis* in early spring or as soon as I can lift the plants from the field. Like *Acanthus*, the root system is very thick and contains many visible eyes that can be removed and immediately potted. The remainder of the root system can be cut up into 1-inch pieces and placed horizontally in a flat, lightly covered with medium, and placed in a cool greenhouse.

DIVISION

Division is the most common and foolproof method of propagating perennials. As with other propagation methods, timing is still important. For instance German, Siberian, and Japanese irises are best propagated in summer after flowering. The rhizomes are lifted, some foliage removed to facilitate replanting. *Hemerocallis* are among the toughest plants and can probably be divided any month of the year. However, early spring before shoot elongation and in summer after flowering are usually the most convenient times for the propagator. Commercially, a few *Hemerocallis* are divided every year so the clumps do not get too large, but most remain in the ground for 2 years before they are lifted, the soil removed from the root system, and the fans divided. The fans of some, like 'Pardon Me', can be snapped apart using your fingers, but most fans must be cut apart. A few, like 'Mary Todd' seem to be so brittle that even under the best of conditions, neat division seems nearly impossible. Finally, for those new cultivars where you are trying to increase numbers, and where the base of the fan is at least 2 inches in diameter, the propagator can often cut the single fan vertically in half. Some *Hemerocallis* cultivars produce scape plantlets that can be removed when they are 4 to 6 inches long and stuck like a cutting. No rooting hormone is necessary and the plantlets can be stuck directly into small pots or cells.

Peonies are also popular as either cut flowers or as garden plants. However, timing *Paeonia* propagation is most critical and must be done in late summer or fall; spring-divided plants often fail to re-establish. Most peonies are grown in the field for 2 to 3 years before division is attempted. Plants are lifted, soil is removed from the root system, and 2- to 3-eye divisions are removed with the aid of a stout knife and pruning shears.

Hosta is the number one shade perennial and most are propagated by division. Like *Hemerocallis*, these are tough plants that can be propagated almost any month of the year. Traditional division methods are employed, although shoots are separated during the growing season, while eyes are divided when the plants are dormant. Here too, when numbers are important and the eyes or shoots are sufficiently large, the entire structure can be sliced in half longitudinally. Some *Hosta* taxa, particularly cultivars of *H. tokudama*, under field or container conditions, normally do not form many new eyes. Here, the formation of new eyes can be encouraged by disturbing the shoot during the growing season in a variety of ways. Some insert a needle and destroy the growing point during active growth, usually in late summer. Others remove the shoot nearly to the top of the crown early in the growing season.

In summary, the propagator employs a variety of methods to propagate perennials. Sometimes more than one method will be used on the same plant, depending on the season or the available facilities. The key to successfully propagating perennials is in-depth knowledge of the plant's growth habit and by taking advantage of season and facilities.

Propagation of Magnolias: Rooting Techniques, Post-Rooting Care, and Overwintering of Rooted Cuttings

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Magnolia species and cultivars of *Magnolia acuminata*, *M. denudata*, *M. kobus*, *M. liliiflora*, *M.* ×*loebneri*, and *M.* ×*soulangiana* comprise an important sector of both retail and landscape contract sales for Specimen Trees Wholesale Nurseries Ltd.

Specimen Trees Wholesale Nurseries Ltd. is located in Pitt Meadows, a part of the greater Vancouver area in southwestern British Columbia. The nursery is comprised of 480 acres, 16 acres in container, 6 acres under poly greenhouse, and a 9000-unit pot-in-pot system.

We produce four species and 13 cultivars of magnolias (see List A). Approximately 2000 units of each magnolia taxa are produced in rooted plugs, #2 pot, or #15 pot. Field-grown stock is grown from 1.25 m to 3.5 m in size.

The greatest hurdle we have overcome over the past 8 years, is the successful propagation of magnolias from cuttings, making them a viable crop for our business. Magnolia cuttings are readily rooted, however, the overwintering of the cutting has proven most difficult.

CUTTING STOCK PARAMETERS

Without exception, juvenile plants produce the best cutting material. We have found that cutting off 2- to 3-year-old plants has produced the best percentages in rooting.

The time of the year for taking cuttings is best done in the month of July to early August when the plants are still in active growth. The cutting material from the tree will vary in length from 2 to 3 ft. This material is in active growth, in other words, it has not set either flower or terminal buds. We cut in the morning and bring the material into the propagation house where they sit under micro spinners. This moisture keeps the cuttings in a turgid state until they are processed.

The cuttings are taken from the upright growing branches, not from the lower or lateral branches. Care is taken not to take cuttings from trees under any kind of heat stress or disease. The most common diseases in our area are *Pseudomonas syringae* (classic black interveinal blotching of the leaf) and *Microsphaera* sp. (powdery mildew is a white fungal bloom on the surface of the leaf). Both of these diseases can affect rooting percentages and over-wintering success.

PROCESSING OF CUTTINGS

Our propagation crew always produces at least a three-node cutting, which varies in length from 3 to 6 inches. A four- to five-node cutting is used for the smaller leafed cultivars, such as *M. stellata*. Each cutting will have the basal leaf stripped. The cut below the basal bud node is a straight cut. The cutting is dipped into ethanol-based IBA (5000 ppm). We use the brand Stimroot. Because of the pubescent nature of the magnolia stems, we do not use powdered rooting hormone as it cakes too heavily causing the end to rot. The dipping process only encompasses the bottom 1/4 inch of the cutting. We have tried higher hormone treatments, but find this causes burning of the cutting. We have also tried wounding, but we find this to cause necrosis of the basal end of the cutting. Special quality control is continually administered by our crew when handling the cuttings. They are always looking for diseased material.

ROOTING SUBSTRATE AND VESSEL

We have tried over the years a number of mixes and vessels for rooting magnolias, and have found the following to be the best.

The mix is comprised of coarse peat, coarse perlite, shaved styrofoam beads(from 1 to 3 mm in size)(1 : 4 : 5, by volume). The shaved styrofoam is the most important ingredient in the mix, as it offers excellent air porosity, water movement, and light density.

The pH of the water in Pitt Meadows is 4.6 and the pH of the rooting substrate is about 5.6. The water in the Pitt Meadows is exceptionally pure and has a salt reading of 5 ppm. Because magnolia cuttings root easily and are also very susceptible to root trauma, we use 219 round and 529 square Jiffy products. Prior to this, we tried rooting magnolia cuttings in deep flats and plug trays, but both products had downfalls somewhere along the production line.

Both the 219 plug and the 529 polypak are peat moss cups, which we pack with the rooting substrate. The beauty of these peat plugs are that they are deep, so they hold the cutting securely, they are a semisterile product, and they offer no root disturbance at the time of transplanting.

The three-node cuttings are placed into the plugs to a depth of $1\frac{1}{2}$ inches with care to place the leaves, if possible, in one direction. The plugs eliminate the problem of overcrowding in the flats. This is very important because of the large leaf size of some magnolia cuttings. In the case of *M.* ×*soulangiana* and *M. accumata* cultivars, plugs are often skipped to give more space for their larger leaves. Once cuttings are stuck, they are watered in by way of a watering can, applying a 1% Captan solution.

Once the plug trays are stuck they are placed on the misting benches; receiving a bottom heat temperature of 75F (25C). The misting cycle is 5 sec on with 5-min delay. The cycle starts at 9:30 AM and goes off at 5:00 PM. The reason for the long mist cycle and period is because, magnolia leaves will leaf scorch; the leaf must be uniformly wetted. During the next 4 weeks the first signs of callusing are observed. In and around week 6 sporadic rooting takes place.

WINTER HUSBANDRY

During the early part of October visual inspection of the magnolia cuttings would show approximately 56% rooted and, in the case of some *M. stellata* cultivars, as high 80%. We have found that the plants that are still at the callusing stage will root during the winter months. Therefore, the only procedure we implement at this time is the removal of leaves. We only remove the leaves when the cutting has cast them. There are two reasons for this: the first reason is, it stops any movement of the cutting in the Jiffy pot; the second reason is, so there is no wounding of the leaf attachment area. During this period, we cut the mist cycle back to half its original cycle; the bottom heat stays the same.

By the first of November, all the leaves are removed. The above-ground section of the cutting is dormant, but below ground we still find that rooting is taking place. At this time, the mist cycle comes on every third day for 20 min around 11:00 AM.

This prevents the plug from drying out. The bed temperature is dropped to 55F (13C). The cuttings are held in this state during all the winter months. The air temperature varies from just above freezing to a high of 50F (10C).

As the days get longer in February, the bottom heat of the beds are turned back up to 70F (21C). The mist cycle is on once a day for 20 min around 11:00 AM; this stimulates root growth. About 90% of the cuttings will now be rooted. With roots now active, we top dress the plugs with Nutricote 17-7-9. I also feel that liquid feed would be beneficial at this time, but our system does not allow for it.

BUD BREAK

Around the first week in March, the buds start to swell. We now remove the plugs from the mist benches and put them into our hardening-off area. Here, the air temperature is approximately 50F (10C). The reason for removing them from the heated benches is because, if the leaves break dormancy on the benches they flush very tender and are very susceptible to fungal attacks.

The rooted cuttings sit in the hardening-off area, depending on the year, from late March to early April. If you are in the business of selling plugs, grading and positive identification of strong rooted cuttings is very easy, as they have extensive root systems; to the point of pushing themselves right out of the plastic plug trays. Because magnolia cuttings are so susceptible to root disturbance, you can now present to your potting crew an easily handled liner.

In this day and age, where plastic waste is becoming more and more of a problem, this alternative of a peat plug eliminates the need for 2¼-inch–plastic pots.

In closing, we have had great success using this same technique on *Carpinus betulus* 'Fastigiata', *Cornus kousa*, *C. mas*, *Davidia involucrata*, and *Parrotia persica*.

LIST A

Magnolia 'Butterflies' (*M. acuminata* × *M. denudata* 'Sawada's Cream')
M. denudata (syn. *M. heptapeta*)
M. kobus
M. stellata 'Royal Star'
M. ×*loebneri* 'Ballerina'
M. ×*loebneri* 'Leonard Messel'
M. ×*loebneri* 'Merrill'
M. 'Ricki' (Kosar hybrid)
M. 'Randy' (Kosar hybrid)
M. 'Susan' (Kosar hybrid)
M. sieboldii
M. ×*soulangiana* 'Alexandrina'
M. ×*soulangiana* 'Rustica Rubra'
M. 'Legend'
M. liliiflora 'Nigra'

"Liner Propagation and Production" Question-Answer Period

PETER CATT: Can you help with the problem we've seen with the strength of the fertilizer solution on newly rooted magnolia cuttings?

SANDY HOWKINS: We leave the rooted cutting in the plug until it has started vegetative growth. One of the reasons we feed it is so the root system does get used to a salt-based fertilizer. When you transplant the cutting still in the peat plug into a container medium containing 10 lb of fertilizer per yard, the plant is protected somewhat by that peat plug.

LAINE MCLAUGHLIN: Do the peat pots come with holes poked into them?

SANDY HOWKINS: Yes.

ANONYMOUS: Can you use the same procedures for evergreen magnolias?

SANDY HOWKINS: Yes, you can. The only difference is that we do cut the leaves and we only take off the top 1/3 and the cutting has 5 or 6 nodes.

Seedling Propagation of Four New Zealand Podocarpus Species

Robert Appleton
Main South Road, Wakefield, Nelson, New Zealand

BACKGROUND

New Zealand (N.Z.) forests have suffered a systematic destruction of the forest cover from the time of settlement 4000 years ago that was only accelerated by colonization 150 years ago.

This destruction, particularly of coastal and lowland forests on more accessible sites was principally for timber and clearing for agricultural production. This has ceased in recent years with a ban on all indigenous logging except from certified sustainably managed forests. Fortunately, extensive areas have been set aside in national parks, national forests, and reserves. Of the 6 million ha, 1 million ha remaining is privately owned. However, the publicly protected lands are not fully representative of the whole range of N.Z. landscapes, natural areas, and ecosystems. Some of the under-represented areas are the estuaries, freshwater wetlands, scrublands, tussock grasslands, and lowland forests.

In recent years, conservation has become of much wider interest to the public in general and many groups have been pressing the case for protection of natural features in the landscape. The Queen Elizabeth the Second Traditional Trust has a significant and essential role in assisting to redress the current imbalance in the range of natural areas protected in N.Z. One challenge when seeking to protect natural features and landscapes can be working with private landowners and involving them directly in the protection and restoration of areas. The Trust

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Since 1977 just over 780 open space covenants have been registered nationwide, involving some 27,200 ha; a further 450 covenants involving 42,700 ha are in the pipeline and proceeding towards registration.

A very good example of the exploitation of our indigenous forest resource is the N.Z. kauri —*Agathis australis*; kauri, is the most famous of N.Z. native trees and one of the largest trees found anywhere in the world. Tane Mahuta in the Waipoua Forest is 51.2 m tall with a girth of 17.2 m and has been calculated to be over 2000 years old. The largest recorded kauri on record was 21.8 m to the first branch and 23.43 m in girth. Of the estimated 1.2 million ha of original forest only about 142 ha remain.

PODOCARPUS

Podocarpus is an extensive genus with 72 species distributed throughout N.Z., Australia, Malaysia, India, Japan, East Africa, and Central and Southern Africa of which four species of forest trees are endemic to N.Z.

Podocarpus totara **- totara.** The totara is a tall massive trunked forest tree. In its early stages it is a spreading bushy tree, but as it gains height it acquires a massive trunk and dense foliage. A totara tree may live to a great age of up to 800 years and the Maori people prized its durable timber to manufacture war canoes and ceremonial carvings on meeting houses. All totaras are dioecious with pollen shed in November and December. The seed grows quickly after pollination and a red fruit receptacle attracts birds which feed off the fruits and spread the seed.

Dacrycarpus dacrydiodes **- kahikatea/white pine.** The kahikatea is our tallest native tree with mature specimens recorded at 60 m. It is found throughout N.Z. in forests up to 600 m in altitude where it is often the dominant tree species in swampy areas. The kahikatea seedling changes through juvenile, semi-adult, and adult foliage stages. The male cones and female ovules are borne at the tips of branchlets on separate trees. The female tree glows a faint red when its berry-like receptacles are ripe.

Prumnopitys taxifolia. *Prumnopitys taxifolia* is a round-headed robust tree to 25 m. The young shoots are lush and colorful in the spring and its exfoliating bark which flakes off in thick rounded chunks leaves reddish blotches on the trunk. The wood is a deep red, very hard with a handsome close grain. The seed once pollinated takes 12 to 18 months to mature. About 10 mm in size, the seed is a deep blue-black color, its stalk never swells to form a fleshy receptacle as in most other N.Z. podocarps.

Prumnopitys ferruginea **- miro/brown pine.** Miro forms a tall round-headed forest tree to 25 m. Miro is a slow-growing tree, preferring shady situations. Seed crops do not occur every year. Purple when ripe, the seed takes 12 months to mature.

The fruits of the miro are the favorite food of the native wood pigeon. They will come long distances to gorge themselves on the ripe drupes which smell strongly of turpentine. Hence, the pigeon play an important role in spreading the seed throughout the forest.

SEED COLLECTION AND STRATIFICATION

The four species give two quite distinct stratification and seed-handling procedures.

Totara and Kalhakatea. The seed must be collected fresh and handled promptly. Twenty percent shade cloth makes ideal screens to lay under the seed trees once seed fall has begun. Seed should be collected every second day and once cleaned of twigs and trash, stored in a air-tight container in a cool store, but sown as quickly as possible. It is important that seed moisture is not lost as this will result in rapid loss of seed viability.

Matai and Miro. The seed will drop from the trees in late autumn or can be collected from the trees if the birds are removing it all. Matai requires a minimum of 12-month cool moist stratification in moist sawdust or peat and is subsequently sown in the autumn. Miro requires a longer stratification under the same conditions as matai and should be sown after a 24-month cool moist period.

SEED SOWING

Appletons' Tree Nursery practices a fixed seedbed production system with the majority of seed sowing occurring in the autumn. The seedbed is thoroughly ripped using a Howard paraplow and 10 cm of composted pine bark is added to the growing area. The raised bed is formed by a rotohoe with a modified bed-forming attachment. Raised seed beds of 15 cm in height aid drainage and encourage earlier germination and more accurate undercutting.

The four species respond well to higher levels of soil nutrition. This is achieved by a combination of coated, slow-release fertilizer, side dressing of balanced NPK granular fertilizer, and foliar feed. Seed is broadcast by hand at an ideal seedling density of 200 plants per meter.

Previous crop records and a cut test are used as a guide to seed density at sowing. The seed is covered with sawdust and an arch of 40% shade cloth or manuka brushwood for shade and wind protection.

Seed is subjected to a 5-month winter-frost period which helps overcome the chilling requirement prior to germination. Germination occurs in September and careful attention must be paid to pest and disease control. The shade is removed once the plants are 10 cm tall, choosing a cloudy day, so as to allow hardening off.

A reciprocating undercutter is used to cut the tap root of the plant to produce a compact fibrous root system. It is vital that the plant is not stressed, breaking the active growth cycle. Soil moisture at or near field capacity reduces soil movement and plant stress. Irrigation is advisable during periods of desiccating winds. Using good cultural growing practices it is possible to achieve seedlings averaging 35 to 45 cm in height in two growth seasons.

By producing well grown robust open-ground seedlings, Appletons' Tree Nursery offers tree planters an economical tree stock option for restock of existing and planting of new areas.

MANAGEMENT OF FOREST REMNANTS

The three options for managing forest remnants are natural regeneration, regeneration using nurse trees and revegetation.

Natural Regeneration. Where livestock and fire are excluded, natural regeneration may be sufficient to ensure the survival of the forest remnant. The regeneration will occur through the growth of seedlings from seed trees and birds carrying seeds from nearby areas.

Regeneration Using Nurse Trees. Nurse plants can be utilized for accelerating the natural process of regeneration by creating a favorable microclimate for the germination and growth of native seedlings. This approach is most useful on exposed sites where the nurse plants provide shade and shelter.

Revegetation. Revegetation or restoration can be described as new or supplementary planting to accelerate the natural process of regeneration. This is often the best approach in managing small forest remnants where the bush has become open to sunlight and exposed to the wind because of milling, grazing, or windthrow. In these situations the natural process of regeneration may take a very long time even if browsing animals are excluded because the site will be invaded by grasses and other weeds such as old man's beard. Revegetation using fast-growing trees that occur naturally in lowland forest communities will suppress the grasses and other weeds by excluding light and allow the process of succession to proceed. Revegetation may also make it possible to form a more complete plant community by including plants from nearby stands that no longer occur in the remnant being replanted.

THE SEQUENTIAL ORDER OF NEW ZEALAND FOREST DEVELOPMENT

The New Zealand bush (forest) passes through six clearly defined stages before becoming climax broad-leaved forests.

Stage 1 - No Vegetation. As to be seen after a bushfire, volcanic eruption or major sandblow, and is represented by no plant growth.

Stage 2 - Primary Herbaceous Colonization. These are the first plants to appear and are dominated by grass and broad-leaved herbs. *Carex*, *Poa*, *Danthonia*, and *Celmisia* are to be seen at this stage.

Stage 3 - Woody Colonizers. Woody colonizers may be both shrubland plants and forest trees. The shrubland plants are dominated by *Leptospermum*, *Kunzea*, *Cassinia*, *Weimmania*, and *Sophora*. Stage 3 is also dominated with exotics such as gorse, *Pinus*, and *Eucalyptus*.

Stage 4 - Primary Broad-leaved Forest. This stage of development is the home of *Pittosporum*, *Myrsine*, *Melicytus*, *Pseudopanax*, *Knightia*, *Coprosma*, *Griselinia*, *Hoheria*, and tree ferns (both *Cyathea* and *Dicksonia*)

Stage 5 - Softwood Forest. The softwood trees are the giants of the forest - *Agathis*, *Podocarpus*, *Prumnopitys*, *Dacrocarpus*, and *Dacrydium*.

Stage 6 - Climax Broad-leaved Forest. *Vitex*, *Dysoxylum*, *Corynocarpus*, *Beilschmiedia*, *Syzgium*, and *Phopalostylis* dominate Stage 6.

The sequential order of progression does not change in any part of the country or in any ecological habitat—only the genera makeup alters. Each genus will be represented from the correct sequential stage.

All stages will become climax in sites of adversity. For example, Stage 1—primary herbaceous colonization will remain as grassland in perpetuity when it is so severe that the woody colonizers can't take over. Stage 2—woody colonizers will remain shrubland in perpetuity in sites that are so severe that they cannot be taken over by primary broad-leaved forest, etc. The natural forest is a place where all plants are trapped in sites of adversity, except the climax broad-leaved genera. These occupy the sites of luxuriation, marginalizing all other plants to the limit of their survivability.

It takes about 1000 years for a forest to reach Stage 6—climax broad-leaved forest in a site of luxuriation.

Acknowledgements. Martin Conway and Graeme Platt.

Quality Assurance to the Customer of Pot-Grown Liners

David Hutchinson
17 Purkess Close, Brownhill Road, Chandler's Ford Eastleigh, Hants SO53 2ED Great Britain

WHY THE NEED FOR QUALITY ASSURANCE?

The propagation, growing, and marketing of plants for garden and environmental planting have seen many changes. The customer is tempted to purchase plants with eye-catching sales promotion displays and makes that vital purchase on impulse and not necessarily by experience. The garden plant buyers and managers, many of whom have trained and been recruited from the food and retail side of the large corporate businesses, are familiar with quality management systems. They demand complete assurance that the supplier provide on a set date a specific quality plant.

These trends are set to continue which in turn presents the propagator, the nursery grower, and the supplier with new challenges and standards in order to be successful in supplying the market.

A small group met in December 1994 to develop a system to demonstrate their commitment to supplying the customer with consistent quality and service. The group of five primary liner growers formed the Association of Liner Producers.

THE OBJECTIVE OF THE ASSOCIATION

The objective is to improve the sales and marketing of liners by overcoming the diversity of quality found in the pot-grown liner industry. In addition, they act as a forum to voice their views on matters affecting their industry such as quality standards, research funding, and promotion and marketing. The Code emphasises the need for high quality plant production and customer care that also complies with chemical, pesticide, and health and safety legislation.

THE CODE OF PRACTICE

The Code of Practice demonstrates to the customer that the Association members are growing crops to a consistently high quality standard with due diligence to meet legal and environmental requirements. Compliance with the Code ensures that quality plants will be grown to uniform standards. The Code of Practice is divided into five sections: (1) plant quality, (2) nursery hygiene, (3) plant health, (4) customer relations, and (5) management systems

1) Plant Quality.

Specifications. Specifications were established by the members studying customer's requirements. They include plant size, shape, and the number of breaks.

Naming. All plants must be true to name.

Root Quality. The roots must be alive and active. At the point of despatch all plants must have a sufficient quantity of active roots to hold the root ball intact.

Nutrient Status. The nutrient status of the compost must be sufficient to provide adequate nutrition throughout the life of the crop. It must also have some residual life. The plants must not appear starved.

Labelling and Cultural Information. Plants must be correctly labelled with a minimum of one label per unit.

Nursery Hygiene. The nursery must be free from sources of infection, i.e., pests, diseases, and weeds.

Incoming Plants. Plant material entering the nursery must be thoroughly examined for any signs of pest, disease, or weed. Quarantine immediately any doubtful consignments.

Resources and Materials. Growing media and containers must be stored in a manner to minimize the risk of contamination. Water sources and water tanks must be covered and free of waterborne diseases.

Vermin. Mice, rats, and rabbits must be kept under control within the nursery using legal methods.

2) Plant Health. A nominated staff member must be responsible for plant health monitoring and the control systems. They must be able to recognize common pests diseases and weeds.

Monitoring. There must be an effective system for monitoring pest, disease, and weeds levels. Inspections should be carried out weekly and the observations recorded. Any notifiable pests or diseases identified must be reported.

Information Exchange. Knowledge of information regarding pests, diseases, or weeds is exchanged between members.

Pests and Diseases. All plants must be visibly free from pests and disease. Where biological control is used, pests may be present, providing they are in balance with the control agents.

Specific pest: *Otiorhynchus sulcatus* (vine weevil), this serious widespread pest demands that all plants receive preventative treatment. The nursery must have an overall strategy for long-term control. If there is any change in the control procedure then the customer must be notified.

Weeds. Plants must be free from live weeds. Dead weeds are allowed, provided they do not detract from the overall appearance.

Traded Stock. It is the member's responsibility to inspect all traded stock.

3) Customer Relations.

Order Acknowledgment and Processing. Each nursery must have a system to monitor the progress of an order from arrival to despatch and invoicing. This must be available for inspection. All orders must be acknowledged within 2 weeks of reception.

Losses and Shortages. All losses or shortages are to be notified to the customer at the earliest opportunity.

Substitution. The substitution of varieties/cultivars must only be carried out with the agreement of the customer.

Complaints. All members must operate a complaints system. A senior person must be nominated to deal with complaints.

Delivery and Transport. Customers must receive notice prior to delivery.

Plants must not be in transit for more than 4 days.

It is the producer's responsibility to ensure that plants arrive at the customer's site in good condition.

The producer is responsible for goods lost in transit. Any disputes with the haulage company are settled by the producer.

Packaging. There should be adequate space for the plants so that damage in transit is avoided. There should be no crushing, obvious damage, or excessive bending in transit.

4) Management Systems.

Health and Safety. All members must have an updated policy statement, which complies with all the legal requirements.

Food and Environmental Protection Act (FEPA) Requirements. All FEPA requirements must be met. The records required for the use and storage of any pesticides on the nursery must be kept for inspection.

Control of Substances Hazardous to Health (COSHH). The assessment must be up to date and complete. It must be reviewed annually and constantly updated as "new" substances or working practices occur.

Environmental Policy. There should be a written environmental policy statement, It should consider the use of peat and its alternatives. The use of recycled water and recyclable materials is encouraged wherever possible. Members must comply with the current legislation regarding the disposal of waste materials/products.

Inspecting the Code of Practice.

- **Inspection visit.** The visit is carried out by a suitably qualified independent third party appointed by the Association.
- **Timing.** Twenty-four hours notice is given prior to inspection. Presently each nursery is inspected once during the growing season at a time when liners are being despatched.
- Inspection criteria — A balance is struck between:

Quality of plants at point of despatch;

Quality of plants growing on the nursery;

Nursery hygiene and business practice.

The nursery must demonstrate that it has effective systems in operation to meet the customer care and nursery management requirements.

- **Liners ready for despatch**. At least 20 cultivars/types of liners must be available for inspection at the time of despatch.
- **Specification.** Plants should be at or above the specifications in the A-Z Association Manual.

- **Grading.** Plants must be even throughout the batch and labelled accordingly.
- **Balance.** Plants should be sturdy and well balanced with substantial breaks of equal weight. Root and shoot growth must be in balance. The plants should be fit for their purpose (i.e., quickly growing into a finished plant).

Growing Crops of Liners in the Nursery. All growing crops of liners are inspected. Crops will be inspected for pest, disease, and weed levels and also for vigor and other likely problems. Consideration is given to the overall appearance of the crop (i.e., leaf color, nutrition, root growth) and root loss caused by over or underwatering and possibly old pest or disease damage.

Nutrition. Plants must not appear starved.

Watering at Despatch. They must have sufficient water for transit and not be dry.

Root Quality. There should be sufficient root to hold the root ball together when knocked out of the pot. The roots should be alive and active.

General Appearance. The plants should have a good overall appearance. They should appear vigorous with strong growing shoots.

They should be correctly labelled with at least one label per unit. Labelling should be carried out in such a way that it is easily understood by the customer.

Pesticide Application Records. Should be up-to-date and correct. In addition, to see that they are applied and recorded.

Roads and Access. Are inspected for freedom from weeds.

Rubbish. The nursery should be free from rubbish, discarded materials, and other items which would harbour harmful organisms that may cause problems with plant quality.

Compost Storage. All compost materials should be stored in a manner which minimises the risk of any pests, diseases, or weed contamination.

Water Storage. Water will be stored in a way to minimize pest, disease, or weed contamination.

Pest and Disease Monitoring. A system must be operated where crops are inspected on a regular basis. Records should be kept and be available for inspection.

Order Processing and Customer Care and Delivery. Systems must be in place to ascertain their effectiveness. Relevant documents and records should be kept for at least 12 months.

Order Reception. A nominated person should be responsible for recording the reception of an order and to ensure that it is acknowledged and processed.

Order Processing. All orders will be acknowledged and completed within 14 days of receipt. This is usually in writing, but can be verbal if recorded in writing and dated.

There should be a satisfactory system for notifying customers of shortages and omissions.

Delivery. To ascertain whether liners are arriving within the time scale indicated, there should be a system whereby customers sign and date a delivery note at the time the goods are received.

Complaints. There must be a satisfactory complaints procedure in place. All complaints should be logged and any action noted.

5) Management Systems. All systems should meet the legal requirements of all nursery businesses. The Inspector will inspect the documentation for:

- Health and safety policy statement
- Up to date COSHH assessments
- Risk assessments
- First aid facilities
- Accident book
- Accident and emergency procedures

Failure to adequately fulfil any of these legal requirements bars applicants from the membership of the Association.

WHAT IS THE RESULT?

In the 2 years that the scheme has been operative, all the members have found that customer satisfaction has increased. The interest and responsibility of the staff is more focussed leading to a reduction of complaints and increased efficiency.

THE FUTURE

Never before have garden/environmental plants been so popular and in demand. The market needs to be assured that suppliers can satisfy the demands of the customer.

An Industry led Code of Practice is a way of demonstrating the nursery's total commitment to the customer.

Acknowledgements. William W. George, David A. Ann, Founder Members; Patrick F. Fairweather, John M. Hedger, David West, John Billington, and Nigel J. Timpson

Propagation of Crape Myrtle (*Lagerstroemia indica* L.) from in Vitro Plants Derived from Shoot Tips

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We reported already the propagation of crape myrtle by culturing nodal explants from in vitro seedlings. However, it is more desirable for clonal propagation to obtain regenerants using an explant from a greenhouse-grown plant. From that point of view, we studied propagation of crape myrtle using shoot tips of a dwarf type of plant grown in pots. At first, donor plants were produced by culturing shoot tips on the Murashige and Skoog (MS) medium. Nodal segments and shoot tips excised from the in vitro plants were used as explants. The axillary buds were easily induced from the meristems of nodes on the MS medium without hormones. The combinations of hormones, such as benzyladenine (BA), naphthaleneacetic acid (NAA), and gibberellic acid (GA_3) had little promotive effect on the induction of axillary buds. The multiplication of shoots occurred through two types of organogenesis, one is branching by enhanced induction of axillary buds from the shoot and the other is formation of adventitious shoots. Benzyladenine (1 mg liter^{-1}) was effective for multiplication, while NAA and (GA_3) added to the medium containing BA had little additional effect on multiplication. The growth of shoot tips excised from the in vitro plants was better in the MS medium than in the half-strength MS medium and Woody Plant Medium. The shoots formed from the two types of explants rooted easily in the half-strength M.S. medium without NAA. After acclimatization, the regenerated plants grew normally in pots and came into flower with the same color as that of the donor plant. A scheme for micropropagation of crape myrtle based on the present experiments is shown in Fig. 1.

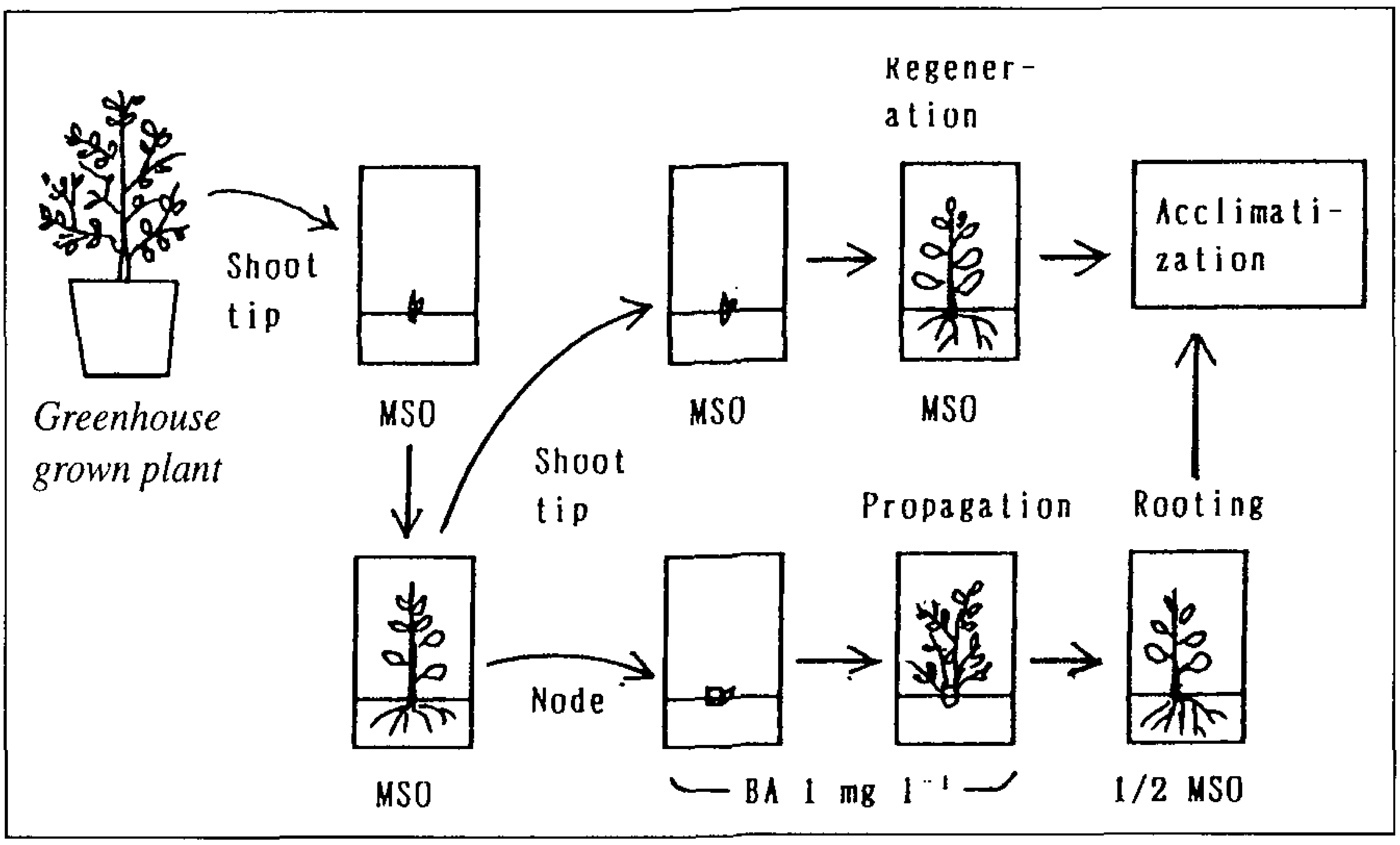

Figure 1. Scheme for micropropagation of crape myrtle using shoot tip explants derived from greenhouse-grown plants.

"Propagation in Other Parts of the World" Question-Answer Period

DICK BIR: Could you speculate on the hardiness of the *Podocarpus* you showed?

ROBERT APPLETON: My particular covenant is at about 200 m. There is an alpine species that goes right to the bush line. We could easily find *Podocarpus* that would go right to the bush line. I don't know what zone that is, but it is pretty northern. You would be talking about a frost period for every month of the year. One of the advantages for that type of plant is that it is very small and would have a great deal of ornamental value in gardens.

ARDA BERRYHILL: David, how do you, as an extension officer, fit into that scheme and is it open entry?

DAVID HUTCHINSON: I fit in by helping each nursery get a program focused on the business side of doing the code of practice. That is, get the staff together and go through the training programs to see that they can meet their commitment. I do that on a contractual basis with each company. I do not do the actual inspections; that's left to a third party.

BRUCE MACDONALD: Did your crape myrtle plants from tissue culture flower at a much shorter height and has your work been developed into the greenhouse industry in Japan?

TOMOHIDE YAMAMOTO: Yes, to both of your questions.

BRUCE BRIGGS: How can we encourage people to be better plants people and better propagators?

DAVID HUTCHINSON: I think, as an I.P.P.S. member, it's up to all of us. We're always in contact with people. We, as employers, are always outward going in recruitment. It's up to us to make sure it's not only a job or work, but that it is enjoyable. This is an important question since qualified propagators are in demand today.

BARBARA COE: Have you been micropropagating other crape myrtles besides *L. indica* 'Little Chief'?

TOMOHIDE YAMAMOTO: No.

BRUCE MACDONALD: How is your liner association funded?

DAVID HUTCHINSON: The association is supported by fees collected for its services. Basically, there is a flat rate fee to join. In addition to that, sponsorships are obtained from certain companies as well to help finance some of the running of the association. The actual fees for inspection are paid by new members and by each member each year.

Pre-chilling and Gibberellic Acid Improve Seed Germination in *Lewisia* Species and *Meconopsis betonicifolia*

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Germination of naked embryos in *Lewisia tweedyi* was almost 90% within 4 weeks of decoating, suggesting that the species has a seed-coat-imposed dormancy. Maximum germination of whole seeds after 32 weeks under axenic conditions was 66.7% in *L. tweedyi* and 87.8% in *L. cotyledon*. Moist pre-chilling in combination with gibberellic acid (GA_3) treatments improved germination in *L. cotyledon* and *Meconopsis betonicifolia*. Low percent germination over extended periods of time limits the commercial production of *L. tweedyi*.

INTRODUCTION

Seed dormancies of many herbaceous garden perennials including *Meconopsis betonicifolia* Franch and native species, such as montane *Lewisia tweedyi* (A. Gray) Robinson and *L. cotyledon* (S. Watson) Robinson, limit their production in highly controlled environments.

Lewisia tweedyi is highly valued as an ornamental (Straley, 1988), but has been cultivated only by alpine specialists who report very low percent germination over long periods of time (Colley and Mineo, 1985). Lewisias (Portulacaceae) are members of the Centrospermae; a linear peripheral embryo surrounds centrally located perisperm (Bittrich, 1993). Atwater (1980) reported seed-coat-imposed dormancies in the Centrospermae. In this study, we determined if dormancy in *L. tweedyi* is imposed by the seed coat by observing the germination of decoated seeds (Côme and Corbineau, 1992).

Lewisia cotyledon and *M. betonicifolia*, the blue poppy, are minor commercial crops in some areas of Europe and western North America. Aelbrecht (1989) found that pre-chilling increased *L. cotyledon* germination. However, germination recommendations are inconsistent and imprecise. Methods are based on stratification for unspecified periods in a garden cold frame. The objective of this study was to improve germination by testing the effects of moist pre-chilling and gibberellic acid on *L. tweedyi*, *L. cotyledon*, and *M. betonicifolia*.

MATERIALS AND METHODS

Germination of Naked Embryos. *Lewisia tweedyi* seed was surface sterilized in 15% NaOCl for 15 min before carefully removing the entire testa with a dissecting needle. Three, 25-seed replicates of decoated and whole seeds were sown in 10-cm petri dishes on 3 layers of Whatman No.1 filter paper moistened with 5 ml distilled water. Dishes were incubated in the dark at 22C for 4 weeks. Germinated seeds (radicle > 1 mm) were counted and percent germination (PG) was calculated. A t-test was used to compare the difference between the two treatment means.

Axenic Germination of *Lewisia* Taxa. *Lewisia cotyledon*, *L. tweedyi*, *L. tweedyi* 'Alba', *L. tweedyi* 'Rosea', and *L. tweedyi* 'Elliot's Variety' seeds were obtained from Ashwood Nurseries (West Midlands, U.K.). One hundred seeds of each species and cultivar were surface sterilized and sown individually in 30-ml test tubes filled with 15 ml of one-tenth MS (Murashige and Skoog, 1962) agar medium, pH 5.5; sugar was not added to simulate in vivo germination conditions. Test tubes were placed in a growth room set at constant 19C with a 16-h photoperiod or pre-chilled at 4C in the dark for 4 weeks before transfer to the growth room. Number of germinated seedlings was recorded weekly and overall PG calculated after 32 weeks.

***Lewisia* Seed Treatments.** Gibberellic acid (Sigma, St. Louis, MO) at concentrations of 0, 1.0, or 10 mM was dissolved in pure acetone to volume based on improved germination in some perennial species after organic infusion of GA_3 (Persson, 1993). *Lewisia tweedyi* and *L. cotyledon* seeds were immersed for 24 h in covered beakers containing the GA_3 solutions at room temperature. Decanted seeds were sown in petri dishes. *Lewisia tweedyi* seed was pre-chilled (3±0.5C) for 2, 4, 8, or 12 weeks and *L. cotyledon* for 2, 4, or 8 weeks. After pre-chilling, seeds were removed to a growth chamber set at 18±2C with a 16-h photoperiod.

Petri dishes containing 25 seeds each were randomly placed in 2 plastic containers during pre-chilling and re-randomized during germination in all combinations of factors and levels (2 plant species × 3 levels of GA_3 × 4 or 5 levels of pre-chilling × 2 blocks × 2 replicate dishes). Number of germinated seeds (radicle > 1 mm) was recorded at the time of removal from the pre-chill and then weekly for 10 weeks. Percent germination was calculated and the data analyzed using the PC-SAS software package (SAS Institute, 1985).

Blue Poppy Seed Treatments. *Meconopsis betonicifolia* seed was obtained from two commercial sources, Jelitto Seeds and Thompson & Morgan, and from the University Botanical Garden. They were immersed in an aqueous solution of GA_3 at concentrations of 0 or 10 mM for 24 h. Decanted seeds were sown in petri dishes (2 replicates of 50 seeds per treatment) to test seed quality from different sources or directly in styrofoam plug trays containing a commercial peat-based medium. Petri dishes were incubated at 5C for 6 weeks and then moved to a 12/10C (day/night) greenhouse for germination. Plug trays were divided into three 60-cell sections and seeded sequentially for different pre-chilling periods. Plastic-wrapped trays were pre-chilled for 4, 6, or 8 weeks at 5C before transfer to a cool (12/10C) or warm (24/22C) greenhouse for germination. Number of live seedlings was counted weekly.

RESULTS AND DISCUSSION

Seed-Coat-imposed Dormancy in Lewisias. Impenetrable seed coats impose dormancy on many herbaceous plants and unselected wild species (Kelly et al., 1992). Germination within 4 weeks of decoating suggests that the covering structure imposes dormancy in *L. tweedyi*. Mean PG (3 × 25-seed replicates) was 86.9% for naked embryos and 0% in the control ($P = 0.001$).

Low PG over extended periods of time is characteristic of plants growing in extreme habitats (Gutterman, 1993), such as montane environments. Individual seeds of *L. cotyledon* and *L. tweedyi* sown under sterile conditions germinated throughout the entire 32-week test period. Maximum overall germination after 32 weeks was 77.9% in *L. cotyledon* and 61.4% in *L. tweedyi*.

Seed Treatments to Improve Germination. Seed dormancies are an advantage in nature, but they must be overcome in cultivation. Germination performance of wild and other perennial species has been improved by pre-chilling (Bratcher el al., 1993) and gibberellic acid treatments (Sulaiman, 1993).

Pre-chilling or GA_3 increased PG in both *Lewisia* species (Table 1), but maximum germination was 59.0% in *L. cotyledon* ($P = 0.05$) and 28% in *L. tweedyi* ($P = 0.01$) after pre-chilling in combination with 10mM GA_3. Percent germination was different (P=0.001) between *L. tweedyi* and *L. cotyledon*.

Table 1. Percent germination in *Lewisia tweedyi* and *L. cotyledon* soaked for 24 h in 0, 1.0, or 10.0 mM gibberellic acid (GA_3) in acetone after pre-chilling at 3±0.5C for 0, 2, 4, 8, or 12 weeks. Seeds were evaluated over 10 weeks in a growth chamber at 18±2C with a 16-h photoperiod.

	Plant species	
Treatments	*L. tweedyi*	*L. cotyledon*
Pre-chilling (weeks)		
0	4.7	34.2
2	4.2	35.3
4	9.3	37.7
8	13.8	48.3
12	19.3	—
Significance	***	***
GA_3 in acetone (mM)		
0	6.6	36.8
1.0	9.4	38.0
10.0	14.8	41.9
Significance	***	***

*** Significant at P=0.001.

Maximum live seedlings in *M. betonicifolia* was 88% after 4 weeks in a cool greenhouse with seed obtained from Jelitto, soaked in a 10 mM GA_3 aqueous solution and sown in plug trays, in combination with a 4-week prechill ($P = 0.01$).

Khan et al. (1992), Bradbeer (1988), and Corbineau and Côme (1995) discuss the role of GA and stratification in seed dormancy and germination. Gibberellic acid mimics moist chilling and moist chilling induces the production of GA. When the seed coat is impermeable to oxygen, chilling increases the oxygen supply to the embryo. When secondary dormancy is induced at warm temperatures, GA stimulates metabolic activity in the embryo.

Implications for Growers. Germination of *L. tweedyi* would be improved by scarification of the testa to overcome the coat-imposed dormancy. Soaking seeds in a 10 mM aqueous solution of GA_3 followed by moist pre-chilling for 4 weeks is effective for *L. cotyledon* and *M. betonicifolia*. Growers should also be advised that seed quality is variable (Fig. 1).

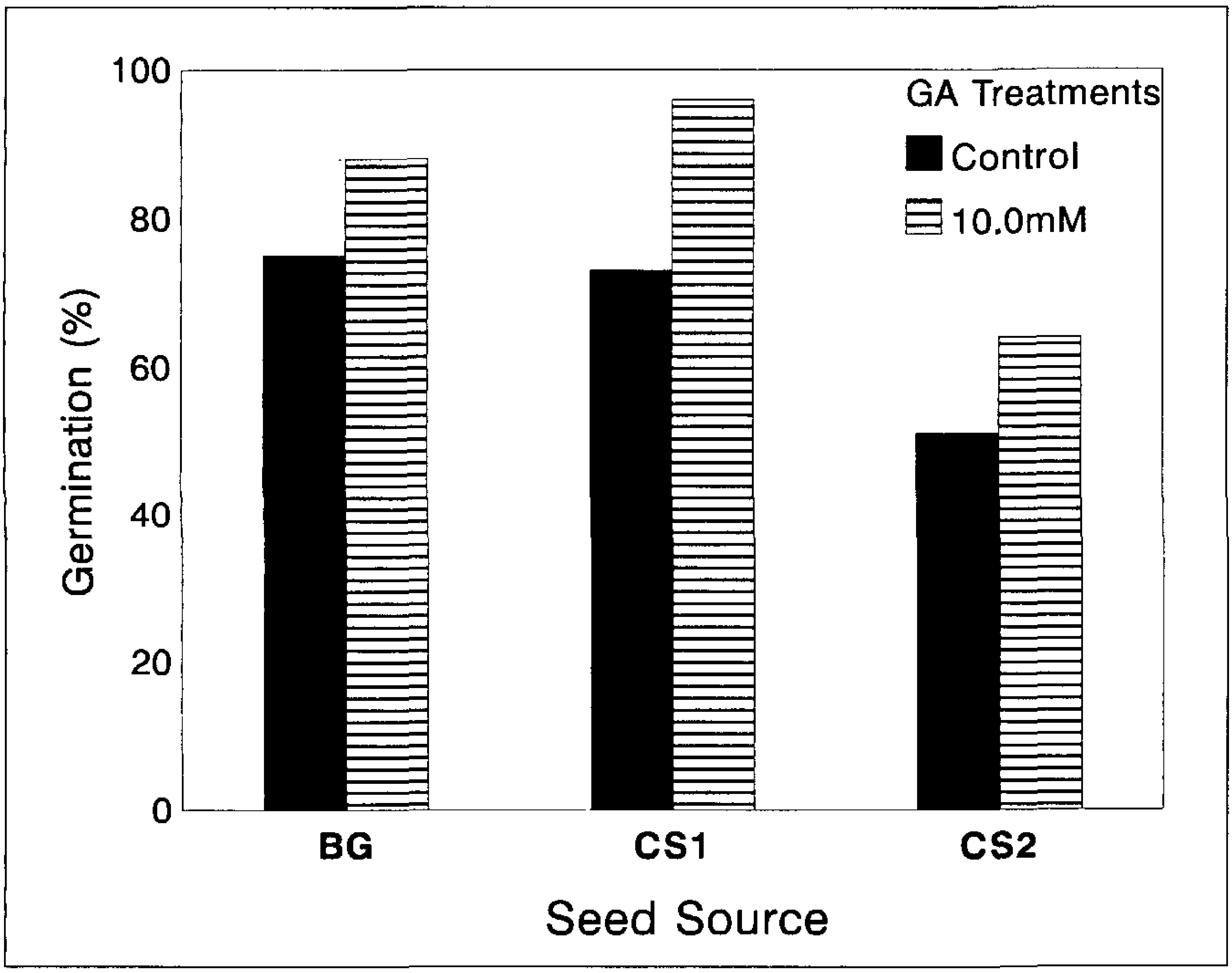

Figure 1. Percent germination in *Meconopsis betonicifolia* soaked for 24 h in 0 or 10.0 mM gibberellic acid (GA_3) in water after pre-chilling at 5C for 6 weeks. Seeds were evaluated from three different sources: a botanical garden (BG), and two commercial suppliers (CS1) or (CS2).

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Propagation and Production of *Arbutus menziesii*

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Arbutus menziesii is one of the most distinguishing features of the British Columbia (B.C.) inner south-coast landscape. These majestic trees characteristically grow on exposed rocky cliffs overlooking the sea, but will also thrive on well-drained wooded inland slopes. Their individual unique shapes amaze and attract even the most casual observer. Long limbs extending out over the water, often appear to defy the laws of gravity. Their branches, short, twisted, or crooked create very interesting, even exotic shapes. In striking contrast, they can also be very short and symmetrical, as if meticulously pruned. In B.C. they are typically associated with garry oak (*Quercus garryana*) and Douglas fir (*Pseudotsuga menziesii*).

One of the most interesting characteristics of the tree is its shedding, paper-like bark, revealing a smooth and satiny, olive to reddish-brown trunk.

The range of the tree extends north to approximately 50°N latitude (200 km north of Vancouver, B.C.) and as far south as Baja, California. In the northern part of the range it grows in a narrow corridor, usually within 10 km of the ocean. It occurs from sea level to 300 m and will grow to a height of 30 m.

In this region the tree flowers form April through May. It is an ericaceous plant and has typical bell-shaped flowers borne in dense terminal clusters... quite a show!

Berries develop over the summer. The number of berries each year appears to be quite variable. They ripen and can be collected from October through to December. They may be yellow, but preferably, a mid-red color appears to be optimal. Our berries are usually collected from 1 Nov. to 20 Nov. In this area one does not want to play Russian roulette with the weather. In late November, one can often get cold outflow winds bringing temperatures of -5 to -10C. The entire berry will freeze and soon after thawing will fall to the ground. Quickly after, the pulp of the berry rots and the seeds disappear. The berries can be collected very quickly; however, they are often high in the tree and one has to be creative in order to retrieve them. Having found a nice specimen, collecting the berries for my purposes takes about a hour.

The berries are fresh and plump at this stage and are ready for cleaning. Our current method is to remove the seeds from each berry by hand, using a sharp knife. One and one-half liters of berries, cleaned by hand in 12 h, yields enough seed for 3000 plants. The seed is then divided up into 100- to 150-ml batches, mixed with 500 ml of well drained, washed concrete sand and 5 ml of Benlate. The batches are bagged and then refrigerated at 2C. This takes place between approximately 25 Nov. and 15 Dec.

Keep an eye on the seeds, checking for germination or mold, approximately once a month. I have never had a problem with mold when stratifying this way. Obviously, one has to make sure the seeds are relatively clean of berry pulp before stratification.

The seeds will start to germinate anywhere from 15 February to 15 March. They should be sown before the root radical gets too long and at risk of mechanical damage.

As *Arbutus* spp. do not like having their roots disturbed, we sow directly into 3 inch × 3 inch × 3 inch pots with two germinating seeds per pot. We have sown into

2¼-inch pots, but the plants are so vigorous they outgrow the pot within 8 weeks and then either have to be shifted or their growth will be checked.

The mix we use is well drained with little fertilizer. It is coarse peat, pumice, and perlite (1 : 1 : 1, by volume) with micronutrients added at 1 lb per yard and a slow-release fertilizer. We use Nutricote 16-10-10 type 180 at a low rate of 5 lb $yard^{-1}$.

In our climate it seems that the earlier the seeds are sown the better. They will not toler^)5 the significant amounts of heat that may occur in our area in April. This past spring we sowed the majority of our crop on 19 March and it has done very well. The seeds that germinated later and were sown 31 March have not done nearly as well.

The germinating seeds in pots are then grown on in heated polyhouses, which have minimum temperatures of 0C and at least enough humidity control to eliminate free-standing water on the leaves. If you observe *A. menziesii* in the wild they do not thrive as understory plants, but are always reaching for the wind and light. They will develop leaf spots if free-standing water is left on their leaves for extended periods of time.

Within 5 months the crop will be ready for shifting to 1- and 2-gal containers. The same mix used in the 3-inch pots is used in the larger-sized containers. We heat our greenhouses in September and October to minimum temperatures of 13C. This way the plants will put on another flush of growth and will fill a 1-gal container by November of the same year. The 2-gal container-grown plants will be ready for sale after the first flush of growth the following spring. Thus far, the largest we have grown is 3-gal containers.

While all of this sounds wonderful and should always work perfectly, we all know there are pitfalls in any system. *Arbutus menziesii* has a habit of inexplicably wilting and dying. I have had plants analyzed and the lab indicated the presence of *Phytophthora*. We have attempted treatment with Ridomil, but not on a regular enough basis to know if it makes a difference.

More than likely there is a mycorrhizal association in nature that is missing in our nursery-grown plants. I have not done any work on this yet.

Another point of interest is that even minor root damage at the crown of the plant, when transplanting, can kill the plant. Therefore, especially with young plants, turning the container upside down and knocking the pot off the roots is preferable to pulling the plant out by the stem. Furthermore, do not bury the crown of the plant when shifting to larger-sized containers.

Arbutus is a west coast native plant which, if more readily available, would be utilized more. At times it can be difficult to establish in the landscape. It requires a very well drained, sunny to part shade location with a minimum amount of fertilizer and more neglect than attention. It appears to thrive in these conditions.

Arbutus is such a unique and beautiful tree, I think it deserves the effort and attention it will take to work out the problems associated with establishing it more readily in the urban landscape.

The Role of Copper-based Root Control Treatments in Closed Subirrigation Systems

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Closed subirrigation systems offer the potential of water and nutrient savings along with increased growth rates and no polluting runoff. The use of a copper-based root control chemical on weed matting over capillary matting, as well as on the inside of pots, can prevent root penetration into the capillary matting and improve root development without having any adverse effects on growth rates.

INTRODUCTION

Recent work by Mayotte, Hall and Connellan (1996) has shown that "closed" subirrigation systems, where runoff is collected and re-used in capillary watering of nursery crops, can substantially reduce water use when compared to overhead sprinkler systems. Many workers over the last decade have shown that these subirrigation methods can also reduce the fertilizer requirements of crops while still maintaining rapid growth rates, since leaching of nutrients incorporated into the growing medium is largely eliminated. A further significant consequence of the use of "closed" capillary systems is that the environmental problem of nutrient-rich runoff leaving the nursery is, to a large extent, eradicated. This pollution aspect of nursery production is attracting substantial attention in Australia as it is elsewhere. Mayotte et al. (1996), by measuring electrical conductivity (EC), pH, and a range of individual nutrient ions, also showed that the build-up of nutrient salts in the closed, recirculating, irrigation system was not an issue for concern — at least for short-term crops. The solution remaining in the irrigation tanks for each system was dumped as a result of experimental necessity at the conclusion of each trial since no system of disinfestation of water was used. The three forms of subirrigation studied in comparative trials with an overhead sprinkler system were: constant flow on capillary matting, intermittent flow on capillary matting, and ebb and flood. Water inputs into each irrigation system were recorded as was the amount of runoff from the overhead sprinkler system. Dry mass of top growth was used to provide an indication of the comparative performance of each system. In this series of trials the capillary matting systems each utilized a cover of black woven polypropylene fabric (weed mat) over the capillary matting to reduce algal growth on the capillary matting and to help prevent root penetration from the container into the matting. It certainly helped prevent algal build-up but did not entirely prevent roots from the base of the container from growing into the capillary matting.

For a number of years the nursery at Burnley College has been painting a dilute solution of SpinOut™ (a copper hydroxide, 100 mg liter^{-1}, root control agent in a latex paint — Griffin Corp., Valdosta, GA) onto weed mat covering capillary sand beds in order to prevent root penetration into the sand. It has proven quite effective in this role. However, we were concerned that copper may build up to toxic levels if this technique, or that of painting the inside walls of containers to prevent root circling, was to be used in a recycling system. Two trials (Thornby, 1997) were conducted growing small crops on 'closed' capillary matting systems with four different combinations of treatments using SpinOut™. These were established in order to assess the impact of SpinOut™-treated pots and weed mat on root circling within the pot, root growth into the capillary matting, and copper concentration in the recirculating water supply.

MATERIALS AND METHODS

In the trials to assess the impact of a copper-based root-control chemical in "closed", or recirculating, capillary irrigation systems, three different SpinOut™ treatments were used: the first on the inside of containers to control root circling, the second on weed mat to control root penetration into the capillary matting, and the third combining pot treatment with weed mat treatment. With a control this produced four treatments:

1) Neither pots nor matting treated;
2) Both pots and matting treated;
3) Pots treated, matting untreated;
4) Matting treated, pots untreated.

Sufficient replication was used to allow statistical analysis and a randomized block design ensured edge effects were eliminated. Four species were used per trial and these were predominantly Australian native tree and shrub species which had not previously been tested for their response to SpinOut™.

A series of trays were placed in an unheated glasshouse. The trays were established with a gradient of 1 in 40. The trays had drainage holes at one end and the trays were fitted with 3-mm fibrous capillary matting. The trays were then connected with irrigation lines and return lines from the drainage holes, all made from 15-mm flexible plastic pipe. Water was supplied to each tray from 100-liter cylindrical tanks equipped with submersible pumps. The containers used throughout the trials were 150-mm black plastic pots suitable for use on capillary beds — that is, they had drainage holes on the base to allow for a capillary connection to the matting.

In those treatments where SpinOut™ was applied to the weed mat it was diluted 1 : 1 (v : v) with water in order to avoid clogging the weave. Where pots were treated, undiluted SpinOut™ was applied by brush to the inside of the containers. Plants were hand-potted from 50-mm tubes (liners) 24 h after painting the inside of the pots. The potting medium was a composted pine bark with an air-filled porosity (AFP%) of approximately 15%.

The medium had an incorporated controlled-release fertilizer (16.5N : 4.1P : 9.6K) at 4 kg m^{-3}, trace elements in the form of Micromax® (1 kg m^{-3}), and with the pH adjusted using dolomitic lime to 5.5 to 6.0.

The plant species used in Trial 1 were: *Eucalyptus torquata, Acacia pendula, A. iteaphylla*, and *Callistemon speciosus*. In Trial 2 the species used were: *E. alligatrix, C. citrinus, A. pycnantha*, and the non Australian native, nonwoody *Salvia splendens*.

Water samples were taken from the supply tanks at the conclusion of each trial and assessed for pH, EC, iron (Fe), and Cu levels. Copper toxicity usually manifests itself as iron deficiency symptoms (Handreck and Black, 1994). The iron and copper were measured using Reflectoquant® (E. Merck) test strips and a calibrated strip reader. The test strips used had a stated range of 5 to 200 mg liter^{-1} Cu. The growing medium was also analyzed for copper content at the conclusion of the trial.

The trials were terminated when excessive root growth was apparent from the base of control (no treatment) containers. Root growth into the weed mat was then assessed using a devised 1 to 5 scale where 1 represented no root growth into the matting and 5 represented no control over root growth from the pot. A similar 1 to 5 scale was used to determine the amount of root circling within the container. Finally each plant was decapitated at the surface of the medium and top growth dry mass measured in order to assess if the treatments were having any impact on growth rates. The means of dry mass were then statistically analyzed using the analysis of variance.

RESULTS

A concern with the use of SpinOut™-treated weed mat or containers in a "closed", or recycling, subirrigation system was the possibility of copper build-up in the irrigation supply having an adverse impact on growth rates. The analysis of variance of the dry mass of the aerial portion of the plants indicated no statistically significant reduction in growth as a consequence of the treatments except for *E. torquata* where the two treatments where pots were treated provided significantly increased growth (Table 1).

Table 1. Aerial portion dry weights in grams (means of treatments by species).

Species	Neither mat nor pot treated with SpinOut™	Both mat and pot treated	Pots only treated	Mats only treated
TRIAL 1				
Eucalyptus torquata	3.68 a	4.91 b	5.15 b	3.18 a
Acacia pendula	13.70	12.52	12.76	12.53
A. iteaphylla	4.14	4.02	4.40	4.54
Callistemon speciosus	6.11	5.96	4.36	8.08
TRIAL 2				
E. alligatrix	1.20	1.45	1.51	1.50
C. citrinus	2.18	2.04	2.10	2.12
A. pycnantha	2.82	2.75	2.32	1.97
Salvia splendens	4.33	5.43	4.05	4.89

The concentration of copper in the irrigation water at each sampling and for each treatment was below the threshold of accuracy of measurement of the technique — in this case 5 mg liter^{-1}. As there was no impact on growth and no visible symptoms observed, it was assumed that the actual level of copper content in the irrigation supply was below that which would cause toxicity.

The effect of the treatments on root growth into the capillary matting is provided in Table 2. While the technique of using a devised, and somewhat subjective, scale to measure the effectiveness of the treatments is less than ideal, the results do provide clear evidence that the treatments of painting the weed mat and pots or simply the weed mat, results in minimal root penetration into the capillary mat. The lowest means indicate the least penetration of roots into the capillary matting underlying the weed mat.

Table 2. Root growth into matting (means of treatments by species).

Species	Neither mat nor pot treated with SpinOut™	Both mat and pot treated	Pots only treated	Mats only treated
Trial 1				
Eucalyptus torquata	4.8	1.0	2.1	1.3
Acacia pendula	4.5	1.1	2.0	1.3
A. iteaphylla	3.8	1.0	1.8	1.0
Callistemon speciosus	3.3	1.0	1.6	1.0
Trial 2				
E. alligatrix	2.5	1.0	1.0	1.0
C. citrinus	3.5	1.0	1.2	1.3
A. pycnantha	3.5	1.0	1.2	1.3
Salvia splendens	4.3	1.0	1.0	1.0

Table 3. Degree of root circling in containers (means of treatments by species).

Species	Neither mat nor pot treated with SpinOut™	Both mat and pot treated	Pots only treated	Mats only treated
Trial 1				
Eucalyptus torquata	5.0	1.3	1.3	5.0
Acacia pendula	5.0	1.3	1.4	5.0
A. iteaphylla	4.9	1.0	1.4	5.0
Callistemon speciosus	4.6	1.1	1.5	4.9
Trial 2				
E. alligatrix	3.3	1.2	1.0	3.3
C. citrinus	4.5	1.0	1.3	4.5
A. pycnantha	4.5	1.0	1.3	4.5
Salvia splendens	5.0	1.0	1.0	5.0

Table 3 provides evidence of the effectiveness of the copper-hydroxide-based root-control treatments in preventing root circling within the container.

The results of the analysis of the growing medium at the conclusion of the growing trial were: control, 56 mg kg^{-1}; both matting and pot treated, 68 mg kg^{-1}; pot only treated, 66 mg kg^{-1}; matting only treated, 103 mg kg^{-1}. Clearly the growing medium, including the control, contains moderate levels of copper. Micromax® — the trace supply used — contains 0.5% Cu in the form of copper sulfate. Total copper levels in soils vary widely, but are usually in the range of 1 to 50 mg kg^{-1} although much of this is unavailable.

DISCUSSION

Mayotte et al. (1996) have shown that "closed" (recirculating) subirrigation systems offer a viable alternative to overhead irrigation. That work provided evidence that these systems would deliver water savings of between 43% to 49%, depending on the system employed and assuming that a system of disinfestation of water was being used. These systems also offer the potential of no leachate-enriched runoff leaving the nursery and polluting groundwater or streams. This work also showed that, at least with some of the test species, statistically significant increases in growth rates could be achieved from subirrigation systems. Other researchers have also found this to occur. Presumably, these enhanced growth rates were achieved by eliminating the water stress which can occur between irrigations when using overhead sprinklers and by minimizing fertilizer loss in the leachate. Also, by eliminating the large losses of nutrients in leachate, fertilizer savings should be possible when using subirrigation systems. Other workers such as Clemens, et al. (1981) have shown this to be possible.

One problem that growers have found when using capillary matting systems is that of root penetration into the matting. At Burnley this has been controlled by the use of copper-treated weed mat over the capillary matting. The current study has shown that the copper treatment of the weed mat or pots treated to control root circling causes no reduction in growth rates. A cautionary note is that these trials took place using a small number of plant species and a relatively short growth period.

The results obtained for the copper concentration of the irrigation water were low [below the limits of accuracy (5 mg $liter^{-1}$) for the measurement technique employed]. When these low concentrations are coupled with the results for the dry mass of plants in both trials, which clearly indicated no adverse impact on growth from the copper treatments, the level of copper appears to be safe for the growing of the species tested in recycling, capillary irrigation systems. Copper ions from the root-control paint appear not to be particularly mobile over the medium term (2 to 3 months) or, if they are released from the paint, they are possibly 'fixed' on cation exchange sites within the growing medium. The moderate concentrations of copper in the growing medium at the conclusion of the trial probably reflect this. Why the matting only treatment was substantially higher than the treatment where both matting and pots were treated is difficult to explain. In any event this copper is clearly not particularly mobile, as evidenced by the content of copper in the irrigation water and had no adverse impact on the growth of the trial crops.

CONCLUSION

The use of a copper-based root-control paint on weed mat in a closed, or recirculating, capillary irrigation system had no adverse effects on the trial plants. Growth rates were not adversely effected and no toxicity symptoms were observed although only a small number of species were used in the trial. The copper does not appear to be particularly mobile and less than 5 mg liter^{-1} of copper was present in the recirculating irrigation water. The treated weed mat was effective at preventing root growth into the capillary matting and the treated pots were effective at preventing root circling in the containers. The treatment of the weed mat appears to overcome the problem of root penetration into the capillary matting while still allowing the use of "closed", or recirculating, subirrigation systems with their inherent benefits.

At this stage the results are encouraging; however, further work is required with a broader range of species over longer growing periods to ensure that the copper treatments do not represent a toxicity problem to crops.

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"Seed Propagation" Question-Answer Period

DAVE HANNINGS: What is the final recommendation for germinating the *Lewisia* cotyledons?

CHRISTIA ROBERTS: You need high-quality seeds. Soak them in 10 mM GA solution for 24 h. Sow them into plugs. Pre-chill them at 0 to 5C for 4 weeks. Germinate them in a greenhouse kept at 15 to 18C and expect 85% germination.

BRUCE BRIGGS: We've noticed that seeds sown in vitro tend to have slower shoot growth than those germinated the conventional way. Have you seen this?

CHRISTIA ROBERTS: I didn't compare outside versus axenic germination. I germinated all my seeds axenically to observe germination without any disease or rotting and I was looking for a consistent source of high-quality explants for tissue culture studies.

MARTIN GRANTHAM: I know that cytokinins can be of use in getting seeds to germinate under suboptimal conditions given that any dormancy had been satisfied and I wondered whether you tried them with the *Meconopsis*.

CHRISTIA ROBERTS: I did not try it. I would stay with the use of gibberellins since the secondary dormancy in *Meconopsis* is a thermodormancy and GA is effective under those conditions.

New and Unusual Plants

Ken Brown
Terra Nova Nurseries, Inc., 12162 SW Scholls Ferry Rd. #126, Tigard, Oregon 97223

Pulmonaria 'Victoria Brooch' PPAF

COMMON NAME: Victorian brooch lungwort

ORIGIN: *Pulmonaria vallarsae* 'Margery Fish' × *P. rubra* 'Barfeld Pink'. The name came from the berry-colored large blooms with ruby-red calyces on the silver background. The clustering and colors give mind to a Victorian brooch.

HARDINESS: U.S.D.A. Zones 4 to 9.

HABIT AND GROWTH RATE: 'Victorian Brooch' produces a low (9 inch) mound of numerous, highly silvered leaves with a unique undulating margin derived from its *P. rubra* heritage. Flowers very early.

ORNAMENTAL FEATURES: 'Victorian Brooch' incorporates the best traits from its parents: From 'Margery Fish', 'Victorian Brooch' inherited silvered leaves and a strong, though compact growing habit; from *P. rubra*, 'Victorian Brooch' inherited a unique flower color not seen before in *Pulmonaria*. Bloom period in Oregon was nearly $2^1/_2$ months long!

CULTURE: Most *Pulmonaria* are drought and shade tolerant. Lusher conditions produce lusher plants and can open the way for mildew problems. Overhead sprinklings should be avoided for most *Pulmonaria*. A compost-enriched soil is beneficial. 'Victorian Brooch' has shown greater mildew resistance than most cultivars, even resisting while in contact with another diseased *Pulmonaria*. While 'Victorian Brooch' can be grown in morning sun in the Pacific Northwest, partial shade is recommended in the rest of the country.

PEST/DISEASE PROBLEMS: All *Pulmonaria* are susceptible to mildew in the right conditions. Plants are somewhat prone to aphids, but are quite resistant to root weevil and spider mite.

LANDSCAPE VALUE: This plant produces fabulous silver accents that are compatible with tall *Hosta* (i.e., *H.* 'Krossa Regal'). Flowers are produced in March. It could be grown in a shady rock garden possibility, along borders, and is drought tolerant. They adapt to large containers as a foliage accent or a foil for spring bulbs.

PROPAGATION: Tissue culture or division. Seed is not an option.

Tiarella 'Cygnet'

COMMON NAME: Cygnet foam flower.

ORIGIN: Much work has been done in the last few years by Don Jacobs of Eco-Gardens, Charles Oliver of The Primrose Path, and Sinclair Adam of Dunvegan Nursery. Our selective crosses of plants from these progressive sources has yielded a fascinating array of seedlings of leaf forms, glossiness, and habit never seen before in this genus. *Tiarella* 'Cygnet' was chosen out of 3000 seedlings for its form, leaf color, and compact growth habit.

HARDINESS: U.S.D.A. Zone 5.

HABIT AND GROWTH RATE: 'Cygnet' was chosen for its remarkable leaf shape, large leaves, and outstanding flowers. It has *T. cordifolia* and *T. wherri* parentage. A small pot will grow to a lush, dense mound 20 in. across in one season. Blush-pink flowers emerge 7 in. above the foliage in early spring.

ORNAMENTAL FEATURES: 'Cygnet' has some of the most unusual foliage we have seen on a *Tiarella*. The leaves are semiglossy and the blush-pink flowers are profuse. Prefers semishade and is quite tolerant of deep shade. Reblooming has been observed, particularly on new growth. Leaf color intensifies in fall.

CULTURE: Tolerant of most soils, but prefers a moist soil rich in humus. Keep away from strong winds.

PEST/DISEASE PROBLEMS: Spider mites affect all Tiarellas in dry, hot situations. 'Cygnet' shows very good mildew resistance.

LANDSCAPE VALUE: Excellent in the shady border. Works well with *Hosta*. Tolerates the deepest shade and handles dry shade well once established.

PROPAGATION: Tissue culture, division, tips.

***Heuchera* 'Ebony and Ivory' PPAF**

COMMON NAME: Ebony and ivory alum root

ORIGIN: [(*Heuchera micrantha* × *H. americana*) × (*H. villosa purpurea*)] × *H. sanguinea* 'June Bride'

HARDINESS: U.S.D.A. Zone 4-9.

HABIT AND GROWTH RATE: Growth is vigorous and mounding. It does not go woody as some. Spreads slowly to an 18-in.-wide mound. Masses of significant creamy bloomscapes appear in June through July. Flower stalks can go as tall as 20 in. and are profuse.

ORNAMENTAL FEATURES: This *Heuchera* is unique in having extremely dark, ruffled leaves in spring. Flowers are large and ivory colored and produced in profusion. Foliage is evergreen in milder climates. Great in full sun.

CULTURE: The *H. americana* breeding has produced a plant that is shade tolerant, humidity tolerant, and mildew-resistant. Prefers a well-drained soil with a moderate amount of compost.

PEST/DISEASE PROBLEMS: As with all *Heuchera*, vine weevil is a problem but it is mildew resistant. It seems very resistant to spider mite and white fly.

LANDSCAPE VALUE: Excellent for borders or rock gardens or crevices. Foliage stays remarkably neat all season with the spring coloration of the emerging leaves producing quite a show. Try with gold foliage, dwarf feathery astilbes, and ferns.

PROPAGATION: Tissue culture, division. Seed is extremely variable and progeny should not be listed under this clonal name.

Martin Grantham
UC Botanical Garden, 200 Centennial Drive #5045, Berkeley, CA 94720-5045

Hydrangea peruviana

Hydrangea peruviana × *H. serratifolia*

Hydrangea asterolasia

Sven Svenson and Robert Ticknor
Oregon State University, 15210 N.E. Miley Road, Aurora, OR 97002-9543

Daphne caucasica 'Summer Ice'

Wilbert G. Ronald
Jeffries Nurseries Ltd., P.O. Box 403, Portage la Prairie, Manitoba R1N 3B7 Canada

Today I wish to speak about three new plants that hold promise for the nursery industry.

***Potentilla fruticosa* 'Pink Beauty'**

This new potentilla results from over 20 years of breeding work at the University of Manitoba. This woody flowering shrub bears clear pink semidouble flowers from early spring until frost. It is a vigorous plant growing to 3 ft in height, with healthy dark green foliage. It propagates readily from softwood cuttings. Propagation is licensed under Canadian Plant Breeders Rights Cert. #0174, U.S. Plant Patent and European Plant Breeders Rights. The U.S. Agent is Baileys Nurseries Inc. while SNP is our European agent.

***Tilia mongolica* 'Harvest Gold'**

A selection of Mongolian linden with exceptional golden fall foliage and a ascending crown form. It has a sturdy trunk, healthy disease-free foliage and hardiness to northern zones. It is propagated by budding to seedlings of *Tilia cordata* which is the rootstock of choice for most lindens.

***Fraxinus americana* 'Northern Blaze'**

This white ash seedling has wintered in northern zones where white ash has traditionally failed. Trees are strong growing with dark green summer foliage and fall golden brown leaves. Plants are budded on seedlings of *F. pennsylvanica,* (green ash).

These three new cultivars represent real improvement over anything previously available in these species. Contact Jeffries Nurseries Ltd., Box 402, Portage la Prairie, MB. R1 N 3B7, Canada for further information.

Bruce Macdonald
University of British Columbia, Botanical Garden, 6804 Southwest Marine Drive, Vancouver, BC V6T 1W5 Canada

Lonicera 'Mandarin'

Clematis chiisanesis 'Lemon Bells'

Clematis koreana var. *fragrans*

Large-Scale Production of *Osteospermum*: Ten Years of Development Effort

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INTRODUCTION

In 1980 we began to grow *Osteospermum* using a pink and a white cultivar obtained from another nursery where they had been grown without success. Our production was until 1985 based on these two cultivars. During this time we often had a large percentage of dead plants during the propagation and production phases. Propagation occurred by cuttings which were planted directly in the sales pot with one cutting per pot. After approximately 14 days the cuttings had formed roots and the acclimatization could be started. A weak root system, especially in the pink cultivar, resulted in sales problems and we had many complaints. Despite warnings from the sales organization we considered, however, that *Osteospermum* had the potential to become a success.

In 1985 we collected the cultivars available in English nurseries and gardens in order to test their production potentials. These plants were of very variable quality and became the basis of our first breeding attempts. These were made in 1986 and we observed a relatively large variation in the offspring. Two years later we realized the potential of these crossings, as the mortality was much less than in the old cultivars. We have since 1990 in cooperation with Linda Noack, Team Grow-how, had an intensive breeding program within *Osteospermum*. At the same time we have improved production methods.

Today we have 10 to 12 cultivars which are all protected by plant breeders rights within EU. They all have the trademark SUNNY, and they are the result of 10 years breeding work. Three years ago we started a new chapter in the production of *Osteospermum* by getting all cultivars tested and freed for specific diseases. We have now approximately 30 cultivars approved in the AAE system (classmark used only for propagation material from an approved elite plant station) located at Dan-Elite in Snoghøj, Denmark. The work is done with skill by Dan-Elite and we feel well prepared for future demands to propagation material.

PROPAGATION SCHEDULE

First, I will briefly describe a production season with build up of stock plants and propagation by cuttings. During August and September we obtain elite cuttings from Dan Elite for our stock plants. Cuttings are treated with Floramon A and rooted in 40-mm peat blocks which we make ourselves. After sticking, cuttings are sprayed with *Verticillium lecanii* for biological control of white flies and are covered with plastic. Temperature during root formation is 19 to 20C and ventilation is given at 22C. During root formation 360 cuttings per m^2 are planted.

Roots are formed within 10 to 14 days and acclimatization starts. We are very careful during this phase and start with only very small punctures in the plastic. During the next 4 to 6 days punctures are increased gradually whereafter the plastic is removed. After a further 12 to 14 days the plants are pinched to 4 to 6 leaves, and they are then ready for potting in 13-cm pots. Temperature is still kept at 19 to 20C to keep the plants in a vegetative growth stage. Stock plants are grown at a density of approximately 30 m^{-2}, and they are trimmed weekly until we start harvesting cuttings. The stock plants have to be trimmed as we do not want very large cuttings and further the leaves should not be too large. After taking cuttings, 3 to 4 leaves should be left on the shoot so 2 to 3 new shoots can develop on the stock plant.

CUTTING QUALITY AND HANDLING OF CUTTINGS

1) A cutting has 3 to 4 fully developed leaves and a strong stem with short internodes, so new shoots can develop as near to the soil surface as possible after the plants have been pinched. In this way the end product becomes as compact as possible.

2) Cuttings are placed in boxes at approximately 5C until delivered to nurseries.

3) Cuttings of *Osteospermum* can, depending on cultivar, be stored at 5C for 14 days without any increase in mortality.

Plantlets for sale and for our own production are rooted in 40-mm, Ellegaard peat pots. Stock plants are treated with Cycocel in order to continuously be able to harvest strong compact cuttings. *Osteospermum* needs relatively large amounts of growth retardants during the growing period. Growth retardation starts immediately after pinching by watering with Cycocel.

FINAL COMMENTS

Much emphasis in our breeding work has been on cultivars giving few problems during production, i.e., cultivars that can be produced on a large scale. Production of cuttings and plantlets in Denmark is restricted to a few nurseries which work on a contract basis. In addition, only a few nurseries are allowed to produce end-products. This gives a stable and high quality production of cuttings and plantlets. All stock plants are renewed each year by cuttings from Dan-Elite and the number of units produced is controlled by Gasa Plant License International (GPL International). The production of AA cuttings (classmark for plants originating from AAE material and grown under strict control) in Denmark is restricted to three nurseries, which, since 1997, have been approved for AA production. Our results show that *Osteospermum* SUNNY™ can be produced on a large scale.

Leaf Abscission of Cuttings

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INTRODUCTION

Leaves supply cuttings with necessary carbohydrates for the life processes. Leaves are also important for supplying the cuttings with hormones needed for root formation. Leaf abscission or leaf drop will, therefore, make it difficult for cuttings to undergo changes necessary for the development of a new root system. It is, therefore, of great interest to obtain increased knowledge of factors which may initiate unwanted leaf drop.

Leaf drop which occurs in the fall is initiated by a decreased flow of auxin out of the leaf. The decreased auxin level initiates synthesis of ethylene in the nodal region, and this ethylene activates enzymes that degrades the cell wall at the base of the petiole and subsequent leaf drop. The increased ethylene level also initiates senescence of the leaf which enables the plant to mobilize all the nutrients present in the leaf before the leaf falls off. The validity of this has been shown, not only by measurements of auxin and ethylene during leaf abscission, but also by the use of transgenic plants that are unable to synthesize ethylene. When ethylene synthesis is prevented, senescence and leaf drop occurs at a much slower rate than normally observed (Isaac et al., 1995). It can, therefore, be concluded that ethylene is the hormone that is most important for initiation of leaf drop.

Cuttings are taken from plants in good growth. We would, therefore, not expect either auxin production to decrease nor ethylene synthesis to be initiated. However, several environmental factors additionally influence ethylene synthesis. Because ethylene is not only a ripening and senescence hormone, but also a stress hormone, any treatment that will cause stress may also initiate ethylene synthesis. We know (Veierskov et al., 1982) that carbohydrates accumulate in cuttings to very high levels and high levels of carbohydrates in leaves have been suggested to accumulate as starch whereafter the chloroplasts begin to malfunction and photooxidative stress occurs. This process can be counteracted by high levels of soluble carbohydrates which can down regulate the rate of photosynthesis and make production and demand meet (Foyer, 1998).

MATERIALS AND METHODS

We designed an experiment with two cultivars of *Hibiscus rosa-sinensis* — an easy-to-root cultivar, Holiday, with no tendency for leaf drop, and a difficult-to-root cultivar, Cardinal, that has problems with leaf drop during root formation. The aim of the work was to see if the known carbohydrate accumulation in the cuttings was caused by an inability to down regulate photosynthesis, and if unwanted leaf drop occurred because of this. The cuttings were rooted under greenhouse conditions at midsummer. During the 30-day rooting period samples were taken for carbohydrate determinations and measurements of photosynthesis.

RESULTS

The photosynthesis rates of the cuttings responded immediately to the rooting condition. In both cultivars photosynthesis decreased to about 20% of the level observed in similar leaves on intact plants (Fig 1) However, the level of soluble carbohydrates increased 250% to 500% during the first 10 days of rooting (Fig. 2). The initial level was three times higher in the easy-to-root cultivar compared to the difficult-to-root cultivar (Fig 2). The level of carbohydrates tended to decrease when roots began to emerge (Day 15 to Day 20 in 'Holiday', Day 20 to Day 25 in 'Cardinal').

DISCUSSION

When cuttings are rooted in a high light environment during midsummer a dramatic down regulation of photosynthesis is observed. Several explanations exist for this down regulation The cutting has lost its root system which supplies the tissue with water and hormones important for normal stomata function However, in this experiment there was no indication of the cuttings being water stressed Another explanation is that there is no longer a sink for the produced carbohydrates because cutting growth ceases. The photosynthetic apparatus responds to this by the observed down regulation (Fig. 1) It is notable that this down regulation occurs during the first 3 days in both cultivars even though carbohydrate accumulation during this period only occurs in the easy-to-root cultivar (Fig 2) We, therefore, conclude that the observed down regulation of photosynthesis is not regulated by carbohydrate accumulation

Although it was not possible to cause leaf abscission in the difficult-to-root cultivar, it is notable that this cultivar had a much lower level of soluble carbohydrates in the leaves of intact plants, and a five-times accumulation occurred during the rooting period It is our belief that this high level of carbohydrate accumulation can stress the photosynthetic apparatus, induce ethylene formation, and be the cause of leaf abscission

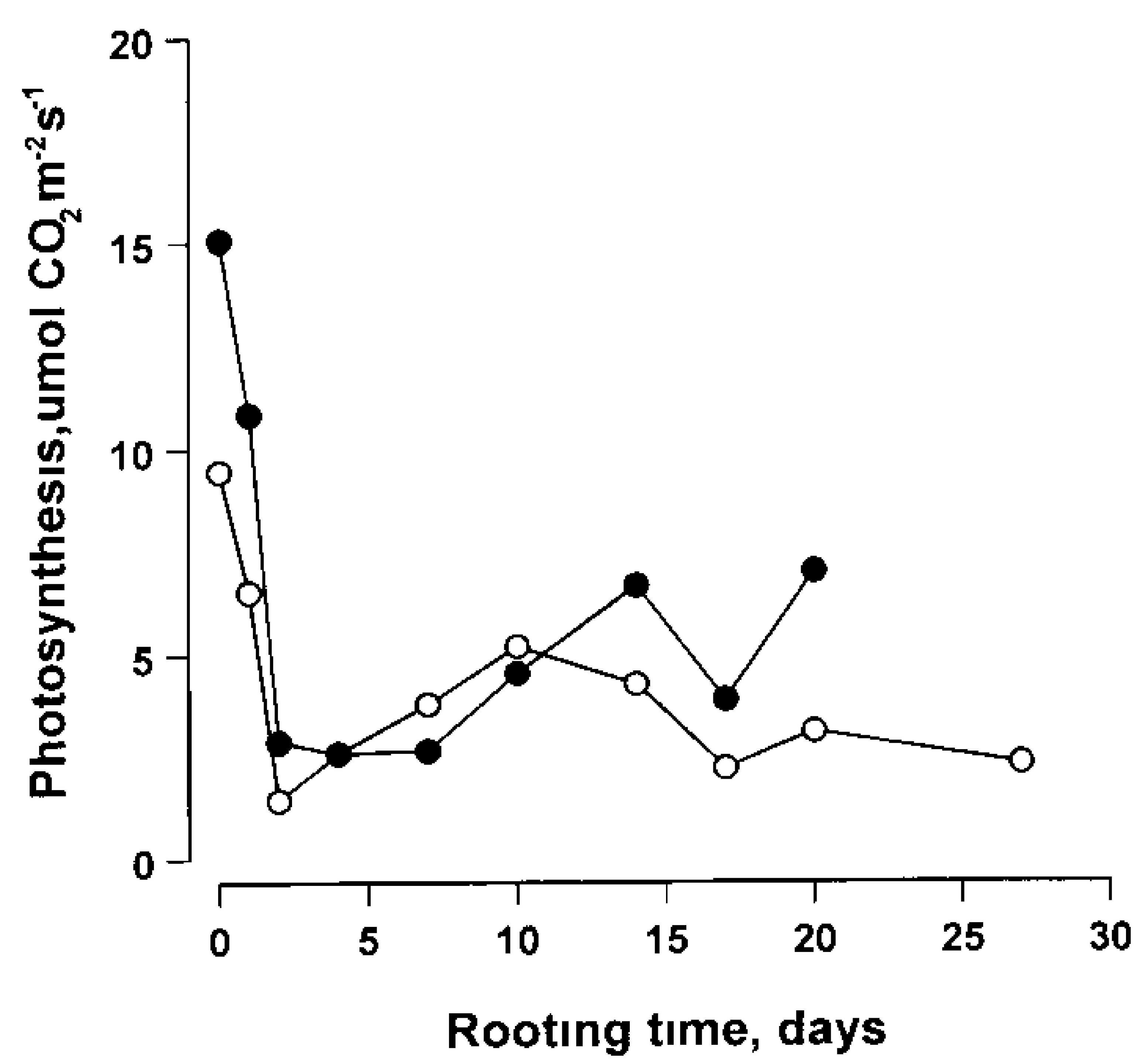

Figure 1. Photosynthetic CO_2 uptake in cuttings of *Hibiscus rosa-sinensis* during the rooting period Closed circles represent 'Holiday', an easy-to-root cultivar, open circles represent 'Cardinal', a difficult-to-root cultivar.

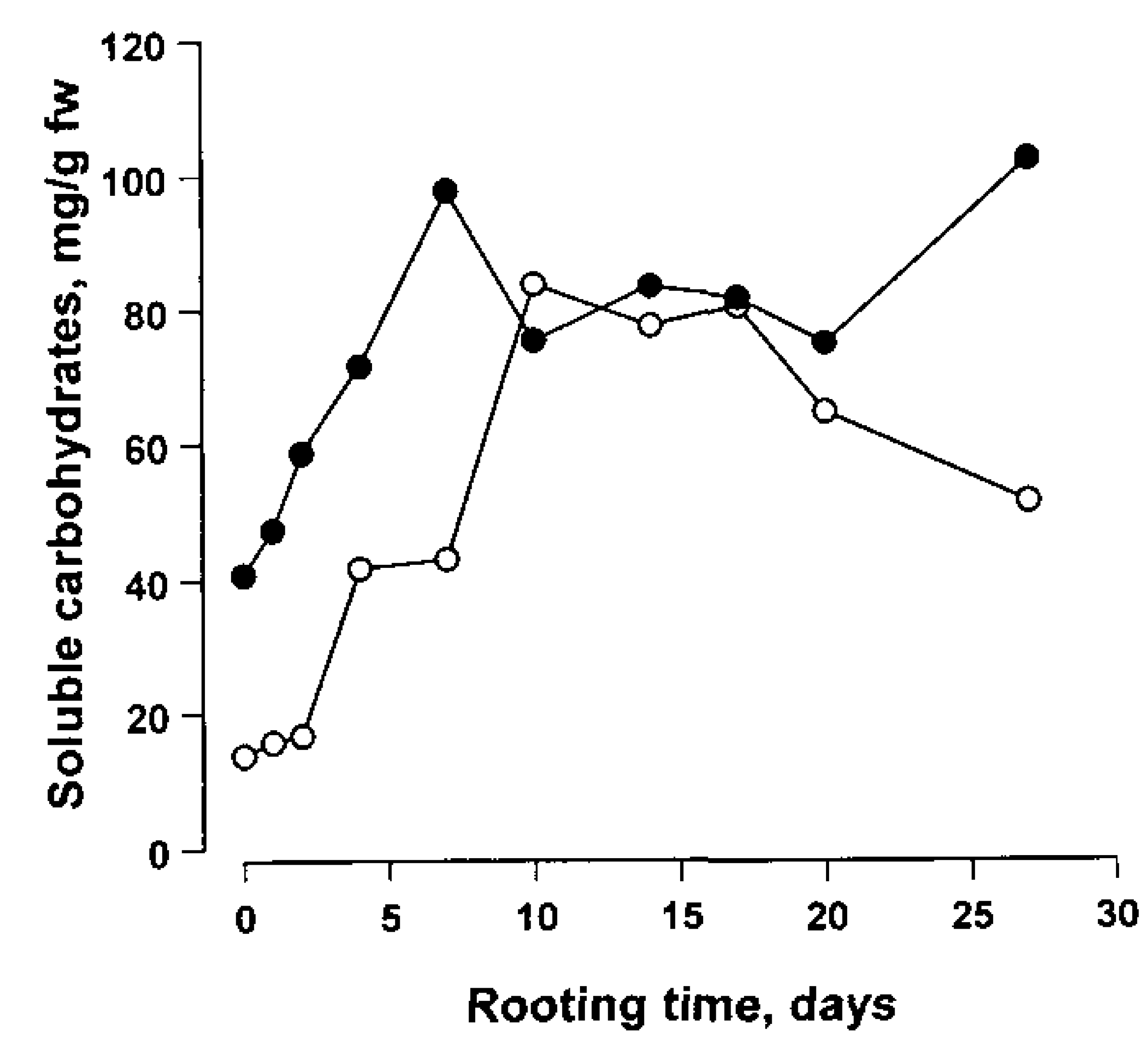

Figure 2. The level of soluble carbohydrates in cuttings of*Hibiscus rosa-sinensis* during the rooting period. Closed circles represent 'Holiday', an easy-to-root cultivar, open circles represent 'Cardinal', a difficult-to-root cultivar.

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Relationships between Stockplant Management and Rooting Environments for Difficult-to-Propagate Cuttings

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Syringa vulgaris **'Madame Lemoine' is difficult to root from leafy softwood cuttings and, at best, can be propagated during a brief period in early summer just before the end of rapid shoot growth. Stockplants must be pruned severely during the previous late winter, and growing shoots in the dark for 2 weeks after budburst improves subsequent rooting compared to normal light-grown cuttings, by reducing stem thickness without reducing leaf area. This treatment appears to increase the carbohydrates available for rooting by reducing the amount needed for stem respiration. The environmental requirements for rooting these cuttings, which are of the same cultivar but differ in their rooting potential, were investigated by setting up gradients of light and wetting perpendicular to one another to give 16 combinations. Dark-preconditioned cuttings in high light had the highest survival rate when wetting was sufficiently generous to prevent wilting. In heavy shade they rotted in greater numbers, and more extensively, than other cuttings. Survival rates determined rooting, with the highest rooting levels produced by dark-preconditioned cuttings in the high light/high wetting zones, and least rooting when they were propagated at the lowest light level. Normal, light-grown cuttings failed to exploit the high light conditions as well as the dark-preconditioned ones, but they survived and rooted relatively better in the low light conditions. There is a general benefit from selecting relatively thin-stemmed cuttings of difficult-to-propagate taxa from any source and rooting them in 20% to 25% available light with generous wetting.**

INTRODUCTION

There are commercially important ornamental shrubs for which there are no reliable methods of summer propagation by leafy softwood cuttings. For example, the double, white-flowered, French-hybrid lilac cultivar *Syringa vulgaris* 'Madame Lemoine' is grafted normally onto rootstocks of the common lilac. This combination produces numerous suckers from its roots which can eventually out-grow the cultivar. These suckers must be removed regularly to prevent the bush reverting to the common type, a problem that would be avoided if the selected cultivar could be rooted by cuttings and grown on its own roots.

Plants such as 'Madame Lemoine' are used as models in a combined physiological, biochemical, and molecular biology programme at HRI-East Malling aimed at understanding the processes which control adventitious rooting in difficult-to-propagate plants. This paper describes the importance of correct stockplant management for producing ready-rooting cuttings of *S. vulgaris* 'Madame Lemoine', and how the optimal balance of light and leaf wetting in the propagation environment is determined by the way cuttings were produced on the stockplant.

[1] Retired 31 Jan. 1997.

MATERIALS AND METHODS

Experiments took place between 1989 and 1995. General conditions are described here, with any changes required in particular experiments described with the relevant results.

Stockplants and Dark-preconditioning Treatments. Well-established hedges of *S. vulgaris* 'Madame Lemoine' were pruned during early March of each year to leave approximately 10 cm of the previous annual growth. As shoots began to grow in early May, they were either left to develop normally (light-grown) or the stockplants were covered with ventilated structures of opaque black polyethylene supported on metal frames (dark-preconditioned). After approximately 2 weeks strips of the black polyethylene cover were removed so that chlorophyll developed in the shoots. As a guide, no more than 50% of the roof area was removed in particularly sunny weather so as to avoid scorching. For further details see Howard and Ridout (1992).

Collection and Preparation of Cuttings. Shoots were collected in early June at about 8:00 AM, taken to a cool humid room, and sprayed with water at intervals during cutting preparation. Distal cuttings were prepared to a mean length of 20 cm with leaves removed from the proximal node, and with at least one pair of fully expanded leaves above. The stem base was treated with 1.25 g liter^{-1} indolylbutyric acid (1250 ppm IBA) dissolved in 50% (v/v) aqueous acetone for 5 sec to a depth of 8 mm and the distal leafy part was dipped in an aqueous suspension of 2 g liter^{-1} benomyl.

Rooting Environment. Cuttings were inserted to a depth of approximately 7 cm in a rooting medium consisting of sphagnum peat and finely granulated pine-bark (1 : 1, v/v), held in square plastic pots set down on a bed of fine sand to facilitate rapid drainage.

Rooting took place in one of two facilities and was assessed after approximately 4 weeks. Normally, cuttings were propagated at 20C bottom heat in a polythene house with air temperature partially controlled by shading to give approximately 20% available light in conjunction with forced ventilation operated at 27.5C. A fan-distributed "wet fog" (Agritech) system in the polythene house was controlled by an evapostat with timer back-up. This wet-fog system also always operated during periods of forced ventilation to ensure that leaves were constantly wet and that the air was visibly foggy during daylight hours (fog house).

A controlled propagation environment (CPE) was constructed by erecting a transparent polyethylene (50 µm) enclosure supported on a metal framework in a temperature-controlled room. A row of high pressure sodium lights (Philips 400 W SON-T SGR 104-400) was installed above and along one edge of the structure, which, together with a vertical reflector of black/white sandwich polyethylene hung inside the structure, produced a light gradient across the propagation bed. A wetting gradient perpendicular to the light gradient was achieved by placing a pneumatic fogging nozzle (Type 052 Sonicore) at one end of the structure, with the frequency of fogging controlled by timer to give 25 sec on and 75 sec off during the 12-h light period.

For experimental purposes each gradient was subdivided into four levels, thereby creating different combinations of light and wetting. The mean levels of photosynthetic photon flux density along the light gradient at cutting level were 289, 154, 28, and 17 µmol m^{-2} s^{-1} during a 12-h photoperiod, and the mean water depositions along the wetting gradient were 209, 103, 39, and 13 µm h^{-1}. These conditions reflected well the range of light and wetting in the fog house, except that the lower light levels were more extreme than those measured during dull weather and reflected also conditions at dawn and dusk. Additional details are given by Howard and Harrison-Murray (1995) and further developments of the CPE concept to produce "environmental fingerprints" for cuttings are described by Dr. Harrison-Murray in the Region of Great Britain and Ireland section of this volume.

RESULTS

Stockplant Conditions.

Pruning Severity and Apex Removal. A reduction in the severity of annual winter pruning to leave approximately 30 cm, instead of 10 cm, of the previous year's growth reduced the highest level of rooting obtained during the following summer from 78% to 17%. Removal of the shoot apex, either 2 weeks before collecting the cuttings or at the time of cutting collection, had no significant effect on percentage rooting, but halved the numbers of roots produced per cutting from a mean of 6.9 to 3.4 (mean of apex removal on both occasions). Shoot apices begin to abort naturally during the later stages of propagation.

Shoot Condition and Season of Cutting Collection. High levels of rooting were confined to cuttings collected during early June, when up to 80% success was obtained just prior to the cessation of shoot extension. By July, cuttings had become heavily lignified and rooting fell to below 20%. This brief period of optimal rooting was determined by the condition of the stem tissue. Similar seasonal trends in rooting were obtained in the variable conditions of the fog and in stable CPE conditions. Delaying shoot growth by holding dormant container-grown plants in cold-store for a month at 2C produced a peak in rooting similar to that in cuttings from normal stockplants grown in the field, but delayed by 1 month. For further information see Howard (1996).

Effects of Dark-preconditioning on the Ratio of Cutting Leaf Area to Stem Weight, and Rooting. The main effect of growing shoots in the dark for 2 weeks before weaning into approximately 50% light for a further 2 weeks before cutting collection, was to increase significantly the ratio of leaf area : stem weight (or thickness) and rooting, compared to normal light-grown cuttings. The relationship between the leaf area : stem fresh weight ratio and rooting could be predicted from a log-linear model (Table 1).

Dark-preconditioning reduced the leaf area : stem weight ratio by causing a reduction in the dry matter content and the thickness of the stem without reducing leaf number or area. These cuttings photosynthesised at similar rates to normal light-grown ones (results not shown), but the respirational demands of the smaller stems of the dark-preconditioned cuttings were less; it was concluded that more carbohydrates were available to support rooting.

By separating cuttings into different size grades before rooting, it was shown that relatively small, thin-stemmed cuttings rooted best, irrespective of their source, and that the model had general application beyond the effects induced by dark-preconditioning.

Table 1. Experimentally observed rooting percentages and root numbers per rooted cutting compared to those predicted by a log-linear model incorporating area and numbers of leaves, and stem fresh weight (stem diameter gave virtually identical results)

	Light-grown		Dark-preconditioned	
	Observed	Predicted	Observed	Predicted
Rooting (%)	16	14	74	68
Root numbers per rooted cutting	5 3	7 9	26 1	18 5

Responses of Light-grown and Dark-preconditioned Cuttings to Light and Wetness Gradients During Propagation. On the 10th day, just prior to root emergence, measurements of the dry weight of the basal 35 mm of stem (rooting zone) were compared with those taken at the start of the experiment The largest gains in dry matter occurred in the dark-preconditioned cuttings in the high light/heavy wetting zones, with much smaller dry matter gains in the normal light-grown cuttings. Gains in dry matter were smaller in the high light/low wetting zones, where cuttings were stressed severely. All cuttings at the two lowest light levels, irrespective of wetness, lost dry matter during the first 10 days, and, at the lowest light level, this was more severe in the dark-preconditioned cuttings. Under the most favourable conditions the proximal 35 mm of stem in the dark-preconditioned cuttings showed an increase of approximately 40% in dry matter, while in the least favourable conditions they showed a loss of the same magnitude

Basal rotting was evident in some light-grown cuttings in most environments. Among the dark-preconditioned cuttings this was less serious or absent in high light, but was more frequent and more extensive in low light The combination of high light and low wetting caused both types of cuttings to wilt permanently, despite the rooting medium being watered directly

The extent to which cuttings survived in the different environments determined the frequency of rooting. Dark-preconditioned cuttings, which neither rotted nor wilted in the high light/heavy wetting zones, rooted in the largest numbers; no cuttings from either source rooted in the high light/low wetting zones where serious wilting occurred

The frequency of rooting decreased generally as light levels decreased, but light-grown cuttings performed slightly better than dark-preconditioned ones at the lowest light level, reflecting the high levels of rotting in the latter. No rooting occurred in cuttings from either source in the lowest light/heaviest wetting zone Rooting responses are shown in Figure 1.

DISCUSSION

The use of well-established, field-grown stockplants is particularly important in subjects where rooting occurs for only a brief period, because the numbers of cuttings which root readily can be maximised by severe winter pruning and, if desired, by

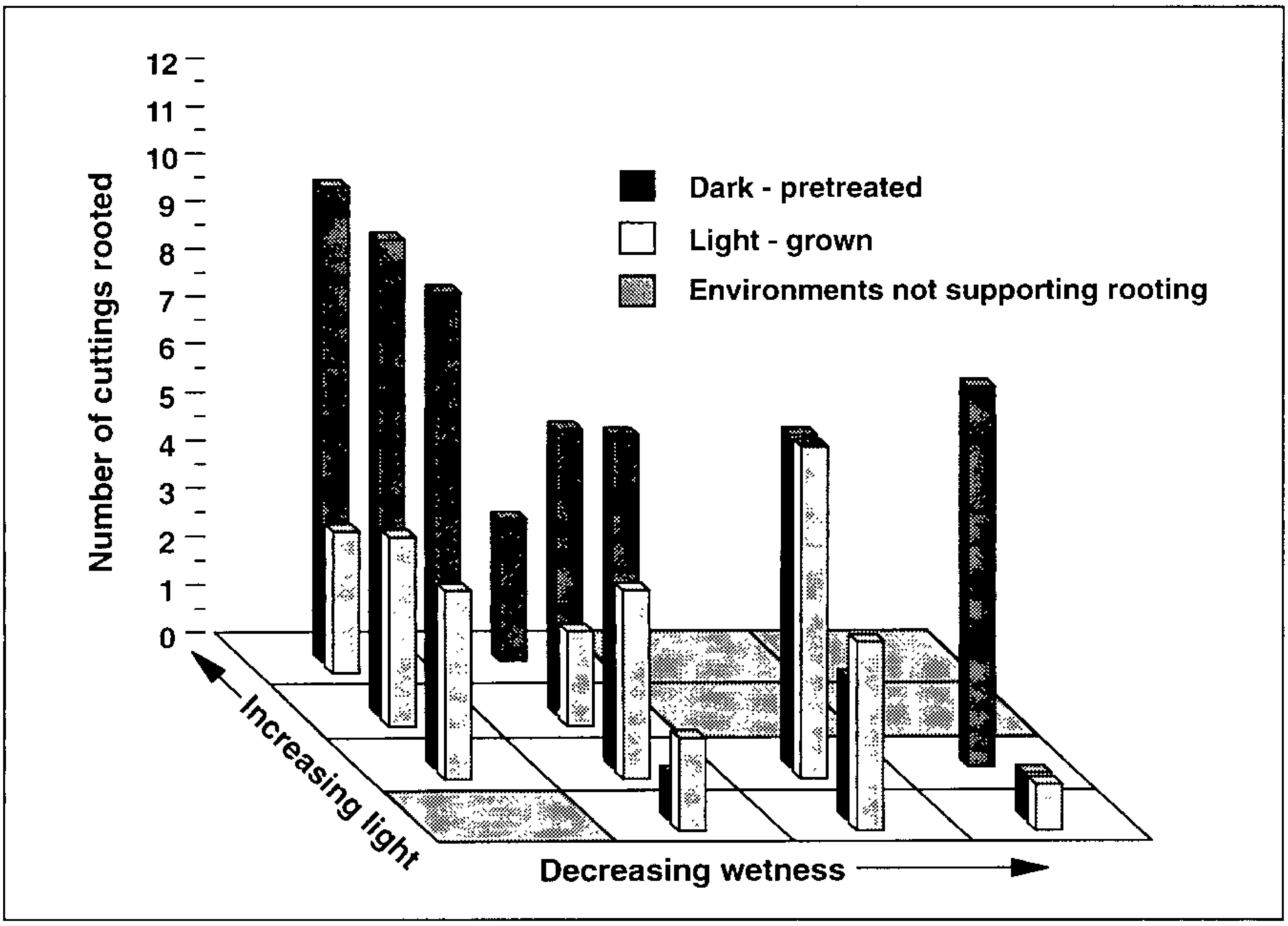

Figure 1. Numbers of rooted cuttings out of 12 from dark-preconditioned and light-grown sources when propagated in different combinations of light and wetness.

dark-preconditioning. Shoots from container-grown plants rooted equally well to those from the field, but cutting production per stockplant was much lower.

It is not necessary to retain the shoot apex which can, therefore, be pinched out to encourage lateral production. The timing of collecting cuttings is critical and they must be propagated during the later stages of rapid shoot extension. Delaying propagation beyond early June in south-east England, or preparing cuttings at a relatively old (proximal) node, will result in little or no rooting.

The advantage of dark preconditioning appears to be an increase in leaf area : stem mass ratio, effectively maintaining similar photosynthetic ability, but with reduced respirational demand, compared to thicker-stemmed light-grown cuttings. Under suitable environmental conditions dark-preconditioned cuttings accumulated more carbohydrate (measured as dry matter increase) in the rooting zone of the stem. This reduced the frequency and extent of rotting and increased rooting compared to normal light-grown cuttings. These experiments showed also that there is general advantage when propagating difficult-to-root subjects in selecting relatively thin-stemmed cuttings.

These difficult-to-root cuttings showed a remarkable ability to root over a wide range of rooting environments, as long as the balance of light and wetting was correct. At high light, wetting had to be heavy to avoid wilting and, at low light, wetting had to be minimal so as not to exacerbate rotting. These combinations are the opposite to those often found in commercial practice where high light is often accompanied by relatively dry conditions, and heavy shade with relatively wet conditions — circumstances which gave no rooting in these experiments.

Acknowledgements. This work was funded by the Ministry of Agriculture, Fisheries, and Food. Figure 1 is reprinted by permission of the Journal of Horticultural Science and Biotechnology.

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Bud-Grafting Difficult Field-Grown Trees

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Despite the widespread use of chip-budding, which enables faster and more complete union formation between rootstock and scion compared to traditional T-budding, there are various ornamental trees for which bud-take in the field remains unreliable and inconsistent among years and in different nurseries. Generally, the chance of success was increased by completing budding by early August, and by ensuring that rootstocks were growing vigorously during the budding period to ensure maximum cambial activity. Chip-buds of *Acer platanoides* 'Crimson King' are prone to dying before unions have formed, and experiments suggested that a root-derived factor is important in maintaining the viability of the scion during the slow union-forming process. Bud-take was correlated closely with the extent of root growth, and was depressed severely if root growth was restricted. It was necessary to avoid physical damage to the large buds of *Betula pendula* 'Dalecarlica' which was caused by pressure from the rootstock stem as it swelled within the budding tie. Degradable rubber ties which did not cover the actual bud were preferred. On the other hand, the use of polyethylene tape to cover the small buds of *Robinia pseudoacacia* 'Frisia' provided adequate pressure to ensure the differentiation of tissues in the rapidly developing callus, which otherwise enveloped the scion-chip without forming a union.

INTRODUCTION

A high percentage bud-take and the production of good stands of uniform trees are essential for commercial success when raising ornamental trees in the field. This is mainly because most production costs — such as those associated with the preparation of land; the purchase, planting, and maintenance of rootstocks; the production of scionwood; and the budding operation itself — are incurred irrespective of success rate and the proportion of first-grade trees harvested.

If nursery operators cannot understand how to achieve consistently good results with a particular subject, their inclination is to bud more rootstocks in the hope of achieving adequate numbers of trees. This makes the process increasingly cost ineffective. It is much more cost-effective, and hence profitable, to improve techniques and management so that higher yields are obtained from less work. During the 1970s the widely used T- or shield-budding technique was shown to be anatomically less efficient than chip-budding, which provided close cambial contact between rootstock and scion, resulting in rapid union formation. The use of chip-budding resulted in stands of fruit trees with greater uniformity and higher quality, compared to those from T-budding (Howard et al., 1974). The anatomical superiority associated with chip budding was confirmed subsequently for a range of ornamental trees (Skene et al., 1983).

[1] Retired 31 Jan. 1997.

Despite this technical progress, there are ornamental trees which remain difficult to produce because bud-take is inconsistent between years and between nurseries. Three species in particular were investigated at HRI-East Malling, *Acer platanoides*, *Betula pendula*, and *Robinia pseudoacacia*. This paper summarises the main reasons for unreliable bud-take in the context of their particular characteristics.

MATERIALS AND METHODS

General experimental conditions are described here, with those specific to particular experiments referred to when describing the results.

Rootstocks and Planting Conditions. One-year-old rootstocks of *A. platanoides*, *B. pendula*, and *R. pseudoacacia* were obtained from a commercial source and held in a jacketed cold store at 2C until planted into a well-drained sandy loam soil that had been fumigated the previous autumn with chloropicrin. Spacing was at 40 cm in the row, with varying distances between rows to reflect plant vigour. Trickle irrigation was applied as required.

Scionwood and Budding. *Acer platanoides* 'Crimson King', *B. pendula* 'Dalecarlica', and *R. pseudoacacia* 'Frisia' scions were obtained from severely winter-pruned stockplants, with the leaf removed at collection to leave a short section of petiole. Budsticks were kept cool and moist at all times by wrapping them in damp hessian and were usually used within 8 h of collection.

Budding was by the chip method (Howard, 1974) at a height of 15 cm. The bud was held in place with a 25-mm-wide strip of either transparent polyethylene or degradable rubber, as indicated in particular experiments. Bud-take was assessed at the time of releasing the ties, again the following spring, and finally in relation to the number of trees harvested, which are the data referred to in this paper.

Relevant Characteristics of the Rootstock-scion Combinations.

***Acer platanoides* 'Crimson King'.** Union formation is relatively slow, with budding ties needing to be retained for 6 weeks, which is 2 weeks longer than for other species. Low bud-take appears to be associated with the inability of the scion-chip to survive and, often when ties are removed even after 6 weeks, the chip is found to have produced little or no callus and to detach easily from the rootstock; frequently the scion-chip is stained black with a water-soaked appearance. In contrast, copious callus is produced from the exposed cambial region of the rootstock stem.

Earlier work showed that inconsistencies among years were not weather-related but were associated with the field in which the budding was done (Howard, 1993); the experiments described for *A. platanoides* focused particularly on possible field-related factors.

***Betula pendula* 'Dalecarlica'.** Scion shoots on the budwood trees grow rapidly but the lower axillary buds develop into laterals, leaving only distal buds available for budding. These are large, prominent and soft, and often they fail to grow in the spring following budding despite the bud-chip appearing to have formed a union. Rootstocks often stop growing early in summer if the weather is dry or cool, or if they are damaged by residual herbicides. Experiments with *B. pendula* focused on the apparent need to bud rootstocks while still growing rapidly, and the need to avoid physically damaging the bud.

***Robinia pseudoacacia* 'Frisia'**. Rootstocks grow rapidly and are often excessively thick when budded. Polyethylene budding tape constricted the stems sometimes so that they would break during strong winds. This led to the routine use of degradable rubber ties, but high levels of bud-take were rarely achieved under these conditions, and experiments with *R. pseudoacacia* focused on whether the use of rubber ties was appropriate.

RESULTS

Acer platanoides 'Crimson King'.

Root Activity. Bud-take was compared for rootstocks grown in 2.0-litre pots, in the field, and in 75-cm-deep sand beds. Over a number of years major and consistent differences were obtained, with typical bud-takes of 33%, 77%, and 100% for pot, field, and sand bed, respectively.

The poor results for pot-grown rootstocks were obtained irrespective of large differences in shoot growth caused by growing under polythene or outside, and the consistently high bud-take in the sand beds was obtained irrespective of large natural variations in rootstock vigour.

Detailed measurements of root systems showed that the mean length per plant of structural roots for pot-, field-, and sand-bed-grown rootstocks was 420, 575, and 1260 cm respectively; examples are shown in Fig. 1.

The importance of root growth was confirmed when bud-take was increased on average from 20% to 53% when pot size was increased from 2.0 to 7.5 litres. Conversely, in the field bud-take was reduced from 79% to 13% by enclosing root systems in porous mesh bags at planting. The chance of bud failure was less where roots had escaped from the neck of the mesh bags.

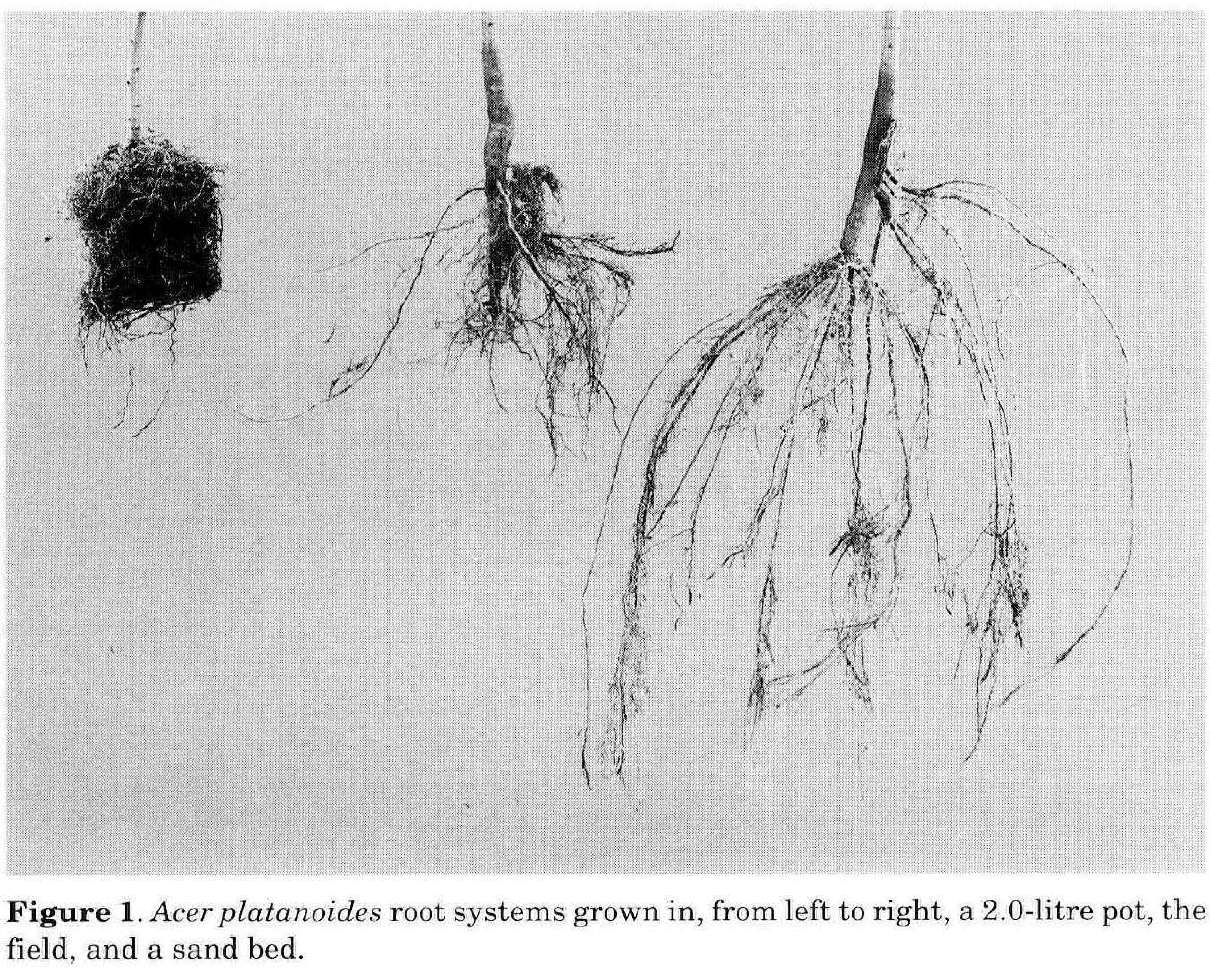

Figure 1. *Acer platanoides* root systems grown in, from left to right, a 2.0-litre pot, the field, and a sand bed.

Timing of Budding. Delaying budding from 2 Aug. to 23 Aug. decreased bud-take significantly from 83% to 52%.

Factors found to be Unimportant. The size of rootstock at planting (within the approximate 5- to 10-mm diameter range) had no effect on subsequent bud take. Various treatments aimed at altering the water status of the rootstock were also ineffective and, contrary to the view held by nurserymen, the considerable bleeding of xylem sap from the cut stem for 1 or 2 weeks following budding was not associated with budding failure. There was little influence from obtaining scion shoots from trees grown by various methods in pots and in the field, and neither was there an influence of the position of the bud on the budstick.

***Betula pendula* 'Dalecarlica'.**

Rootstock Growth and Budding Dates. In *B. pendula* 'Dalecarlica' many of the first-formed buds develop into laterals. Consequently there is a tendency to delay budding until late August or early September. Although this proved very successful in some years it cannot be relied upon because, in dry or cool summers, or where damage occurred from residual herbicides, rootstock growth, and hence cambial activity, decreased rapidly and bud-take was reduced.

Budding on 2 Aug. and 6 Sept. was compared for rootstocks planted on 1 March or 16 May. Late planting, aimed at prolonging rootstock growth into late summer, proved feasible as long as rootstocks had been maintained in good condition in a jacketed cold store and were established with the benefit of irrigation if required. Early budding and late planting combined to give the maximum rate of stem swelling (cambial activity) at the time of budding. Budding in early August gave 82% bud-take, irrespective of when rootstocks were planted, but there was a benefit of late planting for September budding, which improved bud-take from 23% to 47% compared to normal early planting. Bud-take was reduced significantly also by reducing severely the number of shoots growing on the rootstock prior to budding; this is linked closely to a reduction in cambial activity.

Bud Ties. The possible importance of physical damage to the scion bud was investigated using treatment combinations of rubber and polyethylene, with the tape covering or not covering the actual scion bud. Budding took place on 10 Aug., 24 Aug., and 7 Sept. to determine the effect of pressure on the covered buds declining as growth rate reduced through the growing season.

Bud-take increased with progressively later budding, by using rubber rather than polyethylene ties, and by not covering the bud. These results reflected the extent to which buds had been flattened under the tie, often leading to failure, or to weak trees the following spring. Following budding on 10 Aug., a bud-take of 66% from the rubber-not-covered treatment was reduced to 48% with polyethylene, and to 29% when the polyethylene tape covered the bud. After budding on 7 Sept., a bud-take of 97% from the rubber-not-covered treatment was reduced to 88% using polyethylene and to 75% when the polyethylene tape covered the bud. The superior results from the latest time of budding compared to the earliest budding were associated with an approximately five-fold reduction in the rate of stem swelling, reduced flattening of the bud, and many fewer trees in the following year with weak maiden shoots.

Data from budding on 24 Aug. are less easy to interpret, with all treatment combinations falling within the range 64% to 67% for bud take. However, the smallest maiden trees were produced by the polyethylene-covered treatment (147 cm) and the largest by the rubber-not-covered treatment (231 cm), suggesting that the debilitating processes observed in the earlier treatment were still operating, but at a reduced level.

***Robinia pseudoacacia* 'Frisia'.**

Bud Ties. A comparison on 1 Aug. between rubber and polyethylene ties covering or not covering the actual bud gave 83% bud-take with polyethylene covering the bud and 23% with rubber not covering the bud. This was in complete contrast to *B. pendula* 'Dalecarlica'. Other treatment combinations gave intermediate results. Initially, a high proportion of rubber-tied chip buds appeared to have formed a union, but these failed to produce trees and were prised easily out of the rootstock, suggesting that they were held in place simply by the enveloping rootstock callus.

DISCUSSION

Chip-budding is a technically sound procedure which facilitates rapid union formation, and so it provides a basis on which to investigate other factors that might cause inconsistent and often low levels of bud-take.

Rapid growth of the rootstock during budding provides the necessary cambial activity, which was a requirement common to all species. This was best guaranteed by budding not later than early August in south-east England, with the added option of delaying the planting of rootstocks so that their peak growth coincided better with the availability of mature budwood. Later budding, which is feasible using the chip-budding method because the "bark" does not have to be lifted as in T-budding, can produce excellent stands of high quality trees, but there is a risk in not being able to predict the onset of cold weather.

The rapid growth of some rootstocks has implications for the way the chip-bud is tied in, because the swelling rootstock stem can be constricted within the budding tie. This causes physical damage to the chip, and especially the bud, if this is covered. The large soft buds of *B. pendula* 'Dalecarlica' are particularly sensitive, so degradable rubber strips should be used which do not cover the actual bud.

In contrast, the small sunken buds of *R. pseudoacacia* 'Frisia' were not subject to physical damage, and pressure from the polyethylene tie was required to prevent the formation of a large pad of undifferentiated rootstock callus which held the scion-chip in place, but without forming a union.

The relationship between root growth and bud-take in *A. platanoides* 'Crimson King' revealed the complexity of the physiological processes which influence bud-take. It is proposed (Howard and Oakley, 1997) that failure in this subject is because the chip bud cannot remain viable during the prolonged period needed for union formation, despite completely wrapping the chip and bud with polyethylene tape, which caused no damage to the small buds of this cultivar. It is possible that a plant growth regulator produced in the roots, such as cytokinin, is required to maintain the chip-bud in a viable condition and that this is transported in the copious xylem sap which bathes the chip-bud, especially when root growth is particularly active.

Further evidence that special steps need to be taken to maintain 'Crimson King' chip-buds in a viable state comes from the fact that prophylactic fungicide sprays applied to the rootstock, and the dipping of the budwood, are beneficial and partly offset the detrimental effects of impaired root growth. Because there is no regulatory framework at present for the use of fungicides in this context, results are not given in this paper.

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Increasing Number of Adventitious Roots Accelerates Axillary Bud Growth in Cuttings

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The promotive effect of an increasing number of roots per cutting on onset of axillary bud growth, stem growth, or number of leaves can be explained by phase controlled synthesis and transport of growth regulators. The production of cytokinin in adventitious roots is suggested to be proportional to the number of adventitious roots. This may increase the content of cytokinin in the axillary buds resulting in accelerated onset of bud growth.

INTRODUCTION

Root growth and other functions of roots are intensely investigated and the complexity of root : shoot relationships in intact plants has been reviewed by Troughton (1974) and Wilson (1988). Root : shoot relationships in cuttings have, however, only been dealt with in few cases.

Although root formation in cuttings of many plants is an initial barrier to successful plant propagation, specific treatments of stock plants or cuttings can overcome in part the difficulties in root initiation and growth. The success criterion *per se* is the percentage of cuttings forming roots and ultimately the percentage of plants that survive and begins to grow. The significance of the number of roots per cutting for onset of axillary bud growth and subsequent growth of the cutting is less evident and only few investigations have dealt with this subject.

In rooting experiments with *Origanum, Mentha,* and *Melissa* Kuris et al. (1980) found that auxin promoted root formation in cuttings. Their results show that an increase in number of roots increased the fresh weight of shoots. In *Mentha* additionally plant height and branching was promoted by an increase in number of roots. Results by Gad et al. (1987) indicate that a 4-chlororesorcinol mediated increase in number of roots in *Pelargonium peltatum* cuttings slightly increases the number of leaves, total dry weight, and leaf fresh weight.

Experiments with *Schefflera arboricola* (Hansen, 1986a) demonstrated the effect of topophysis and cutting stem length on root formation in leaf-bud cuttings and in *Stephanotis floribunda* (Hansen, 1989) root formation could be controlled by topophysis and temperature during rooting. These results were later analyzed to elucidate the root : shoot relationship and except for the topophysis related results for *Stephanotis* the results showed a positive relationship between number of roots and onset of axillary bud growth and subsequent plant growth (Hansen and Kristensen, 1990).

Separate experiments with *Schefflera arboricola* tip cuttings also showed that with increasing cutting size the number of roots increased and that this was positively related to subsequent plant growth (Hansen,1986b). Further, plant growth rate was higher in cuttings forming many roots than in cuttings forming few roots (Figure 1).

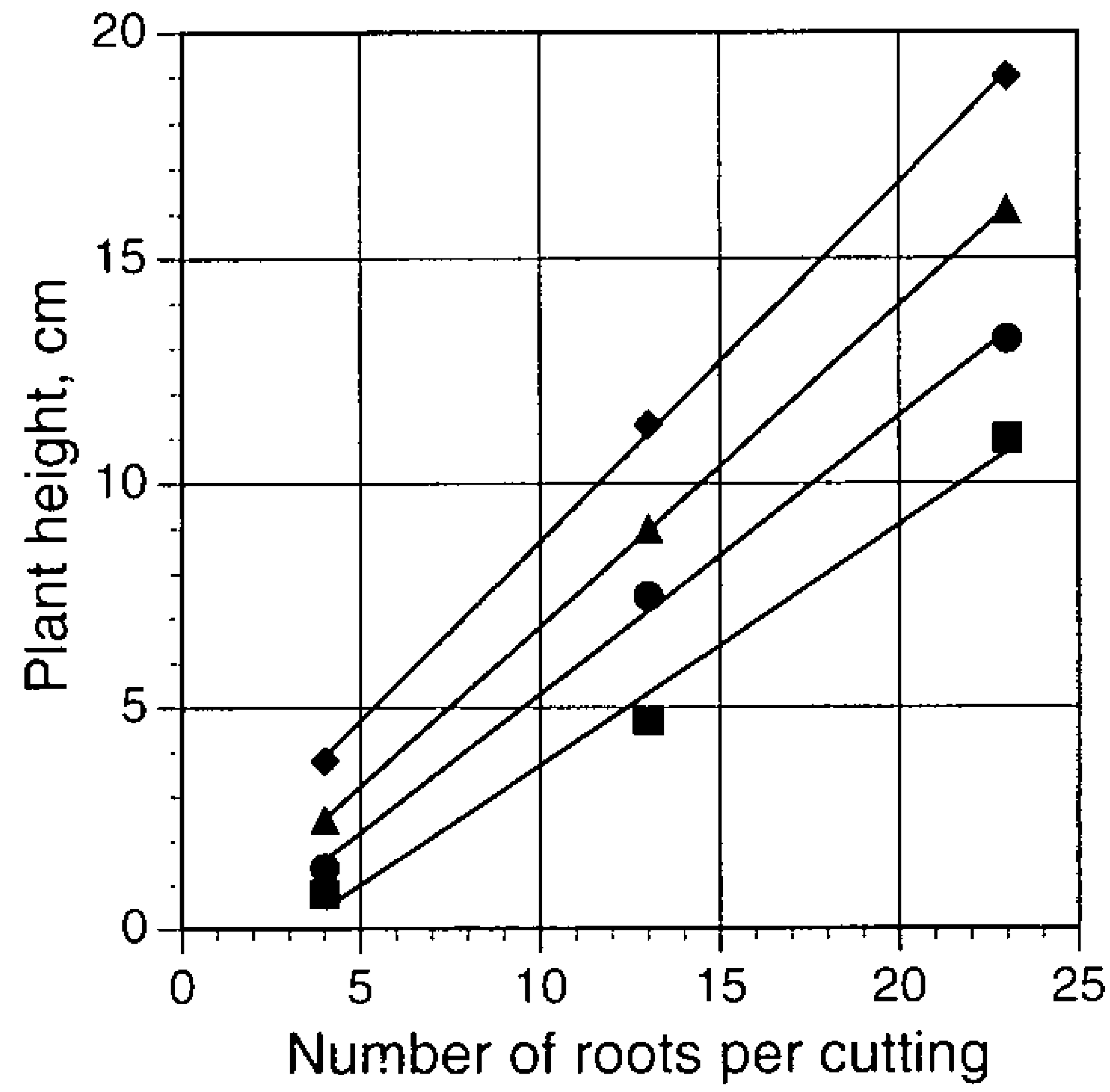

Figure 1. Relationship between plant height and number of roots per cutting in *Schefflera arboricola*. Average rooting results after 28 days for differently sized tip cuttings, large cuttings producing many roots, small cuttings producing few roots. Plant height was measured after 33 (■), 44 (●), 56 (▲), and 71 days (◆) from cutting and planting.

At least two ways of explanation are obvious to explain the relationship between number of adventitious roots and onset of axillary bud growth: (1) Some factors such as water and/or nutrient uptake are mediated by the roots to accelerate axillary bud growth, (2) Roots produce growth regulators to stimulate axillary bud growth.

PHYSIOLOGICAL EXPLANATION

Water and Nutrient Uptake. Water (Tschaplinski and Blake, 1985) and nutrient uptake (Wott and Tukey, 1967) are necessary for axillary bud growth and subsequent plant growth and may under certain conditions promote these processes. Under the controlled experimental conditions for *Schefflera* (Hansen, 1986a, b) and *Stephanotis* (Hansen, 1989) it is, however, not likely that water and/or nutrient uptake influenced the experimental results. It is much more likely that root produced growth regulators exert an effect on axillary bud growth.

Role of Bud Produced Auxin. In intact plants the terminal bud produces auxin which is transported basipetally and inhibits the growth of axillary buds (apical dominance). It is also well-known that auxin stimulates adventitious root formation in cuttings and that the presence of axillary buds in decapitated cuttings influences the formation of adventitious roots (Roberts and Fuchigami, 1973; Eriksen, 1973, 1974). Although the major auxin source, the apical meristem, has been removed in leaf-bud cuttings the axillary bud soon begins to synthesize auxin (Gocal et al., 1991) which is transported basipetally in the cutting and is involved in the initiation of adventitious roots. Within certain limits root formation is generally improved at increasing auxin levels in the cutting.

Root Produced Cytokinin. Cytokinins are the most prominent growth regulators produced by the roots and translocated to the shoot (Featonby-Smith and Van Staden, 1981). With leaf cuttings of *Phaseolus vulgaris* Engelbrecht (1972) and Featonby-Smith and Van Staden (1981) showed that the cytokinin activity in the cuttings began to increase early during root formation, and that the cytokinin level was high at the stage where the roots penetrated the epidermis. Changes in endogenous cytokinins in relation to root formation have been reviewed by Van Staden and Harty (1988).

If the amount of cytokinin synthesized in the root apex (Short and Torrey, 1972) is positively correlated with the number of adventitious roots as suggested by Eriksen (1974) then cuttings with many roots produce more cytokinin than cuttings with few roots and more cytokinin can be transported to the stem and axillary buds of cuttings with many roots.

Cytokinin and Axillary Bud Growth. Cytokinins stimulate axillary bud growth in intact plants (Sachs and Thimann, 1964; King and Van Staden, 1988) and in cuttings (Wickson and Thimann, 1958). Further, Nakano et al. (1980) found that cytokinin activities in buds of intact vines and cuttings of *Vitis* were low prior to bud growth but increased concomitantly with bud growth. Quamaruddin et al. (1990) also observed an increasing cytokinin content in *Pinus sylvestris* buds during dormancy release reaching a peak just before bud growth. Recently Dieleman et al. (1997) reported a high cytokinin content in buds forming the buttom breaks in *Rosa*, and their study support the findings that root produced cytokinin is transported to the axillary buds.

CONCLUSION

We suggest that auxin and cytokinin control root formation and axillary bud growth as outlined above. The acceleration of onset of bud growth in *Schefflera* and *Stephanotis*, therefore, may be a result of an increased cytokinin production in the roots. Practical observations that root formation normally precedes or coincides with axillary bud break support our explanation, and results by Mertens and Wright (1978) that root growth in *Ilex crenata* is preceding shoot growth by 7 to 14 days are in agreement with our hypothesis.

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Timing Methods Used in Propagation Practices

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INTRODUCTION

Midwest Groundcovers is a wholesale plant nursery that grows and sells landscape plants to customers in the Chicagoland area as well as the entire midwest region of the United States. We have nurseries near St. Charles, Illinois and Glenn, Michigan consisting of approximately 320 acres of land, 2000 hoop houses, and 70 heated greenhouses. The St. Charles nursery is primarily container production and the Glenn Farm nursery is primarily field production of groundcovers and perennials. Over 500 taxa of plants are produced for sale in container sizes ranging from 2-inch flats to 5-gal pots. These crops include groundcovers, shrubs, evergreens, roses, perennials, grasses, and vines. The 1997 production schedule included 15 million cuttings, 6.5 million plants in flats, and 2.5 million plants in pots. Space for producing container material at St. Charles has been pretty much entirely developed. At Glenn Farm, production space for both the container crops and field crops is currently being expanded. However, even with expansion, space is still at a premium. Planning, scheduling, and timing are crucial in every step of every process that we use to produce plants.

PRODUCTION SCHEDULING

The production scheduling process that we use starts with setting projected sales for each plant and size. From these goals production personnel determine the quantities of each size of each plant to produce and the timing of production in order to meet these goals. Our job is to make sure that we have these crops ready for sale in the quantities requested, with the qualities desired at exactly the right time and then to exceed our customers expectations. The methods we use for producing what is needed and when to do it are constantly being reviewed with the objective being continuous improvement. Timing is critical to continuous improvement.

The next step is to start at the end of the production cycle (being sold!) for the largest size produced of each plant and work backwards through the different stages required. This includes the time for top and root development, any pruning requirements, and any over wintering time involved in the final ready date for that crop.

THE CALENDAR YEAR

In the propagation department there are generally two different types of timing used: (1) the calendar year, and (2) the phenological year. Our calendar year schedule incorporates a type of rolling calendar. Everything that needs to happen gets written down in the time period that it should happen. Some processes or jobs occur on a monthly or weekly basis throughout the year and are written into the calendar for every time that they should be done. Other jobs might be done only in a specific month, such as October, and are written down only for October. Beginning to cover houses for the upcoming winter is an example of an October-only job.

At the end of each month we review what happened or didn't happen, what went well, and what didn't go so well. If something needs to be dealt with immediately, or needs to be moved to a different calendar time because it didn't work where we had it, then we can make those adjustments. This works very well for keeping people on track with the tasks that are supposed to be accomplished. Especially for those jobs that are done so seldom that people can easily forget about them until it's too late. An example would be ordering shade compound in early February so that you have it to put on the greenhouses in early March before plants get burned. When we're finished with the previous months' review we also go through an early-warning review for the upcoming month.

THE PHENOLOGICAL YEAR OR MOTHER NATURE'S CALENDAR

The second type of timing process that we use in propagation is much more seasonal in nature and based more on phenology than the first. This is Mother Natures' calendar. Because we are an "outdoor" nursery the actual propagation of plants is much more dependent on this than the calendar year. We have a limited time available to stick cuttings, for roots to develop, and, if necessary, to get plantlets established in the next container size before winter sets in.

Usually we can count on a normal seasonal progression of growth during the year. However, there are years when everything is delayed because of a late spring. There are also years when everything is ready much earlier in the year than anticipated. Spring 1997 for us was about two weeks behind Spring 1996. Spring 1996 was 7 to 10 days behind the spring of 1995.

Some plants have a very large window of opportunity in which to take cuttings and root them successfully. With these plants a delayed spring really isn't too difficult to work around. *Pachysandra terminalis* 'Green Carpet' is one of these. We can stick them at almost any time of the year and be successful at it. It may not be practical but, we could still do it if we had to.

Some plants have more of a medium-sized window for successful rooting. Still others seem to have a very narrow window of opportunity. And some seem to have no window at all and may be more easily propagated in another way (grafting, root cuttings, layering, etc.). These last two groups are the ones that I'm most interested in learning when to propagate. They are the ones that eat up the most profits proportionally.

One of the timing methods we are investigating for propagating difficult-to-root plants is based on phenological events occurring in other plants. These indicator plants may be able to "tell" us when the difficult plants are at their peak for rooting success.

When I started at Midwest Groundcovers as the pest management foreman the most valuable tool I had (and still use) for knowing when certain insect pests were at their most vulnerable stage(s) was the book *Coincide* by D. A. Orton and T. Green. Until this book was printed most recommendations that I saw for applying insecticides were based on the calendar year and the historical average date that an insects' vulnerable stage would appear. These calendar-based recommendations haven't been much help in years that spring arrived earlier or later than normal.

Coincide matches the development of an insect pests' vulnerable stages to accumulated heat degree days and to easily observable phenological events (like flowering or seed fall) occurring on certain indicator plants. For example, European alder leafminer damage to *Alnus glutinosa* from the hatching larvae begins at about the same time that *Spiraea* ×*vanhouttei* blooms and *Euonymus* scale crawlers hatch at the same time that *Catalpa speciosa* begins blooming. For the 10 years that I've been paying attention to this phenomenon, when this catalpa tree bloomed the scale crawlers hatched within a couple of days. Without fail, regardless of how late or early the spring was. Whether it was 16 May or 15 June, both the bloom and hatch occurred at virtually the same time. What a great system for timing the application of pesticides and being sure that your time and money are well spent!

When I became the propagation manager in 1994 I was aware that certain plants were best propagated at certain times. I was also very aware that I had a lot to learn about all of the crops that we propagated. One of the difficulties I've had in learning has been to interpret and adapt how another person "knows" when cuttings are ready to stick. In 1995 responsibilities for the Michigan nursery were added to my job description. This meant working with a wider range of crops in two different climates.

At some point during these last three years it struck me that a lot of what I had heard and read about propagating sounded very much like the calendar-based recommendations for insect control. Both were based on the normal, average time for success in that particular area. Examples include: "We stick them at the end of May"; "Finish the sticking by the 4th of July"; and "Collect and immediately sow the seed 50 days after pollination". I knew what they were talking about and when they were talking about doing it. The problem was, I couldn't really determine when that actually was in "plant-time" if they were in some other climate. Because of this we are collecting temperature and phenological event data with the idea that we may find a few indicator plants that will help tell us when to propagate some of those narrow-windowed plants more successfully on a routine basis.

Some additional applications or benefits from this may include:

1) Reduced need for rooting hormones and the regulations that come with them.

2) Propagation of "clean" stock plants from plants infested with scale insects by taking cuttings after the plant has flushed but before the crawlers have hatched. I know of at least one propagator doing this now for *Cotoneaster acutifolius*.

3) Determination of the most successful time of seed collection, processing, and sowing to avoid complicated dormancy and sporadic or lengthy germination times.

4) Information exchange with other propagators. Telling me to take the cuttings when *Hydrangea arborescens* 'Grandiflora' blooms says a lot more to me than "mid-July", especially if I'm in Chicago and you're in Denmark, or New Zealand and you say mid-January!

I know, of course, that there are other factors besides accumulated degree days that influence plant growth and development. Fertilization, pruning, type of climate, accumulation of and type of light, and growth regulators are just a few. However, I also know that there are other factors that affect insect growth and development and yet using indicator plants to control some of the worst insect pests certainly works. So at this time I can't see any reason why this won't work to some degree or another in propagation and plant production.

Now I have a request. If anyone out there is using or trying to use propagation by indicator plants or accumulated degree days in some form or another I would like to hear about what you're trying it with and how it's coming along.

Two good sources for learning how to measure accumulated degree days, set up your own indicator plant data base and more on the pros and cons of accumulated heat degree days are found in Orton and Green (1989) and Delahaut (1996).

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Applied Grafting in the Production of Ornamental Trees

Joel Klerk
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BACKGROUND

The firm started in Spring 1980 as a part-time nursery on a rented area, without starting capital. Today we produce about 20,000 shade and ornamental trees and about 10,000 lilacs. We employ 4 to 5 persons all year round. It has from the start been our goal to produce trees of high quality with due respect to the environment.

TREE QUALITY

The quality of the trees is characterized by three parameters: (1) biological quality, which determines the vitality of the trees, (2) aesthetical quality, which decides its ability to accomplish a certain purpose and finally, (3) trade quality, which describes a standard level. There is no doubt about biological quality. Aesthetical quality and standard can in certain cases go against each other.

A high quality tree can be defined as having a strong and well developed root, a strong stem base, and a strait stem. The crown must consist of branches equally distributed around a central axis. Among several biological qualities we consider the energy level of the tree, the amount of energy which can be mobilized, as the most important single factor for a successful transplantation.

GRAFTING

In order to accomplish our quality goal, we start with the rootstock and the scion. Rootstocks are mostly purchased as 1/0 or 2/0 plants with well developed and branched roots. Poorly growing plants are not used. Scions are taken from 2-year-old trees in good growth. Only the lowest 1/2 to 2/3 part of the scionwood is used, which includes the most energy rich and most mature part of the scion. The grafting technique is the conventional whip graft. The grafts are made in January to March, stored in a cold store, and planted directly in the field in May.

Grafting materials used are rubber strips and commercial grafting wax, but these materials are considered less important. It is necessary to handle the plants under cold and humid conditions and to avoid unnecessary wounding. A strong union is assured by grafting so that the cambial layers fit together on both sides, downwards and preferably also on the top. The scion is cut, so a little piece is left for binding just above the top bud.

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We graft many different trees: *Betula*, *Carpinus*, *Crataegus*, *Fagus*, *Fraxinus*, *Malus*, *Prunus*, *Sorbus*, *Quercus*, *Syringa*, and *Tilia* with good results. Species as different as these have very different growth rhythms, however, they can be treated in the same way because we believe the most important factors are the energy level and water content of the plant.

Transplanting is made in fertilized and deeply prepared soil that can be irrigated. Rootstock sprouts are removed in June when they are small, and again in August. New leader shoots are tied up in June and unnecessary shoots are removed.

INCOMPATIBILITY

False incomparability is due to poor grafting work and is a result of excessive callus growth which rejects the scion. Such grafts should be discarded during the first season as they will, in most cases, break before the saleable size is reached. Genuine incompatibility is often seen in *Quercus* and *Fagus* and is more problematic because the symptoms frequently are delayed 10 to 20 years.

Growing Pot Plants with Reduced Phosphorus can Improve Root Structure and Avoid Drought Stress

Kristian Borch

Danish Institute of Agricultural Sciences, Department of Ornamentals, Kirstinebjergvej 10, DK-5792 Aarslev, Denmark

INTRODUCTION

To increase consumer satisfaction, growers have to produce high-quality plants which are compact, stress tolerant, and free from diseases. This often does not harmonize with growers attempts to keep the production period as short as possible by growing bedding plants with optimum light, temperature, and a surplus of fertilizer to maximize growth rate. Such conditions often produce plants with elongated, lush shoots. However, this is at the expense of root development, and in turn poor stress tolerance. Therefore, it is recommended that before shipping growers harden their plants by giving a short period of lower temperature and reduced fertilizer and water at the end of the production cycle (Serek, 1990). This practice encourages root growth at the expense of shoot growth and is advantageous because plants with well developed root systems which exploit the medium uniformly and with room for further growth are best at withstanding the fluctuations in soil moisture which occur during shipping, handling, and in the hands of the consumers.

REDUCED PHOSPHORUS LEVEL

It is possible to improve plant quality and stress tolerance even more by encouraging strong root growth during production by reducing the phosphorus (P) levels in the root zone. Ornamental plants are typically grown with phosphorus levels much higher than those found in fertile soils. This may have detrimental effects. Studies using alumina-buffered phosphorus fertilizer (Al-P) show that plants can grow well at P levels as low as 10 μM P (Lynch et al., 1991). We have investigated the effects of reduced phosphorus (1/50 of the concentration traditionally used) on development and quality in marigold (*Tagetes* Janie Tangerine™). We specifically tested the

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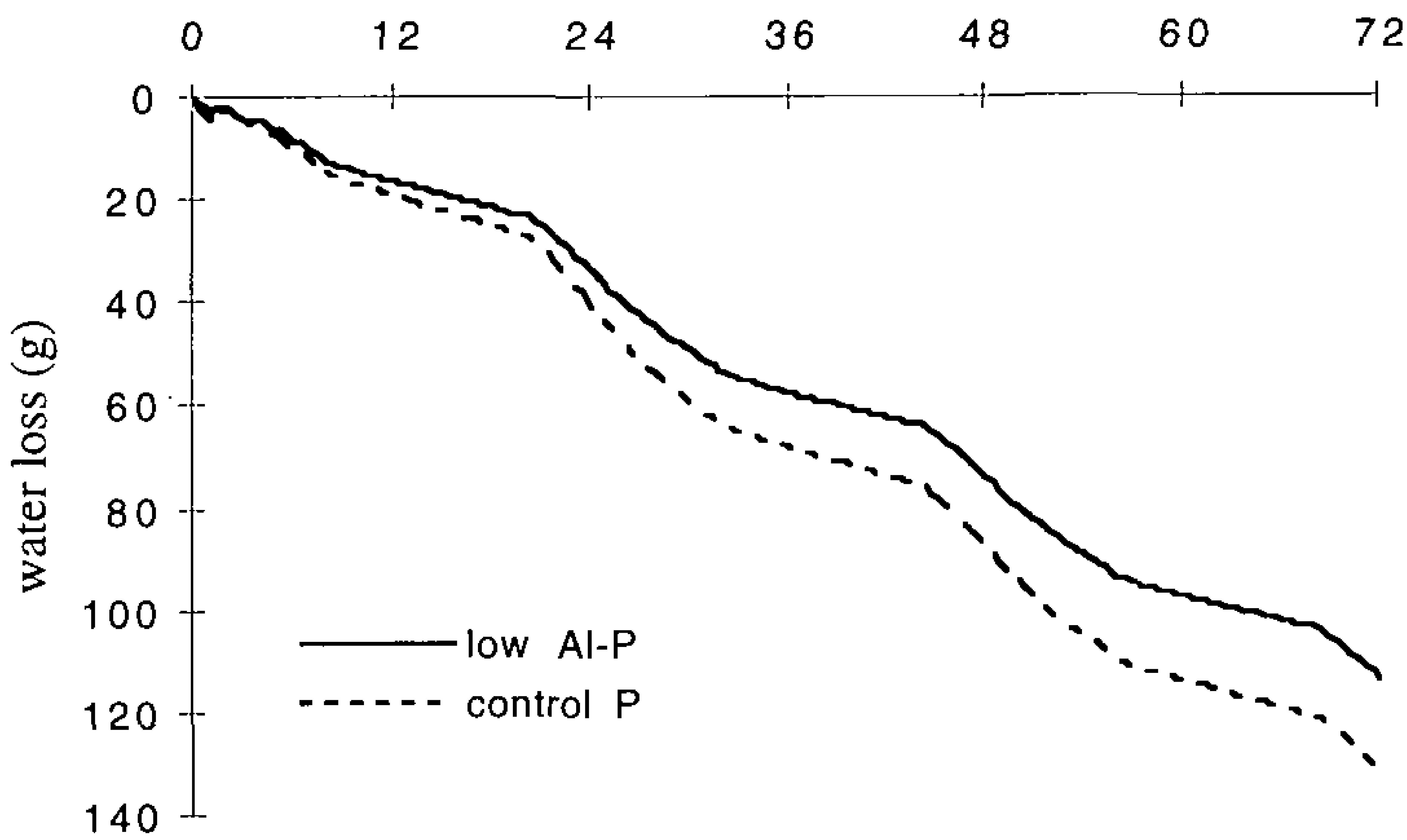

Figure 1. Transpiration monitored as gravitrometric water loss (transpiration) from the growth media of marigolds (*Tagetes* Janie Tangerine™) in 10-cm pots at anthesis grown with two levels of P (control P and low P (Al-P)) for 72 h. Values are means of eight plants.

The roots in the Al-P-buffered plants were more evenly distributed throughout the growth medium whereas the roots in the high-P control plants were confined to an area under the drip tube (Fig. 2). The explanation of this improved root distribution is probably the lack of a guiding P gradient in the Al-P-buffered growth medium. In contrast drip irrigation will create a high P concentration in the drip area guiding the roots to proliferate in this constricted area. Thus, reduced leaf area together with improved root distribution in marigold plants may account for the improvement in drought avoidance in the Al-P plants.

ROOT STRUCTURE

Root structure is very important for P acquisition when P resources are scarce because root uptake of P is predominately by diffusion, due to the very low concentrations of this ion in the free soil solution (Barber, 1995). Simultaneously, root architecture, proliferation, and mass affect the rate at which root systems remove moisture from soils (Faber et al., 1991) because the water flow in soil is often the largest resistance for the soil-plant-atmosphere continuum (Nobel, 1991). Therefore, we investigated if the improved drought resistance in low-P plants could be related to improved root structure. It was evident that the plants responded to reduced P availability by decreasing lateral root density and increasing root length at the expense of shoot growth. When lateral root density is decreased and root

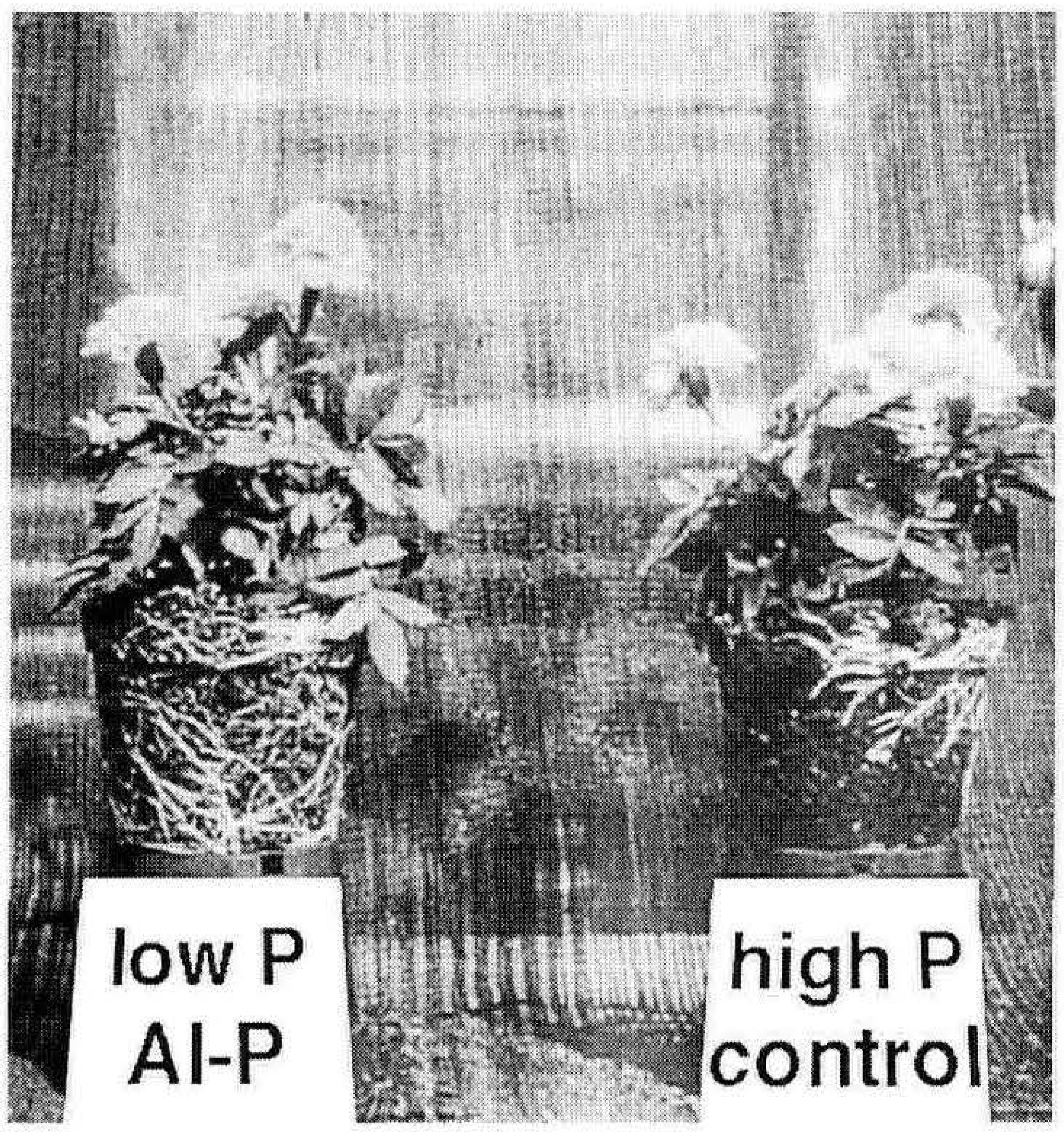

Figure 2. Marigold (*Tagetes* Janie Tangerine™) fertigated with high P, or buffered with low P concentration from alumina charged with P amended in the growth medium. Note how the root of the high P control plant is restricted to an area right under the drip tube.

length is increased soil volume exploration will be enhanced increasing the possibility of finding a P-rich patch in which it will branch vigorously to exploit the P (Snapp et al., 1995). This will also have a positive effect when water becomes depleted and the transport distance becomes larger, because a reduced lateral root density will give a better "space-filling" capacity and an improved ability to explore the medium for water (Fitter, 1986) avoiding drought stress. On the other hand, increased lateral root density is expected to become irrelevant for water uptake resistance during low water potentials in the pot because the depletion zones overlap (Fitter et al., 1991).

Thus, reduced P will improve root structure and the space-filling capacity enhancing water utilization. Moreover, the decreased leaf area will also reduce momentary water uptake and thereby save water resources. Both these features can improve water stress avoidance by the plant. If we better understand the changes in root architecture and morphology that occur during low-P conditions, it will enable us to prepare an ideal root zone which will allow maximum growth and development of the root system and thereby improve plant tolerance to stress factors.

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Supplementary Lighting to Stock Plants and Cuttings of *Kalanchoe blossfeldiana* v. Poelln.

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Stock plants and cuttings of *Kalanchoe blossfeldiana* 'Goldstrike' and 'Charme' were subjected to different levels of supplementary lighting during cultivation in a greenhouse at low levels of natural light. The effects on yield and quality of cuttings, and on rooting and growth of the cuttings were studied. Based on increases in number of cuttings, fresh weight, dry weight, and dry matter content of the cuttings, a doubling of the supplementary light level to the stock plants from 73 to 146 μmol m^{-2} s^{-1} was beneficial. The formation of roots in the cuttings was delayed by a doubling of the supplementary light level to the stock plants, while growth increment of the cuttings was unaffected by this treatment. Increasing levels of supplementary lighting during propagation strongly promoted rooting, growth increment, and quality of the cuttings, irrespective of stock plant lighting. The growth performance of the cuttings was modified by natural light conditions during propagation. From a practical viewpoint, these results indicate that 30% to 50% more cuttings could be harvested from stock plants of *K. blossfeldiana* by a doubling of the currently used level of supplementary lighting during cultivation. Subsequent growth of the cuttings is mainly influenced by the level of supplementary lighting during propagation.

INTRODUCTION

The production of *Kalanchoe blossfeldiana* in Norway is scheduled on a year-round basis. Under low natural light conditions during late autumn and winter (Oct. to March), production of cuttings and subsequent rooting and growth of the plants rely on use of supplementary lighting. Many growers use high pressure sodium vapor (HPS) lamps to provide additional lighting of stock plants and rooted cuttings for 20 h day^{-1} with a photosynthetic photon flux (PPF) of 60 to 70 μmol m^{-2} s^{-1} at plant level. Previous studies have shown that pot plants can utilize much higher levels of supplementary lighting during winter, especially with respect to cutting yield of stock plants, rooting ability, and growth rate of cuttings (Moe, 1977; Borowski et al., 1981). The objective of the present experiment was therefore to determine if a doubling of the currently used level of supplementary lighting could increase productivity of *K. blossfeldiana* stock plants in northern latitudes during winter, and to study possible after-effects of stock plant lighting on subsequent rooting and growth of the cuttings. Interactions of different levels of supplementary lighting to stock plants and cuttings were also studied.

MATERIALS AND METHODS

Stock Plants. Rooted cuttings of *K. blossfeldiana* 'Goldstrike' and 'Charme' were obtained from a local grower and potted in fertilized peat in 12-cm pots on 13 Sept.

The plants were placed in a growth room maintained at 20C with 73 µmol m^{-2} s^{-1} supplementary lighting provided by HPS lamps for 20 h day^{-1}. On 6 Oct. the plants were pinched and placed in greenhouse compartments maintained at 22C with 73 or 146 µmol m^{-2} s^{-1} supplementary lighting provided by HPS lamps for 20 h day^{-1}. Number of plants per light level was 36. The plants were subjected to ebb-and-flood irrigation with a growers' standard nutrient solution (EC = 1.5 mS cm^{-1}) when considered necessary. Relative air humidity (RH) was not controlled, and varied between 40% and 80%. The PPF levels were measured during night at plant level by means of a Lambda LI-185B instrument with quantum sensor (400 to 700 nm).

Terminal cuttings were harvested weekly from 13 Oct. until 22 Feb. (19 weeks). Number of cuttings per plant and fresh weight of cuttings were recorded at each harvest. Fresh and dry weight of samples of 10 cuttings from each stockplant treatment were recorded at 10 harvests evenly distributed throughout the harvesting period. Dry matter content of the cuttings was determined after drying at 80C until constant weight.

Cuttings. Rooting and growth increments of cuttings from the two stock plant treatments were investigated on cuttings harvested 18 Nov., 1 Dec., and 11 Jan. At each harvest 10 cuttings from each treatment were randomly selected, weighed, and inserted in 5 cm × 5 cm plastic plugs containing perlite saturated with a growers' standard nutrient solution with an EC of 1.5 mS cm^{-1}. A second group of 10 cuttings was randomly selected, weighed, and inserted in 5 cm × 5 cm plastic plugs containing fertilized peat. The cuttings were placed in a greenhouse compartment maintained at 22C with 36, 73, or 146 µmol m^{-2} s^{-1} supplementary lighting provided by HPS lamps for 20 h day^{-1}. Relative humidity was not controlled, and the cuttings were covered with two layers of a white polyethylene sheet (Agryl) the first week after insertion in order to reduce transpiration. The cuttings were watered daily with the aforementioned nutrient solution.

After 14 days number of roots per cutting and length of the longest root were recorded on cuttings rooted in perlite. After 35 days number of lateral shoots and fresh and dry weight of the cuttings rooted and grown in peat were recorded. Percentage increase in fresh weight and dry weight was calculated, and dry matter content was determined as aforementioned. The three harvests were treated as replicates in a general linear models procedure analysis of variance of rooting and growth parameters. Details of light conditions during the experimental periods are shown in Table 1.

RESULTS

Stock Plant Production and Quality of Cuttings. Average cutting yield per plant per week increased from 3.1 to 4.6 (48%) in 'Goldstrike' and from 5.0 to 6.7 (34%) in 'Charme' when the supplementary light level increased from 73 to 146 µmol m^{-2} s^{-1} (Table 2). The mean fresh weight of the cuttings increased from 3.2 to 3.5 g (9%) in 'Goldstrike' and from 2.6 to 2.9 g (12%) in 'Charme' by doubling the supplementary light level. A doubling of the supplementary light level increased mean dry matter content of the cuttings from 6.1 to 7.2% (18%) in 'Goldstrike' and from 5.4 to 6.7% (24%) in 'Charme'. Mean dry weight per cutting at the weekly cutting harvest increased from 60.5 to 115.9 mg (92%) in 'Goldstrike' and from 70.2 to 130.2 mg (85%) in 'Charme'

Table 1. Light integrals in mol m^{-2} day^{-1} at plant level during experiments with supplementary lighting of *Kalanchoe blossfeldiana* stock plants and cuttings.

				Supplementary light		
				36	73	146
Production stage		Period	Natural light	Light integrals from natural + supplementary light		
Stock plant cultivation:		06.10.-22.02.[Z]	1.9	-	7.2	12.4
Cuttings:						
Rooting	1	18.11.-01.12.	0.9	3.5	6.2	11.4
	2	01.12.-14.12.	0.8	3.4	6.1	11.3
	3	11.01.-24.01.	1.0	3.6	6.3	11.5
Growth	*1*	*18.11.-22.12.*	*0.9*	*3.5*	*6.2*	*11.4*
	2	01.12.-04.01.	0.9	3.5	6.2	11.4
	3	11.01.-14.02.	2.2	4.8	7.5	12.7

[Z]06.10-22.02 = 6 October to 22 February

Table 2. Effects of doubling the supplementary light level to stock plants of *Kalanchoe blossfeldiana* 'Goldstrike' and 'Charme' on cutting yield, fresh weight, dry matter content, and dry weight of cuttings harvested for a period of 19 weeks. Values for cutting parameters represent means ± SE (n = 10).

Supplemental light level (μmol m^{-2} s^{-1})	Mean number of cuttings harvested per plant per week	Mean fresh weight of cuttings (g)	Mean dry matter content of cuttings (%)	Mean dry weight of weekly cutting harvest (mg)
'Goldstrike'				
73	3.1	3.2±0.2	6.1±0.3	60.5±4.0
146	4.6	3.5±0.3	7.2±0.5	115.9±10.6
'Charme'				
73	5.0	2.6±0.2	5.4±0.5	70.2±5.9
146	6.7	2.9±0.3	6.7±0.7	130.2±14.9

After-effects on Cuttings. Number of roots per cutting after 14 days was unaffected by the level of supplementary light provided to stock plants of 'Goldstrike', while in 'Charme' it decreased when the supplementary light level to the stock plants increased from 73 to 146 µmol m^{-2} s^{-1} (Table 3). In both cultivars length of the longest root decreased by a doubling of the supplementary light level. No after-effects of supplementary light to the stock plants or interactions of stock plant and light treatment of cuttings on growth increment of cuttings were detected.

Cutting Treatment. Increasing the level of supplementary lighting from 36 to 73 µmol m^{-2} s^{-1} and further up to 146 µmol m^{-2} s^{-1} significantly increased number of roots per cutting and length of the longest root in 'Goldstrike' (Table 4). In 'Charme' number of roots per cutting and length of the longest root increased when the supplementary light level increased from 73 to 146 µmol m^{-2} s^{-1}.

Increasing the level of supplementary lighting from 36 to 73 µmol m^{-2} s^{-1} and further up to 146 µmol m^{-2} s^{-1} significantly increased fresh and dry weight increment, dry matter content, and number of lateral shoots per cutting in both cultivars after 35 days (Table 5).

In both cultivars fresh weight increase and number of lateral shoots after a growth period of 35 days were greater in cuttings from the third harvest compared with cuttings from the two first harvests (Table 6). A similar pattern was observed for dry weight increment in cuttings from 'Goldstrike'. In 'Charme', dry weight increment of the cuttings differed between all harvests. Lower dry matter content of cuttings from the third harvest compared with cuttings from the two first harvests was measured in both cultivars.

DISCUSSION

The production of cuttings by stock plants of *K. blossfeldiana* 'Goldstrike' and 'Charme' cultivated under low natural light conditions was strongly enhanced when the supplementary light level was increased from 73 to 146 µmol m^{-2} s^{-1} (Table 2). The magnitude of this response was in agreement with results from previous experiments which showed increasing yield of cuttings from stock plants of the same cultivars of *K. blossfeldiana* at supplementary light levels up to 183 µmol m^{-2} s^{-1} during autumn and winter (Willumsen and Rogstad, 1995). Increase in cutting yield due to supplementary lighting has also been reported for stock plants of other cultivars of *K. blossfeldiana* at increasing, but much lower levels of supplementary lighting (Nielsen et al., 1984; Andersson and Amsen, 1985). A higher yield of cuttings of approximately equal size and fresh weight per cutting obtained by weekly harvests, indicate that a main effect of the doubling of the supplementary light level in the present experiment could be attributed to a faster growth rate and/or better lateral branching of the stock plants as earlier found in *Begonia* (Bertram et al., 1989) and *Campanula* (Moe, 1977) at increasing levels of supplementary lighting.

In addition to increasing cutting yield, the doubling of the supplementary light level also improved dry matter content of the cuttings (Table 2). This is a common response of stock plants subjected to supplementary lighting, and is often used as an index of cutting quality (Molitor and von Hentig, 1987). Further, the increase in dry weight per cutting was nearly proportional to the increase of supplementary light level (Table 2). This response is in agreement with the findings of Mortensen (1983) which did not indicate any signs of light saturation of photosynthesis and dry matter accumulation in *K. blossfeldiana* plants at total PPFs below 350 µmol m^{-2} s^{-1}.

Table 3. Main effects of doubling the supplementary light level to stock plants of *Kalanchoe blossfeldiana* on rooting of the cuttings after 14 days. Values represent means of 3 supplementary light levels to the cuttings.

	'Goldstrike'		'Charme'	
Supplemental light level ($\mu mol\ m^{-2}\ s^{-1}$)	Number of roots per cutting	Longest root (mm)	Number of roots per cutting	Longest root (mm)
73	48.5	17.1	18.3	6.4
146	47.8	14.5	12.6	5.1
Significance	ns	$P<0.01$	$P<0.001$	$P<0.01$

Table 4. Main effects of supplementary lighting to cuttings of *Kalanchoe blossfeldiana* on rooting of cuttings after 14 days. Values represent means of 2 supplementary light levels to the stock plants. Mean separation in columns by Duncan's multiple range test, $P\leq0.05$.

	'Goldstrike'		'Charme'	
Supplemental light level ($\mu mol\ m^{-2}\ s^{-1}$)	Number of roots per cutting	Longest root (mm)	Number of roots per cutting	Longest root (mm)
36	40.1c	13.9c	14.1b	5.0b
73	46.4b	15.1b	14.8b	5.6b
146	58.1a	17.4a	18.6a	6.8a

Except for number of roots per cutting in ‘Goldstrike’, a doubling of the supplementary light level to the stock plants decreased root formation and appearance of the roots after 14 days, irrespective of supplementary light levels supplied to the cuttings (Table 3). These results demonstrate that root formation in cuttings of *K. blossfeldiana* is influenced by the light conditions during the growth of the stock plants, and that an optimal response with respect to rooting performance of the cuttings, is achieved at low or moderate levels of total PPF as observed in most other plant species (Hansen, 1987). The present results also show that increasing level of supplementary lighting provided during rooting strongly promotes rooting performance, irrespective of supplementary light level provided to the stock plants (Table 4). A similar response to increasing levels of supplementary lighting was obtained with respect to growth increments on a fresh and dry weight basis, and on quality of the rooted cuttings with respect to dry matter content and number of lateral shoots after 35 days (Table 5). The strong enhancement of fresh and dry weight gain and improved lateral branching in cuttings propagated after the third harvest compared with the two first harvests (Table 6) most probably is a result of increased total PPF during late February and March. A similar deviation in rooting pattern between harvests as a result of increasing natural light levels was reported in *Begonia* by Bertram et al. (1989). The fact that no beneficial after-effects of a doubling of the supplementary light level to the stock plants on growth increment of the cuttings were observed, further suggests that subsequent rooting and growth of the cuttings is less influenced by stock plant lighting when propagation takes place under supplementary lighting. It has, however, to be kept in mind that the cuttings in the present experiment were shaded during the first week of rooting. This treatment may have influenced root initiation. However, the generalized response curves of irradiance to stock plants and cuttings on rooting proposed by Moe and Andersen (1988), which suggest lower light levels to cuttings than to stock plants during propagation, does not seem to be valid for *K. blossfeldiana*.

Table 5. Main effects of supplementary lighting to cuttings of *Kalanchoe blossfeldiana* ‘Goldstrike’ and ‘Charme’ on growth of cuttings after 35 days. Values represent means of 2 supplementary light levels to the stock plants.

Supplemental light level ($\mu mol\ m^{-2}\ s^{-1}$)	Fresh weight increase (%)	Dry weight increase (%)	Dry matter content (%)	Number of lateral shoots per cutting
		‘Goldstrike’		
36	208	201	6.4	4.4
73	228	249	6.9	5.2
146	319	397	7.6	6.2
Significance	P<0.001	P<0.001	P<0.001	P<0.001
		‘Charme’		
36	175	184	5.6	4.6
73	221	279	6.9	5.2
146	245	379	7.6	7.0
Significance	P<0.001	P<0.001	P<0.001	P<0.001

Table 6. Main effects of harvest date of *Kalanchoe blossfeldiana* 'Goldstrike' on growth of cuttings after 35 days. Values represent means of two supplementary light levels to the stock plants, and three supplementary light levels to cuttings. Mean separation in columns by Duncan's multiple range test, $P \leq 0.05$.

Harvest date	Fresh weight increase (%)	Dry weight increase (%)	Dry matter content (%)	Number of lateral shoots per cutting
'Goldstrike'				
18.11.	183b	240b	7.8a	4.8b
01.12.	180b	227b	7.6a	4.7b
11.01.	393a	373a	5.5b	6.3a
'Charme'				
18.11.	159b	218c	7.8a	4.0b
01.12.	154b	278b	7.6a	4.2b
11.01.	340a	346a	5.5b	7.9a

In conclusion, the present observations suggest a maximal response of photosynthesis and growth of the stock plants by doubling the currently used supplementary light level, and make it clear that a supplementary light level of 146 μmol m^{-2} s^{-1} will improve both quality and growth of cuttings harvested from *K. blossfeldiana* stock plants during late autumn and winter in northern latitudes.

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Somatic Embryogenesis in Monocotyledonous Plants, State of the Art and Perspectives

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WHY MONOCOTYLEDONOUS PLANTS

A whole range of important agricultural and horticultural species are monocotyledonous plants. These include food, forage, industrial, and ornamental crops (Table 1). Somatic embryogenesis is possible in many monocotyledonous species, but with more or less success. Although our knowledge since 1958, when somatic embryogenesis was first reported, has increased considerably concerning the factors controlling initiation, development, maturation, and germination of somatic embryos, it is still far from routine in most plant species.

WHAT IS SOMATIC EMBRYOGENESIS

Somatic embryogenesis is the development of an embryo from a somatic cell. This is in contrast to the zygotic embryo which develops from a zygote, the fusion product between an egg and a pollen cell. Other cells than the gametes are somatic and cells from any tissue can in theory be the source of somatic embryos. Therefore, somatic embryogenesis is a type of vegetative propagation. Somatic embryogenesis is not a phenomenon restricted to in vitro culture, but is also known from nature in the form of certain types of apomixis.

In principle all somatic cells can develop into embryos, but the best choice of explant tissue is often young and meristematic, e.g., young leaves, immature zygotic embryos, and immature inflorescences. When the explant tissue is exposed to

Table 1. Examples of monocotyledonous plants in which somatic embryogenesis is possible.

Food crops	Cereals (corn, rice, wheat, millet, etc.) Vegetables (yams, leek, onion, garlic) Fruit (banana, date, coco) Sugarcane, oil palm
Forage crops	Cereals (corn, rice, wheat, millet, barley, etc.) Grasses (orchardgrass, rye grass, etc.)
Industrial crops	Fibers (coco, *Miscanthus*, bamboo) Oil (oil palm)
Ornamentals	Pot flowers (*Dieffenbachia, Spathiphyllum,* etc.) Cut flowers (*Alstroemeria*, lilies) Flowering outdoor plants (lilies, tulips, *Yucca*)

growth regulators, most often an auxin and sometimes in combination with a cytokinin, embryos may develop directly (direct embryogenesis) or there may be an intervening callus phase (indirect embryogenesis). Indirect embryogenesis is best suitable for mass propagation because maintenance and propagation of callus is possible. In contrast to the zygotic embryo, somatic embryos are without an endosperm and a seed coat.

PERSPECTIVES

Despite being an interesting tool for investigating the developmental sequence from single cell to whole plant, somatic embryogenesis can in practice be used for mass propagation, as a tool in breeding programs, and for germplasm conservation. Mass propagation through somatic embryogenesis may result in the production of plantlets or artificial seed. Economically, artificial seed will probably never be able to compete with normal seed, however, today somatic embryogenesis can be an alternative to other types of vegetative propagation of high value crops. In the breeding for new culitvars somatic embryogenesis may shorten the breeding cycle or may be used to propagate the parent plants for hybrid seed production. Moreover, mutations may be induced by treatment with mutagenes, or mutations may arise due to the in vitro culture conditions (somaclonal variation). New traits may be introduced to a cultivar either by somatic hybridization or transformation. Regeneration of plants from in vitro cultures is a prerequisite for the current transformation systems.

EXAMPLE 1. SOMATIC EMBRYOGENESIS IN OIL PALM

The French ORSTOM-CIRAD group has for the last 20 years investigated the possibilities of using somatic embryogenesis for commercial clonal propagation of oil palm (*Elaeis guineensis* Jacq.) (Rival et al., 1997). The research started in the beginning of the 1970s and resulted in 1982 in the transfer of knowledge to a pilot-scale laboratory in West Africa followed by additionally three pilot-scale laboratories in Indonesia and Malaysia in 1985-86. Furthermore, in 1987 a production laboratory was opened in France. The pilot-scale labs were designed to produce 250,000 plants per year. To date, 1 million plantlets have been produced by somatic embryogenesis resulting in 2500 ha with cloned material.

Clonal propagation of oil palm through somatic embryogenesis, as outlined in Fig. 1, is restricted by:

- High production costs. The price of clonal-propagated plantlets is five times the price of seedlings from selected material because somatic embryogenesis still involves many labor-intensive steps. The existing protocol is not suitable for large-scale propagation because the propagation rate is too low and it is difficult to fulfill the growers choice of cultivar and delivery time.
- Lack of genetic fidelity. In commercial plantings 5% of the plants develop abnormal flowers, which in severe cases prevent fruit set.

In order to reduce the production costs the possibilities of harvesting somatic embryos from suspension cultures and of processing embryos into artificial seed are currently being investigated. Later such systems may be automated. In addition, research is carried out to develop a quality control for genetic fidelity.

EXAMPLE 2. SOMATIC EMBRYOGENESIS IN ORCHARDGRASS

For a number of years a group of scientists at the University of Florida have been working on somatic embryogenesis in orchardgrass (*Dactylis glomerata*) (Gray et al.,1993). In contrast to oil palm the research in orchardgrass aims at developing more efficient breeding methods and not at mass propagation. Orchardgrass is open pollinated, self incompatible, and can not be cloned efficiently by conventional methods. Therefore, cloning by somatic embryogenesis, in combination with microspore or anther culture, reduces the production time of new cultivars. New cultivars can also be produced by transformation or somatic hybridization followed by plant regeneration through somatic embryogenesis. Another possible use of somatic embryogenesis is propagation of the parents for hybrid seed production (F_1 seed).

The use of somatic embryogenesis in orchardgrass, as outlined in Fig. 2, is like in oil palm limited by relatively high production costs, but also by genotypic differences in ability to form somatic embryos.

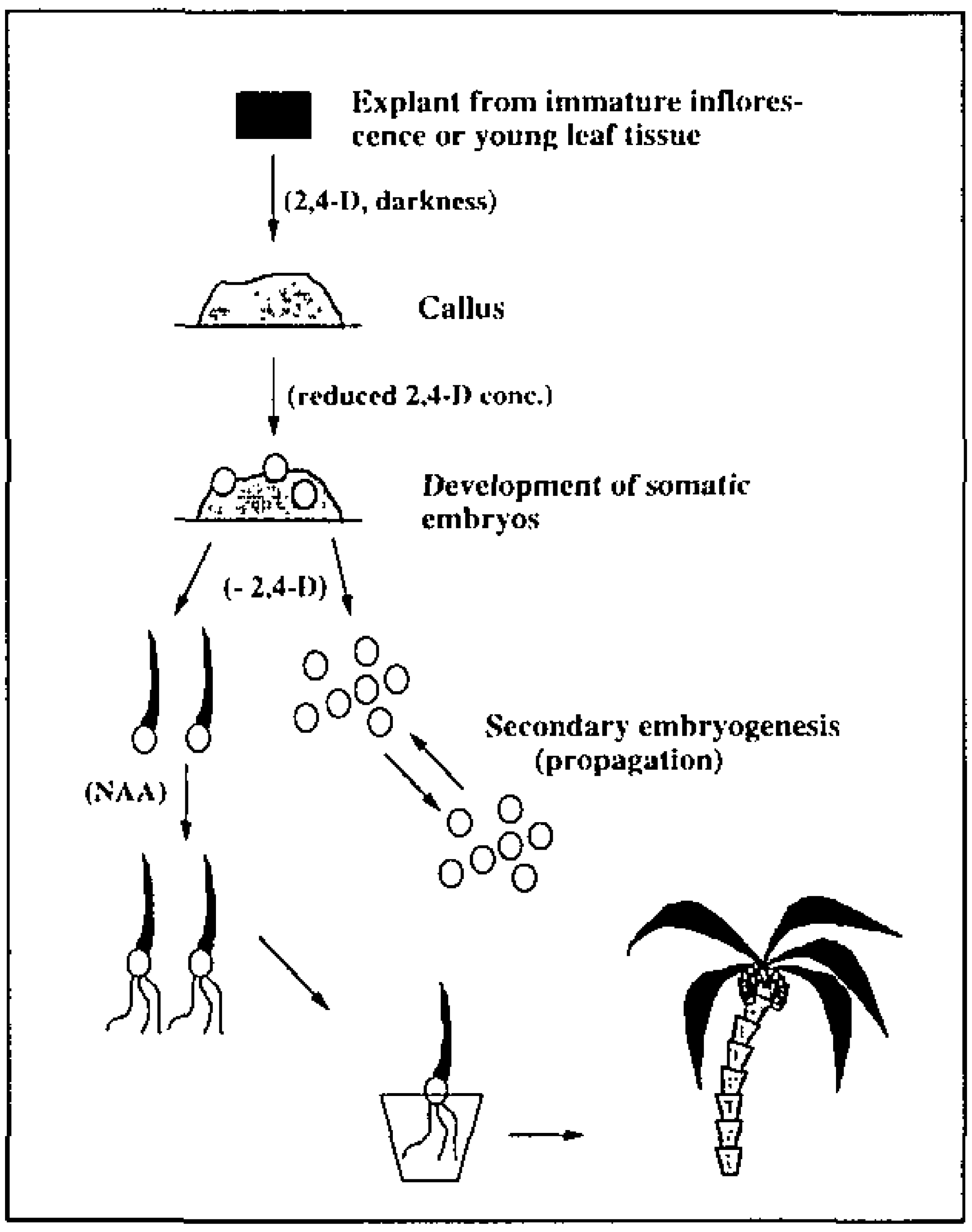

Figure 1. Outline of somatic embryogenesis in oil palm (*Elaeis guineensis* Jacq.).

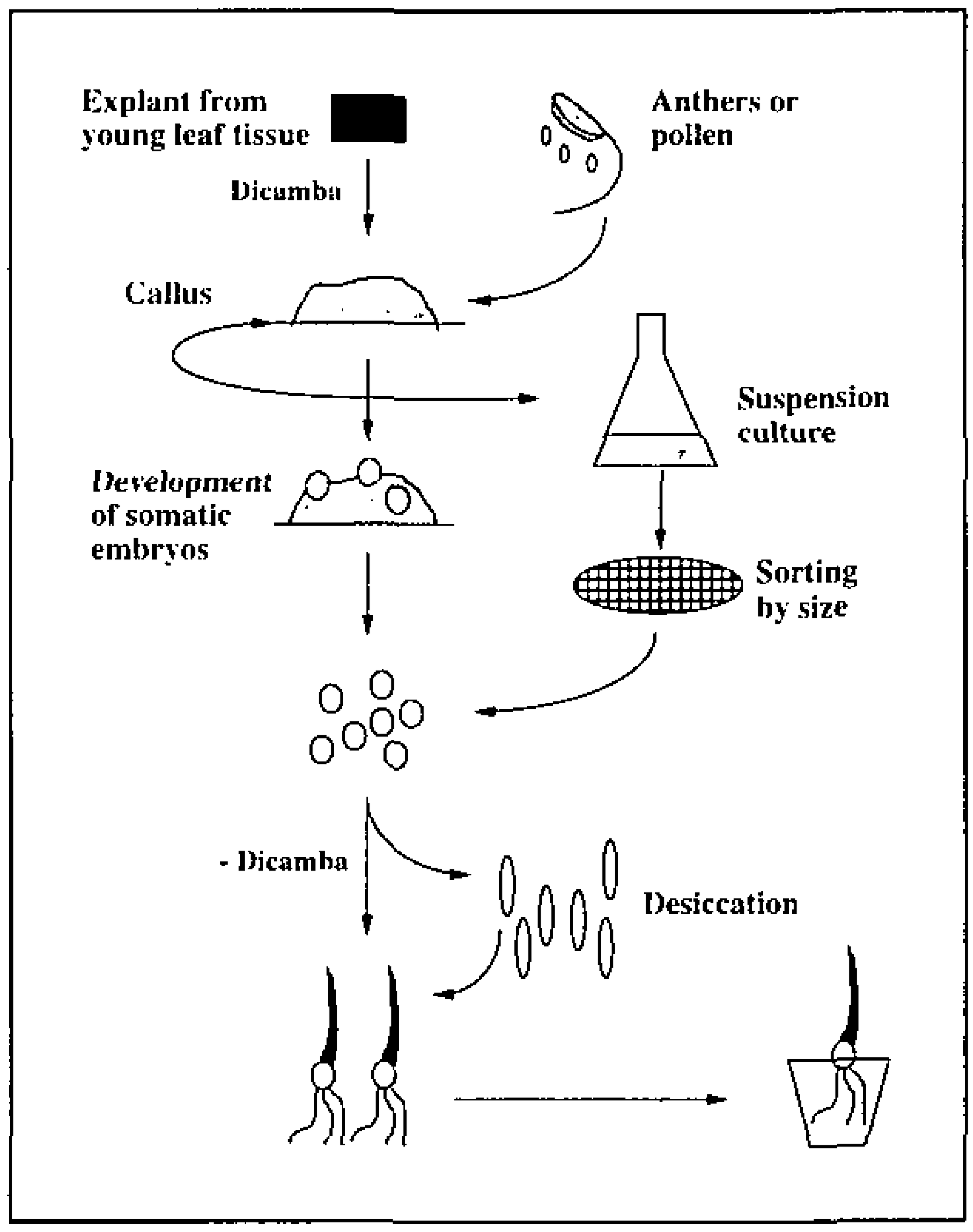

Figure 2. Outline of somatic embryogenesis in orchardgrass (*Dactylis glomerata* L.).

LIMITATIONS IN THE USE OF SOMATIC EMBRYOGENESIS

There are still a number of limitations in the use of somatic embryogenesis:

- Although it is possible to produce somatic embryos from many plant species large genotypic differences exist. This means that many of the most valuable cultivars and hybrids are difficult to propagate.
- Basic research on the induction and development of somatic embryos is not sufficient.
- Somaclonal variation, variation induced by the in vitro growth conditions, is at present not controllable. This is a problem when the offspring need to be true to type.

- Callus and suspension cultures often lose their ability to produce somatic embryos after a shorter or longer period of culture.
- In grass species the regeneration of albino plants (lacks functional chloroplasts) can be a problem in certain genotypes.
- It is very difficult to obtain a complete synchronization of embryo development within a culture, a very important prerequisite in automation of artificial seed production.

CONCLUSION

For some monocotyledonous plants relatively good somatic embryogenesis systems have been developed, but for most species there are still a number of limitations to the commercial application. In high-value crops where plantlet or seed prices are high, somatic embryogenesis may be a way for mass propagation. The use of somatic embryogenesis for mass propagation may be extended if it is possible to control somaclonal variation and to obtain a high degree of automation. Somatic embryogenesis may also be an efficient tool in the breeding of new cultivars.

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Improved Grafting Techniques for Nursery Stock

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INTRODUCTION

Grafting has with increasing labor costs become an expensive way of propagating plants. An important factor for the bottom line in this process is a high percentage of successful grafts. In a number of genera, e.g., *Malus*, *Pyrus*, *Sorbus*, *Salix*, and *Tilia*, this is easy to obtain. In other genera, however, a low percentage of "takes" can make grafting an unreasonably expensive method of propagation. In particular species of *Juglans*, *Quercus*, *Corylus*, and partly *Acer* can be tricky in that respect. Therefore, there are good reasons to optimize every step in the grafting process in order to ensure high grafting success especially for the more difficult-to-propagate species. The methods presented below by the author are meant as a source of inspiration for other propagators.

GRAFTING PLANE

The grafting plane was first seen in Australia where it is used for grafting of the macadamia nut tree with its very hard wood. It is a small woodworking plane equipped with a disposable heavy duty razor blade (Fig. 1). The advantage of using this tool is that the cut surfaces under correct use are perfectly plane so that even the slightest callus growth can ensure cambial contact that is a prerequisite for a good result. Another advantage is that it is possible to fit rootstocks and scions with very hard wood which are up to a couple of cm in diameter.

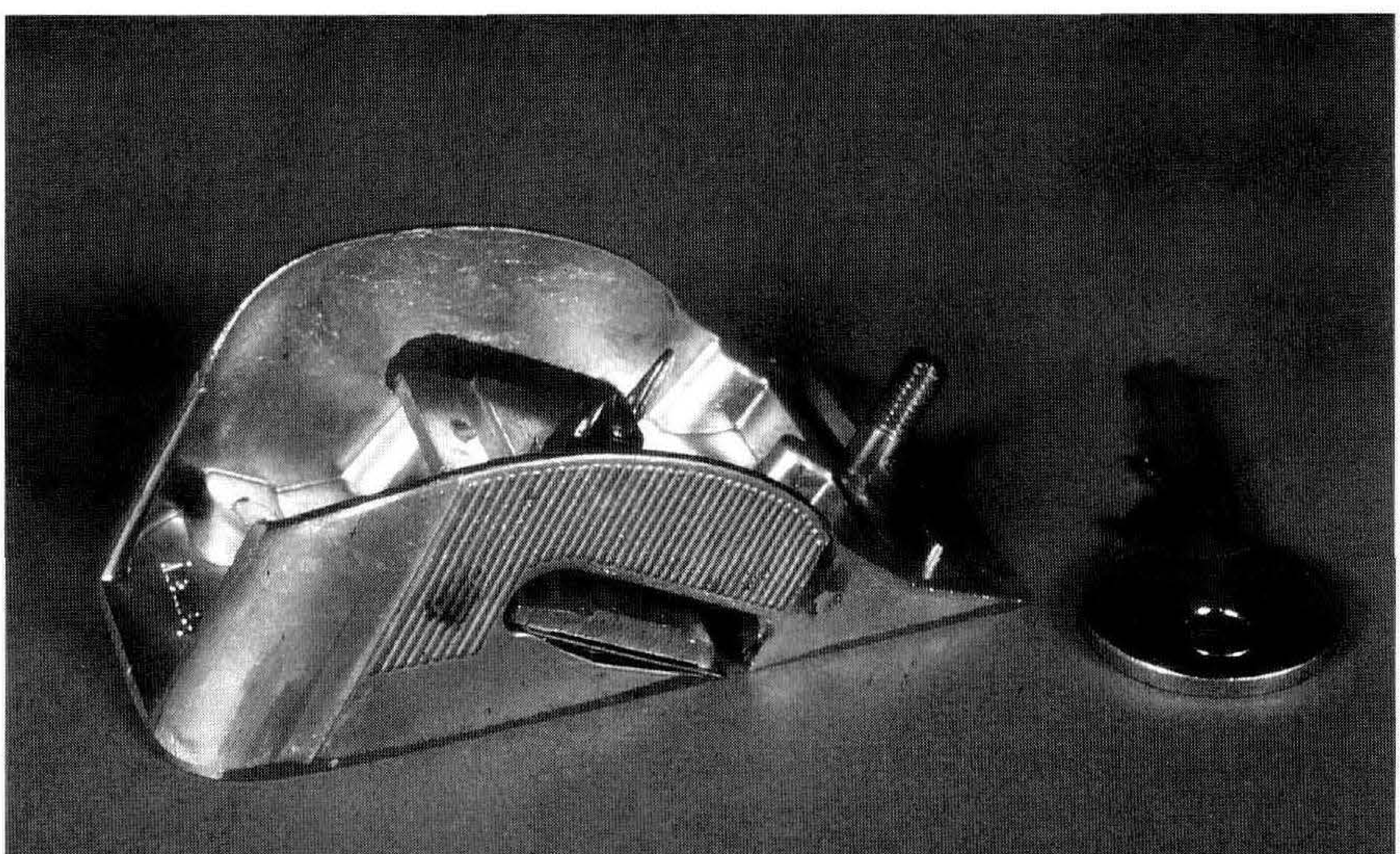

Figure 1. The grafting plane is a small woodworking plane equipped with a disposable heavy duty razor blade. It allows for accurate fitting of scions with thick and hard wood.

HOT CALLUSING

Certain species require high temperatures before the callus formation starts. In particular hazelnuts and walnuts are known for this (Sitton, 1931). When grafting these genera the traditional way it is often found that the scion bursts in spring and dies a couple of weeks later due to lack of cambium contact. At Oregon State University (Corvallis, Oregon, U.S.A.) the hot-callusing technique was developed in the 1970s. The idea is to give heat to the graft union while keeping the root and top quiescent (Lagerstedt, 1981). In practice this is done by placing the graft union over a thermostatically controlled hot water pipe and keeping the union insulated from the winter cold with a suitable material. In this way a union is formed while keeping the root and top quiescent and there are no problems with bud burst prior to the formation of a proper union.

PARAFILM

Parafilm is a transparent wax film which for a long time has been used in laboratories for sealing of glass and other items, but recently a grafting film of the same material has become available. The film is prepared for cutting into suitable lengths. Parafilm can be stretched 6 to 8 times its own length and then becomes self adhesive; combining the need for tying and sealing. It is, however, still necessary to seal the cut top of the scion which can also be done with a small piece of Parafilm. See Beineke (1978) for a presentation of the product.

SUMMER GRAFTING

Species that are difficult to graft by conventional winter grafting can sometimes be grafted successfully during the growth period. The scions are either cold-stored wood from last year, which is the easiest material to work with, or alternatively shoots from present years growth can be used. The latter is called green grafting. As the evaporation during the growth season is larger than in the wintertime it is necessary to protect the union with a polythene bag, which should be white in order to avoid excessive solar heating. When the scions start to grow the outer corners of the bag are cut in order to harden the shoots. After another week the entire bag is removed. It is important that this happens before the first leaves are fully unfolded as they otherwise will be burned by the sun. The method has been successfully used for the grafting of *Juglans* and *Quercus* species. If the grafting is done on potted rootstocks in a greenhouse the callus formation is very fast and can sometimes be seen after 4 to 6 days.

SEED GRAFTING

Seed grafting, also called nurse-seed grafting, is a grafting method in which extra small scions are inserted on the sprouts from germinating seeds (Jaynes, 1965). This way the grafting process has some in vitro resemblance as everything is very tiny and all the cuts are done with a razor blade. The advantage of this method is that the time for cultivation of the rootstock is shortened and sometimes it is possible to produce a grafted tree in the same time as just the production time of the rootstock for normal grafting. Naturally the method is only applicable for species with large seeds and seed sprouts, e.g., *Aesculus* which is ideal to start with. Other genera that have been propagated using this method includes: *Quercus*, *Juglans*, *Corylus*, *Castanea*, and *Ginkgo*. In China the method has been used on a semicommercial scale for the propagation of walnut trees (Li and Tang, 1990). The small scions were obtained by stimulating the scion trees to form numerous side shoots using defoliation and hormone treatments. In other places the method is used to some extent by hobbyists and it does not seem to have relevance in Danish nurseries where none of the species are of economic significance in grafting.

CHIP BUDDING

Several decades back British trials showed us that chip budding when used correctly is superior to T-budding. Chip-budded trees have a higher growth rate and more laterals than T-budded trees (Howard, 1977). The reason for this is faster cambial contact during the healing process. For various reasons, however, the method has never become standard in Denmark where T-budding continues to be most widely used. My own experience is that difficult-to-bud species should be budded early in the season where the formation of callus is fastest. Trees budded later than 1 Aug. have a tendency to loose the chip over winter. This does not apply for the easy-to-bud genera mentioned above, where even chip budding in the beginning of September can yield satisfactory results.

CONCLUSION

Grafting is an ancient propagation method which is thought to have originated in China more than 3000 years ago. It is significant in the evolution of the different grafting techniques that the most progress has occurred as a result of individual experimentation and testing of new methods. Comparatively little genuine research has been conducted in the area. As several of the problems in grafting still remain to be solved it is hoped that the creativeness and the experiments will continue in the future.

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Physiological Basis of Topophysis in *Rosa* Hybrids

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Aspects of growth readiness and plant architecture are integrated into one organ, the bud. Topophysis, the positional effect of axillary buds along the shoot axis on their growth and differentiation, is an important factor as it may determine whether an axillary bud grows readily or with difficulty. Topophysis is a decisive tool for synchronizing the development and flowering in roses. Results show that growth potential, growth efficiency, and plant quality can be improved by 14% to 49% in roses by selecting proper cutting positions. Topophysis in *Rosa* is an independent phenomenon which is intrinsic to the axillary bud. At present, there is no convincing physiological explanation of the relatively stable states of behavior exerted by topophysis. We suggest that topophysic prevention of growth may be related to lack of promoters or to the presence of inhibitors of growth within the bud.

INTRODUCTION

Light dramatically affects rose plant development and growth and apical dominance is sensitive to changes in photosynthetic photon flux density (PPFD) and spectral quality. Apical dominance is weakened by high PPFD (Andersen, 1976), and red light (Vince-Prue, 1977). During apical dominance differentiation of rose leaf initials proceeds inside the apparently nongrowing axillary bud at a very low level (Marcelis-van Acker, 1994). After being released from apical dominance (correlative inhibition) by decapitation visible growth is resumed in rose axillary buds. The upper nodes of a growing rose shoot are neoformed, i.e., formed after release from inhibition, and the number of preformed nodes depends on age (Marcelis-van Acker, 1994). After a certain developmental stage axillary buds become independent of their chronological age, they all contain the same number of leaf initials, and are termed ontogenetically mature. Bud growth potential is determined by genetic and other factors including ontogenetical age, environment, and position of meristem.

Cyclophysis. This is the process of ontogenetical ageing and maturation of the meristem (Seeliger, 1924; Olesen, 1978). Ontogenetical ageing is genetically programmed, accelerated by improved growth conditions, and difficult to reverse (Fortainer and Jonkers, 1976). Cyclophysis is most advanced in the apical meristem, as this has had the biggest total growth behind it (Olesen, 1978).

Periphysis. Periphysis covers the qualities determined by environment and manifests itself as a certain aftereffect caused by previous conditions (Büsgen and Münch, 1927; Schaffalitzky de Muckadell, 1959; Olesen, 1978). It is a carry-over effect of the environment on the propagule into the progeny plant but without causing a permanent effect on the genetic nature of the plant (Hartmann et al., 1990).

Topophysis. Topophysis is the effect of axillary bud position along a shoot axis on growth and differentiation. It is a decisive tool for synchronization of development and flowering in roses. Topophysis (Ortsnatur), derived from *topos* =place and *physis* =nature/constitution, as first defined by Molisch (1916), is the persistent growth and differentiation, without genetic change, of a plant cutting, depending on the source tissue (Kenneth, 1963). Topophysis covers the effect of the position on the plant of the propagule on the type of vegetative growth subsequently shown by the vegetative progeny (Molisch, 1929; Hartmann et al., 1990). Doorenbos (1965) *generalized topophysis as the phenomenon where plant parts maintain, to a certain* extent, their individual characteristics when excised and grown as separate plants.

Topophysis, thus, is an important factor as it may determine whether an axillary bud grows readily or with difficulty. Results (Bredmose and Hansen, 1996) have shown that the growth potential, growth efficiency, and plant quality of roses can be improved by 49%, 14% to 34%, and 20%, respectively, by selecting proper cutting positions. Topophysis is of more than just practical interest because it cannot be adequately explained on the basis of the usual concepts of the function of chromosomes and their genes (Robbins, 1964). At present, there is no satisfactory physiological explanation of the relative stable states of behavior exerted by topophysis. We studied topophysic effects on growth and differentiation until anthesis in three rose cultivars by growing cuttings originating from seven stem positions.

MATERIALS AND METHODS

Position effects of single-node, five-leaflet-leaf cuttings on subsequent bud and shoot growth and flowering were recorded from the most apical cutting position to the most basal one in single-stemmed cut rose plants (see Fig. 1). Cuttings were excised, on mature harvestable flowering stems, 5 to 10 mm above and 40 to 50 mm below the node. Average stem diameter and fresh weight of cuttings were 5.2 mm and 2.0 g, respectively. Cuttings were dipped in a 0.15% Captan solution, and the basal part was treated with 0.3% indolebutyric acid before inserted 2 cm in rockwool cubes (7.5 cm × 7.5 cm × 6.5 cm) at 178 plants m^{-2}. Plants of *Rosa* 'Korokis' Kiss™ floribunda-tea rose, 'Tanettahn' Manhattan Blue™ hybrid tea rose, and 'Sweet Promise' Sonia™ grandiflora rose were grown at 24.7C average air temperature in 20-h photoperiods at an average PPFD of 327 $\mu mol\ m^{-2}\ s^{-1}$ from natural and supplementary light. The plants were grown on ebb-and-flood benches, irrigated with a complete nutrient solution, and supplied with carbon dioxide to a level of 1000 μl $liter^{-1}$. Seven cutting positions, three cultivars, and four replicates were combined in a factorial design with eight plants per treatment. Several parameters related to bud growth, shoot growth, fresh weight production, and flowering were recorded. For more details including statistics see Bredmose and Hansen (1996).

RESULTS AND DISCUSSION

As the three cultivars reacted similarly to the treatments average results are presented.

Developmental Time. Time from excision/planting until onset of axillary bud growth, visible flower bud, or anthesis was less in plants originating from apical bud positions than from basal positions (Table 1). In general, bud growth occurred earliest in cuttings originating from position two, which indicates the transition between sylleptic (bud growth occurs continuously) and proleptic buds (buds having a period of inhibition) (Bredmose and Hansen, 1996). Regarding the onset of bud growth our results agree with other investigations on positional effects in roses (Jensen, 1967; Zieslin et al., 1976; Bressan et al., 1982). The plastochrone, the average number of days for a node to develop, was not significantly influenced by the position of the axillary bud (Table 1). Genotypic effects (Table 1) showed that Manhattan Blue™ hybrid tea rose developed much slower, and required 48% more time to develop a node, than the other two cultivars.

Table 1. Topophysis effects (F probability ≤ 0.05) on time from excision/planting until axillary bud growth, visible flower bud, and anthesis, and on plastochrone as average of three cultivars and four replicates; and cultivar effects (F pr ≤ 0.001) as average of seven bud positions and four replicates. Cutting positions are numbered in descending order. (After Bredmose and Hansen, 1996). Length of period between developmental phases is shown in parentheses.

	Time from planting until					
	Bud growth (days)		Visible flower bud (days)		Anthesis (days)	Plastochron (days node^{-1})
Cutting position:						
1 most apical	21.0	(13.0)	34.0	(14.4)	48.4	3.9
2	20.2	(13.5)	33.7	(14.1)	47.8	3.6
3	22.2	(13.6)	35.8	(14.1)	49.9	3.7
4	23.5	(14.5)	38.0	(13.7)	51.7	3.9
5	25.4	(14.1)	39.5	(13.5)	53.0	3.9
6	25.8	(14.1)	39.9	(13.8)	53.7	3.9
7 most basal	26.1	(15.2)	41.3	(13.9)	55.2	4.0
Lsd (p = 0.05)	1.8		1.8		1.7	(Pr<F)
Cultivar:						
Kiss™ floribunda-tea rose	19.1	(13.1)	32.2	(14.9)	47.1	3.3
Manhattan Blue™ hybrid tea rose	31.1	(15.3)	46.4	(14.1)	60.5	4.9
Sonia™ grandiflora rose	19.9	(13.6)	33.5	(12.7)	46.2	3.3
Lsd (p = 0.05)	1.2		1.2		1.2	0.2

Differentiation of root initials is dependent upon either applied or endogenous auxin, although the mode of action is unclear (Hartmann et al., 1990). Hansen and Kristensen (1990) found that the onset of bud growth in *Schefflera* and *Stephanotis* was accelerated by an increasing number of roots per cutting. In *Rosa* hybrids (Jensen, 1967; Gislerød, 1983) and *R. centifolia* (Al-Saqri and Alderson, 1996) the number of roots is also dependent on nodal position.

Quiescence of axillary buds in rose plants can be released by exogenous application of benzyladenine (Ohkawa, 1984). Most likely, root-derived cytokinins transported via the xylem (Dieleman et al., 1997) into the buds are involved in the acceleration of bud growth (Qamaruddin et al., 1990). Thus, upon excision resumption of growth in an axillary rose bud may depend on its own cytokinin content and following root formation also on the supply from adventitious roots (for details see Hansen and Bredmose, 1998). After root formation an independent plant is established and this may explain the apparently lack of further position dependency in our results concerning development time, as illustrated by the almost similar figures for length of periods between developmental phases in Table 1. Thus, regarding developmental time topophysis in roses mainly affects the onset of bud growth (Bredmose and Hansen, 1996).

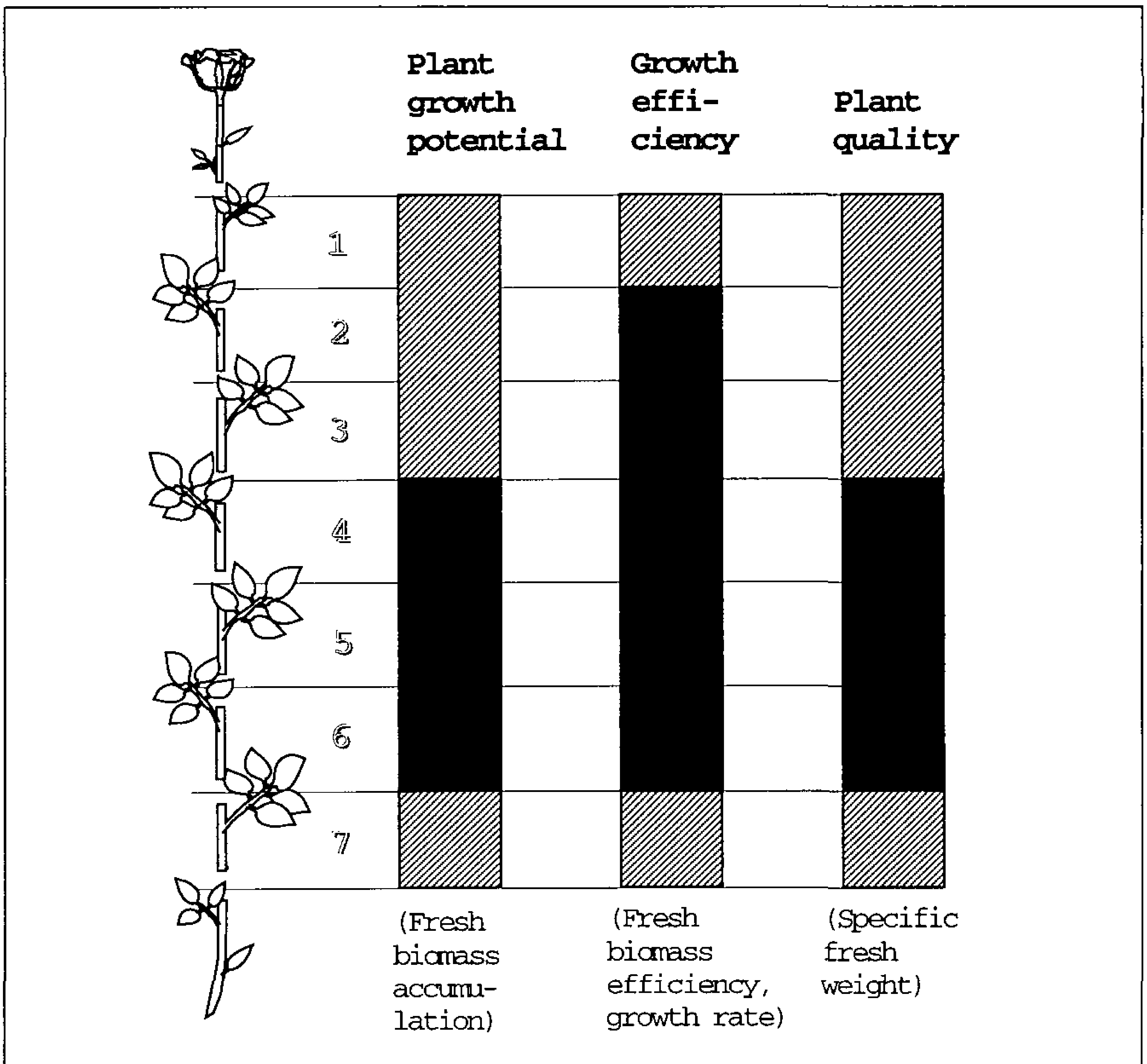

Figure 1. Influences of topophysis (after Bredmose and Hansen, 1996) on rose axillary bud growth potential (expressed by fresh biomass accumulation), plant growth efficiency (expressed by fresh biomass efficiency and by growth rate), and plant quality (expressed by specific fresh weight) of rose. The darkest area of columns show optimal cutting positions. Average of three rose cultivars ('Korokis', Kiss™ floribunda-tea rose; 'Tanettahn', Manhattan Blue™ hybrid tea rose; and 'Sweet Promise', Sonia™ grandiflora rose) grown as single-stemmed roses. The original seven cutting positions are shown schematically at left side of figure. (Graphics: Ebbe Elbrønd Andersen, Department of Ornamentals).

Growth Potential, Efficiency, and Plant Quality. Topophysic influences (Bredmose and Hansen, 1996) on bud growth potential (represented by fresh weight accumulated per bloom), plant growth efficiency (represented by fresh weight accumulation rate and by elongation rate), and plant quality (represented by fresh weight accumulated per cm of stem) in roses are illustrated in Fig. 1. Axillary buds from positions 4 to 6 possess the highest growth potential, axillary buds from positions 2 to 6 generally have the highest growth efficiency, and axillary buds from positions 4 to 6 give the best plant quality (Fig. 1). Consequently, selection of cuttings according to their position on the parent shoot reduce heterogeneity in subsequent bud and shoot growth.

Topophysis is Intrinsic to the Axillary Bud. Our results indicate that topophysis in *Rosa* is an independent phenomenon determined by factors intrinsic to the bud (Bredmose and Hansen, 1996), as also reported for *Citrus* (Halim et al., 1988; Jones et al., 1976), and noticed in *Populus* (Rohde et al., 1997). This suggestion is based on four reasons:

1) Halim et al. (1988) generally found no anatomical differences in the vascular system between buds and stem of differently positioned *Citrus* buds; and similar observations were done in roses by Zamski et al. (1985).

2) Isolated nodes grown on nutrient medium should all sprout equally if only nutrient gradients are responsible, however, Zieslin et al. (1976) found that rose axillary buds grew faster *in vitro* if they originated from upper rather than from basal positions.

3) For ontogenetically mature axillary buds of rose, like those in the present experiment, Marcelis-van Acker (1994) found that the chronological age of the bud did not clearly affect the subsequent shoot growth.

4) Finally, Halim et al. (1988) reported that inhibition of *Citrus* bud growth is intrinsic to the axillary bud because the inhibition was found in situ as well as in vitro. Also research by Jones et al. (1976) suggested that the state of inhibition in *Citrus* is related to inhibitors within the bud. In addition Rohde et al. (1997) noticed that at least the two most basal axillary buds on *Populus* shoots were prevented from growth by a mechanism other than apical dominance, and suggested that they are endodormant, i.e., the prevention is caused by factors intrinsic to the bud.

Though our buds carried stem tissue, we suggest that the prevention observed in *Rosa* also is caused by factors intrinsic to the bud. Because comparative studies, by Marcelis-van Acker and Scholten (1995), with axillary rose buds, revealed that the developmental process is very similar in vitro and in situ. Therefore, we suggest that topophysis in *Rosa* is an independent phenomenon which is intrinsic to the axillary bud rather than being controlled by correlative influences (apical dominance) at the time of bud development.

Influence of Inhibitors and Promoters. Gradients in inhibition due to position of buds, like those reported here, have been correlated with an accumulation of especially abscisic acid (Jones et al., 1976; Zieslin et al., 1978). Positive correlations between axillary bud growth and adventitious root formation in cuttings of *Schefflera arboricola* and *Stephanotis floribunda* have been attributed to root-produced cytokinin transported to the buds (Hansen and Kristensen, 1990). It could be interesting to investigate if inadequate levels of cytokinin in the buds (Ohkawa, 1984; Hansen and Kristensen, 1990; Qamaruddin et al., 1990; Dieleman et al., 1997) could cause the prevention of growth observed.

Buds forming the basal shoots on roses derive their cytokinin from the roots (Dieleman et al., 1997). Maybe a rose cutting is capable of de novo synthesis of cytokinins, as Dieleman et al. (1997) mention as a possibility, in addition to import from the phloem. However, most likely a balance between cytokinins and abscisic acid is involved, as has been proposed for regulation of basal rose bud growth (Zieslin and Khayat, 1983), possibly in interaction with other growth regulators. The addition of cytokinin appeared necessary for pea buds to develop when isolated from the intact plant (Gould et al., 1987).

In the concept of Positional Information (Wolpert, 1971; as cited by Greyson, 1994) developing and differentiating systems contain molecules (morphogens) that influence cell differentiation, and the pattern of morphogen distribution reflects sites of synthesis and the direction of their transport. Patterning in plant meristems could be based on intercellular, mechanical stimuli, or morphogens could be plant growth regulators (Greyson, 1994).

Aspects of growth readiness and plant architecture are integrated into the organogenic capacity of one organ, the bud. In many cases the influences of various endogenous and exogenous factors on the growth processes in buds are unsolved. Concerning the endogenous regulation this is largely due to the lack of early monitorable components in early stages (Rohde et al., 1997). In genetically transformed *Populus* Rohde et al. (1997) found the expression of two chimeric cell cycle genes to reflect the growth activity of the buds, and this occurred prior to visible changes in bud morphology. As for roses, in *Populus* axillary bud growth inhibition increased basipetally. Application of such molecular indicators may allow refinement of knowledge about bud growth and perhaps, topophysis.

Hormone Gradient Model of Stafstrom. Generally auxins are synthesized in the shoot apex and transported basipetally, and cytokinins are synthesized in root apices and transported to the shoots. At any point along the plant axis a relative and absolute level of each hormone exists. If buds grow when the level of cytokinin to auxin is high, and if the sensitivity of buds to these growth regulators vary according to their position, then the hormone gradient model (Stafstrom, 1993) might account for the observed positional effects on the time necessary for onset of bud growth (topophysis). But not necessarily for all other topophysic effects. Further, auxin may promote synthesis of a secondary inhibitor (Stafstrom, 1993), which could be abscisic acid.

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Improved Rooting in Woody Species by Reducing Stock Plant Irradiance

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In two experiments the benefits of reducing the irradiance to stock plants on the rooting of woody plant cuttings were demonstrated in the apple rootstocks *Malus* Ottawa 3 and Malling 26, *Rhododendron* 'Britannia' and 'Unknown Warrior', and in *Juniperus horizontalis* 'Andorra Compact'. In cuttings of *R.* 'Purple Splendour' and *Kalmia* 'Ostbo Red', and seedlings of *Kalmia* no positive effect of etiolation was found. The temperature during etiolation did not seem to have a significant effect on the rooting response.

INTRODUCTION

The effects on root formation of manipulating the irradiance during stock plant growth and development seem to vary between species (Moe and Andersen, 1989). If one considers the carbohydrate level of the cuttings as the decisive factor, it would seem correct to provide high irradiances, e.g. by using supplemental light in a greenhouse. However, especially in the case of trees and shrubs, it has been shown that high irradiances to stock plants can reduce the rooting percentage. In such cases it would be reasonable to reduce the stock plant irradiance. Maynard and Bassuk (1987, 1989) demonstrated that several species of herbaceous and woody plants respond positively to different kinds of etiolation and shading.

The irradiance can be reduced in several ways:

- Excluding light from developing shoots from bud break (etiolation);
- Etiolating the shoot, but letting part of it adjust to light before taking the cutting (localized etiolation);
- Letting the shoot develop in light, but subsequently exclude light from the part of the shoot that will become the base of the cutting (blanching);
- Reducing the irradiance to the whole stock plant (shading).

In experiments at the Horticultural Crops Research Laboratory in Corvallis, Oregon and at our department at the Agricultural University of Norway we have studied how some of these methods of reducing the irradiance affect the rootability of cuttings in some woody species.

EXPERIMENT 1

Stock plants of the apple rootstock *Malus* Malling 26 (syn. 'M26') and Ottawa 3; *Rhododendron* 'Britannia', 'Purple Splendour', and 'Unknown Warrior'; and *Kalmia* 'Ostbo Red' as well as *Kalmia* seedlings were etiolated from bud break at two temperatures (18 or 28C) (Hansen and Potter, 1997). After 2 to 4 weeks of etiolation the stock plants were moved to a greenhouse under ambient light conditions. The etiolated plants were divided into two equally sized groups. In one group the base of each shoot was wrapped with aluminum foil to exclude light and thus provide a localized etiolation. Shoots on the remaining plants were allowed to develop in light. Control plants were grown in a growth chamber at a constant photon flux density of 250 μmol m^{-2} s^{-1} at the two temperatures and subsequently moved to the greenhouse along with the etiolated plants. During a period of 6 to 10 weeks of light acclimation the plants developed new, normal leaves and pigmentation on previously etiolated stems. The aluminum wraps were then removed, and cuttings were obtained. The base of each cutting was dipped in 0.8% IBA talc, wounded by removing strips of bark on opposite sides of the cutting base (*Rhododendron* and *Kalmia*), inserted in flats containing a peat and perlite mixture (1 : 1, v/v) and placed under intermittent mist in a polythene tunnel in a greenhouse. Each cutting was scored for rooting twice; after 6 and 14 weeks for apple rootstocks and after 12 and 20 weeks for *Rhododendron* and *Kalmia*. The rooting percentage and the quality of rooting, assessed by number of roots in apple rootstock cuttings and rootball diameter in *Rhododendron* and *Kalmia* cuttings, were scored.

In apple rootstocks the localized etiolation (wrapped cuttings) produced a higher rooting percentage than the nonwrapped cuttings and the control (Table 1). The same was observed for *Rhododendron* 'Britannia'. In 'Unknown Warrior' both etiolation treatments were effective in producing a higher rooting percentage. In 'Purple Splendour' and *Kalmia* there was no difference between rooting of cuttings from the etiolated plants and from the control plants, irrespective of assessing rooting percentage or root quality (Table 2).

Temperature generally had only a minor influence on rooting (Table 1). Cuttings of Ottawa 3 rooted better when the stock plants were grown at 18 than at 28C. An interaction was observed between temperature and stock plant etiolation in *Kalmia*. Control cuttings rooted better when the stock plants had grown at 28C, while etiolated cuttings generally rooted better when stock plants had grown at 18C.

EXPERIMENT 2

Stock plants of *Juniperus horizontalis* 'Andorra Compact' were grown on a raised bed in a polythene covered greenhouse from 29 May to the first week of November (Thorvaldsdóttir, 1990). The irradiance in the greenhouse was set to be 100%, and shading was 70% or 50% of this level. The shaded stock plants were fertilized in four different ways providing 12 possibly different C/N (carbohydrate/nitrogen) ratios within the stock plants at the end of the growing season. Cuttings were obtained 3 and 10 November. The base of each cutting was dipped in 2% IBA talc, inserted in flats containing perlite, and placed in a fog chamber. During rooting supplemental light was given to provide equal irradiance for all the cuttings during rooting. Rooting was scored twice, 11 and 16 weeks after sticking.

A significantly improved rooting (both percentage and number of roots) was observed after shading the stock plants (Table 3). On average the number of roots increased from about 4 in non-shaded stock plants to almost 6 in cuttings from 50% shaded stock plants.

An interaction between irradiance and fertilization of the stock plants was observed. The reason for this interaction was thought to be differences in the C/N ratio. The C/N ratio was, as expected, higher at the highest irradiance (Table 4). However, rooting was better at the lower irradiance. This is not in agreement with the theory advocated by others that a high rooting percentage is positively correlated with a high C/N ratio.

Table 1. Rooting percentages of stem cuttings from plants forced to grow in darkness (etiolated, E) or in diurnal light (control, C) at two temperatures. Etiolated stems were either left nonwrapped (NW) or wrapped (W) with aluminum foil. F-test nonsignificant (NS) or significant (*) at P≤0.05.

		Control		Etiolated nonwrapped		Etoliated and wrapped		F-test		
		Temperature (C)						C vs. E NW	C vs. E W	Temp.
Species/cultivar	Total no. cuttings	18	28	18	28	18	28			
Malus										
Malling 26	331	56	63	56	54	83	82	NS	*	NS
Ottawa 3	192	91	71	86	58	100	94	NS	*	*
Rhododendron										
'Britannia'	275	75	77	78	79	90	91	NS	*	NS
'Purple Splendour'	441	91	94	88	85	92	94	NS	NS	NS
'Unknown Warrior'	288	76	84	91	89	92	91	*	*	NS
Kalmia										
'Ostbo Red'	255	53	71	67	38	69	61	NS	NS	NS
seedlings	203	19	38	51	27	55	33	NS	NS	NS

Table 2. Roots per cutting (*Malus*) and rootball diameter (*Rhododendron* and *Kalmia*) in stem cuttings from plants forced to grow in darkness (etiolated) or diurnal light (control). Data pooled from the two temperature treatments. Means separation within rows by multiple range test at $P \leq 0.05$.

		Control	Etiolated nonwrapped	Etiolated wrapped
Species/cultivar	No. of cuttings	No. of roots per cutting		
Malus				
Malling 26	109	4 b	4 b	11 a
Ottawa 3	106	7 b	10 b	13 a
		Rootball diameter (mm)		
Rhododendron				
'Britannia'	134	56 b	67 a	66 a
'Purple Splendour'	305	72 NS	72	75
'Unknown Warrior'	164	68 b	72 b	83 a
Kalmia				
'Ostbo Red'	41	34 NS	39	41
seedlings	33	43 NS	46	36

Table 3. Effect of irradiance to stock plants of *Juniperus horizontalis* 'Andorra Compact' on rooting of winter stem cuttings. Means separation within columns by multiple range test at $P \leq 0.05$.

Irradiance (%)	Rooting (%)	Roots per cutting
100	66 b	3.8 c
70	84 a	4.8 b
50	85 a	5.6 a

Table 4. The C/N ratio [(ratio between content of carbohydrates (g per 100 g dry matter) and content of nitrogen (g per 100 g dry matter)] in stock plants of *Juniperus horizontalis* 'Andorra Compact' after combinations of fertilizer programs and irradiances. Rooting (%) in brackets (After: Thorvaldsdóttir, 1990).

	Irradiance (%)					
	50		70		100	
Osmocote®* 2.5 kg m^{-3}	2.60	(83)	2.41	(86)	3.30	(74)
Id. + supplement**	2.99	(83)	3.87	(83)	4.31	(71)
Humusan®*** 5.0 kg m^{-3}	1.92	(82)	2.77	(74)	3.27	(57)
Id. + supplement**	2.48	(92)	2.34	(89)	3.61	(61)

* = Osmocote® Plus 3-4 months (15N-5K-12P);
** = 600 ppm $Ca(NO_3)_2$ 3 times; 14, 17, and 18 weeks after planting;
*** = Humusan® dried poultry manure (4.1% N).

DISCUSSION

The cultivars in Experiment 1 were chosen to represent both easy-to-root taxa (Malling 26 and 'Purple Splendour') and difficult-to-root taxa (Ottawa 3, 'Britannia', 'Unknown Warrior', and *Kalmia*). However, there was no real relationship between the supposed ease of rooting and the actual rooting. Even some of the difficult-to-root cultivars rooted quite easily.

It is well documented that etiolation and blanching of stems can improve adventitious rooting. However, the response to such treatments differs among species and cultivars. For example, etiolation improved rooting in the *Rhododendron* cultivars 'Britannia' and 'Unknown Warrior', while it did not improve rooting in 'Purple Splendour' (which rooted excellently after all treatments).

The time period for light acclimating *Rhododendron* shoots is several weeks, because the shoots should be somewhat mature before taking them as cuttings. This means that the shoots will get an extended time in light. One would think that such a long light period would nullify the positive effect of etiolation on rooting. But even after a light acclimation period of 10 weeks the positive effect of etiolation on rooting remained. The effect of temperature during etiolation remains obscure. Patience and Alderson (1984) found better rooting after stock plant growth at 25 than at 15C in *Syringa vulgaris*, while our experiment only showed small differences between etiolation at 18 or 28C. In those instances where we found a significant effect, the lower temperature gave the best result.

Several theories have been put forward to explain the positive effect of light exclusion from (part of) the stock plants on rooting of cuttings (Maynard and Bassuk, 1989). These theories include changes in stem anatomy, sensitivity to auxin, and changes in the content of phenols. In addition, etiolation starting from bud break results in reduced thickness of the stem, which in turn may reduce the demand for carbohydrates and increase the survival as a cutting (Howard, personal comm.).

The proposed theories do not fully explain why a limited irradiance reduction (shading) can have positive effects on rooting in several woody species. A suggested explanation for such results has been a reduction in the break-down of auxin, and that the resulting higher auxin content then improves rooting. The C/N ratio does not seem to be helpful in indicating rootability of conifer cuttings.

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Micropropagation of *Eustoma*

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INTRODUCTION

Eustoma (syn. *Lisianthius*) has been propagated and longterm stored in vitro at our laboratory as a service for our traditional breeding. The aim was to store important breeding lines in the laboratory and to use the in vitro lines for micropropagation of parent plants in the production of F_1 hybrids. In vitro storage is more convenient than keeping stock plants in the greenhouse and better than storage of seed because the lines are not totally inbreed (homozygotic) and the offspring will not be identical to the parents.

MICROPROPAGATION

It is not difficult to start tissue cultures of *Eustoma* as long as the stock plants are healthy and are growing well. Leaves and flowers are removed from the shoots before they are surface disinfected in a 3% korsolin solution. Due to the very smooth stems it is very easy to disinfect *Eustoma*. Nodes are used as explants. The same medium is used during culture establishment and for further propagation. The MS medium (Murashige and Skoog, 1962) is supplied with 6-benzylaminopurine (0.1 mg liter^{-1}). Subculture is performed every 5 weeks. Shoot clusters are divided into smaller pieces at each subculture. Temperature during propagation is 23C, and daylength is 16 h. Rooting is done on MS medium supplied with 3-indolebutyric acid (1.0 mg liter^{-1}).

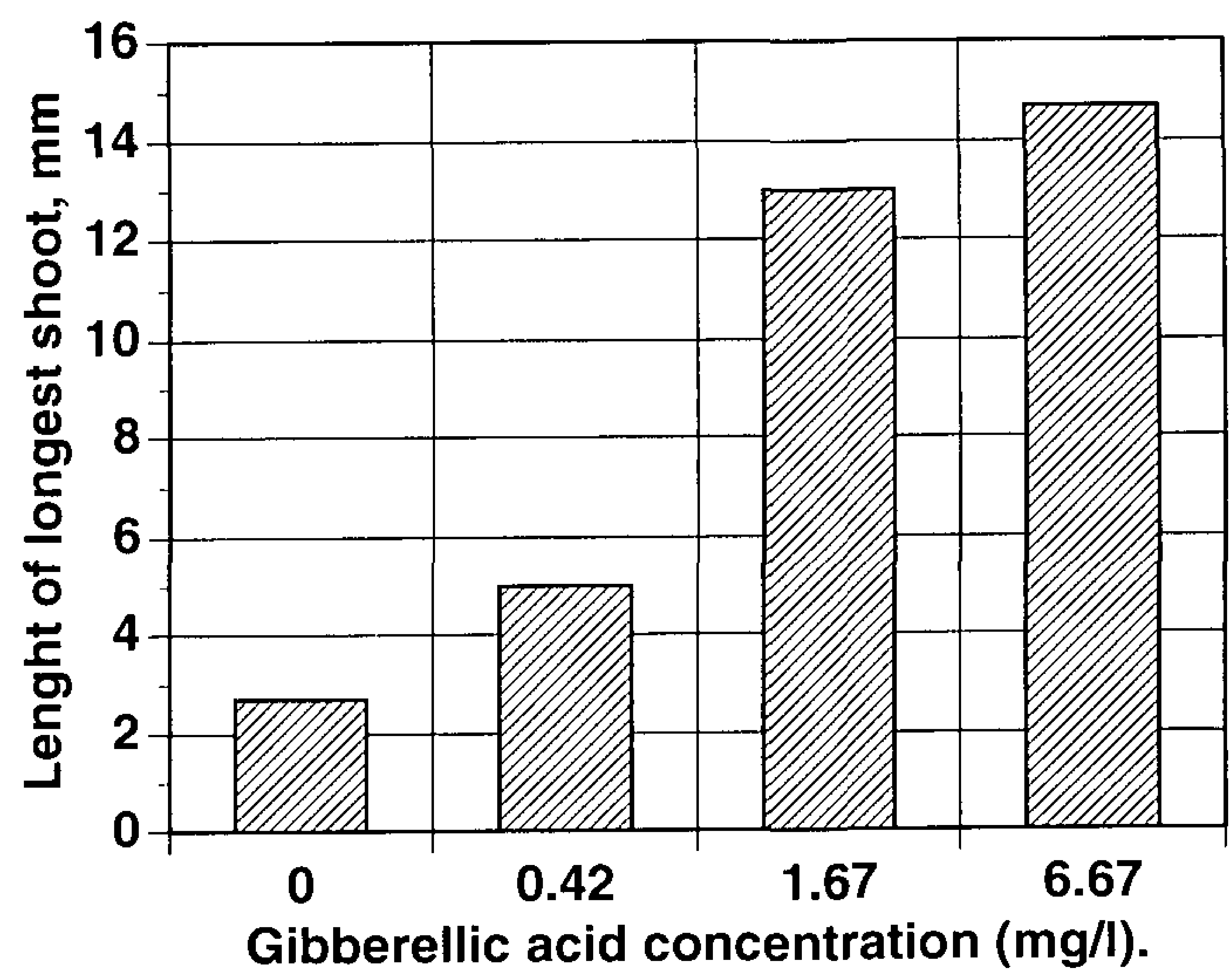

Figure 1. Effect of gibberellic acid concentration on in vitro shoot elongation of *Eustoma*.

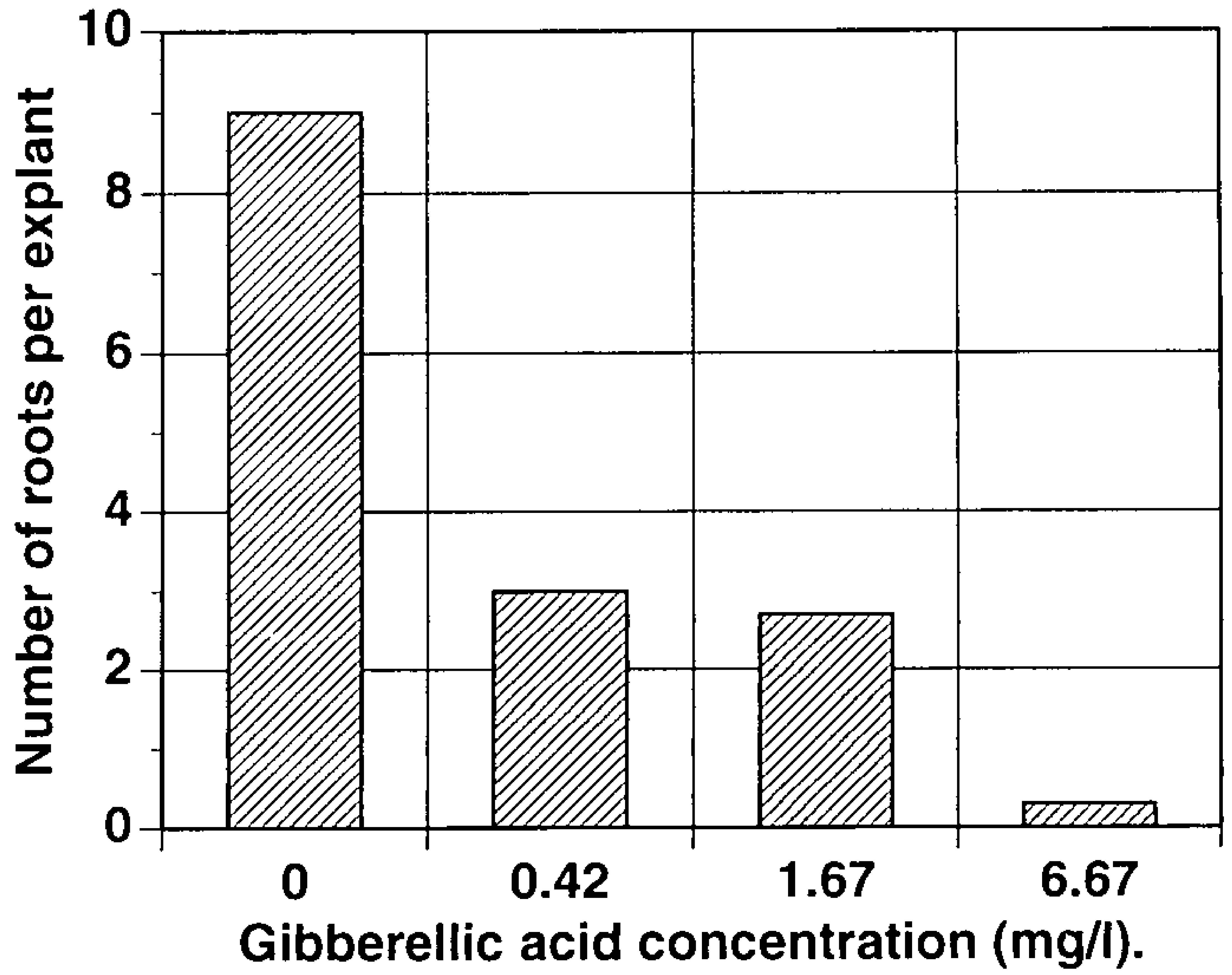

Figure 2. Effect of gibberellic acid concentration on in vitro root formation of *Eustoma*.

AXILLARY AND ADVENTITIOUS SHOOT FORMATION

Shoot formation is abundant but both axillary and adventitious shoots are produced. Adventitious shoots emerge on leaves and petioles. One has to be careful not to use adventitious shoots for further multiplication and thereby risk the production of abnormal plants. It can, however, be very difficult to identify whether a shoot is of adventitious or axillary origin. Both shoot types are easily multiplied and possible diverging plants can only be identified after their development in the greenhouse.

There is a great variation in the ability of different genotypes to produce quality plants in tissue culture. Generally, the optimal concentration of cytokinin and temperature differ, callus formation varies, different compactness of shoot clusters is observed, and the rooting ability can vary as well.

In order to distinguish whether shoots in very compact clusters were of axillary or adventitious origin we tried to increase shoot elongation by adding gibberellic acid (GA_3). Furthermore we hoped that the plants would show a subsequent increase in stem elongation in the greenhouse. Shoot elongation is stimulated by GA_3 in vitro (Fig. 1) and the increase in shoot length increased with increasing GA_3 concentration. This made it easier to distinguish between axillary and adventitious shoots. However, GA_3, inhibited root formation as shown in Fig. 2. This made initial establishment of the plants more difficult in the greenhouse and resulted in poorer growth. The stimulating effect on stem elongation was not persistent during subsequent growth.

ELONGATION AND FLOWER INDUCTION

In order to obtain stem elongation and flower induction in vitro plants were grown at either 18 or 23C during in vitro root formation. The experiment demonstrated that the temperature during root formation had a distinct effect on subsequent growth in the greenhouse. When rooting occurred at 23C plants continued to grow as rosettes after transfer to the greenhouse at 22C. When rooting occurred at 18C some of the genotypes had a normal stem elongation during subsequent growth at 22C in the greenhouse (Fig. 3). There were large differences between the two genotypes tested.

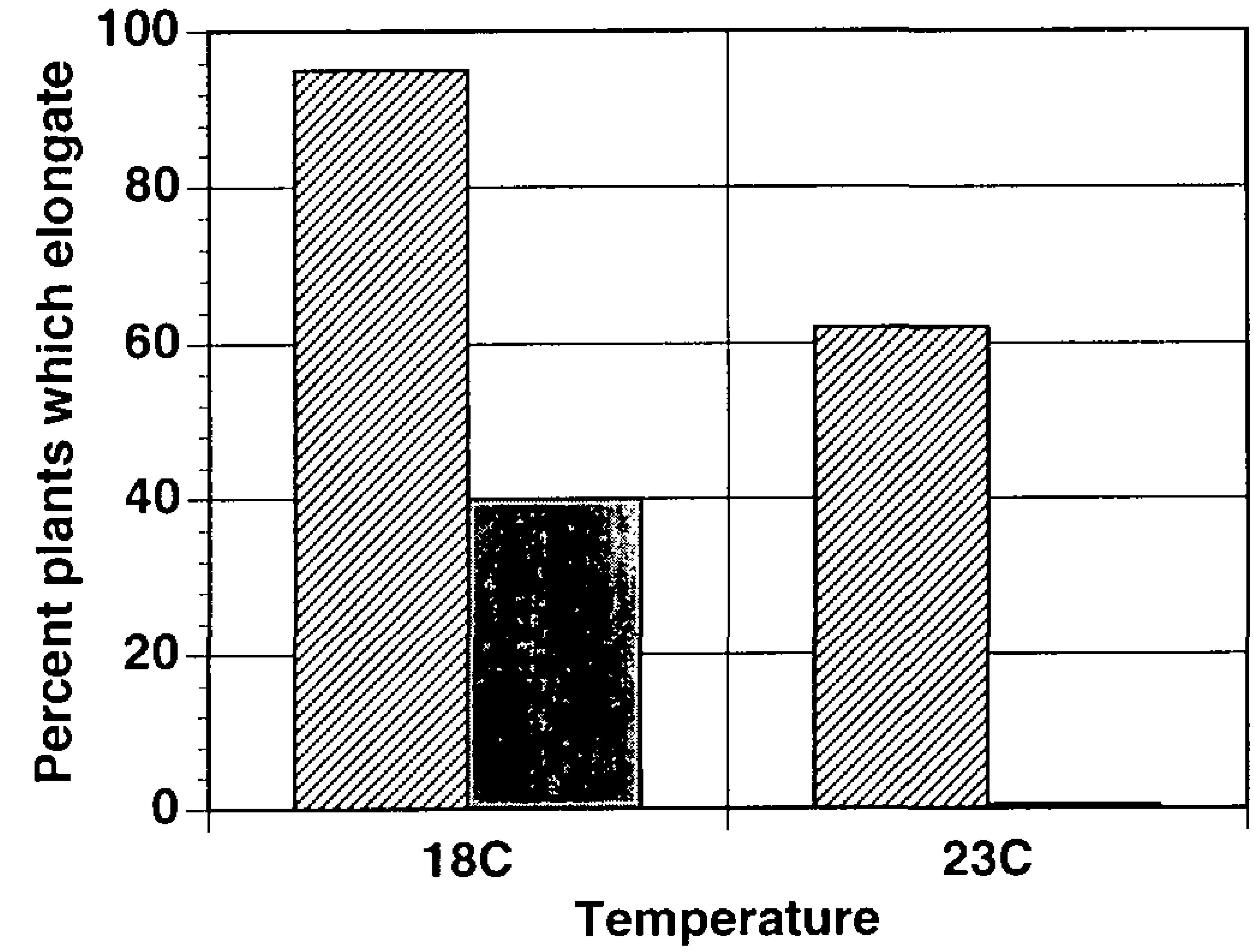

Figure 3. Effect of in vitro rooting temperature on ex vitro shoot elongation of the *Eustoma* genotypes 53425 ▨ and 53518 ■.

DISCUSSION

The addition of GA_3 to in vitro cultures of *Eustoma* makes it possible to distinguish between axillary and adventitious shoots which is important for the application of in vitro propagation in *Eustoma*. Research also demonstrated that it is possible to control stem elongation of *Eustoma* in the greenhouse through the temperature during in vitro rooting. This can be used to control transplanting dates of the various parent lines for seed production to make sure that the parent lines in an F_1 hybrid flower simultaneously.

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Somatic Embryogenesis of *Cyclamen persicum* Mill. in Bioreactors

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Propagation experiments were carried out in a series of six self-constructed and self-built bioreactors controlling temperature, oxygen level, stirring speed/direction, and light quality. The bioreactors are all fully automated and computer controlled. They provide excellent experimental conditions for controlled environments of the liquid cultures. Light quality, the factor investigated in these experiments, showed that blue light had a positive effect on production of proembryogenic masses (PEM) and somatic embryos in hormone-free medium. The experiments also showed that somatic embryogenesis responded to CO_2 level. Higher CO_2 levels were correlated with increased PEM, but the CO_2 level was not controlled, only measured. Ethylene concentration is believed to be another important factor, but was not measured in these experiments. Comparisons between cultures grown in bioreactors and suspension cultures in flasks on shakers clearly demonstrated that bioreactors have an enormous effect on cell proliferation and embryo formation. However, bioreactors require higher technical skills of the operator, as well as extreme care to prevent microbial contamination of the cultures, since the loss of 2 liters of suspension is a substantial loss in a commercial setting, compared to a flask of 100 ml.

INTRODUCTION

Today the commercial propagation of *Cyclamen persicum* Mill. is through seeds, preferably by F_1-hybrid seeds which are relatively expensive. *Cyclamen* is used as a pot plant and as a bedding plant (southern Europe in winter) and is one of Europe's largest flower crops, especially in Germany, Italy, and France. Hybrid seed production requires pure parent lines produced by six to seven generations of selfing. Even F1-hybrid seeds are sometimes not uniform enough in production. *Cyclamen* suffers from inbreeding depression which can show up as a sudden breakdown of viability during inbreeding. Vegetative propagation of *C. persicum* has so far been performed only on a small scale due to a number of obstacles. Tuber division yields low numbers as a meristem on each part is required to produce shoots. In vitro techniques have only recently become efficient enough, even though the first report on in vitro propagation was published more than 40 years ago (Mayer, 1956). However, the work published since Mayer (1956), such as Geier et al. (1983), Hoffman and Preil (1987), or Schwenkel and Grünewaldt (1991), has not solved the fundamental problems for an in vitro mass propagation scheme for *Cyclamen*.

Somatic embryogenesis (SE) would be an ideal way to produce masses of uniform "clonal seeds". One of the advantages of SE compared to axillary or adventitious bud propagation techniques, is that embryos are bipolar structures with functional *shoot and root meristems (Preil, 1994). Also, propagation through SE seems to give* less problems with somaclonal variation than other in vitro techniques, especially techniques based on regeneration from callus formation (Geier et al., 1992). There seems to be a selection towards normal plants with diploid nucleus through SE in poinsettia, even though suspension cultures contain high variation in ploidy level. Recent publications have reported SE on solid medium (Kiviharju et al.,1992; Takamura et al., 1995; Schwenkel and Winkelmann, 1995). Kreuger et al. (1995) successfully produced masses of SE from liquid cultures with no variation in ploidy level.

The process of SE production can be divided into several steps: initiation of embryogenic cultures, proliferation of pro-embryogenic masses (PEMs), development of SE, maturation, and germination of SE into plants. The first three stages take place in liquid medium, as described by Kreuger et al. (1995). Large-scale production of *Cyclamen* embryos in liquid cultures would be greatly enhanced by the use of bioreactors. Bioreactors are controlled growth vessels for liquid in vitro cultures under sterile conditions.

Schwenkel and Winkelman (1995; 1998) in Germany have developed a protocol for SE in *Cyclamen* using ovaries for initiation of embryogenic callus. Through COST 822, working group 2, our laboratory has been given two of the German genotypes and their protocol for production of SE on solid medium. Our contribution to the COST 822 cooperation in the Cell and Tissue Culture Group of the Agricultural University of Norway is the development of methods for SE in bioreactors, investigation of light quality effects, and the protein changes occurring during development from single cells/clusters to SE in *Cyclamen*. This research is possible because of our six identical bioreactors built by our Department of Agricultural Sciences (Heyerdahl et al., 1995) which enabled factorial experiments in bioreactors and our previous work on embryo specific protein changes in birch suspension cultures (Hvoslef-Eide and Corke, 1997).

MATERIALS AND METHODS

The six identical bioreactors in the Cell and Tissue Culture Group enables us to accurately monitor and control of growth conditions in liquid cultures. Our computer-controlled bioreactors are equipped for on-line measurement and control of temperature, agitator speed and direction, pH, and pO_2. Furthermore, we can vary light conditions (daylength, quantity, and quality). Bioreactors may be compared with a phytotron, a greenhouse compartment where the physical environment is under full control. The bioreactors in our laboratory have been especially designed for plant cell growth with low shear forces and gentle agitation to produce as little stress as possible and support proliferating cultures with high viability. Using bioreactors for plant propagation is a great challenge with many pitfalls along the road (Heyerdahl et al., 1995). Worst case scenario is to believe fully in the measurements the computer gives you, without cross checking. All the parameters measured may be wrong and give a false answer far from reality. Having six identical bioreactors enables us to run factorial experiments, as well as interchanging the bioreactors when repeating experiments. The reactors are based on batch cultures, which means that we dilute the cultures every 7th or 8th day, after sampling and cell counts. Oxygen is supplied through thin-walled (0.2 mm) silicone tubes which the gas diffuses through into the suspension dependent upon concentrations. This can be done with nonsterile air enriched with oxygen because the pore sizes through the tubes are small enough to filter the microbes, but allow gas exchange. Temperature is regulated in a waterbath, where cold water is added, or heat is provided. The pH is regulated by acid/alkali supplement through sterile filters. Each bioreactor is separately controlled by a computer, and each parameter may be varied with 1-h intervals over 24 h.

The advantages of using bioreactors compared to Erlenmeyer flasks on rotary shakers are: more accurate control of temperature, much improved control of oxygen, the possibility of controlling or monitoring pH, and the ability to grow larger volumes. The disadvantages may be the loss of larger volumes in case of contaminations, and it is more difficult to exchange all medium when removing auxin to induce SE. In spite of this, bioreactors provide an opportunity to produce large volumes with less labor, although they require greater accuracy and higher skills (computer and electronics).

The cultures and the protocol originated from Germany through the COST 822 cooperation. Laboratories in Germany, Italy, Switzerland, The Netherlands, France, and Norway all work on the same genotypes, and the same protocols for maintaining callus cultures and initiating suspensions (liquid cultures). The callus cultures are maintained in jars, in the dark, at 25C and are subcultured every 4 weeks.

Our liquid cultures are initiated by inoculation of 7 g embryogenic callus into a 250 ml Erlenmeyer flask containing 100 ml medium with auxin, placing on a rotary shaker (100 rpm) at 25C for 7 days, thereafter sieving through a mesh of 500 μm, and inoculating into one bioreactor. The bioreactor temperature set point is 25C and growth occurs in darkness for 7 days. When proliferating nicely, this bioreactor culture is used as inoculum for the other bioreactors in the experiments and provides identical starting material. To enhance SE production, the suspensions are sieved through sieves, collected on a 75-μm mesh, and flushed with auxin-free medium prior to inoculating the bioreactors. The bioreactors are autoclaved with 200 ml medium with/without hormones, cooled to setpoint temperature and calibrated for oxygen and pH in advance.

The light quality experiments were performed with four light qualities; darkness, daylight (OFT bioLIGHTSYSTEMS), blue filter (Strand filter No 419, primary dark blue), and red filter (Strand filter No 406, primary red). All light treatments were given the same light quantity; 5 $\mu mol\ m^{-2}s^{-1}$ for 18 h. The bioreactors were kept constantly at 25C, 100% saturation of oxygen (calibrated with 100% air through medium at 25C, without plant cells for 24 h), 30-rpm stirring speed, and change of stirring direction every 10 sec.

Plant cell growth was monitored through cell counts, packed cell volume (PCV) and proliferation of PEM. The latter two were done by sampling 10 ml aliquot of suspension, letting it sink in a pipette for 10 min, and reading the volume of PCV/PEM directly in milliliters.

RESULTS AND DISCUSSION

Factorial experiments revealed differences between bioreactors with regard to cell growth and embryo production. We, therefore, had to develop as uniform conditions in the bioreactors as possible and investigated the possible causes for the variation. By providing darkness in all bioreactors, and keeping the temperature, oxygen content, and stirrer speed constant, we discovered that the gas exchange varied from bioreactor to bioreactor. There was a high degree of correlation between gas exchange and embryo production (Table 1). Bioreactor 1 had a high gas exchange, with depletion of CO_2, and poor growth/PEM over the period from Day 9 till Day 16. The other three bioreactors had more CO_2 trapped and had better embryo production over the same period. These results could be due to high CO_2, or possibly ethylene accumulation. We did not measure ethylene and this provides an uncertainty. Kvaalen and von Arnold (1991) have published results for Norway spruce clearly showing the importance of CO_2 and oxygen, but have also provided data on the importance of ethylene for embryo formation.

Table 1. Measured CO_2 level in head space of bioreactors compared to packed cell volume (PCV) of *Cyclamen persicum* Mill. under somatic embryogenesis inductive conditions (hormone free medium).

Bioreactor no	Gas flow (ml min^{-1})	CO_2 level (ppm) 9 days	CO_2 level (ppm) 16 days	PCV % 9 days	PCV % 16 days
1	206 + 20.0	0.10	0.08	2.0	2.0
3	186 + 7.1	0.70	0.90	2.7	3.7
5	265 + 24.0	0.65	0.90	2.4	3.7
6	205 + 23.3	0.50	0.71	2.4	3.2

Table 2. The effect of light quality on *Cyclamen* suspension cultures in bioreactors and Erlenmeyer flasks on PCV in percent in two different experiments (I and II), number of embryos per 5 ml and number of globular embryos per 15 ml.

Light quality	PCV % I	PCV % II	Embryos per 5 ml (no.)	Globular embryos per 15 ml (no.)
Dark	2.2	3.0	100 + 34.5	2
Daylight	6.3	1.6	55 + 8	0
Red	2.3	2.9	69 + 25	1
Blue	8.2	1.4	71 + 16	5
Dark (flask)	-	0.1	0	0
Light (flask)	-	0.1	0	0

A plausible explanation for the difference in gas exchange between bioreactors, despite the fact that the gas flow was equivalent, could be the age and thereby number of autoclave treatments of the silicon tubes. They were only changed if a leak was observed. We tried new sets of tubing, autoclaved them several times, measured the gas exchange between each autoclave sterilization and found that the gas exchange deteriorated slowly. This is yet another factor to take into consideration when performing experiments in bioreactors, besides all the other pitfalls described by Heyerdahl et al. (1995).

In medium with hormones, light quality effects on *Cyclamen* cultures were difficult to interpret because the internal variation was too large. Earlier results in birch and *Begonia* (Hvoslef-Eide and Sæbø, 1991) have shown that red light was beneficial compared to darkness or blue light. However, all the cultures grew better in bioreactors compared to Erlenmeyer flasks; the doubling time of *Cyclamen* in bioreactors was 2 days, while Erlenmeyer flask cultures doubled in 1 week. This was similar to results for poinsettia suspension cultures (Preil, 1991; Preil and Beck, 1991).

When the medium lacked hormones and the aim was production of SE, Erlenmeyer flasks hardly gave any growth at all and no embryos were produced in 4 weeks (Table 2). Two experiments were contradictory regarding PCV results after 4 weeks. However, when counting embryos beyond the globular stage after 4 weeks, blue light clearly gave better and more advanced embryos. When taking previous experiments with birch (unpublished results) into consideration, as well as other literature (Chee, 1986), we would recommend blue light to enhance SE.

Our theory on the effect of light quality is that blue and red light resemble hormone effects, either through direct influence on production and/or degradation or hormone sensitivity (Kendrick and Kronenberg, 1994). In birch we could use red light to replace auxin in the medium, and obtain similar growth, while blue light triggered embryo formation (unpublished results). Chee (1986) states that blue light can enhance IAA destruction and shoot growth through IAA oxidation. Red light is reported to stimulate the formation of the IAA oxidation inhibitor quercetin (Mumford et al., 1961) and will therefore favor cell growth, but inhibit embryogenesis. It is well established that a strong auxin is a prerequisite for embryogenesis, but it must be removed to allow embryo development (Fujimura and Komamine, 1980). Blue light would, therefore, be beneficial to stimulate embryo development after red light has enhanced auxin-promoted cell growth. This would explain why we obtained the best quality embryos under the blue light regime. It is plausible to believe that removal of auxin/blue light treatment may well inactivate genes producing proteins that are inhibitory for embryogenesis, since removal of auxin results in proteins disappearing both in carrot (Kiyosue et al., 1991) and birch (Hvoslef-Eide and Corke, 1997).

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Dollars, Sense, New Plants, and Propagation

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PLANT ACQUISITION AND TESTING PROGRAM AT THE UNIVERSITY OF GEORGIA.

Considerable thought has gone into the operation of our plant acquisition and testing program at the University of Georgia. Occasionally the wheels are spinning and the net gain borders on zero. At other times, I am most gratified at the responses of the nurseries in Georgia and the Southeastern U.S. Perhaps the positive effect of the program has never been more evident than with the butterfly-bush (*Buddleja*) evaluations. Over 75 species and cultivars have been tested. One nursery in Georgia has taken cuttings of 38 cultivars. No visitor has left without at least one new cultivar! Today I report my top five butterfly-bush choices and evaluation at a recent field day (23 Sept. 1997) when 126 individuals voted on their top five butterfly bushes.

Dirr's current favorites	Field day top five
B. davidii 'Potter's Purple'	*B.* 'Honeycomb'
B. davidii 'Summer Beauty'	*B. fallowiana* var. *alba*
B. 'Honeycomb'	*B.* 'Moonshadow'
B. 'Summer Rose' (*B. davidii* 'Raspberry Wine')	*B. davidii* 'Royal Red'
B. davidii 'Peace'	*B. davidii* 'Nanho Purple'

Also presented are several introductions and/or promotions from the University of Georgia that have met with positive reception from the nursery and gardening communities.

***Buddleja lindleyana* 'Gloster'**

Clethra alnifolia.

- Selected compact clones grown from open-pollinated seed of 'Hummingbird'. Two selections are compact with lustrous dark green foliage and 10- to 15-cm long (4 to 6 inches) flowers.

Chamaecyparis thyoides, Atlantic whitecedar

- Forty-five clones now in our trials.
- Amazing variability.
- Easy to root and container grow.
- Have consumer appeal in a container or as a field-grown plant.
- 'Webb #1', 'Blue Sport', 'Okefenokee Compact', 'Glauca Pendula' are promising; many blue forms that are as handsome as *Cupressus arizonica* var. *glabra* 'Blue Ice', 'Blue Pyramid', and 'Carolina Sapphire'.

Ilex glabra

- 'Nigra' — Continues to impress us as the most lustrous dark green and foliage retentive cultivar in our trials.
- 'Green Billow' — A compact branch sport of 'Nigra' which shows promise and is one-third the size of 'Nigra'; discovered by Mark Griffith.

***Itea virginica*, Virginia sweetspire**

Too much leaf spot (*Phyllosticta* sp.) in our area with this species and 'Henry's Garnet'; interestingly 'Saturnalia' is resistant.

Loropetalum chinense* f. *rubrum

- Too many: have observed 4.6 m (15 ft) high 'Burgundy'.
- 'Zhuzhou Fuchsia' is the most upright growing and most cold hardy.
- 'Ruby' is possibly the smallest, exceptional in a garden setting in groupings or in masses.

Thuja plicata

- 'Spring Grove' — Collected from Spring Grove, Cincinnati by the author. Close scrutiny indicated hybrid between *T. occidentalis* × *T. plicata*. Six feet high in 2 years in our evaluations from a small 1-gal plant.
- Also in our evaluations are *T.* 'Green Giant' and *T.* 'Giganteoides', both hybrids.

***Thuja occidentalis* 'Wansdyke Silver'**

This is one of the few variegated (cream) conifers that has persisted without crisping. Although the literature lists this as a *T. occidentalis* selection, it is closer to *T. plicata.*

***Hydrangea arborescens*, smooth hydrangea.**

- The progenitor species of 'Annabelle' and 'Grandiflora'; interestingly, I found a rather nice lace-cap type at Bernheim Arboretum in the research forest.
- My wife, Bonnie, and I discovered a delicate sterile-flowered type in the North Carolina mountains, needless to state it has been propagated and named 'Highland Lace'.

The next best plant looms around the curve in the road!

Daylily (*Hemerocallis*) Production Propagation and Breeding

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Jon's Nursery Inc., 24546 Nursery Way, Eustis, Florida 32726

WHAT MAKES A DAYLILY DESIRABLE AND PROFITABLE?

I believe that the number one cultivar on the list should be one that offers repeat blooming cycles, has double flowers, excellent flower color, and resistance to fading in the sun. Other desirable traits include: plants with a good balance of floral scape to foliage size, foliage with resistance to summer heat, and a high yield of bibs for propagation by division that leads to profitable mass production.

DEVELOPING SUPERIOR NEW CULTIVARS FOR THE TRADE

Our philosophy at Jon's Nursery for developing superior new cultivars is to establish close relationships with successful professional breeders. This is just one of the ways that we bring in new and exciting plant material showing promise. By relying on professional breeders we also avoid tying up production space that occurs with the very land-intensive breeding process. Breeding and selecting daylilies entails tying up land during the evaluation of thousands of seedlings with little or no commercial value. Better land usage and screening efficiency occurs when we buy plants that appear to have commercial value and place them in an evaluation area for climactic and developmental trials. Crosses with siblings, parents, and outside cultivars can also be conducted more efficiently in developing new cultivars and discarding plants with undesirable characteristics.

Breeding and Selection. In an effort to create tetraploid daylilies, some hybridizers apply colchicine (a naturally occurring plant alkaloid) that is applied to mitotic cells, such as shoot apical meristems or root tips to induce polyploidy, i.e. diploids (2N) can develop into a tetraploids (4N). Tetraploid plants can have larger flower sizes and other desirable changes in morphology. Mutations can also be induced by radiation from x-rays and ultraviolet light.

PROPAGATION

Daylilies may be propagated by seed, however seedlings will not be true to type (except for species) and they usually produce an inferior plant in floral characteristics compared to the parental lines. That is why at Jon's Nursery we utilize seed propagation only for breeding and selection purposes.

Propagation at Jon's Nursery. Propagation for commercial production at Jon's Nursery is done by division — chopping away most of the root mass and soil of 1-gal stock plants with machetes. We then divide, using knives or simply separating by hand, so that each resulting new plant has a portion of the crown and at least one bud with a few stubby roots. Year-round propagation of daylilies at Jon's Nursery is successful in part because of our mild winters. During hotter, late summer propagation, divisions are planted into 40-cell, rose-pot-size trays containing a mixture of Canadian peat and perlite mixture (1 : 1, v/v) and placed in a shade house to root out.

Stock plants are produced by dividing plants during the fall and direct sticking into 1-gal containers to form plants for the next year's new source of propagules. Rooted cell packs from summer propagation can then be planted anytime of the year, thus replacing plants sold during the spring through the summer, and assuring that well rooted sellable 1-gal material is ready early in the following spring.

Daylilies may also be rooted by proliferations or offsets, which are unrooted plantlets formed along the nodes on scapes late in the bloom cycle. These are handled as unrooted liners. Some breeders claim to have success in creating a proliferation of unrooted plantlets.

DAYLILY PRODUCTION AT JON'S

For production at Jon's, daylilies are planted in 6-inch pots with a well drained soil mix of pinebark, peat, sand, and slow-release fertilizer. Over the years, we've used different media and all performed well with daylilies. Major plant pest problems are with thrips and aphids, which we control with air blast applications of Cygon 2E. This provides good systemic control without the use of restricted-use pesticides. Occasional spider mite problems can be spot treated with specific miticides that are labeled for use on *Hemerocallis*.

WHERE DO WE GO FROM HERE?

At Jon's Nursery we are promoting a line of tetraploid daylilies selected for their upright rigid foliage, more compact and heavier scapes, larger and thicker flowers — and of course the very rich flower colors which we believe tend to make truly superior plants.

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Propagation of Weeping Yaupon Holly

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INTRODUCTION

Weeping yaupon, *Ilex vomitoria* f. *pendula*, is a plant in much demand by our customers. It is used by landscapers as a dramatic focal point because of its unique growth habit. It is not currently available in large quantities because of difficulty in rooting. Hence, rooted liner plants are in high demand by other nurseries wanting to produce this species.

PROPAGATION OF WEEPING YAUPON HOLLY

When to Take Cuttings. The best propagation wood should be taken from well nourished plants using current season's growth that has hardened off. The best times are late spring or early summer after the new growth has hardened and turned gray, and before the daily temperatures have gotten extremely hot; also early fall from late September to early October. In our hot, southern U.S. Gulf Coast climate, I prefer the early fall sticking time. The fall days are warm but moderate and night temperatures range from 16 to 18C (60 to 65F). Of course, this time frame can be adjusted to your own climatic situation. Take your cuttings early in the morning while the day is still cool and the plants are turgid.

Cutting Techniques and Preparation. As soon as a substantial number of propagules have been harvested, they are moved to a shaded area and kept moist to avoid any stress. As previously mentioned, the cutting base should have changed from green to a light gray color prior to harvest. Branched leafy cuttings 15 cm (6 in.) long are taken and the top third of the growth is removed. A branched cutting helps maintain a higher humidity around each plant when stuck close to each other. Maintaining humidity keeps your cuttings from getting too dry and dropping their leaves. Try to retain a branch no further than 2 cm (0.75 inches) from the base to prevent the cutting from being stuck too deeply. Any branch closer to the base should be removed. This creates what we call a "strip wound" and promotes better callus formation.

Auxin Treatment. Each prepared cutting is quick-dipped in alcohol based IBA at 1870 mg liter^{-1} for 3 sec. Throughout the years we have tried formulations ranging from 15,000 mg liter^{-1} K-IBA to 10,000 mg liter^{-1} IBA, to no chemical treatment. None of these treatments were better than 1870 mg liter^{-1} IBA, which is the auxin concentration used with all of our yaupon cultivars.

One important cautionary note: do not use any formulation containing NAA, which has proven toxic to our yaupon cultivars. Leaves will abscise, stems will burn, and most of the cuttings will die! Many rooting formulations contain NAA, so be cautious when using these products on yaupon. Talc preparations may not be as much of a problem but I would not feel safe using any containing NAA with yaupon.

Lining Out the Cuttings. At Flowerwood Liners, we stick or "line out" our unrooted cuttings one per pot in either Lerio SR225 or SR325 pots, which are placed in trays holding 64 or 36 pots, respectively. The liner pots are filled with propagation mix utilizing a flat filling machine. The filled trays are set down in beds in a gutter connected house manufactured by Caves International of Hammond, Louisiana. Each irrigation/mist zone holds 570 filled trays. Our rooting medium doubles as a growing mix, so it must be able to drain well yet hold enough moisture to produce plants. The propagation/liner medium consists of propagation grade pine bark, Canadian peat moss, and horticultural perlite (3 : 2 : 2, by volume).

We add two preplant nutrient and pesticide formulations to the propagation/liner media:

Formulation One — used during early spring and warmer months:

4.5 kg m^{-3} (7.5 lb yd^{-3}) — Nutricote 18N-6P-8K
1.8 kg m^{-3} (3 lb yd^{-3}) — magnesium sulfate
3.0 kg m^{-3} (5 lb yd^{-3}) — dolomitic limestone
1.5 kg m^{-3} (2.5 lb yd^{-3}) — Talstar for ant control

Formulation Two — used during fall and winter for quicker release during cooler temperatures in the greenhouse:

4.8 kg m^{-3} (8 lb yd^{-3}) — Osmocote 16N-8P-12K plus minors
3.0 kg m^{-3} (5 lb yd^{-3}) — dolomitic limestone
1.5 kg m^{-3} (2.5 lb yd^{-3}) — Talstar for ant control

I prefer to direct stick the cuttings into 6-cm (2.25 inch) pots (this is the SR225 pot). A higher humidity can be maintained around each cutting without constant overmisting. The small slick leaves will not hold water for any length of time and most of your mist ends up in the rooting medium. Rooting cuttings in larger pots is more difficult. Flowerwood Nursery's field operation prefers a 10-cm (4 in.) pot, but the cuttings don't root well with that much air movement around them. Multiple cuttings could be used except most growers do not want a multistem weeping yaupon.

Misting. We mist with a Phytotronic 1626 D time clock plus a 24-h clock to daily turn the mist on and off. The mist lines have a Senniger Super Spray nozzle with a No. 12 orifice and a convex deflector pad. All cuttings are rooted initially under 47% to 51% shade.

On a newly stuck mist/irrigation zone of weeping yaupon, it is best to use a slightly heavier mist to overcome the shock of being cut, trimmed, and stuck in rooting beds. During the first week, start the mist cycle 1 to 1½ h after sunrise and turn it off for the day 1 h before sunset. The next week raise the start time to come on 2 h after sunrise or just after the morning condensation has dried off. Turn the mist off in the evening about 2 h before sunset to allow excess moisture to dry off the leaves before dark. A typical beginning misting schedule could be as follows:

7:30 AM to 9 AM — mist every 20 min;
9:00 AM to 10:30 AM — mist every 15 min;
10:30 AM to 12 Noon — mist every 10 min;
12:00 NOON to 2:00 PM — mist every 6 min;
2:00 PM to 3:00 PM — mist every 10 min;
3:00 PM to 5:00 PM — mist every 15 min;
5:00 PM to 6:00 PM — mist every 20 min.

The schedule uses an 8-sec mist and is written for Central Daylight Time.

As we reduce the mist, the start times are raised to 8:00 or 8:30 AM and the stop times are changed to 5:30 PM A typical reduced mist schedule could be:

8:30 AM to 9:30 AM — mist every 30 min;
9:30 AM to 11:00 AM — mist every 15 min;
11:00 AM to 2:30 PM — mist every 10 min;
2:30 PM to 4:00 PM — mist every 15 min;
4:00 PM to 5:30 PM — mist every 30 min.

Reducing the amount of mist and preventative fungicidal sprays help reduce disease problems.

All yaupon taxa are generally stuck in the same greenhouse, but the more difficult cultivars are kept on separate misting control zones to be able to tailor a schedule for their needs.

Chemical Treatment. We spray weekly in the rooting beds with fungicides, alternating between Clearys 3336 and Chipco 26019. The spraying is usually done after the mist has been turned off and re-entry times are no problem. Since yaupon is very susceptible to spider mites, we spray with miticides as needed. Leaf miners are a problem we previously controlled with Meta-Systox R, however, it is a restricted-use pesticide and carries a "danger" label. We now utilize less dangerous pesticides.

RESULTS AND DISCUSSION

Rooting results of weeping yaupon are often sporadic. Long after dwarf yaupon has rooted, a small percentage of weeping yaupon cuttings will be unrooted, but callused. Cuttings stuck in October do not usually root until February or March. As the cuttings callus, the mist is dramatically reduced, with one 30-min cycle in the morning and late afternoon, and 20-min cycles during midday. As the days warm in the spring, we change the misting interval to overcome additional daytime heat. By April, maybe 50% of the callused cuttings will be rooted. If no more root by early May, the mist is permanently terminated and the liners are fertilized with 12N-6P-6K at 49 g m^{-2} (1 lb 100 ft^{-2}). Any remaining callused, unrooted cuttings are discarded, since we don't want to damage rooted liners with any further effort to get recalcitrant cuttings rooted.

A good rooting percentage is usually 60%, and frequently only 40%. These low percentages would not be acceptable with most species, but the demand for weeping yaupon increases its value and it is worthwhile to produce. After rooting, weeping yaupon grow easily and rapidly, and a salable liner is very easy to produce.

New Marketing Ideas to Meet the Needs of Our Changing Nursery Industry

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INTRODUCTION

The nursery industry has always been a dynamic industry that has had to constantly follow the fads and fashions of the gardening public and landscape industry as well as keep up with the technology of the industry and the lifestyles of our customers. Our large nurseries are getting larger, our midsize nurseries are struggling to find the best size to maintain profitability while still being able to compete with the big nurseries, and our small nurseries are looking for niches. Our industry is so large and diverse that there is still a place for everyone but we must be more creative, use more of our horticultural skills, concentrate on quality, and use marketing skills to create our niches.

TRENDS IN THE INDUSTRY

Nurseries compete with each other through quality, production, and transportation costs. It is difficult for small nurseries to compete in the area of production due to the advantage of economy of scale held by the larger nurseries. Buying in large quantities allows nurseries to realize substantial discounts on all production supplies. Their costs are also spread out over a larger number of plants. A small nursery has the competitive option of reducing transportation costs by offering personal, convenient service to a local clientele and providing higher quality plants. The other option is to find a niche.You can choose not to compete, do something a little different and take advantage of your horticultural skills, creativity, and artistic talents. We are fortunate in our industry that our options in this area are only limited by our imagination.

It is interesting and helpful in making the choice of which niche to pursue — to first, study and observe trends in our industry and our society. Perennials, which were at one time a cottage industry, are now mainstream. Where they were once grown in blocks of 100 plants or less in a plantsman's back yard nursery, they have now moved to blocks of several 1000 and have become part of the mega nurseries' product mix.

Mass market retailers, who at one time devoted a small section of their floor space to poor quality plants and gardening items, now employ all their marketing skills and financial resources to exploit this market of unlimited potential. They now devote more space to higher quality plants and are providing trained people to sell and service these products. Where our industry overwhelmingly defeated the marketing order to promote our products, these large retailers have moved in to fill that need by bombarding our spring gardeners with horticultural TV ads and sponsoring gardening programs and an entire cable channel, HGTV. This has been good for our industry. It has certainly contributed to the trend of making our larger nurseries larger, but the greater contribution has come by making products more easily available to the gardening public and reaching people who would not have made a special trip to their local garden center. The florist segment of our industry discovered and has been profiting and enjoying this market for many years. How many people currently buy flowers and flower arrangements from their local grocery store, who previously not have made a trip to the florist?

This trend is in its infancy. Drive though any neighborhood and see how many (or how few) homes are displaying "Southern Living Gardens". Six assorted, nondescript, round "bushes" are slammed against the foundation of a typical house landscape with two trees evenly spaced on opposite sides of the walk leading to the front door. It is not that most people do not want a pleasing landscape. But it takes a great deal of knowledge and artistic skill or a professional landscape designer with these skills to create these special garden scenes. This can be seen as a great opportunity for the continued growth of our industry.

Organic Gardening Magazine conducted a survey in 1991 which identified four marketing segments of our gardening public. They were labeled as dabblers, decorators, cultivators, and masters. There were many interesting facts uncovered in this survey but one fact that can change our outlook on how we market plants is that the groups that we most often target for our sales represent only 21% of total industry sales. These groups are the masters and the cultivators. They represent the hard-core gardeners. They are the Latin spouting, gardening enthusiasts that others come to for advice on producing show roses (*Rosa* hybrids) or basketball-sized tomatoes. The other two groups are made up of weekend hobbyists and those gardeners whose goals are to just enhance the beauty of their homes. These are not our most knowledgeable or enthusiastic gardeners. However, this group makes up 79% of gardening sales. The mass-market retailers are probably targeting and reaching this group as well as others that have never thought about gardening.

We are part of an aging population that is growing very slowly. We are becoming increasingly more affluent with more demands on our time. Our focus is on the family, health, environment, and spending more time at home. These trends point toward great opportunities for our industry and probably are part of the reasons we are enjoying more commercial prosperity over the past few years.

MARKETING IDEAS TO TAKE ADVANTAGE OF TRENDS

Define Common Problems Among Gardeners. As a small grower, how can you take even greater advantage of these trends and opportunities? You can start by targeting the population of gardeners that are spending 79% of the money. Take a look at all the things a gardener does. Ask them what tasks take the most time and are the most frustrating chores for them to accomplish. Use your horticultural skills and creative talents to produce products that are less time consuming for the gardener to install and maintain and help them produce the "Southern Living Garden" without all the knowledge required to attain this look. Also, explore ways to offer them a finished product so that they do not have to wait 3 to 5 years to realize their vision. Take advantage of their increasing affluence along with their lack of knowledge and time. Again, the florist industry is ahead of our segment of the industry in tapping this market. As soon as flowers come off the auction floor, designers are waiting to take the raw products and create a finished floral arrangement or container garden for display and sale in your local grocery store or mass market.

Offer Convenience. This thought of providing convenience for our customers is nothing new. It is pervasive in all the products we buy. The next time you walk through the grocery store, note all the things that have been done in recent years to take the hassle out of your life and save you time. Fruit displays offer colorful, enticing, pre-cut, cleaned fruit that is artistically arranged for serving. You also find packaged salads ready to serve, meats and cheeses cut and layered ready to go on your submarine sandwich and ATM machines at the checkout to help you conveniently pay for these other conveniences. Our own industry has made some slow advances toward offering easier ways to a beautiful garden. We sod much more than we seed. We sell 1- and 3-gal perennials in flower now where we once sold bareroot parts in a plastic bag. We even offer espalier plants now ready to plant against the side of our homes. These products have evolved as customers have demanded the change. **Think of what we could do if we made convenience and problem solving our goals and aggressively marketed our ideas for offering instant modular landscaping for "no wait, no hassle" beautiful gardens**.

Quality. The first thought in producing any of these projects is to begin with quality as your major goal. This is your other competitive option in dealing with large nurseries. Many large nurseries also produce high quality plants but you certainly cannot compete unless you have equal or superior quality products. Working with the Christmas tree industry has helped me develop an outlook which requires that I look carefully at plants that we have for sale. Christmas trees are typically thought of as a forestry crop, but there are few crops that are managed as intensively as Christmas trees. Intensive management of a plant crop is the definition of horticulture. Christmas tree growers, through consumer demands, must now evaluate each tree to be sure it has four good sides, is well shaped, and pest free. We should take this same approach to quality, rather than the forestry approach of evaluating quality by looking at blocks of plants. Look at each plant and decide if you would purchase that plant from the retail garden center or put it in your yard or living room. That is the way your customer evaluates your plants.

The following projects are some of the ideas, in various stages of evaluation, that we are exploring at Auburn University.

Alternative Christmas Trees. Producing alternative Christmas trees in containers has already been a success. Leyland cypress was the most highly rated plant as a container Christmas tree but various hollies were also ranked very high by consumers as a product they would buy if plants were available. These products were decorated and displayed in garden centers, botanical gardens, and the State Fair for consumer evaluation. Other trees that were displayed were *Magnolia grandiflora* 'Little Gem' and several other magnolias, Arizona cypress, and *Cedrus deodara* (deodar cedar).

Grafting Opportunities. Use your grafting skills, knowledge of plant material and creative skills to produce new and exciting products for the landscape. Oregon growers are already involved in using the best attributes of various cherry species to engage in "tree building". They take a good rootstock, *Prunus avium*, and select an attractive trunk, *P. serrula*, and then top it off with a weeping tree form, Yoshino cherry (*P.* ×*yedoensis*) or other attractive cultivars. You are only limited by your imagination! We are grafting English hollies on to *Ilex* 'Nellie R. Stevens' understock to see if we can overcome problems of growing English Holly in the South. We have found a new grafting technique (to us) from China that has proven to be very effective in grafting oaks, pecans, and other trees. We are looking at selecting superior cultivars and evaluating understocks of oaks to solve problems such as chlorosis of pin oaks on high, dry, high pH soils in urban areas. We have found we can graft mature oaks successfully which will allow us to rid the consumer of an aesthetic problem of juvenile leaf retention on some oaks. This also allows us to provide wild life enthusiasts with oak trees that bear nuts the second year rather than the typical 6 to 16 years. It is still too early in the research to evaluate reported graft incompatibility problems. Jeff Sibley, a faculty member at Auburn University, is looking at grafting Chinese pistache (*Pistacia chinensis*) to capture the best qualities of fall color and growth habit. Sourwood (*Oxydendrum arboreum*), fringe tree (*Chionanthus virginicus*), stewartia (*Stewartia*), and many other opportunities await the budding opportunist.

Plants on Standards. European growers and western nurseries have exploited the art of putting various plants on a standard for use in patio and balcony gardens. *Rhododendron*, rose, azalea, *Euonymus*, willows (*Salix*), Japanese maples, and many other plants have been lifted up to eye level to display a plant's ornamental qualities or facilitate and accentuate the display of a weeping growth habit. We are trying several of these plants and exploring ideas for new products. It is fun to think about all the possibilities. The consumer and the grower do not know what they are missing, yet!

Instant Hedges and Ugly Fences. How many times have you heard a gardener request a fast growing screen plant? They want something that will produce an instant 12-ft screen and then stop growing. Having nothing to solve this problem, the consumer buys an 8 ft, $6 to $10 per foot ugly fence and installs it at 2 to 3 times this price only to have to cover it up over 3 to 4 years with a pretty vine or shrub. Can we give them an instant hedge at a comparable price? We are looking at production systems to address this problem. Can you take those ugly fence sections and lattice arbors and provide these sections already covered in the pretty vines for modular installation of a fence? This would provide the look of an established landscape in some of the stark, bleak, clear-cut new construction sites.

Parterre Gardens. What about parterre gardens? How often do you get people returning from their travels to Longwood Gardens or the formal French gardens and hear them talk of how nice it would be to have one of those designs in their back yard? Can we grow these finished garden designs and offer them in a glossy pictorial catalogue for designers, landscape architects, and garden centers to provide instant elegance, a touch of Paris and royalty in their back yard. This takes knowledge, expertise, and skill that certainly the typical gardener and most designers do not possess (the problem, the answer, the opportunity, and the niche).

Using Existing Plants in a New Way. There is also the opportunity to take existing plants that are not often purchased and offer new ways in which these plants can be used effectively in the landscape. I was very impressed with the use of redosier dogwood (*Cornus sericea*) and yellow twigged dogwood (*C. sericea* 'Flaviramea') as a formal hedge (very effective in winter). Have you seen smoke tree used as a mass planting and cut back each year as a large ground cover? Some of our semidwarf crapemyrtles (*Lagerstroemia*) are being used in this fashion. Travel, reading, and trying to explore different forms of each plant will give you a number of new ideas to try.

Container Gardens. Container gardens are on the rise to offer year-round color and aesthetic appeal to business and home entrances and patios and decks. We provide the containers, media, fertilizer, and plants but no guide for success. Just as florists provide finished arrangements, so should we. Few people have the knowledge of plants, color, texture, size, form, shape, growth rate, and adaptability of combinations of plants to create effective container plantings. All this knowledge required screams NICHE!!!

Window Boxes. Fads and fashions are common in our industry. At one time window boxes were "quite the thing". They probably phased out because of failures of design and being too time consuming to wait for development of the finished product. Let's bring them back, instant, new, and improved, and low maintenance, a touch of nostalgia from grandmother's house. Professionally designed, colorful, effective, seasonally replaceable insert boxes of beautifully arranged flowers, and foliage plants for use in window boxes could be fashionable today. It is no wonder gardening is our number one hobby! It is so much fun to think of the possibilities.

Good-looking Fruit Trees. Have you ever found a good looking fruit tree in a garden center? They are usually the crooked, twisted, cut off stick jammed in the back of the garden center with a picture of an apple or peach dangling from a broken branch. A gardener has to have great imagination and patience to envision fruit on that ugly stick. How do you begin to convert that stick into a well branched, properly pruned fruit tree? Do you have faith that this tree will produce a "Super Ruby-red Scrumptious" apple cultivar or 3 years later will you find a "Grungy Green Reject" apple. Wouldn't it be nice if some grower would produce an apple tree in a container that was already pruned properly and had that delicious apple dangling from the branches. There is no vision to ponder. Reality is in front of you and a taste away. A nursery in Tennessee is already exploring this niche as well as growing the trees as an espaliered pot-in-pot production crop.

Children's Gardens. Children's gardens are a current topic in popular horticulture magazines. It is strange to think that people with children have disposable income but I often wander by $500,000 homes and see tricycles parked in the garage. They are obviously not in the noble profession of horticulture. Can we use our talents to produce topiaries or kits for topiaries for their education and enjoyment? This is an area that offers great opportunities for creative, children-loving horticulturists. How can you take thoughts of magic carpets, castles, and dinosaurs and use horticulture products to enhance those dreams?

Espalier Plants. We are currently producing these plants on a small scale and in small containers. We could be producing larger scale plants for instant coverage and softening of large stark, blank, glaring walls. We could follow the European nurseries and produce trees growing in a single plane for narrow streets or formal drives. Fruit trees would fit well here too.

Bareroot Plant Production Revived. A final area that we are investigating is the possibility of bringing back bareroot plants as a viable, reliable, and inexpensive way to market trees and other plants. Dr. Dan Struve, at Ohio State University, is conducting research on accelerated growth of trees in small containers in an inert media that can be easily removed from the roots for shipping or transplanting. We have followed up and cooperated with Dr. Struve in taking the process one step further to produce trees in large containers for bareroot export sales and to reduce costs for shipping and handling of trees for mass plantings of larger trees or for use in urban plantings. We are using a product called Profile made by Aimcor Corporation as the inert medium for producing these trees. This project is in its first year of evaluation. We are also re-exploring the possibility of producing sod, bareroot groundcovers by planting groundcover liners in beds underlined with landscape fabric painted with Spin-out in Profile medium. Hopefully we can produce a product to offer an instant mature landscape appearance by harvesting these plants as a solid sod. We are using a sod netting to help hold the plants together. This is also in the early stages of evaluation.

These are a few of the ideas that we are trying — but these ideas barely scratch the surface of the opportunities that we could develop to expand our horticulture base and our customer's gardening enjoyment. Our industry is so diverse that there are opportunities for everyone, big and small. Use your horticultural skills, artistic talents, and creative ideas to create a niche. As you develop your production ideas, take a tip from big business and develop your marketing strategies at the same time so that when the products are ready for sale there will be waiting, eager customers ready to buy the new products.

Propagation and Cultivation of Selected Gingers in the Subtropics

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INTRODUCTION

Gingers are a large group of exotic plants with an unmistakable tropical appearance. Currently, taxonomists recognize 40 genera and over 1500 species of gingers. As a result of recent collecting trips into China, Burma, Malaysia, and Thailand, many more exciting species and cultivars are soon to be introduced. Fossil records indicate that gingers have been around for at least 65 million years and have inhabited such unlikely places as the North American plains, Canada, and even Russia. Their ancient past gives clues to their best kept secret.

Cold Hardiness of Gingers. Despite their tropical appearance, many gingers are surprisingly cold hardy, especially *Hedychium* and *Curcuma*, which thrive and bloom as far north as Atlanta, Georgia and Raleigh, North Carolina (U.S.D.A. Zone 7). Some gingers such as *Alpinia, Hedychium,* and *Costus* are evergreen in warmer climates, although frost will damage or kill the foliage of most gingers. Others such as *Curcuma, Globba,* and *Kaempferia* are deciduous, experiencing a dormancy period even in the tropics. This deciduous nature allows temperate gardeners to enjoy many more gingers that their tropical origin might indicate. For example, *Globba winitii*, a native of Zone 10, can successfully grow to bloom in Zone 7 provided soil is sufficiently well drained to keep the rhizome from rotting during the dormant winter months.

Forms and Habitats. Most gingers complement their exotic foliage with beautiful, often fragrant flowers. Gingers range in size from tiny groundcovers like *Kaempferia* to giant *Hedychium* and *Alpinia* best used as background plants. Gingers prefer moist, fertile soil, and are generally considered to be shade plants. Many, especially *Curcuma* and *Hedychium*, will thrive in full sun provided they have adequate moisture. They are remarkably free of most diseases and pests that plague other perennials. This, combined with their easy culture, exotic foliage, and tropical blooms, make gingers one of the most exciting crops on the market today.

PRODUCTION OF GINGERS IN GAINESVILLE, FLORIDA

We have been growing gingers in Gainesville, Florida (Zone 8b) for 8 years. Our average minimum temperate is -8C (18F) and we usually average 18 nights with temperatures below 0C (32F). *Hedychium* taxa are grown in full sun with overhead irrigation. *Curcuma* taxa are also grown in full sun with the exception of *C. roscoeana*, which is grown under 50% shade cloth. *Globba, Alpinia, Costus,* and *Kaempferia* are also grown under 30% to 50% shade depending on the species.

Hedychium is left in the field during the winter months with overhead irrigation. Plants are covered with 6-mm black plastic or freeze-protection cloth only if the temperature is expected to stay below freezing for 4 to 6 h.

Costus, Curcuma, Kaempferia, and *Zingiber* are removed from irrigation and covered with clear plastic in a shady spot to keep them dry for the duration of winter. Fertilization and watering is resumed as new growth appears in the spring.

Alpinia is carried over in a cool greenhouse (temperature is kept above freezing) as the foliage recovers slowly from a hard freeze, and it will not bloom if the canes freeze. Soil medium consists of fresh pine bark, Florida peat moss, and sand (6 : 4 : 1, by volume), and MicroMax® trace element formulation incorporated at 1.2 kg m^{-3} (2 lb yd^{-3}). The pH is 5.5 to 6.0. SCOTT'S Pre-Mix® 24N-7P-8K with minors is applied at regular intervals throughout the growing season. No additional high phosphate fertilizers are used, as strong vegetative growth seems to be the key to large and frequent blooms.

DESCRIPTION AND PROPAGATION OF SELECTED GENERA

Alpinia. Although the largest genus of gingers with over 150 species, only a handful are grown in the U.S. due to their tropical nature. With the exception of *A. purpurata*, which has beautiful, large, pink, red, or white bracts and is grown throughout the tropics for cut flowers, most *Alpinia* are grown for their luxurious dark green or variegated foliage. *Alpinia zerumbet* 'Variegata' is by far and way the most popular *Alpinia* in the U.S. Tissue culture has made this plant an integral part of most landscapes in central and south Florida, and no self respecting Wal-Mart or Home Depot throughout the Southeast would consider their collection of tropical foliage plants complete without at least a few dozen of these wonderful plants.

Alpinia species can be grown from seed but require hand pollination if the natural pollinators are not present. Hybrids are possible and a few have been introduced. Division is a reliable and a relatively quick method for increasing stock to commercial quantities of rare and lesser known species. Tissue culture is the only way to keep up with the evergrowing demand for the few cultivars that have gained enough popularity to require production in the tens of thousands.

***Costus* (spiral ginger).** *Costus* and a few other lesser known genera have been removed from true gingers, family *Zingiberaceae,* and placed in their own family, *Costaceae*. However, most growers and many scientist still consider them gingers and they will be treated as such here. Most spiral gingers are from Central and South America, although a few are native to Africa and Southeast Asia. *Costus* is more tropical in nature than other gingers and has no winter dormancy. Spiral gingers may show foliage damage at 7C (45F), and none will tolerate frost. Even though they freeze to the ground by mid fall, they recover rapidly in spring. They will provide exotic spirally arranged foliage throughout the warm months even if they do not bloom. Some spiral gingers are hardy to Zone 7, but few will bloom north of Zone 8. Spiral gingers heights range from flat stemless groundcovers to giants 6 m (20 ft) tall. Flowers may be large and crepe-like with frilled margins, produced by a collection of small bracts, or stiff and tubular, emerging from large suppressed bracts, which form a colorful, waxy cone. In either case, flowers are produced singly or in small numbers from terminal inflorescences for a period of several months. Light requirements for *Costus* taxa range from shade to full sun although most prefer at least partial shade for best color.

Costus is unique in the ginger group in that it has true stems and can be rooted easily from stem cuttings. Cuttings taken from the top third of the stem have the highest rooting success and may be placed upright in the rooting medium with at least two nodes below the medium, or entire stems may be laid horizontally and covered with 6 to 13 mm (0.25 to 0.5 in.) of loose medium. Spiral gingers are also readily propagated by division during the growing season. Seeds may be obtained from many species if hand pollinated. Seeds should be sown immediately and may need bottom heat.

***Curcuma* (hidden lily).** Somewhat similar in appearance to short-stalked bananas, hidden lilies have broad, paddle-shaped leaves that are somewhat pleated, and range in height from 0.6 to 2.1 m (2 to 7 ft). Inflorescences may be terminal, peering just above a whorl of leaves, or on a leafless lateral stalk. Bracts form showy "cones," varying in color from white, greenish to pink, red, or orange. Flowers are yellow to white or sometimes purple, emerging from bracts in sequence, starting at the base and spiraling upwards. The bloom cycle usually lasts from 4 to 6 weeks for each inflorescence, though bracts will remain colorful for much longer, some for 12 weeks. Blooming season varies by species. The first bloom in Florida is as early as May, with later bloomers beginning in September. Plants are dormant in winter, which helps explain why they are hardy to U.S.D.A. Zone 7. Most hidden lilies thrive in partial to full sun.

Most hidden lilies that have been cultivated for centuries are sterile; seed production and hybridization, therefore, is limited to the few wild collections that have been made in recent years. Rhizome division is the most common and successful method of propagation. The best time to divide rhizomes of spring-blooming species is just after blooms fade. Summer and fall bloomers should be divided in early spring before rhizomes break dormancy. The success of tissue culture was initially sporadic but has now proven successful for many species.

***Hedychium* (butterfly ginger).** As a group these are the most cold-hardy gingers. Many originate from the Himalayas and will grow and bloom in the Atlanta area. The inflorescence is a terminal panicle of green bracts. Each bract will produce from two to seven orchid-like flowers. The flowers, up to 10 cm (4 inches) across, usually are extremely fragrant, and come in colors ranging from pure white through yellow to peach and orange/red. Butterfly gingers may be small plants, as in the case of the 38 cm (15 inch) *H. muluense*, or soaring giants like 'Pink V', which may reach 3 m (10 ft) tall or more. Height of butterfly gingers is somewhat dependent on light intensity, as is abundance of bloom. They begin blooming in Gainesville in mid-June and continue until frost.

Most taxa, with the exception of the tropical epiphytes, are hardy and bloom in Zone 8 and may into Zone 7 — although in more northern climates such as Zone 7, they may not start blooming until late July in the U.S. In truly tropical areas, butterfly gingers are evergreen and everblooming; *H. coronarium* is considered a noxious weed in the state of Hawaii, and an eradication plan is underway.

Butterfly gingers can be rooted from stem cuttings by laying them horizontally and covering with 2.5 cm (1 inch) of mulch. This method of propagation is not practiced commercially, however, as rhizome division usually produces enough plants to meet demand. Butterfly gingers produce seed readily if hand-pollinated, and unfortunately often set seed when pollinated by moths. This fact is a curse more than a blessing to the nursery industry as more than a few inferior seedlings have been distributed throughout the trade, whether intentionally or through ignorance, under the cultivar name of one parent. **I implore all nurserymen to eliminate**

seed production of butterfly gingers unless pollination is carefully monitored and controlled. Tissue culture is successful with butterfly gingers, but with successful division propagation, it hardly seems worth the trouble or expense.

***Kaempferia* (peacock gingers).** Peacock gingers are an underused group of low herbaceous perennials usually less than 0.3 m (1 ft) tall with large rounded leaves which may be streaked or mottled with varying shades of purple, green, or silver. This dazzling array of iridescent colors gives the group its common name. Peacock gingers prefer deep shade, where they form thick clumps or drifts. Any direct sun will cause the leaves to curl and the flowers to fade. Leaves recover quickly once the sun passes, but the flowers, which only last a day, do not. Flowers are usually violet and white. At least one species, *K. rotunda*, blooms in spring before the leaves appear. Most others produce a profusion of flowers throughout the growing season. Peacock gingers are dormant in winter, which makes them reliably hardy through Zone 8, although a few will survive in Zone 7. Peacock gingers make an excellent replacement where the climate is too warm for hostas to survive, and a good companion plant a little further north.

Peacock gingers will set seed if hand pollinated and some hybrids are being produced. Division is still the propagation method of choice, as peacock gingers multiply readily and offsets are true to type. Tissue culture is also successful although it may take a year or more before the true patterns of some cultivars become evident.

CONCLUSION

Gingers are a wonderfully diverse group of plants that are only now beginning to receive the attention they so richly merit. With reasonable care in the selection and evaluation process, gingers may very well head the list of best perennials in the new millennium.

High Light with Moderated Temperatures Aids the Rooting of Softwood Cuttings

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INTRODUCTION

The optimum environment for rooting softwood cuttings in late spring and summer is to have high light intensity combined with moderate temperature and very high humidity — maintained by frequent and light intermittent misting. Softwood cuttings harvested from plants produced under full sun conditions quickly show stress when light intensity is greatly reduced or temperatures become excessively high causing a drop in humidity and dehydration of soft tissues.

THE CHALLENGE

The practical approach for propagating softwood cuttings has been to provide shade to reduce heat and dehydration. I have experienced a few years when that rooting softwood cuttings was not plagued by high temperatures and the need for shade — or at least less shading was required in those years versus when temperatures were high. During seasons of moderate temperature, softwood cuttings typically dropped fewer leaves, rooted faster, and more easily made the transition from mist environment to full sun conditions. Shifting up to larger containers was accomplished with less stress and plants grew faster following transplanting. On a few rare occasions, softwood cuttings rooted so quickly and with so little stress that the terminal bud never ceased growing. The result was a new tree with vigorous growth, straight stem, and little requirement for staking or pruning. By contrast, when propagation temperatures were high, fewer cuttings rooted, more leaves abscised, and the transition from mist bed to shifting up to larger containers caused more leaf drop and sun scorch; plants made only limited top growth for the rest of the season. The question repeatedly became one of how to consistently reduce temperature during propagation without reducing light intensity.

A NEW APPROACH

When the first greenhouse was built at the new research farm in 1996, I oriented the structure east-west. This was the same orientation as the structure in which I had been conducting research on the old site and which had served as the basis for my experiences and observations for the previous 9 years. The new greenhouse was made of 2-inch square tubing with no internal supports and covered with polygal polycarbonate sheeting and no shade.

A propagation bench 1.2 m (4 ft) wide by 9.8 m (32 ft) long was constructed against the south wall. A frame made of 1-inch PVC schedule 40 was suspended over the propagation bench to support a single layer of clear 6-mil polyethylene, thereby creating a plastic tent. The mist line was also made of 2.5 cm (1 inch) schedule 40 PVC with flora mist foggers spaced every 76 cm (30 inches). The mist line was suspended from the PVC frame that supports the poly. Inside the poly tent a 30-cm-diameter (12 inch) poly tube was suspended above the mist line so as not to interfere with the mist distribution and against the under surface of the top of the poly tent (Fig. 1). The greenhouse was cooled only by natural convection aided by roof discharge vents and side inlet vents.

For 1996 the 30-cm (12 inch) unpunched poly tube was attached to a 30-cm (12 inch) fan jet that took in air from outside the greenhouse. The air passed through the propagation chamber and discharged outside the greenhouse at the opposite end.

The idea was to see if, by passing cooler outside air through the poly tube in the top of the plastic tent, the air temperature in the propagation environment would be lowered. For the technique to work, heat that accumulated at the top of the poly tent would have to move through the wall of the poly tube and be removed by the flow of cooler air. A total of 22 readings were taken during June and July with the fan on or off and over a period of 9 sunny days when the outside temperature exceeded 32C (90 F). Temperatures inside the propagation environment and above the mist area were consistently reduced 3 to 4 C (5 to 7 F) with the fan on compared to fan off.

Since some moderation of temperature was obtained, the fan jet was connected to a thermostat with remote bulb sensor suspended approximately 30 cm (12 inches) above the mist line. The thermostat was set to come on when the temperature inside the rooting chamber and above the mist line reached about 33C (92F) and remain on until the temperature dropped below that set point. On days with intermittent cloud cover, the fan would turn on and off repeatedly with the change in heat load. On cooler days, and earlier or later in the day the fan jet would turn on automatically, run for 5 min or more, then turn off even though the light intensity had not changed. This was further confirmation that heat was being removed from the propagation chamber by the poly tube, but without disturbing the air or humidity inside.

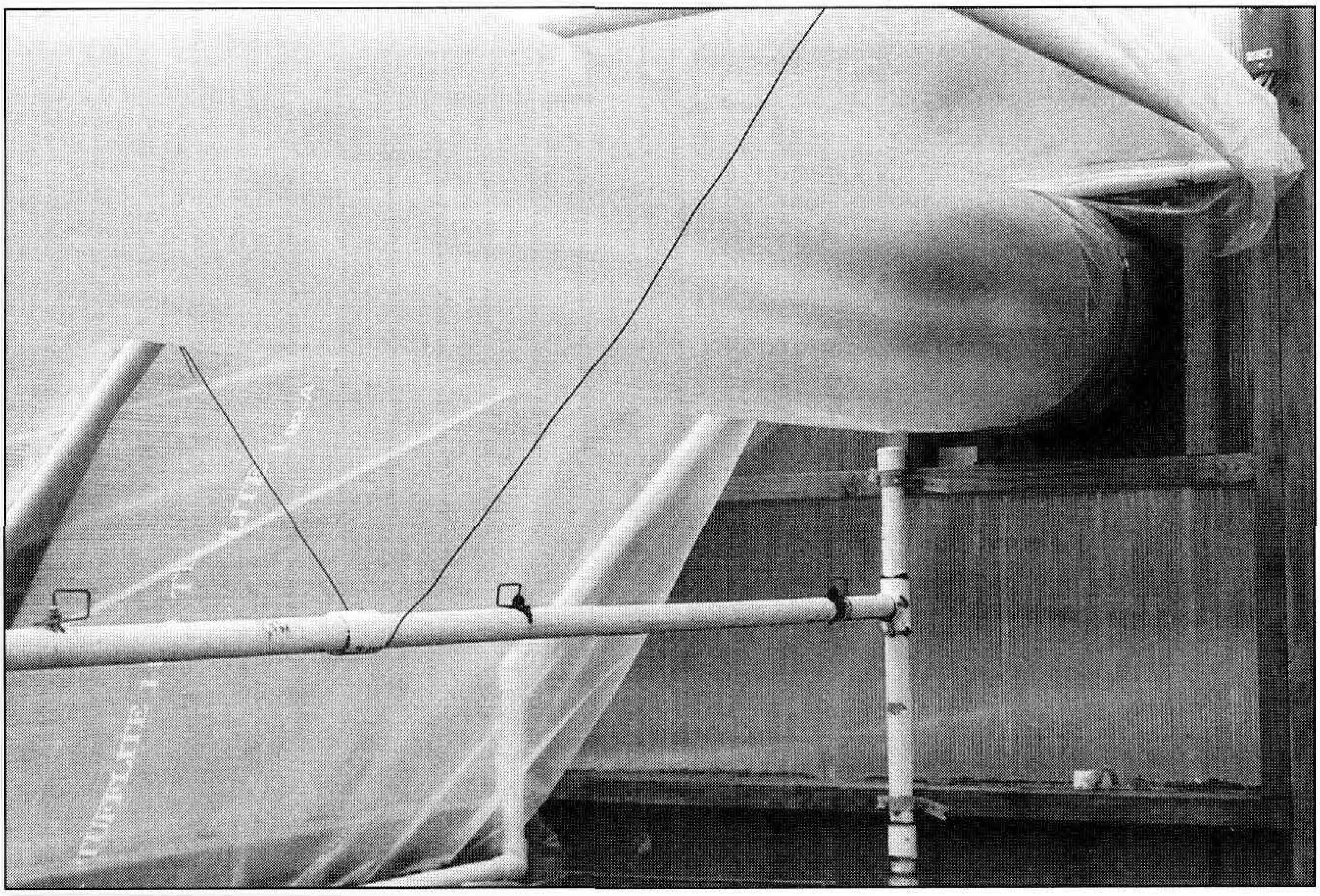

Figure 1. The unpunched poly tube was positioned at the top of the poly tent where heat accumulates and is high enough to not interfere with mist distribution. The poly sheet that encloses the front of the mist chamber has been lifted to expose the positioning inside the propagation chamber.

APPROACH MODIFIED FURTHER

The system was further modified during the 1997 season for propagating softwood cuttings. The fan jet was replaced with a window type evaporative cooler. My reasoning was that if the temperature of the air moving through the poly tube could be lowered several degrees below ambient, that the transfer of heat through the wall of the poly tube would increase further due to the greater temperature differential. A thermostat turned on the evaporative cooler-with-blower when the temperature inside the poly tent reached 33C (92F). Readings were taken during the series of clear days with ambient air temperatures of 33 to 35C (92 to 95F).

REDUCED AIR TEMPERATURE AND GREATER HUMIDITY

A decrease in temperature inside the poly tent of 5 to 6C (10 to 12F) was observed using the evaporative cooler. When the cool air flow was turned off the humidity was 86% to 90% in the air space immediately above the cuttings. With the cool air flow on, humidity ranged from 92% to 98%.

SUCCESS IN ROOTING

Using this technique I was able to root for the first time a seedling redbud (*Cercis canadensis*) as well as the cultivar C. 'Oklahoma.' I was also able to root for the first time, cuttings from a caddo sugar maple (*Acer saccharum* 'Caddo') with desirable form and fall color. Previous attempts to root cuttings of both species had been a failure.

Crape myrtle softwood cuttings were the main species used in the moderated environment. Softwood cuttings of *Lagerstroemia* 'Royal Velvet', 'Dynamite', and 'Raspberry Sunday' rooted well with or without the reduced temperature. Since it was not possible to have both a standard and reduced temperature mist chamber, any data from the rooting of cuttings was confounded by variations in weather conditions during the rooting periods. The root development on the cuttings after 14 days in the mist was noticeably greater during two rooting cycles with cooling compared to two rooting cycles without cooling during July and August 1997.

ANOTHER HELPFUL PROCEDURE

The other modification of the rooting environment to aid rooting of softwood cuttings was to provide some mist during the nighttime hours to avoid dehydration. This was accomplished with a mechanical Dayton 5-min time clock model 2E356, with 2.5-sec trippers. Two trippers are used per 5-min cycle, one provides the full 2.5-sec mist which distributes more water to the extreme of the bench and less near the mist heads. The second tripper was ground off to provide about 1.5 sec of mist which causes mist to be more concentrated along the mist lines. The 5-min clock is controlled by a mechanical 24-h clock, Tork model 8001 with 96 trippers, where each tripper is about 15 min. For day misting, the 24-h clock is set to be on from daylight to dark as is customary during softwood cutting propagation. This allows the 5-min clock to run the mist cycles. For night misting, the 24-h clock is set to allow the 5-min clock to run for 15-min periods, $^1/_2$ h after dark, then 1 h later, 1 h later, then 15 min every 2 h for the rest of the night cycle.

I have used this procedure for 5 years and have found it superior to simply turning the mist off at dark. With a few mist periods during the night, the softwood cuttings do not dry out and leaf drop is reduced. I have observed no disease problems as a result of the procedure.

CONCLUSIONS

I have long felt that with difficult-to-root species, rooting problems are more a limitation of the propagation environment than the potential of the species to root. Lowering temperatures only a few degrees below the threshold of their upper temperature tolerance in the propagation environment can enhance rooting. The cooling procedures described, combined with short mist cycles during the day and misting at intervals during the night cycle help to minimize desiccation and enhance rooting of species previously thought impossible to root.

Computer Propagation and Production Planning with the Help of a Database

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INTRODUCTION

Propagation and production planning is probably the most important task in wholesale nurseries today. To be profitable and to manage production costs, it is important to propagate and grow the optimum combination of cultivars in the sizes and forms the market demands. The cost to develop and maintain bed space is high. Other major expenses include: water, fertilizer, chemicals, and labor. With so many new cultivars being introduced today, it is even more important to be able to compare their demand with the demand for standard crops. We needed a tool to help collect information on our plants, our past sales, our target markets, and the amount of space needed for propagation, jamming plants can tight, and later spacing the crop.

DATABASE SOFTWARE

I chose Filemaker Pro 3.0 by the Claris Corporation because it has a user friendly reputation, yet it offers advanced features for future needs. I use Power Macintosh computers to run Filemaker Pro 3.0, which is also available for Windows and Windows NT.

DEVELOPING THE DATABASE

It is important to remember that a computer and its software are only tools. Calculations must make sense on paper before the first fields are defined. Some of the first fields to define contain a plant identification number, scientific name, and common name. Your imagination and needs will suggest many others. The beauty of a database is the ease in which you can define fields to hold text, numbers, pictures, calculations, and summaries.

THE MAIN MENU

When the program opens, the main menu appears (Fig. 1). From this menu you can go to other submenus and back by simply clicking buttons. Three of the main submenus list several data entry and report choices. These screens include categories for propagation, jamming, and spacing plants. These menus are important because they integrate the different parts of the program together for easier use. From the main menu you can go to the main data entry page.

THE MAIN DATA ENTRY PAGE

The main data entry page is where it all begins (Fig. 2). This is the heart of the program. Without complete and accurate data, reports and summaries are useless. On this page, entry fields are provided to record previous sales, target markets, and production space needed during propagation, jamming, and spacing container plants.

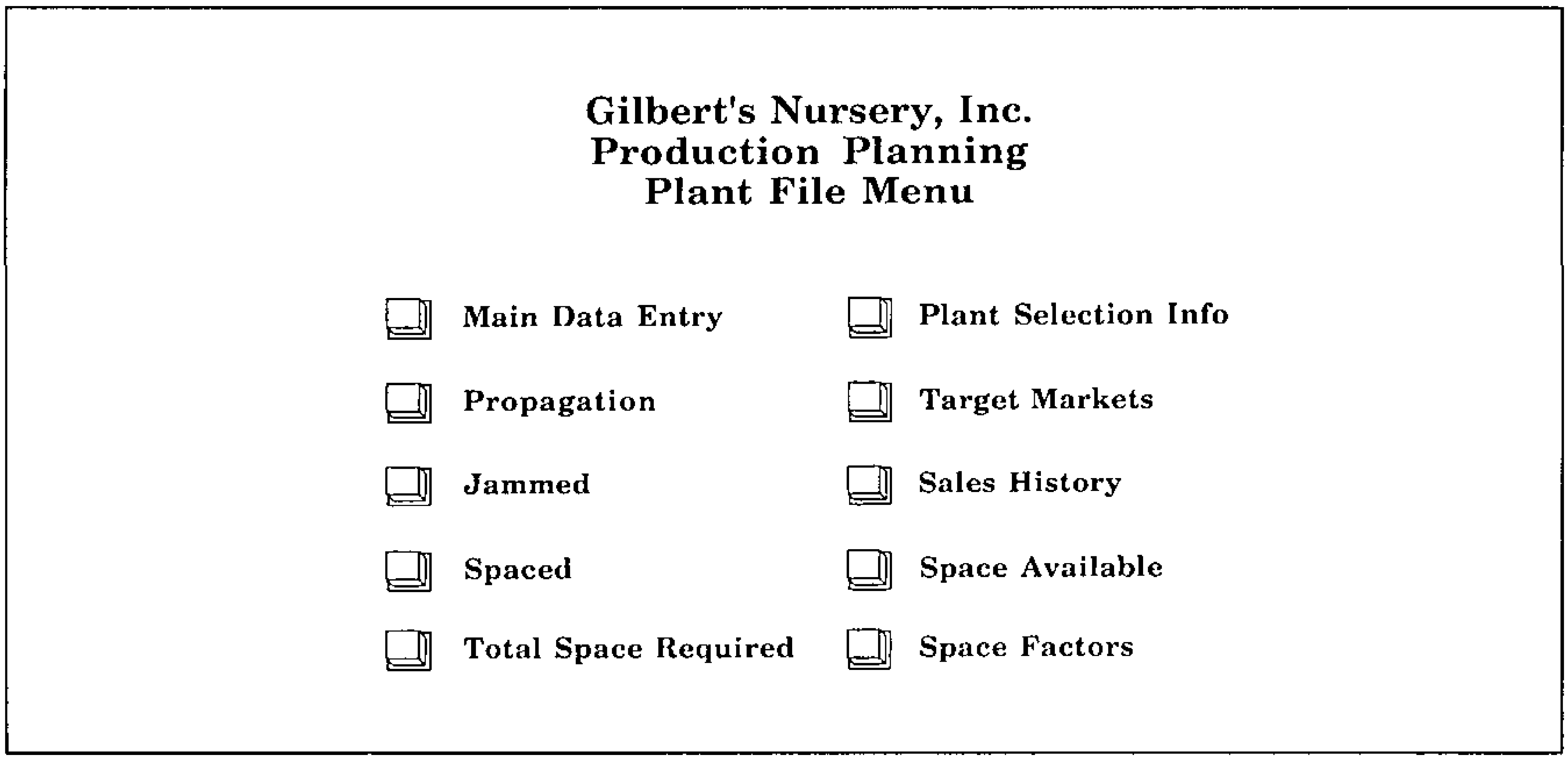

Figure 1. The main menu of the database for production planning with associated buttons for propagation, jamming and spacing plants, space requirements, target markets, and sales history.

Previous Sales. When making decisions on how many plants to propagate and grow, it is important to have all needed and useful information available. Previous sales information fields hold our sales amounts for all the sizes that we grew during the years 1989 to 1997 YTD. This data is imported monthly from a similar sales database on our file server. All sales staff can access this information any time. Information in the sales file is copied to our main database by doing a “relookup” based on inventory number. When this is done all sales figures are updated in minutes rather than hours needed for manual updating. While past sales figures are not the only thing to consider in determining propagation and production amounts, it is good to have them in front of you.

Target Markets. The target market fields concern the markets we are selling to (Fig. 2). These target market fields do not automatically change any of the fields in the space planning part of the program. At the left side of the target market fields are the various container sizes we grow or may grow in the future. At the top of the target market section are target market groups which include retailers, landscapers, distribution centers, growers, and mailorder companies. By having these fields in one place it easier to be realistic when making production choices. Once amounts have been entered for plants being considered for production, it is helpful to view this data as a single line report. Each single line report is on a different layout. In single line format the plants can be sorted in different ways that may suggest changes in amounts either up or down. When our best projections have been entered, it is time to move on to entering propagation amounts.

Propagation Data Entry. I defined fields based on the final selling container size of the plant and the production method required. Currently we propagate in various container sizes from 2-inch pots to 1-gal containers. In the future we hope to grow more liners in 4-inch pots to standardize as much as possible. Some 4-inch liners will go directly to the final selling container size, especially 1-, 2-, and 3-gal sizes. This method should speed production and eliminate the very inefficient method of shifting 1-gal to 3-gal. Larger sizes will still need to be shifted. Some liners may be sold in 3-inch, 4-inch, or 1-qt pots. These items have their own separate reports. They are also added to the grand total reports.

Jammed Container Production Areas. In most cases liners are canned in the spring and placed in a growing area jammed can-tight for several months to a year. After this initial growing period plants are moved and spaced-out in an area to be finished off in the same container, or they are hauled to the canning area and shifted up to larger containers. The quantities of plants that were canned from the previous propagation harvest are entered into the appropriate spread sheet fields. Any of the larger container sizes that can be grown jammed can-tight for a period of time are also logged. When plants in the jammed areas get large enough to need spacing, their quantities are removed from the jammed data entry fields and the amounts actually harvested are entered into the spaced fields.

Spaced Production Areas. Many of the plants placed in these beds will remain there until the order crews pull them. Others may be shifted to larger container sizes.

DATA ENTRY LISTS AND REPORTS

Submenus provide buttons to click to display and print many different lists and reports that are helpful in making production decisions (Fig. 3). In the data entry areas at the left of a submenu screen, each of the production sizes are represented. These data entry layouts are generally single line and represent the same fields as seen on the main data entry screen (Fig. 4). Having single line data entry lists makes it easier to compare plants and quantities. Changes can be made on the screen with these lists. At the right of these screens are lists of reports that may be viewed or printed but cannot be changed on the screen. In all three screens, reports are

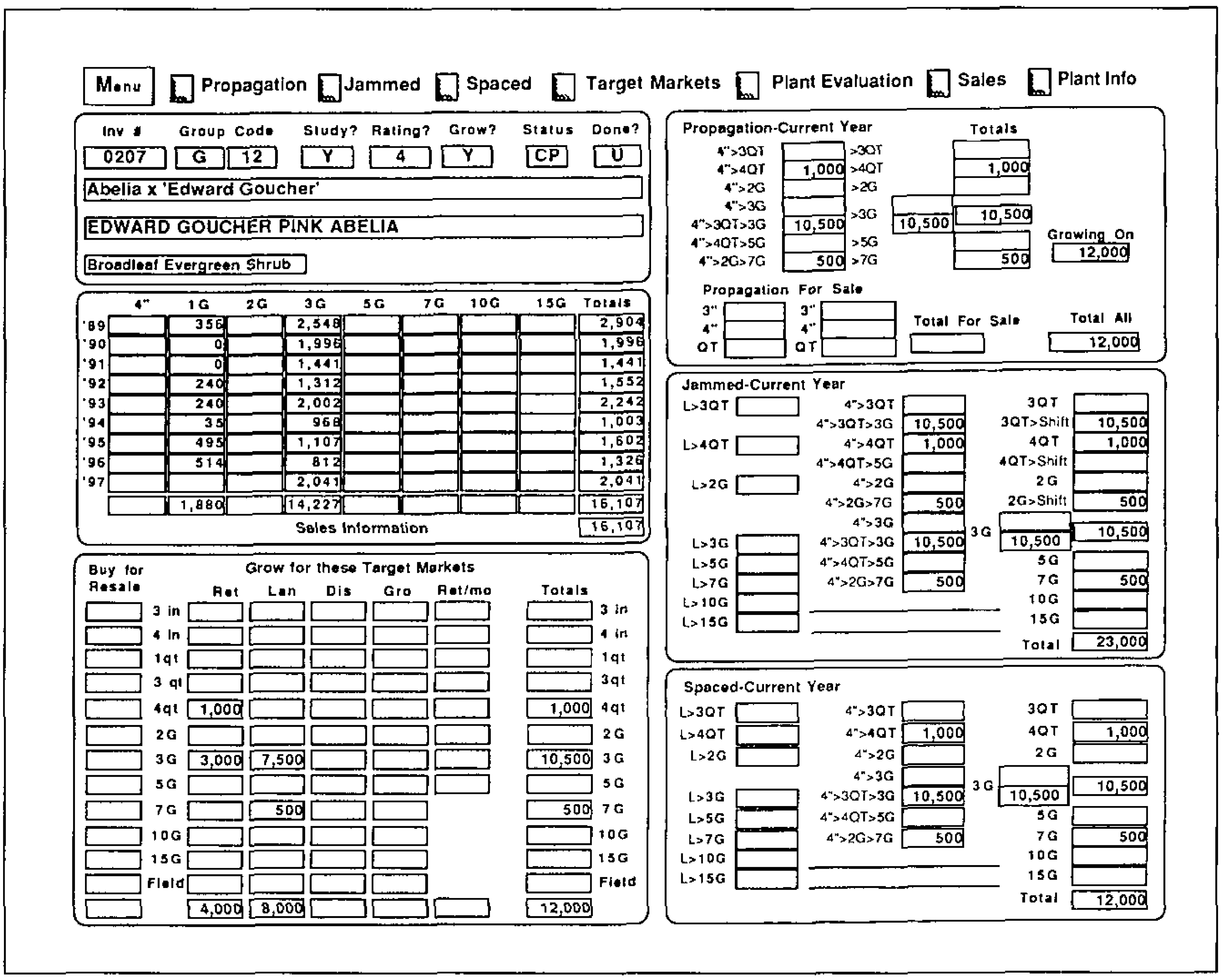

Figure 2. The main data entry layout including the finished plant size, markets targeted, and plant numbers for propagation, jamming, and spacing plants during production.

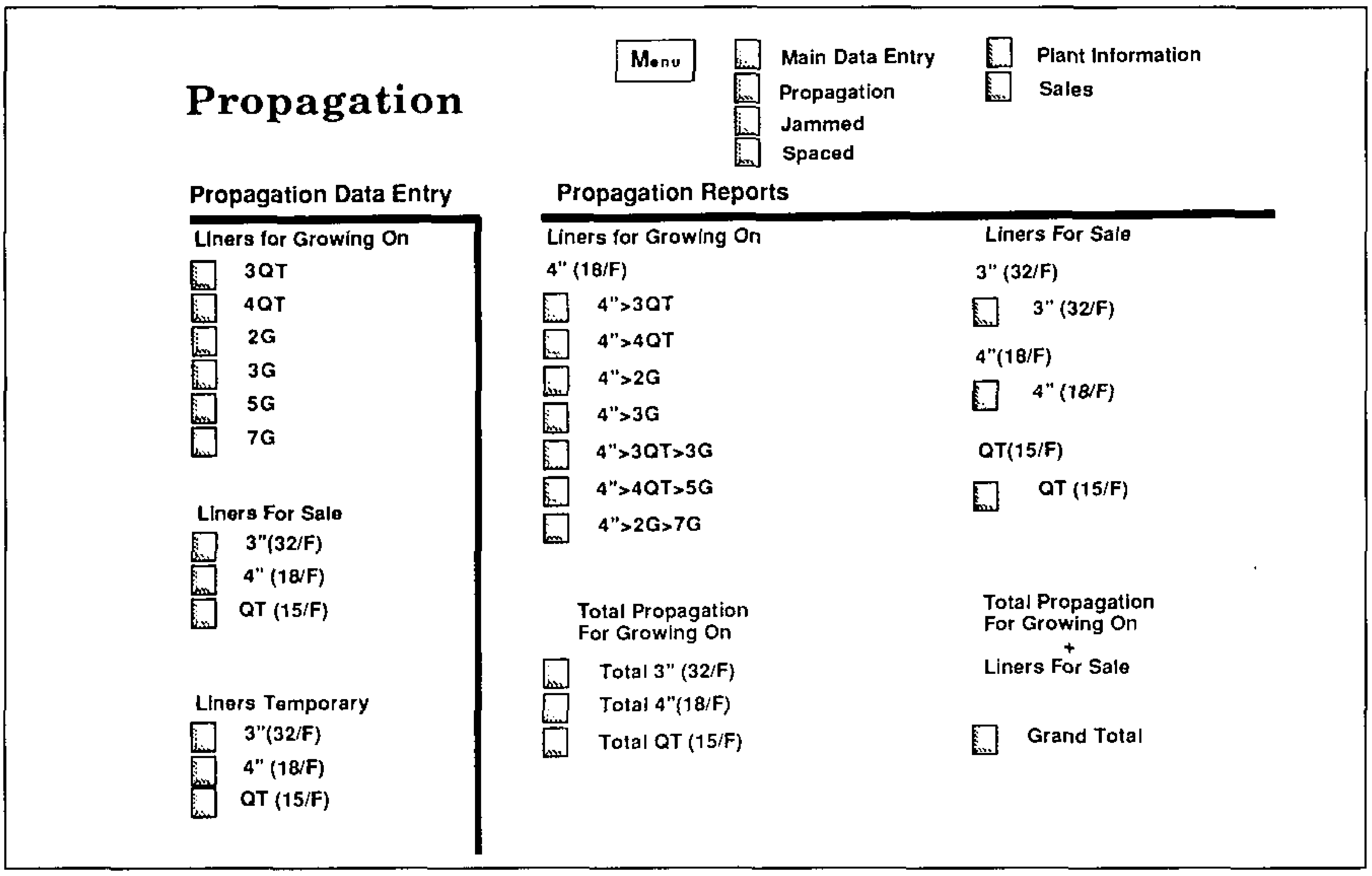

Figure 3. The propagation submenu displays data entry lists and reports. It also displays buttons to return to the main menu or other submenus.

available for each of the methods of production, plus summary reports for each container size. The last report on each screen combines all sizes, and gives grand totals of amounts and space required.

TOTAL SPACE REQUIREMENT REPORT

One very important report shows the plants and the total space needed for propagation, jammed, and spaced production areas (Fig. 5). At the end of the report, the total amount of space available, total space in the current selection, and any deficit or surplus space are listed for comparison. As you can see in this report I must either decrease the amount of production or increase the amount of growing areas needed for jammed and spaced plants. This report can be run at any time to check how actual or planned propagation and production are matching up with actual space available. By knowing this information I can make adjustments as needed.

UPDATING FROM YEAR TO YEAR

I recommend daily data backup. At the end of the current season of growth several things must be done to transition to the next season. All data should have been entered and any corrections made. Hard copy reports should be printed and saved. One of the main reports is a copy of each page of the main data entry screen. This hard copy should be placed in a notebook for future reference. When actual field counts are made they should be recorded by hand on these pages. From the current plant file, a copy should be saved for the next season and named appropriately. At this time sales data should be updated, new target market projections made and new numbers entered for propagation, jammed, and spaced fields.

HOW SPACE IS CALCULATED

The main data entry screen contains fields for recording propagation factors that take into account normal plant losses in propagation (Fig. 2). Total number of flats, and square feet needed use these factors to calculate the propagation units needed to meet production goals (Fig. 5). In the jammed and spaced reports, plant quantities and square feet needed are the primary elements. Another layout includes data fields that represent the square feet of all growing areas of the nursery, but separate production areas needed for propagation, jamming, and growing spaced plants. Actual square feet are entered in these data fields, which is based on the square feet that a single jammed or spaced plant occupies.

SALES REPORTS

Sales reports are single line reports with totals for studying past sales (Fig. 6). Some reports give sales for container sizes for each of the years since 1989. Other

Propagation For Production Data Entry For 3G ☐ Propagation ☐ Menu

G	C	S?	R?	G?	#		4">3G	4">3QT>3G	Total
G	12	Y	7	Y	0200	Abelia chinensis	900		900
G	12	Y	4	Y	0207	Abelia x 'Edward Goucher'		10,500	10,500
G	12	Y	U	Y	0225	Abelia x grandiflora 'Little Richard'		10,000	10,000
G	12	Y	4	Y	0235	Abelia x grandiflora 'Sherwoodi'	6,000		6,000
G	12	Y	U	Y	0237	Abelia x grandiflora 'Sunrise'		1,900	1,900
G	12	Y	5	Y	0462	Agarista populfolia		3,600	3,600
G	12	Y	U	U	0690	Aucuba japonica		1,000	1,000
G	12	Y	4	Y	0720	Aucuba japonica 'Rozannie'		500	500
G	12	Y	4	Y	0781	Azalea 'Ben Morrison'		1,000	1,000
G	12	Y	4	Y	0795	Azalea 'Beth Bullard'		1,000	1,000
G	12	Y	5	Y	0802	Azalea 'Blaauw's Pink'		2,000	2,000
G	12	Y	4	Y	0809	Azalea 'Buccaneer'		1,000	1,000
G	12	Y	5	Y	0844	Azalea 'Coral Bells'		2,000	2,000
G	12	Y	3	Y	0851	Azalea 'Corsage'		1,000	1,000
G	12	Y	5	Y	0865	Azalea 'Delaware Valley White'		2,000	2,000
G	12	Y	5	Y	0886	Azalea 'Fashion'		2,000	2,000
G	12	Y	U	U	0889	Azalea 'Flame Dance'		500	500
G	12	Y	4	Y	0918	Azalea 'Girard's Fuschia'		1,000	1,000
G	12	Y	5	Y	0919	Azalea 'Girard's Hot Shot'		1,000	1,000
G	12	Y	4	Y	0922	Azalea 'Girard's Pleasant White'		1,000	1,000
G	12	Y	4	Y	1167	Azalea 'Girard's Renee Michelle'		2,000	2,000
G	12	Y	4	Y	0921	Azalea 'Glacier'		2,000	2,000
G	12	Y	4	Y	0935	Azalea 'Greetings'		1,000	1,000
G	12	Y	4	Y	0956	Azalea 'Hershey's Red'		2,000	2,000
G	12	Y	4	Y	0977	Azalea 'Higasa'		500	500
G	12	Y	5	Y	0984	Azalea 'Hino Crimson'		2,000	2,000
G	12	Y	4	Y	1012	Azalea 'Joga'		500	500
G	12	U	U	U	1022	Azalea kaempferi 'All Season'		1,000	1,000
G	12	Y	3	Y	1054	Azalea 'Macrantha Single Pink'		2,000	2,000
G	12	Y	3	Y	1068	Azalea 'Martha Hitchcock'		800	800
G	12	Y	4	Y	1082	Azalea 'Mother's Day'		2,000	2,000

Gilbert's Nursery, Inc. Chesnee, SC 11/14/97

Figure 4. Propagation data entry for producing 3-gal container plants.

Grand Total
Space Requirement Summary

G	C	#		Propagation amt.	Propagation flats	Propagation sq ft	Jammed amt.	Jammed sq ft	Spaced amt.	Spaced sq ft
G	15	7861	Stachyurus praecox	660	37	82	1,200	746	600	1,662
G	15	7862	Stachyurus salicifolius	275	15	34	500	311	250	693
G	15	7987	Syringa oblata var. dilatata (NCSU Arb)	550	31	68	1,000	622	500	1,385
G	15	7979	Syringa patula 'Miss Kim'	1,320	73	164	2,400	1,493	1,200	3,324
G	15	7981	Syringa x 'James McFarlane'	2,200	122	274	4,000	2,488	2,000	5,540
G	15	8231	Vaccinium ashei 'Tifblue'	1,980	110	246	3,600	2,239	1,800	4,986
G	15	8233	Vaccinium ashei 'Woodard'	1,980	110	246	3,600	2,239	1,800	4,986
G	15	8320	Viburnum plicatum tomentosum 'Mariesii'	1,100	61	137	1,800	1,099	1,000	2,570
G	15	8327	Viburnum plicatum tomentosum 'Shasta'	1,100	61	137	2,000	1,403	1,000	4,316
G	15	8326	Viburnum plicatum tomentosum	1,100	61	137	2,000	1,244	1,000	2,770
G	15	8328	Viburnum plicatum tomentosum 'Summer	1,100	61	137	2,000	1,323	1,000	3,543
G	15	8351	Viburnum (utile x burkwoodi) Park Farm	3,300	183	411	5,000	3,007	3,000	7,310
G	15	8353	Viburnum x bodnantense 'Pink Dawn'	550	31	68	1,000	622	500	1,385
G	15	8383	Viburnum x juddii	880	49	110	1,800	1,595	1,000	5,816
G	15	8481	Weigela florida 'Minuet'	1,320	73	164	2,400	1,493	1,200	3,324
G	15	8485	Weigela florida 'Red Prince'	1,320	73	164	2,400	1,493	1,200	3,324
G	15	8495	Weigela florida 'Variegata nana'	660	37	82	1,200	746	600	1,662
				1,390,213	77,234	173,004	2,076,060	1,305,934	1,306,306	3,774,179

	Propagation	Jammed	Spaced
Available	166,920	548,700	1,571,895
Needed	173,004	1,305,934	3,774,179
Difference	-6,084	-757,234	-2,202,284

Figure 5. Summary of the grand total space requirement for propagating, jamming, and spacing selected plant species during production.

Sales Report By Can Size 1989-1997 YTD   Sales   Menu

G	C	S?	R?	G?	#		4"	1G	2G	3G	5G	7G	10G	15G	Total
T	63	Y	4	Y	1915	Cercis canadensis 'Forest Pansy'						80			80
T	63	Y	U	U	1917	Cercis canadensis 'Silver Cloud'		80				5			85
T	63	Y	7	Y	1920	Cercis canadensis ssp. texensis		100							100
T	63	Y	U	U	1918	Cercis canadensis texensis						129			129
T	63	Y	4	Y	1919	Cercis canadensis texensis 'Texas		55				74			129
T	63	Y	4	Y	1922	Cercis chinensis 'Avondale'		183				10			193
T	63	Y	5	Y	2041	Chionanthus retusus			33			356			389
T	63	Y	4	Y	5338	Lagerstroemia fauriei 'Fantasy'						142			142
T	63	Y	4	U	5436	Lagerstroemia indica 'Byers White'					275				275
T	63	Y	3	U	5345	Lagerstroemia indica 'Carolina Beauty'		88		75	3,293	272	28		3,756
T	63	Y	U	U	5352	Lagerstroemia indica 'Catawba'		141			492				633
T	63	Y	4	U	5359	Lagerstroemia indica 'Centennial'		959		556	1,672	426			3,613
T	63	Y	U	U	5383	Lagerstroemia indica 'Hope'				36	15				51
T	63	Y	4	U	5422	Lagerstroemia indica 'Victor'		836		552	1,837	1,246			4,473
T	63	Y	4	U		Lagerstroemia x 'Hopi'				0	9				9
T	63	Y	4	Y	5457	Lagerstroemia x 'Natchez'		593	65		3,008	1,023	144		4,833
T	63	Y	4	Y	5464	Lagerstroemia x 'Tuscarora'				30	2	1,057	196		1,285
T	63	Y	5	Y	5835	Magnolia sieboldii		350							350
T	63	Y	3	Y	5929	Magnolia x 'Randy'						58			58
T	63	Y	4	Y	5932	Magnolia x 'Spectrum'						13			13
T	63	Y	U	U	6280	Parrotia persica 'Select'						49			49
T	63	Y	7	Y	6847	Prunus mume 'Peggy Clarke'		50				50			100
T	63	Y	4	Y	6899	Prunus subhirtella var. pendula 'Plena'						191			191
T	63	Y	4	Y	7929	Styrax japonica 'Carillon'						29			29
T	63	Y	U	U	7935	Styrax japonica 'Crystal'						8			8
T	63	Y	4	Y	7940	Styrax japonica 'Issai'						83			83
T	63	Y	4	Y	7942	Styrax japonica 'Pink Chimes'						29			29
T	63	Y	7	Y	7945	Styrax japonicus 'Emerald Pagoda'			81			41			122
T	69	Y	U	U	2575	Cryptomeria fortunei 'Green Grizzly'							23		23
T	69	Y	U	U	2602	Cryptomeria japonica 'Wintergreen'			6			90	20		116
T	69	Y	7	Y	2604	Cryptomeria japonica 'Yoshino'		500	466			434	624		2,024
T	69	Y	4	Y	2615	Cupressocyparis leylandii		10,666	1,388		20,393	7,692	825		40,956
T	69	Y	6	Y	2630	Cupressus ariz. glabra 'Carolina						162			162
T	69	Y	U	U	8098	Thuja plicata 'Giganteoides'						75			75

Totals By Can Size

4"	1G	2G	3G	5G	7G	10G	15G	Grand Total
58,824	959,796	40,374	986,091	46,766	21,751	6,352		2,119,954

Figure 6. Sales report by container size ranging from 4-in. pots to 15-gal containers of selected plant species.

reports give total sales for all can sizes for the same period. These reports are a great way to study past sales by sorting in different ways.

PLANT INFORMATION

Fields can be defined for any plant feature desired. Flower color, flower season, bark color, bark type, plant shape, hardiness zone, propagation method, best propagation time, native range, and pH requirement are among the many features that may be defined. Once the fields are defined and placed on a layout, or layouts, they can be selected and sorted in many ways, once data has been entered.

SOME MECHANICS OF BUILDING A DATABASE

The first step in building any database is deciding what information to collect. Knowing what to do with this information comes next. The heart of any database other than the data itself is the defined fields. In defining fields, it is helpful to work out some system of naming and recording these with an explanation of their use and how they relate to other fields. Filemaker Pro 3.0 will print a list of field definitions which is very helpful. When calculation and summary fields are created it is a good idea to test them by entering certain numbers and **checking the results** on a single record first. Then add more than one record and **test the results** before trusting the new fields. Layouts allow fields to be displayed in many different ways. Different sizes, fonts, and colors can be specified. It is easy to move fields around on a layout. Fields can be copied from one layout to another. There are endless ways of finding, sorting, and displaying information. Scripts are a very useful tool in automating a database. Scripts are a series of operations in the database that can be created and later edited to automate certain operations. A button or graphic item can be added to a layout and attached to a script. When the button is clicked with the mouse the script is performed. One last helpful feature of a database is the ability to import or export data between clones of the same file or to other programs.

CONCLUSION

Filemaker Pro 3.0 has made it easy to develop our database to collect and work with plant information, space planning, and market targeting. It has made us more aware of how much space must be available to produce our plants. It has also given us a tool to make comparisons among plants we grow or will consider growing.

Controlling Liverworts and Moss in Nursery Production

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INTRODUCTION

Liverworts and mosses are persistent weeds that infest containers soon after successfully propagated plants are potted. The light, temperature, humidity, growing media, irrigation, and fertility regimes needed by newly potted plants are ideal conditions for liverwort growth. Often, liverworts can grow faster than the desired plants, smothering crops and profits. Transplanted tissue-cultured plantlets, fern sporlings, seedlings, and cuttings in trays, flats, and liner pots are the most susceptible to liverwort infestations. Changes in pesticide laws (especially for greenhouse use), unavailable chemical products, and changes in cultural routines of growers have all contributed to increased liverwort infestations. Strategies for getting this weed under control are needed. Mosses are often controlled using the same procedures used to control liverworts. The objective of this paper is to provide a starting point from which a grower can formulate a liverwort and moss control program.

What are Liverworts? Liverworts are small plants generally related to mosses and hornworts. They are identified by their mats of green thalli found growing on moist surfaces, such as growing media. Sometimes they are confused with fern gametophytes called prothallus. There are over 10,000 species of liverworts. Most liverworts infesting container-grown plants belong to the genus *Marchantia*, such as *M. polymorpha*. *Marchantia* are complex, thalloid liverworts, and are very adaptable. Most liverworts are mycorrhizal. *Gerronema marchantiae* has been identified as a fungus that forms mycorrhizae with *M. polymorpha*. Without the fungal symbiont, the ability of the liverwort to obtain water and minerals is restricted.

Why are Liverworts Considered Weeds by Nursery Growers? Liverworts growing on walkway surfaces are slippery, creating a safety hazard for employees and customers. Liverworts growing on benching, walls, or floors of the growing area (greenhouse, shadehouse, or outdoor container yard), or on the surface of container growing media, provide a home for fungus gnats, and food for slugs and snails. Liverwort thalli mat down the surface of the growing medium, slowing the entry of water applied during irrigation or rainfall. Liverworts absorb mineral fertilizers intended for use by crop plants. Customers avoid purchasing plants infested with liverworts. Finally, the cost of handweeding to remove liverworts renders many crops unprofitable, and may damage the roots of desired plants.

How do Liverworts Spread into Container Grown Plants? Liverworts propagate themselves in three ways. First, any portion of the prothallus that breaks off the main body can establish itself as a new colony (fragmentation). Second, *Marchantia* produce vegetative propagules called gemmae inside gemmae cups (gemmae cups look like suction cups on the upper surface of the thalli). Whenever water drops from rainfall or irrigation land inside a gemmae cup, the gemmae are scattered by splashing. Finally, *Marchantia* produce air-borne spores inside female fruiting bodies called archegonia (archegonia look like little umbrellas on top of stalks extended above the thalli). Wind can scatter the air-borne spores over great distances. It is the airborne spores of liverworts that usually infest container grown plants, with splashing of gemmae from gemmae cups adding to the infestation after they are established. Our studies do not indicate that liverwort propagules will build-up in recirculating/recycling irrigation systems. In greenhouses, infestations usually begin near doorways or outdoor vents, and then spread down wind toward exhaust fans. The mesh size of insect screening is not small enough to exclude liverwort spores, but may help by restricting spore movement into the greenhouse.

PREVENTING LIVERWORT INFESTATIONS

Since even dead liverwort thalli are unsightly, it is important to prevent liverwort infestations from getting established. An integrated combination of cultural and chemical controls are required. Using physical suppression techniques utilized will lower the risk of liverwort infestation.

Physical Suppression of Liverwort Establishment. Eliminate wet and weedy areas around the nursery. Install insect-exclusion screening around greenhouse vents and doorways. Wash and sanitize cuttings, especially lower leaf surfaces, before sticking. Wash and sanitize all greenhouse surfaces between crops. Products like EcoClear, Zero-Tol, and the quaternary ammonium products are very helpful during the sanitation process. Do not purchase liverwort-infested propagules, and remove any liverworts before potting. To reduce the spread of liverworts by splashing, reduce or eliminate overhead irrigation and mist. Using subirrigation and fog helps reduce the spread and establishment of liverwort colonies. Allow the surface of the growing medium to dry out between irrigation cycles. Keeping the surface of the growing medium loose rather than packing-in the plants during potting helps dry the top surface between irrigation cycles, and allows liverworts spores to be washed down into the darkness of the growing medium where they do not grow (spores require light to germinate). Use medium components that allow for rapid drying on the surface. Liverworts grow rapidly when nitrogen is available in the 75 to 250 ppm range. If your crop can be grown using less than 75 ppm N, you may be able to slow liverwort establishment.

Another physical technique is to apply a fast-drying mulch to the surface of the growing medium (Table 1). We have had good success using rice hulls, hazelnut shells (not crushed), and pumice. Other nurseries report good results using turkey grit and oyster shells. Mulches should completely cover the surface of the growing medium, should not blow away in the wind, and should dry rapidly between irrigation cycles. We have also tested geotextile discs placed on the surface of the growing medium. The discs prevented growth of liverwort, moss, and all other weeds when both sides of the fabric were treated with copper compounds (e.g., SpinOut™), but when the fabric was not treated, liverworts often grew on the soil surface underneath the disc. For some growers, slight changes in their irrigation and fertilization routines and the use of suppressive mulch have eliminated liverworts as a major weed in their nursery.

Table 1. Partial list of surface mulch products observed by nurserymen to slow the establishment of liverworts or moss in container-grown nursery crops. For best suppression of liverworts, mulches need to provide complete cover of the surface of the growing medium, and need to dry rapidly — avoid overwatering.

Material	Comments
calcined clay	fair to moderate suppression if you screen-out fines
cedar sawdust	moderate suppression
coarse sand (turkey grit)	moderate suppression
cocoa shells	good suppression; do not crush shells
corn gluten meal	fair to good suppression; supports growth of algae
crushed granite	moderate suppression
geotextile discs	liverwort grows under it
geotextile discs treated with copper	good suppression
hazelnut shells	good suppression; do not crush shells
oyster shells	good suppression; do not crush shells
perlite	fair suppression
pumice	moderate suppression
rice hulls	good suppression; kill rice seed before use

Chemical Suppression of Liverworts Using Surface Fertilization. Many of the products listed in Table 2 are fertilizers. Integrating these with physical techniques helps prevent liverwort establishment. The application of heavy metal fertilizers on the surface of the growing medium slows liverwort establishment and growth. Iron oxides (such as Granusol™) have been used successfully, compared with copper compounds, which provide only fair liverwort suppression. Zinc compounds are very effective, but have a higher risk of crop plant phytotoxicity. Some growers have used an alternating application of an acidifying fertilizer followed by a fertilizer with a basic reaction. The sudden changes in the pH at the surface of the growing medium helps prevent liverwort growth and establishment. Carefully monitor the pH of the medium when surface fertilization is being used.

Chemical Suppression of Liverworts Using Pre-emergent Herbicides. Many of the products listed in Table 2 are pre-emergent herbicides. All of the herbicides have some suppressive activity against liverworts. We have had the best success using liquid formulations of oxadiazon or oryzalin. Many of these pre-emergent herbicides will also contribute (slowly) to the eradication of existing liverwort populations. Be sure to test the herbicides for phytotoxicity before applying it to your entire crop. Besides leaf burn, defoliation, and other obvious signs of phytotoxicity, watch for damage to roots, poor lateral branching, damage to stems at the soil-line, and overall poor plant vigor. Combining physical techniques, surface iron or copper fertilizer applications, and pre-emergent herbicides has nearly eliminated liverworts in several nurseries.

Table 2. Partial list of chemical products observed by nurserymen to have pre- or post-emergence activity against liverworts in container-grown nursery crops. Test application rates listed on product labels, unless otherwise suggested under comments. Comply with all laws regulating product use in your locality. Best liverwort control is obtained using an integrated rotation of products that work at your location.

Sample chemical name	Brand names	Application timing	Comments
acetic acid (20%)	Vinegar	post-emergence	use a 10% to 75% solution; bad odor; stains roots brown; burns or defoliates soft growth; best on dormant plants; inconsistent
ammonia	Ammonia	post-emergence	3 parts ammonia to 1 part water
benzylkonium chloride	MossOff, Paramos, Surrender	post-emergence	not currently available in the United States
captan	Captan	pre-emergence	good suppression as pre-emergent
chlorothalonil	Daconil, Bravo, Thalonil	pre-emergence	fair suppression as pre-emergent
chloroxuron	Tenoran	pre-/post-emergence	do not apply to *Rhododendron* or *Erica*
cinnamic aldehyde	Cinnacure	pre-/post-emergence	seasonally variable; mild risk of phytotoxicity; limited availability in the United States
copper ammonium carbonate	Croptex, Fungex,	pre-/post-emergence	inconsistent; fair suppression as pre-emergent
copper hydroxide	Kocide, Blue Shield	pre-/post-emergence	inconsistent; fair suppression as pre-emergent
copper oxychloride	Ashlade SMC, COC WP, Cuprokylt	pre-/post-emergence	inconsistent; fair suppression as pre-emergent
copper sulfate	Citriplex, Phyton-27, MicroCop, Top-Cop	pre-/post-emergence	inconsistent; fair suppression as pre-emergent
copper-sulfur-lime	Bordeaux, WetCol 3	pre-/post-emergence	inconsistent; fair suppression as pre-emergent

cresylic acid	Armillatox, Bray's emulsion	post-emergence	inconsistent; not currently available in the United States
dichlobenil	Casoron, Fydulan, Norosac	pre-emergence	fair suppression as pre-emergent
dichlorophen	Biomoss Killer, Debco Professional Liverwort and Moss Control, Enforcer, Fungo, Mostox, Panacide, Halophen	post-emergence	not currently available in the United States
dicofol + acephate	Kelthane + Orthene mixed	post-emergence	one report of good post-emergent control
diflufenican and trifluralin	Ardent	pre-/post-emergence	for walkways and under benches; not available in the United States
dimethyl tetrachloro-phthalate (DCPA)	Dacthal	pre-/post-emergence	good suppression as pre-emergent
dinoseb acetate	Aretit	post-emergence	not available in the United States
dodine acetate	Cyprex, Melprex	post-emergence	no longer available in the United States
ethanoic acid (acetic acid + citric acid)	EcoClear	post-emergence	use like vinegar
ethylene bisdithio-carbamate + Mn and Zn	Mancozeb, Maneb Manzate, Fore, Dithane, Duosan, Karamate, Penncozeb, Ridomil, Zyban, Pace	pre-/post-emergence	good suppression as a pre-emergent; a favorite of many U.S. growers
fatty acids	DeMoss, M-Pede, Safer's Soap, Off-Shoot-O insecticidal soap	post-emergence	moderate risk of phytotoxicity; inconsistent; low temperatures reduce activity
hydrogen dioxide + peroxyacetic acid	Zero-Tolerance	pre-/post-emergence	only one test report; insufficient data

iodophor	Vanodine	pre-/post-emergence	only one test report; fair to good suppression
iron (controlled-release)	Controlled-release fertilizers	pre-emergence	fair to moderate suppression as a pre-emergent
iron oxide	GU49, Granusol	pre-/post-emergence	try 200 g per 10 liters; monitor pH
iron sulfate	lawn sand (many brands), Maxicrop Mosskiller, Turf Tonic	pre-/post-emergence	rate varies with Fe percent in product; use only once; may stain stems; monitor pH
isoxaben	Flexidor, Gallery, Bray's emulsion KnotOut, SnapShot	pre-emergence	fair to good suppression as a pre-emergent
lactophen	Cobra	pre-/post-emergence	unknown phytotoxicity; low volatility; good experimental results; no use label in the United States for nursery crops
lenacil	Venzar, Vizor	pre-emergence	fair to good suppression as pre-emergent; fair risk of phytotoxicity
oryzalin	Surflan, Rout	pre-emergence	fair to good suppression as a pre-emergent
oxadiazon	Ronstar, Regal O-O	pre-emergence	fair to very-good suppression as a pre-emergent
oxyfluorfen	Goal, OHII, Rout	pre-emergence	fair suppression as a pre-emergent
pelargonic acid	Scythe	post-emergence	high risk of phytotoxicity; low temperatures reduce activity
quaternary ammonium compounds and ammonium chlorides	Bioguard, Consan, Physan, Triathlon, Algaen-X, GreenShield	post-emergence	high risk of phytotoxicity
quinoclamin	Mogeton	pre-/post-emergence	best as pre-emergent; some risk of phytotoxicity; not currently available in the United States; a favorite of many European growers
simazine	Princep	pre-/post-emergence	control is slow; moderate risk of phytotoxicity
soaps	dishwasher soap, laundry soap	pre-/post-emergence	moderate risk of phytotoxicity; inconsistent

sodium carbonate peroxyhydrate + sodium carbonate	Terra-Care	pre-/post-emergence	moderate suppression; fair risk of phytotoxicity
sodium hypochlorite (10%)	bleach	post-emergence	high risk of phytotoxicity
sodium metaborate + boron trioxide	BareSpot	pre-/post-emergence	very high risk of phytotoxicity; avoid contact with desired plants or surfaces near desired plants
thiram	Thiram, Thianosan, Tersan, Thylate, Spothrete	pre-/post-emergence	mild risk of phytotoxicity; often used by growers in the United States
zinc chloride	zinc chloride fertilizers	pre-/post-emergence	moderate to high risk of phytotoxicity; good control as pre- or post-emergent
zinc sulfate	zinc sulfate fertilizers	pre-/post-emergence	moderate to high risk of phytotoxicity; good control as pre- or post-emergent

Table 3. Influence of the concentration of cinnamic aldehyde (Cinnacure™) applied days after treatment (DAT), and season of treatment on the percentage of growing medium surface covered with liverworts and the percentage of *Rhododendron* 'Jean Marie Montague' leaves burned.

Application date	DAT	Concentration applied %	Percentage of medium surface covered	Percentage of burned leaves[1]
November 17	3	0.0	38	0
		0.25	17	0
		0.5	8	0
		1.0	0	0
November 17	10	0.0	43	0
		0.25	10	0
		0.5	2	0
		1.0	0	0
November 17	30	0.0	52	0
		0.25	14	0
		0.5	5	0
		1.0	1	0
February 21	3	0.0	32	0
		0.3	26	0
		0.6	5	0
		0.9	0	4
February 21	10	0.0	36	0
		0.3	14	0
		0.6	2	22
		0.9	0	59
February 21	30	0.0	35	0
		0.3	15	2
		0.6	2	21
		0.9	0	57

[1]Phytotoxicity symptoms were leaf burn (desiccation) at locations where the cinnamic aldehyde formed puddles on the leaf surface after application. Inclusion of a non-ionic surfactant to help prevent puddling may help reduce the risk of leaf burn.

Eradication of Existing Liverwort Populations. Eradication of existing liverwort infestations is difficult, and some customers consider dead liverwort bodies more unsightly than live ones. Many products listed in Table 2 include a label specifying their use for post-emergence liverwort control. The risk of damage to your crops when using these products is avoided if liverwort infestations can be prevented. It is important to eliminate established liverwort colonies as soon as possible.

We have recently tested several products, including cinnamic aldehyde (Cinnacure™) and benzylkonium chloride. Effective rates and phytotoxicity of cinnamic aldehyde varied among seasons (see Table 3), but growers testing this product feel it will be a useful tool. Higher rates are needed under cool, moist conditions. We have tested benzylkonium chloride at rates from 1000 to 10,000 ppm, with the 5000 ppm rate providing the most consistent control. However, each cultivar needs to be tested for phytotoxicity. Quinoclamin, cresylic acid, and lactophen may prove to be useful tools in the future.

Some of the products listed in Table 2 that are not fertilizers or herbicides do have a suppressive effect on liverwort populations (such as the combination of dicofol and acephate). Many of these are fungicides, which may help eradicate liverworts by killing the fungal symbiont associated with the liverwort thalli. If you have a need for fungal or insect control, you may be able to carefully select the pesticides that will help you control any liverwort infestations as you seek to control your other pests.

Biocontrol of Liverworts? A couple of nurseries in Washington state have noticed a fungal organism feeding on liverworts and algae on the surface of their containers during the winter cycle. This potential biocontrol agent is very sensitive to dry air, heat, and bright light, and we have not been able to culture it on artificial media. One preliminary evaluation suggested that the fungus is a species of *Fusidium* (a type of fungi commonly found in soils), but this report has not been confirmed.

CONCLUSION

A balanced attack, focusing on prevention, is required to eliminate liverworts and mosses from the growing environment. Since more spores are always arriving on the wind, vigilance is important. Effective management of physical controls, surface fertilizers, pre-emergent herbicides, and post-emergent controls is needed for complete control of liverwort and moss infestations.

Disinfection of Nursery Irrigation Water with Chlorination, Bromination, and Ozonation

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INTRODUCTION

Disinfection is the process by which pathogenic microorganisms are destroyed. There are many ways in which disinfection of irrigation water may be achieved. The degree of disinfection required depends on the source of the irrigation water, the type of disinfectant used, the dosage, and the contact time. Other factors nursery owners may consider when selecting a disinfectant are handling considerations, and equipment and chemical costs per gallon of water. Each of these variables will be addressed and compared for disinfection of irrigation water using chlorine, bromine, and ozone.

WATER SOURCE QUALITY

Irrigation water is typically acquired from ground water, surface water, a pipeline of reclaimed wastewater (where available), or is recycled on-site. Each of these types of sources of water have different characteristics which can be generalized. The characteristics that need to be considered when selecting the most appropriate method of disinfection are turbidity, organic load, inorganic load, pH, and temperature. Groundwater tends to be uniform in quality, low in turbidity and color, but generally contains high concentrations of dissolved inorganics. Surface waters, alternately, tend to vary in quality, with high fluctuations in turbidity and color. Surface waters will also typically have lower mineral contents, but higher organic loads. Treated wastewater effluent will be similar to ground water with respect to uniform quality, low in turbidity and color, but may also be disinfected to some degree. Nursery runoff that is recycled on-site may contain high concentrations of pesticides or insecticides.

Turbidity. Turbidity, or the "cloudiness" of the water source, is perhaps one of the most important characteristics to observe when selecting a water source. Turbidity often interferes with the disinfection process. The suspended solids tend to surround and protect microorganisms from the disinfectant added to the water, thereby preventing the efficacy of the disinfectant. None of the three disinfectants is more effective than the other against turbidity. If the water source being used seems to be excessively cloudy, or turbid, a physical method of pretreatment, such as filtration, may need to be considered prior to the addition of a chemical disinfectant.

Organic Load. Organic materials can also reduce the effectiveness of a disinfectant by adhering to the microbial organisms completely shielding them from disinfection, reacting with the disinfectant to reduce the strength of the disinfectant, or completely neutralizing the disinfectant. The magnitude of the organic load will determine the "demand" of the disinfectant, or the amount of disinfectant required to react with the organics present. Both chlorine and bromine are susceptible to combining with organic matter. The biocidal properties of chlorine are rendered inert or minimally effective when combined with organics. The efficacy of bromine is not hindered when combined with organics (De Hayr et al., 1994). Ozone is an excellent oxidizer against refractory organic compounds, and destroys all organic matter present in the water (Metcalf and Eddy, 1991).

Inorganic Load. Similar reactions occur between disinfectants and inorganics as with disinfectants and organics. Several compounds such as iron, manganese, hydrogen sulfide, cyanides, and nitrogen-based compounds are rapidly oxidized, or consumed, by the disinfectant, greatly hindering the potency of the residual disinfectant. The combination of chlorine with ammonia results in chloroamines. The effectiveness of chloroamines has been reported to be as much as 80 times less than that of free chlorine (De Hayr et al., 1994). On the other hand, the formation of bromamines does not appear to reduce the disinfection properties of bromine. Therefore, far less bromine would be required, compared to chlorine, to achieve the same disinfection results. Again, ozone is also very effective in oxidizing inorganics, such as iron and manganese.

pH and Temperature. The pH of the water to be treated plays a significant role in the effectiveness of chlorine as a disinfectant. Hypochlorous acid is active primarily between a pH of 5 and 9. Over this pH range, the acid dissociates into the weaker hypochlorite ion. The hypochlorous acid is much more effective at disinfecting water, but it only works for a short time. The hypochlorite ion is subject to binding with organic/inorganic matter available in the water, which leads to bacterial inactivation. Hypobromous acid dissociates in much the same way, but, as discussed in previous sections, the effectiveness of the hypobromite ion is not hindered by radical organic/inorganic matter. Bromination, therefore, remains effective over a much broader pH range than does chlorination, (De Hayr et al., 1994). Ozonation, unlike chlorination or bromination, will be effective regardless of the pH of the water supply. However, the pH does influence the reaction pathways which occur. In general, conditions of low pH favor more direct oxidation reactions which provide for better disinfection (Metcalf and Eddy, 1991). Lower pH also allows for ozone residuals to remain in the water longer. The degree of success of disinfection is also indirectly related to temperature. Temperature can affect the rate of reaction of certain steps in the process, such as diffusion through the cell wall. While there is no optimum temperature range for disinfection to occur, the general rule of physical chemistry is that reaction rate will increase with increasing temperatures.

DOSAGE

The dosage is the amount of chemical added to the irrigation water which includes the demand, or the initial amount needed to achieve a certain percent kill, plus a residual amount which is needed if the water is going to be stored prior to use. A residual can be accomplished by using chlorine and bromine. Ozone, generally, does not leave a residual. The demand is primarily dependent upon the quantity of organic or inorganic matter present in the water supply, and is determined experimentally. When applying chlorine, the dosage might be a continuous low concentration, which will keep the water supply chlorinated for a longer period of time, or a higher concentration for a shorter duration. Typically, it will be necessary to apply a dose of 5 to 10 ppm of chlorine to achieve a residual of 1 to 3 ppm of free chlorine. For water sources high in organics/inorganics, it may be necessary to apply a dose of as much as 25 to 30 ppm in order to achieve the same amount of residual free chlorine (De Hayr et al., 1994). Free chlorine in excess of 7 ppm can cause plant damage, reinforcing the need to frequently monitor water for demand and residual.

The dose for bromine is generally lower as breakpoint bromination is not relevant, and the initial dose is, essentially, "free" bromine. Typically, 5 to 10 ppm of bromine is needed to inactivate most microorganisms (Zeitoun, 1996). This dose will not increase much when the source water contains higher organics and inorganics since bromine is hardly effected by the presence of these contaminants. The dose of ozone will equal its demand since there is no residual associated with this disinfectant. Generally, ozone dosage is 1 to 5 ppm (Montgomery, 1985). Ozone dosage is not effected by organics, ammonia content, or pH, so the quality of the water content is irrelevant. Furthermore, if a higher dose of ozone is applied, it can provide a source of oxygen to the plant root system (Zeitoun, 1996).

CONTACT TIME

The contact time, or residence time, is the length of time in which the chemical disinfectant must remain in contact with microorganisms to achieve a desired degree of purity. This amount of time is dependent on many factors, and can really only be determined experimentally. Generally speaking, the longer the contact time, the greater the kill. With chlorine and bromine, the residual can be a small concentration (i.e., 1 ppm) that is maintained continuously in the water stream, or a larger concentration is applied (up to 10 ppm) for 15 to 30 min per day. Bromine reacts much more quickly than chlorine, and requires less contact time. The recommended contact time for ozone is a minimum of 4 min, since it has a half life *of 4 to 20 min. Ozone disinfection should be generated just prior to using the water* for irrigation.

SAFETY

The safest form of disinfectant discussed here would be solid forms of chlorine or bromine. Due to the unstable nature of chlorine gas and ozone, these chemicals can be extremely dangerous if handled improperly. The safest chemicals to use for disinfection from a handling perspective are chlorine or bromine tablets. The equipment used for tablets or powders is far less sophisticated, and requires less training compared to ozone generators or handling of chlorine gas cylinders (Austin, 1989). Phytotoxicity can occur with excessive free chlorine concentrations, which requires frequent monitoring. Phytotoxicity was found to be insignificant to sensitive bedding and foliage plants when bromine concentrations were present in concentrations as high as 100 ppm (Austin, 1989). Excessive ozone is in fact helpful, not harmful, to plants by increasing the oxygen content.

COST

Cost is dependent on the dose which, ultimately depends on the quality of the water supply. This is probably one of the most important factors when deciding which method to use for disinfection. Approximate chemical costs, per pound of chemical, are shown below. These costs were obtained from various chemical supply companies, and averaged together (costs do not reflect the use of equipment for generation and dispersion):

Chlorine gas (Cl_2): \$0.77 kg^{-1} (\$0.35 lb^{-1})

Bromine (Br_2): \$2.20 kg^{-1} (\$1.00 lb^{-1})[granular]

Liquid chlorine (NaOCl): \$2.51 kg^{-1} (\$1.14 lb^{-1})

Ozone (O_3): \$1.06 kg^{-1} (\$0.48 lb^{-1})

Solid chlorine ($Ca(OCl)_2$): \$2.84 kg^{-1} (\$1.29 lb^{-1}) [tablets]; \$2.51 kg^{-1} (\$1.14 lb^{-1}) [granular]

SUMMARY

Overall, the least expensive, most effective method of disinfection seems to be bromination. This chemical remains effective over varying degrees of water quality, residuals can be maintained, it is safe to handle, and does not appear to be harmful to plants regardless of the dose. Another benefit to bromine over chlorine is that phytotoxicity does not occur as frequently as with higher doses of applied chlorine. The downfall of chlorine and bromine is that they both produce by-products, which may or may not be harmful to plant life, where the ozonation process does not produce by-products. Ozonation is highly effective as a disinfectant, and, if the cost of the ozone generator is discounted, can be a cost-effective alternative to disinfection.

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Effect of pH on Efficacy of Pesticides

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INTRODUCTION

Many factors influence the effectiveness of pesticides. These factors in part include: usage rates, timing, water volume, the specific crop, sprayer types and nozzles, and soil type. Two factors that are often overlooked are the quality and pH of the water used as the carrier. This paper will address the effect of pH on the efficacy of pesticides and what can be done to optimize the performance of pesticides.

Understanding pH. First it is necessary to understand what pH is. The pH is a number that indicates the number of hydrogen (H^+) and hydroxyl (OH^-) ions in solution. This is a measure of the acidity or alkalinity of a solution. The scale is from 0 to 14, where pH 7 contains an equal number of H^+ and OH^- ions. Water at pH 7 is neutral. It is important to realize that each point change in the pH of a spray solution represents a 10X change in the acidity or alkalinity of a solution. In some cases only a minor change in the pH can have a significant impact on the performance of pesticides. For example, a change from pH 7 to pH 5 is a 100X increase in acidity.

Efficacy of Pesticides at Different pH Levels. Significant differences in the efficacy of many pesticides occur at different pH levels. Some pesticides work best at a high pH, others work best at low pH, and some pesticides are unaffected by pH. The magnitude of the problem is less than it was in the past. Currently, label directions for use indicate optimum pH ranges for maximum effectiveness and many formulations contain buffers to help alleviate pH problems. This does not mean that the applicator should assume that everything is OK, particularly if the spray water has a very high or low pH.

Why Bother With the pH of the Spray Water? There are three important reasons for concern about the pH of the pesticide carrier. Firstly, pesticides are expensive and in production situations, cost control is very important in producing a nursery crop that can be sold at a reasonable profit; secondly, obtaining less than optimum performance can result in poor control of the target pest which results in crop losses or a lower quality product; thirdly, optimizing the performance of the product should result in less pesticides being used which in turn results in less pesticides being introduced into the environment.

Water quality and pH vary widely in the U.S. Many water sources contain suspended solids, dissolved minerals such as iron, calcium, sodium, manganese, carbonates, and bicarbonates. They also may have high salt concentrations and vary widely in pH. Most water in the United States is in the pH range of 7 to 9. Recycled nursery irrigation water can contain very high concentrations of substances which affect pesticide performance — hence, its use as spray water is not advised.

The Need for Adjuvants. How big is the problem with water quality and pH? C. L. Foy conducted a survey and presented the results at the 3rd International Symposium on Adjuvants for Agrochemicals in 1992. He reported product labels of 19 agrochemical companies involving approximately 485 formulations of crop protection chemicals for use in 1992. Of these chemical formulations, 49% recommended the use of adjuvants, 5% specified that no additional adjuvants be added, while the remaining 46% (including granular formulations) did not mention adjuvant use. Adjuvants are recommended with 71% of herbicide formulations (including defoliants), and 14% of the other classes of crop protection chemicals, including plant growth regulators, insecticides, miticides (acaricides), nematicides, fungicides, larvacides, seed treatments, soil fumigants, and repellents. More than 30 types of adjuvants are mentioned on product labels. Based on this survey, it is evident that the performance of many products currently on the market are impacted by water quality and pH.

The Effect of pH on the Half-life of Chemicals. As an indication of the impact that spray water pH may have on the performance of commonly used pesticides, fungicides, and herbicides, I present the following examples:

- Carbaryl, a common insecticide in the ornamental industry is stable at pH 5, has a half-life of 30 days at pH 7 and a half-life of only 24 h at pH 9.
- Acehpate, another commonly used insecticide has a half-life of 45 days at pH 5, 30 days at pH 7, and 16 days at pH 9.
- Cypermethrin has a half-life of 2 h at pH 5 and above. Within 24 h, over 80% of the active ingredient is gone at all pH levels.
- Benomyl which in the past was a very important fungicide in the ornamental market, has a half-life of 30 h at pH 5 and a half-life of only 9 min at pH 9.
- Captan has a half life of 32 h at pH 5 and a half-life of 2 min at pH 9.
- Atrazine is a herbicide with a half-life of 9.5 h at pH 5 and a half-life of 48 min at pH 9. Fluozifop has a half-life of 150 days at pH 5 out at pH 9 the half-life is reduced to 17 days.

Effects of pH on Other Pesticides, Fungicides, and Herbicides are as Follows:

- Diazinon – Stable for 3 days at pH 4.5
- Dimilin – Stable over a wide range of pH
- Dipel – Unstable at pH greater than 9
- Dursban – Stable at pH 5-10
- Kelthane – Lasts 15 min at pH 10
- Malathion – Lasts 2.5 h at pH 10
- Simitar – Label recommends a buffering agent at high pH
- Talstar – Stable at pH 5-9
- Tempo – Stable over a wide range of pH
- Aliettte – Stable at pH 5
- Banner – Stable at pH 5-9
- Chipco 26019 – Stable at pH 5 for 90 days
- Fore – Decomposed at high and low pH
- Subdue – Stable at pH 5-9

How Applicators Can Optimize Pesticide Performance. What can the applicator do to optimize the performance of pesticides? First, know the pH of the spray water. This can be measured with a pH meter, indicator dyes, or litmus paper.

The use of a pH meter is the most accurate, and inexpensive and accurate pH meters and pens are available through nursery/greenhouse supply houses. Indicator dyes can be added to the spray water and are reasonably accurate and easy to use. Litmus paper is the least expensive method for determining pH, but is also the least accurate. If adjustment of the pH of the spray water is needed, there are basically two ways to do it. One is to add an acid such as sulfuric acid to the spray tank. Use of acids are messy, produce erratic results, are difficult to handle, and are corrosive to equipment. The second method to adjust the pH of the spray water is by using commercial buffering agents. They are easy to use, safe, consistent, and stabilize pH at optimal levels. Over 30 products are available to help with water quality and pH problem. Some of the major companies supplying these products are: Brandt, Setre, Riverside, Helena, and Wilbur Ellis.

References and Information on Pesticide Sensitivity to pH. Where can information be found on the sensitivity of pesticides to spray water pH? The first thing one should do is read the product label to determine if there are any label recommendations. Technical bulletins on products often address the pH issue. Another source of information is company 800 numbers that are often listed on the product labels or on other information sheets. Companies that supply buffering agents are also very good sources of information on pesticide stability and products that should be used in specific situations.

CONCLUSION

In summary, here are some hints on how to optimize the performance of pesticides with respect to pH.

- Know the pH of the spray water;
- Know how sensitive the product you are using is to pH;
- Mix the pesticides just before application;
- Mix only the amount that is to be used;
- If necessary, adjust the pH with a buffering agent.

Innovative Pesticide Application Equipment at Wight Nurseries

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INTRODUCTION

New technologies warrant consideration for our Pest Management Program that help us improve deposition, increase efficacy, and allow more precise and reduced pesticide usage. It is our policy to look for new and refined methods for applying pesticides that enable us to become better stewards to our environment, while maintaining the option to use pesticides in the work place. The Quality Control Department at Wight Nurseries in Cairo, Georgia is currently utilizing two custom-built pieces of equipment that better fit our pest management goals. They are an air-assisted electrostatic boom sprayer and an air-assisted boom herbicide applicator. This paper will describe these two pieces of equipment and their benefits to our pest management program.

ELECTROSTATIC BOOM SPRAYER

Perceived Benefits. In the spring of 1996 our Division I Hawthorn Trail Facility acquired a custom built 7.6-m (25 ft) boom sprayer designed by Electrostatic Spraying Systems (ESS) to be used in the pest management program. After viewing a similar applicator it was our opinion that such a device had a number of benefits to justify the initial cost of the sprayer — advantages we felt would pay back our investment over time. Major benefits included:

- Reduction of pesticide usage with increased deposition, resulting in lower application rates, while applying lower carrier volumes per acre;
- Improved efficacy due to a higher percentage of the pesticide solution reaching the target zone;
- Increased uniformity compared to conventional style hose-rig applicators;
- Reduction in labor cost due to the utilization of a sole operator as opposed to multiple person teams that are required with the hose-rig applicators;
- Increased worker safety and comfort due to the use of an enclosed air conditioned tractor equipped with a filtration system;
- Increased worker productivity — with this climate control tractor rig, conventional personal protective equipment (which is uncomfortable and stressful to employees under high temperature field conditions) was not required.

ESS Boom Design and Operation. The criteria for custom-building this pesticide applicator was based on the needs of our nursery facility. Criteria included: terrace width, maximum and minimum plant height, irrigation system type and sprinkler heights and locations, width of roads, and other site specific variables.

The 7.6-m (25 ft) boom is powered by a 75-hp enclosed-cab tractor complete with a charcoal air filtration system that provides operator safety and comfort. The hydraulic system of the tractor supports the operation of the boom and has 1.2 m (4 ft) of vertical movement. The entire boom assembly can be manually adjusted to give an overall clearance range 0.3 to 2.7 m (1 to 9 ft). The boom also has the ability to fold forward along the length of the tractor to facilitate navigation during transport. The boom can also be pivoted at its axis allowing the operator to match the incline of the terrace being treated. The mechanical agitation of the unit is also powered by this same hydraulic system.

The spray solution is delivered to the nozzles by a small diaphragm pump at 15 psi which allows push-on style fittings to be used that are easy to work with. The pesticide is propelled by an air-assist system that is derived from a power take-off (PTO)-driven compressor mounted on the sprayer. This compressor supplies air at 30 to 40 psi at a high speed which when traveling through the nozzle shears the liquid into small particles that are charged as they pass by an electrode at the nozzle tip. The air-assisted pesticide is propelled into the plant canopy as a dense fog-like spray that gives good uniform coverage and penetration which is effective with even very dense plant canopies. Also, the upper threshold of wind tolerance is much greater than with conventional equipment. The tractor speed is set at 3.2 km h^{-1} (2 mi h^{-1}) which allows for an application rate of 183 liters ha^{-1} (19 gal A^{-1}). The 757 liters (200 gal) tank capacity allows for the operator to treat approximately 3.9 ha (10 A) of production between refills. This is a labor saving feature because there is less mixing, filling-up, and daily travel time required.

The application rates of the pesticides being used must be calculated by the amount of material to be applied per acre. This rate is derived by taking the standard labeled rate and reducing it by one-third. All foliar nutrients, fungicides, and insecticides are applied in this manner. It is standard protocol to buffer the pH of the water carrier, and we prefer to use a product on the market that will indicate when the proper pH has been obtained by turning the water carrier pink. This buffering procedure is done before any pesticides are added to the tank. In order to effectively use wettable powders, it is very important that they remain in suspension in the spray tank — not only to insure an even application rate, but also to minimize clogging of the small orifice sizes that are utilized with the low-pressure liquid system. For this reason, a suspension agent is used to ensure effective use with these types of pesticides. As a consequence, we have found that all chemical formulations can be used — as long as the proper application procedures are followed and vital end-of-day cleaning is performed. The cleaning process involves running clear water through the system to remove all pesticides, then using a tank cleaner to more thoroughly cleanse the system. The operator also cleans a few key parts of the liquid delivery system. There is a monthly cleaning schedule that includes the removal and cleaning of all nozzles on the boom. Daily cleaning procedures take the applicator about 30 to 45 min if done properly, and must not be missed to ensure efficient utilization of the machine.

Effectiveness and Efficiency. The boom sprayer has been in operation for 18 months and it is possible to review its performance and compare it to the previous program, which primarily utilized conventional-style hose rigs requiring two- and three-person teams to operate.

It is our opinion that our pest management has been excellent as a result of the sole utilization of the boom sprayer. This nursery site has large numbers of *Ilex crenata* that historically have high susceptibility to mite infestations. This piece of equipment has effectively controlled mite populations and no hose rig applications have been necessary since the machine has been in use. The same can be said for our disease control which has been good.

A significant goal achieved has been the reduction of annual pesticide usage on the nursery which resulted in a dramatic reduction in pesticide expenditures. The main reason for these savings is the fact that we are using 33% less chemical in all applications, with no perceived reduction in pest control. This carries the saving straight to the bottom line! Key labor savings occurred with the elimination of two applicators from the pest maintenance program, and a decrease in the amount of time required to treat a given acre. As a result of these savings the nursery was able to recover the initial investment in the ESS boom sprayer within the first year of use.

AIR-ASSISTED HERBICIDE BOOM

Introduction. Through many years of evolution at Wight Nurseries the weed control program has developed many approaches. The most predominate means of has been manual weeding. This has included more exotic means such as the use of geese that forage the nursery and feed on weed species, and more importantly, the use of pre-emergent herbicides that has offered varying degrees of success. The application methods of pre-emergent herbicides have varied through the years to include such means as broadcast spreaders, hand shakers, airplanes, and liquid formulations. Since a strong pre-emergence program is a vital component in producing a quality product at minimal cost, we at Wight Nurseries are continually looking for improved methods of application.

In 1995 a team from Wight Nurseries, toured Bailey's Nursery in Saint Paul, Minnesota and was given a demonstration of a boom-style herbicide rig that was being used at their nursery. This particular unit had a 14.6-m (48-ft) boom that could not be folded, but had the ability to change boom height by hydraulically raising the entire trailer assembly. We saw potential in this boom applicator and subsequently had a custom-made applicator manufactured.

Perceived Benefits. This air-assisted herbicide boom applicator is used at our Hawthorn Trail Facility where the previous mode of application consisted of a multiperson team applying the herbicide with Warren Broadcast Spreaders. This is a very common system within the nursery industry and when managed closely can deliver desired rates of application. However, the ability to obtain complete uniformity in the treatment area is difficult since the rate of application can vary from one applicator to another. Also, it is possible to have over- and under-application within the area being treated due to the frequent stopping and starting that is required and the subsequent lack of a proper overlap that occurs. Teams range from one to four people with the conventional Warren Broadcast Spreaders and the manual application process can be very time consuming, and navigation is difficult through the beds of plant material. For these reasons it was believed that a boom style applicator would benefit us with improved coverage and uniformity, resulting in better weed control. Furthermore, the calibration of the application would be easier and remain more consistent, which would decrease herbicide usage by over-application, and improve weed control since proper labeled rates would be used, avoiding improper application rates of the past. Labor would be reduced since only a single operator would be needed and the time required to treat a given acre would be reduced.

Boom Design and Operation. The herbicide applicator was also custom built by ESS and designed specifically for our Hawthorn Trail Facility. The general design of the applicator is relatively simple when compared to the Electrostatic sprayer. It mainly consists of a trailer, a hopper, a distribution chamber that has distribution hoses connected to it, and a 7.6-m (25-ft) boom that supports the tubes over the terrace. The material is gravity feed from the hopper into the distribution chamber, and air assisted through the tubes before being distributed.

The hopper is manufactured by Valmer, a Canadian company, and was initially designed for insecticide applications in agronomic row crops. It has a capacity of 239 kg (525 lb) and is able to treat 2.1 ha (5.25 A) with a label rate of 115 kg ha^{-1}(100 lb A^{-1}) or 1.04 ha (2.63 A) with a label rate of 231 kg ha^{-1} (200 lb A^{-1}). Since the material is gravity feed, the hopper is mounted at the highest point on the trailer to insure that it remains above the boom at all times. When that material leaves the hopper it enters a distribution chamber that equally distributes the material between a series of 15 hoses that carry the material to varying positions along the boom so a wide band application can be made. When the material exits the tubes it is dispersed by a deflection shield causing a fan like pattern that when grouped together along the boom creates a 7.6-m (25-ft) band application. The PTO-driven fan creates sufficient force to carry the material through the length of the boom and also helps the herbicide penetrate dense canopy and reach the target zone.

Calibration of equipment is obtained by utilization of a gearing mechanism that allows for the variation of the rate of dispersal from the hopper. Once this gear is in place, it is synchronized with the tractor speed by a ground wheel that operates the hopper — and couples the rate of dispersal with the speed of the tractor. In other words, the tractor speed can change and the rate of application will also change proportionately, thus allowing constant application of material. This is an important criteria since the tractor speed must change as it begins or ends a terrace and yet the herbicide application rate remains constant. The applicator is currently calibrated to deliver a rate of 115 kg ha^{-1}(100 lb A^{-1}) and when a label rate of 230 kg ha^{-1} (200 lb A^{-1}) is required the operator makes a second pass with the machine over the terrace to achieve this higher rate.

The boom height can be adjusted hydraulically and also boom pitch can be varied to enable the operator to adjust for unlevel terrain. The boom can be folded up along the length of the tractor to facilitate navigation around the nursery.

Effectiveness and Efficiency. This piece of equipment has been a tremendous asset to our herbicide program. Plans are to look into ways of utilizing it in other locations in addition to our Hawthorn Trail Facility. Our weed control has improved and the ease of herbicide application makes it a pleasure to work with. Although we have not seen any major differences in the amount of herbicide being used, it is apparent that our application goals have been met if not exceeded. There has been a reduction in labor required and the only locations we now use individual broadcast spreaders are in those areas of the facility that can not be accessed by the boom — such as shade structures and propagation areas.

Automation of Bedding Plant Production

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INTRODUCTION

Greenhouse and nursery crop growers are continually faced with increased production costs with little opportunity to raise prices. The small-scale grower must specialize in unique crops or capitalize on individualized service to command top dollar for their products and coexist with large-scale growers who target mass merchants. Many growers, large and small alike, are considering more automation in their daily production operations. Automation often requires a major capital expenditure, but when properly planned, it can offset equipment investment by reducing labor costs and enhancing production efficiency.

AUTOMATION

Automation — Setting the Pace to Scale. Chipsea Greenhouse, Inc. of Colorado has made major investments in automating their bedding plant operation. John Wilson, the Production Manager, has stated that "automation is the number one means to create the process or flow, which sets the pace to scale". This means that the size and scope of a production system ultimately determines how efficiently production units of plants (plugs) are processed and sold. A need must first be established prior to automating any production process.

Financial Incentives to Automate. With the recent increase in federal minimum wage requirements, equipment purchases for automation are becoming more attractive. There are many forms and varying degrees of complexity in automation that a bedding plant grower can employ, which allow for increased production efficiency. When choosing to automate, consider first your most tedious and labor-intensive tasks. These may include mixing media and filling trays, transplanting into trays, moving trays, and irrigation. It is important to evaluate each process completely and determine which process is the most efficient or inefficient under your production conditions.

Evaluation of Employee Production Efficiency. After reviewing your production processes — evaluate your single most valuable asset, which is your staff. How your staff interacts with your current production processes requires scrutiny before any automation is incorporated into a new production system. For example, determine how many times an employee touches a plant during cutting production, while transplanting seedlings, or how many trays are moved per employee-hour. Once data are known, one can begin to make changes to increase production efficiency. These changes could be as simple as including an irrigation tunnel on a conveyor to reduce the time to water plugs in a newly transplanted tray, or as complex as a fully automated robotic transplanting line.

Ease of Automating Media Handling. One task easily automated is media handling. Most bedding plant growers can adapt some form of automation for mixing media. This may be as simple as a tractor with a front end loader or as complicated as a drum mixer with continuous feed conveyors. A tractor with a bucket or a drum mixer can yield from 11.5 to 15.3 m^3 (15 to 20 yd^3) media per employee-hour; whereas, smaller mixers, such as modified mortar mixers, may yield only 1.1 to 3.8 m^3 (1.5 to 5 yd^3) media per employee-hour (Hamrick and Beytes, 1998). Filling bedding plant trays can also be labor intensive. Anywhere from 60 to 100 trays per employee-hour can be manually hand-filled, whereas machines can fill 150 to 300 trays per employee-hour (Hamrick and Beytes, 1998). By comparing the expense of purchasing equipment designed to mix and fill trays to the labor costs to perform the same tasks — one quickly recognizes that tray filling equipment is essential to a successful bedding plant program, even if pre-mixed media is used.

Transplanting Systems and Equipment. No other stage of bedding plant production systems has gone through greater changes in efficiency and technology than transplanting during the past 15 years. Seedling plug production has revolutionized bedding plant production allowing more species diversity in the market at reduced costs. Many growers no longer bother to sow and germinate their own seedlings — opting to purchase plugs from specialty propagators. This single decision alone eliminates the need for sowing equipment, germination chambers, and irrigation equipment specific to seedling production. The availability of high quality seedling plugs also has streamlined the transplanting operation allowing for rapid handling of individual plants.

However, the transplanting of bedding plant plugs is one of the most labor-intensive jobs in the greenhouse. It involves repetitive movements, which may lead to carpel tunnel syndrome and other potential injuries to employees. Transplanting equipment is no longer utilized only by major bedding plant growers. Robotic transplanting equipment is now available that can realistically transplant 240,000 plugs into 5000 trays in a 10-h day. One Colorado greenhouse grower uses equipment that requires one employee for media support, one for moving transplanted trays away from the transplanting line, four for patching missed plugs and tagging, and one crew leader — seven personnel in total. Prior to the use of robotic transplanting equipment, this same greenhouse grower's transplanting line could do no more than 2500 trays in a 10-h day with 20 people, resulting in 12.5 trays per employee-hour for hand-transplanting, compared to 71.4 trays per employee-hour for a robotic transplanting system that costs $100,000. Amortizing this investment over 3 to 5 years, one quickly realizes that robotic transplanting equipment is cost effective.

Robotic Transplanters Are Not a Panacea. Robotic transplanters are not always the perfect solution. They will not operate at maximum capacity if plug trays are not evenly filled with quality plants. Also, not all tagging equipment is compatible with some robotic transplanters or operates as quickly. Finally, a means for moving filled trays to the transplanter, as well as removing transplanted trays away from the work area is important to prevent bottlenecks, which reduce productivity. Robotic transplanters also have a plethora of moving parts and sensors requiring maintenance and adjustment by trained technicians for efficient, continuous operation.

Not all large-scale bedding plant growers use robotic transplanting equipment. Another Colorado greenhouse company manually transplants with 24 people and transplants 1750 trays in a 10-h day or 7.3 trays per employee-hour. This transplanting rate is considerably less than the previously discussed manual and automated systems of 12.5 and 71.4 trays per employee-hour. The manual greenhouse production system with 12.5 trays per employee-hour transplants into 12-04 trays, while and the second transplants into 18-04 trays — which require more plugs and time per individual tray.

Many greenhouse growers find that their current staff are capable of transplanting at satisfactory rates, with more precision and flexibility to tray configuration and handling difficult-to-transplant bedding plant species. Petunias are easily transplanted by hand, whereas marigolds, snapdragons, and impatiens have tender stems and are difficult and slower to transplant by hand. Even hand transplanting lines require some degree of mechanization for efficient operation. Automated equipment may include conveyors, media-filling equipment, and tray-moving equipment. However, as personnel skilled in transplanting bedding plants becomes more difficult to find, many greenhouses are considering robotic transplanters.

Automation in the Movement of Plants. Movement of plants away from the transplanting area to the greenhouse or from the greenhouse to the shipping and staging dock is another opportunity for automation increasing production efficiency. Conveyor systems can move 200% more trays per hour compared to carrying trays by hand. Of course this requires a considerable investment in equipment — but is more than offset by labor savings. Monorail trolleys for moving trays can move 150% more trays than by hand, with a minimum of equipment installation in the greenhouse. Other production tasks easily automated include irrigation and pesticide application with appropriate equipment for the greenhouse or production area.

CONCLUSION

Automation of bedding plant production is not for all greenhouse or nursery crop producers, but some degree of mechanization can probably decrease any operation's labor costs. Consider first the most tedious, labor-intensive task and then compare the current investment in labor to the investment costs and calculate the respective savings in labor costs. Also consider idle time that robotic equipment is not being used. Remember to apply all labor expenses, including fringe benefits, to the cost of producing a bedding plant crop.

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Influence of Water-soluble Plant Diffusates on Root Initiation and Growth in *Chionanthus virginicus* and *Vigna radiata* Stem Cuttings

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INTRODUCTION

White fringetree (*Chionanthus virginicus*) is an important and valuable plant for the nursery and landscape industries. Many consider white fringetree a premier specimen plant due to its bold foliage, refinement, dignity, and bloom characteristics (Dirr, 1990). White fringetree is extremely difficult to propagate by stem cuttings and is more commonly propagated by seed, which normally requires up to two years for germination. To date, there are no scientific reports of successful propagation with stem cuttings. Surveys in 1988 and 1995 ranked white fringetree as one of the most difficult plants to propagate (Gamstetter and Gulick, 1996). The surveys showed that although the tree was considered "unavailable," it was one of the top plants in market demand. Propagation difficulties make it an expensive plant in the trade and reduce its usage. By increasing the production of white fringetree, we could lower the cost and satisfy market demands.

Treatments of aqueous diffusates from terminal stems of easy-to-root plants have been known to influence rooting of stem cuttings. Previous research indicated the presence of at least four root-promoting substances, termed "cofactors," in diffusates from easy-to-root softwood cuttings (Girouard and Hess, 1964; Kawase, 1971). In difficult-to-root plants, these cofactors are postulated to be either missing or limited. Exogenous application of these missing cofactors to a difficult-to-root cutting may increase rooting success. The limited amount of research in this area supports this hypothesis. Further results have shown that cofactors have a strong synergistic effect with auxins on root formation of cuttings (Girouard and Hess, 1964; Kawase, 1970, 1972; LeClerc and Chong, 1983). Three experiments were conducted using either black locust (*Robinia pseudoacacia*) or contorted willow (*Salix* 'Erythroflexuosa') water diffusates as a pretreatment on stem cuttings of white fringetree.

PROPAGATION OF WHITE FRINGETREE USING PLANT DIFFUSATES

Experiment 1. The experiment was initiated on 19 Feb. 1996. Fifteen uniform, dormant 3-year-old seedlings were selected and brought into the greenhouse. Plants were then transplanted into 2-gal containers using amended pine bark as a medium. Each plant was fertilized with 20 g of Osmocote (14N-14P-14K). In addition, plants were weekly fertilized with 200 ppm Peters 20N-20P-20K. Ambient lighting was supplemented with 150-W incandescent lamps to provide a 16-h photoperiod. Air temperature controls were set at 28C (82F) days and 17C (62F) nights. Cuttings were harvested 12 weeks later on 10 May 1996. Cuttings were stripped to the four upper leaves and double wounded. Ten cuttings were placed in a willow diffusate (10 g willow diffusate per 100 ml H_2O) for a 24-h soak. Five other cuttings were treated with 3.0% IBA in talc and inserted in the medium. On the following day, the 10 cuttings that soaked in the willow diffusate were divided into two groups. Five of these cuttings were inserted into the medium and the other five were treated with 3.0% IBA in talc and inserted in the medium. The cuttings were arranged in a completely randomized design with five replications.

All cuttings were inserted in Dyna-flats (10 cm × 35 cm × 50 cm [4 inches × 10 inches × 20 inches]) with holes. Flats were filled with a mixture of moistened shredded peat and sand (3 : 1, v/v) to a depth of approximately 7 cm (3 inches), and placed in a propagation greenhouse. This greenhouse was covered with off-white corrugated fiberglass. The cuttings received ambient light and no heat. Cuttings received 15 sec of mist every 12 min from 6:30 AM to 7:30 PM. White fringetree cuttings were harvested after 70 days on 19 July 1996, and evaluated for rooting. Four out of five cuttings propagated using the willow diffusate followed by IBA rooted. Three of the four cuttings rooted heavily, with over 35 roots and an average root length of 8.3 cm (3.3 inches). The fourth cutting rooted moderately well, with 12 roots and an average root length of 8.3 cm (3.3 inches). The only other treatment that induced rooting was the 3.0% IBA with 20% rooting; rooting was poor, with only five roots and an average root length of 6.0 cm (2.5 inches).

Experiment 2. The experiment was conducted on 9 July 1996. This experiment was designed to test an additional easy-to-root plant diffusate, black locust. This experiment used conditions similar to the previous experiment except that the diffusate concentration was higher (680 g per 3.8 liters H_2O [24 oz gal^{-1} H_2O] per 180 cuttings). This experiment was arranged as a completely random design using a 3 × 3 factorial arrangement of treatments with IBA talc (0%, 0.8%, 3.0%) and diffusates (a tap water control, locust and willow diffusates). There were 20 replications per treatment. Cuttings were maintained under a 3.0-mm (0.125 inches) polyethylene tent and provided with intermittent mist. After 76 days on 25 Sept. 1996, white fringetree cuttings were harvested and evaluated for rooting.

Out of 180 cuttings, only one produced roots. This cutting, which had been treated with black locust diffusate followed by 3.0% IBA, produced only four roots. However, over 60% (12 out of 20) of the cuttings treated with either diffusate and followed by IBA developed callus on the wounded area. Cuttings treated with IBA alone developed callus at a rate of 5% (1 out of 20). In some species, callus formation may be a precursor to adventitious root formation (Hartmann et al., 1997). These results suggest that the diffusates may be beneficial in promoting roots of white fringetree, even though these cuttings failed to root. A contributing factor may have been the age and health of the stock plant. The plant was in its mature phase and showing signs of decay and deterioration. Generally, the more juvenile the plant the higher the success rate of rooting. Also, in general, the healthier the plant the better the chances for rooting.

Experiment 3. This experiment was conducted on 9 May 1997. Water diffusates were made using black locust and contorted willow, as described in Experiment 1, at two strengths: 1X (454 g per 3.8 liters^{-1} H_2O [16 oz gal^{-1} H_2O]) and 2X (908 g 3.8 liters^{-1} H_2O [32 oz gal^{-1} H_2O]) per 80 cuttings. Cuttings came from four different sources: (A) 4-year-old juvenile plants in 2-gal containers forced in a greenhouse on

17 Feb. 1997, similar to plants in Experiment 1; (B) juvenile containerized plants forced 4 weeks later than Source A; (C) juvenile plants grown in containers under outdoor nursery conditions; and (D) 5-year-old field-grown plants. In addition to 3.0% IBA in talc, full-strength Dip'N Grow (1.0% IBA and 0.5% NAA) was tested.

Cuttings were collected on 9 May 1997, and placed in diffusates for a 24-h steeping. After steeping, cuttings were treated with either 3.0% IBA in talc or a 5-sec quick-dip in Dip'N Grow. Cuttings were then randomly inserted into the same medium as Exp. 1. The experimental design was a completely random design using a 2 × 2 × 2 × 4 factorial with ten replications. Cuttings were maintained under similar conditions as in Exp. 2 except a polyethylene wall was placed across the propagation bench to deflect the air flow created by the exhaust fans. This was done to prevent the cuttings from drying out. After 73 days on 21 July 1997, white fringetree cuttings were harvested and evaluated for rooting.

A numerical rating scale of five classes was set up for the experiment, where 1 = no roots, 2 = poorly rooted, 3 = average number of roots, 4 = above-average number of roots, and 5 = heavily rooted. Cuttings evaluated at 3, 4, and 5 would be commercially usable. Two independent judges subjectively evaluated the cuttings for rooting by making the closest match to the representative cutting for each class. Data were subjected to analysis of variance and means separated using Duncan's multiple range test at the 5% level.

The three best rooting treatments came from cuttings taken from source-A (4-year-old juveniles forced early). When treated with willow diffusate (2X strength) and Dip'N Grow source-A cuttings had 90% rooting and a rooting scale of 3.7±1.3. Cuttings from source-A treated with willow diffusate (1× strength) and Dip'N Grow had 80% rooting and a rooting scale of 3.5±1.6, while cuttings treated with locust diffusate (1X strength) and Dip'N Grow had 70% rooting and a rooting scale of 2.9±1.5. Of the remaining 29 treatments, 15 treatments produced insufficient roots and the other 14 treatments failed to root.

The two most important rooting factors in Expt. 3 were cutting source and auxin source. Full-strength Dip'N Grow clearly gave better results than 3.0% IBA in talc. Although the first three cutting sources were from the same lot of containerized seedlings, their handling affected propagation results. The lot that was first brought into the greenhouse (17 Feb. 1997) and forced into growth rooted best. We attribute this to the physiological age and maturation of the cuttings. There may be a narrow physiological window where rooting is possible in these still somewhat juvenile fringetrees.

MUNG BEAN ROOTING BIOASSAYS

Four standard mung bean (*Vigna radiata*) bioassays were used to partially characterize and verify the effects of the diffusates. Diffusates were made from chopped, frozen locust or willow terminal stems placed in deionized (DI) water (10 g 300 ml^{-1} H_2O) and stirred for 24 h. This was used to test the effects on rooting of mung bean cuttings of either locust diffusate (LD) or willow diffusate (WD) (5 ml of diffusate with 10 ml DI water containing 8 ppm IBA). A second test used ethyl acetate extracts of each diffusate at pH 3.0 and 7.0 to determine the polar nature of the diffusates. The third tested decreasing serial dilutions of both diffusates. Diffusates were prepared by adding the following amounts of WD or LD to the respective test tubes and bringing the volume up to 15 ml using DI water: 33.3% (5.0 ml), 25.0% (3.75 ml), 16.7% (2.5 ml), 3.3% (0.5 ml), and 0% (15.0 ml H_2O). The fourth test used a silica gel thin-layer chromatography of LD and WD and their extracts at pH 3.0 to characterize indole compounds.

Mung bean seeds were grown in flats containing moistened Pro Mix BX in a growth chamber at 28C (82F) with an 18-h photoperiod for 7 days. On Day 7, cuttings were harvested by cutting off the seedlings' root systems 4.0 cm (1.5 inch) below the cotyledon node. The mung bean bioassay consisted of one mung bean stem cutting per test tube with solution. There was 15 ml of solution per test tube, which was monitored daily and replenished with DI water as needed. After the fourth day, all solutions were discarded and replaced with only fresh DI water. The number of roots were counted and recorded on the Day 10. All mung bean bioassays were replicated three times and their averages reported.

RESULTS OF MUNG BEAN ROOTING BIOASSAYS

Mung bean cuttings treated with locust or willow diffusate in combination with IBA, stimulated the production of roots more than IBA or either diffusate alone. These results suggest that LD and WD have an additive effect with IBA on rooting of mung bean cuttings. These results are similar to Hess's (1964) and Kawase's (1970, 1971) work in which diffusates with indol-3yl-acetic acid (IAA) showed an increased number of roots on mung bean cuttings. This additive effect of the diffusates could be caused by their ability to stimulate rooting and/or enhance the activity of IBA (Hess, 1964; Kawase, 1970, 1971; LeClerc and Chong, 1983).

Ethyl acetate extracts of each diffusate at pH 3.0 produced more roots than extracts at pH 7.0. The pH 3.0 ethyl acetate extracts of both locust and willow diffusates produced a rooting response in the mung bean bioassay equal to or greater than the straight diffusate. At pH 3.0, essentially all acidic components in the diffusate were protonated, making them considerably less polar and thus extractable by the ethyl acetate phase. Under conditions of neutrality (pH 7.0), the majority of ionizable compounds containing acidic groups were negatively charged and therefore not soluble in ethyl acetate. Thus, the compounds remained in the aqueous phase, perhaps accounting for the lower root-stimulating ability of the pH 7.0 extracts. Therefore, we deduce the root-stimulating compounds in the diffusates were ionizable compounds containing acidic groups.

Both diffusates at 33.3% concentration produced the highest mean number of roots. Diffusates at 25.0% concentration were second in root production, followed by 16.7% and 3.3% concentrations, and each was significantly different. Results of these experiments show that both diffusates induced rooting in mung bean cuttings in a linear fashion as concentration increased. Since the root stimulating effect with increasing diffusate concentration was linear and did not plateau, the concentrations required to elicit maximum root production were not established. None of the concentrations had an effect on root length, as all roots were similar (1.4 cm).

Silica gel thin-layer chromatography of LD and locust extract at pH 3.0 showed no detectable color bands when tested for indoles. WD showed five detectable color bands, which were pink and rose in character at Rf 0.05, 0.25, 0.35, 0.68, and 0.93. Willow extract at pH 3.0 showed four similarly colored bands at Rf 0.24, 0.38, 0.54, and 0.73. These colors may indicate the presence of indoles in the WD and willow extract at pH 3.0.

CONCLUSION

Results of this research support the use of easy-to-root plant diffusates followed by auxins to increase rooting of very difficult-to-root plants such as white fringetree. The mung bean bioassay demonstrated that root-promoting substances are in locust and willow diffusate and their pH 3.0 ethyl acetate extracts. Both willow diffusate and willow extract at pH 3.0 tested positive for indoles, but these were not identified. Easy-to-root plant diffusates as postulated by Hess (1959) and Kawase (1970, 1971, 1972) may be the missing ingredients needed to help overcome rooting failure in difficult-to-root plants.

This work is the first to show that locust and willow diffusates followed by auxins can influence rooting of white fringetree. Further work is currently under way using various types of locust and willow diffusate followed by conventional auxin treatments on white fringetree and other woody plant species. As of 25 Aug. 1997, all the rooted white fringetree cuttings are in healthy condition and are producing a flush of new growth.

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Nonchemical Alternatives for Weed Control in Containers

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Studies were conducted to evaluate recycled waste paper mulch for nonchemical weed control in container production of *Rhododendron* 'Fashion' and *Rhododendron* 'Girard's Rose'. Pelletized and a crumbled formulation of recycled paper were evaluated at 2 depths: 1.3 and 2.5 cm (0.5 and 1 inch). A fabric disk and a fabric disk treated with Spin Out™ were also evaluated. Pelletized paper at a depth of 2.5 cm (1 inch) provided weed control equal to Rout herbicide. Plant growth was similar among all treatments, except with Fashion azalea which was smaller when grown in pelletized paper mulch compared to the crumbled paper system. Container medium solution pH and soluble salts were within the recommended range for acceptable plant growth. Fabric disks allowed weed growth around the container circumference and in the area where the disk fits around the plant. The crumbled paper mulch had minimal weed control. Pelletized paper applied at 2.5 cm (1 inch) provided the most effective nonchemical weed control.

INTRODUCTION

Typically granular herbicides are broadcast with a cyclone spreader over the top of container-grown plants. This method of application results in significant nontarget herbicide loss (herbicide falling between pots rather than in the pots). When using round pots placed on 30-cm (12-inch) centers, nontarget herbicide loss of 80% to 86% per application can occur (Gilliam et al., 1990; Porter and Parish, 1993). Most container nurseries make 3 to 5 annual applications of granular herbicide (Gilliam et al., 1990). In many nurseries as much as 13 to 18 mm (0.5 to 0.7 inches) of water is applied daily during the growing season, causing irrigation runoff (Fare et al., 1992). Runoff water may contain herbicides, thereby threatening nearby water bodies.

Two recently developed products with potential to reduce herbicide use in container nursery crop production are made from recycled waste paper. These products are pelletized recycled paper or crumbled recycled paper (Tascon, Inc. Houston, TX). Waste paper is ground with a hammer mill equipped with a series of three screens [the smallest about 6 mm (0.25 in.)], then compressed using pelletizing equipment to form pellets about 5 mm × 25 mm (0.19 to 1 inch). To develop the crumble product, pellets are put through a granulator with variable pressure plates. Both recycled paper products are noncomposted and have a C : N ratio of about 500 : 1 (Edwards, 1997).

Paper in various forms has been evaluated for a number of uses. Pellet and Heleba (1995) evaluated chopped newspaper for weed control for nursery row crops. They reported newspaper mulch at 6.9 kg m^{-2} (4.2 lb yd^{-2}) at 15 cm (6 inches) depth, suppressed weed germination for two seasons without a negative effect on three plant species, while a fourth species had suppressed growth. One problem encountered in the use of chopped paper was the dispersion of paper during windy conditions. Rolling the paper with a lawn roller reduced blowing of small pieces of paper; however, the nuisance created from the blowing of paper was unacceptable.

While recycled waste paper has demonstrated potential for a number of uses in the landscape (Smith et al., 1997), development of these recycled waste products into a manageable form may allow for use in container-grown crops. The objectives of this study were to evaluate recycled waste paper products as nonchemical weed control alternatives for container production and to determine their effect on plant growth.

MATERIALS AND METHODS

Uniform liners of *Rhododendron* 'Fashion' (Fashion azalea) and *Rhododendron* 'Girard's Rose' (Girard's azalea) were potted in trade gallons on 9 Aug. 1995. The medium was a pine bark and peat (3 : 1, v/v) with 9 kg m^{-3} (15 lb yd^{-3}) Nutricote (18N-6P-8K), 3.6 kg m^{-3} (6 lb yd^{-3}) lime, and 0.9 kg m^{-3} (1.5 lb yd^{-3}) Micromax. Plants were grown in full sun and received overhead irrigation as needed.

Two paper products, recycled paper crumble and recycled paper pellets obtained from Tascon, Inc., Houston, Texas, were surface applied at 1.3 and 2.5 cm (0.5 or 1 inch). Phosphorus was applied to the recycled waste paper products in the pots as triple superphosphate, at either 0 or 7.5 mg $liter^{-1}$ (ppm), based on the dry weight of the paper products. Phosphorus was added since previous work had demonstrated sensitivity of some bedding plants to aluminum in the recycled paper (Smith et al., 1997). Other treatments included fabric disks (Texel Corp., Quebec, Canada), and a fabric disk with Spin Out™ (a copper hydroxide root growth regulator) (Griffin, Corp., Valdosta, Georgia), 3.5 kg ai ha^{-1} (3 lb ai A^{-1}) of Rout 3G™ (Scott's Co., Marysville, OH), and a nontreated control. With all mulch treatments 30 prostrate spurge seeds (*Chamaesyce maculata* (L.) Small), were placed either under the mulch or on top of the mulch. Azaleas were repotted into 3-gal containers on 7 May 1996 using the same medium, remulched with the recycled waste paper treatments, and the treatment of Rout 3G was reapplied. The experimental design was a randomized block with eight single plant replications per treatment for each of the two plant species.

Data collected were spurge number per pot 30 and 75 days after treatment (DAT), and spurge fresh weight 75 DAT for 'Fashion' pots only. In 1996 after repotting, spurge number was determined 30 and 60 DAT and spurge fresh weights were determined in pots of both azaleas 60 DAT. Growth indices (height + 2 perpendicular widths/3) were determined for both species 240 and 550 DAT. Medium solution electrical conductivity (soluble salts) and pH of 'Fashion' containers were measured 7, 30, 90, 210, and 240 DAT using the Virginia Tech Extraction Method (VTEM) (Wright, 1987).

Statistical analyses were performed using the general linear models (glm) procedure (SAS Institute, Inc., 1989), with LSD as a mean separation procedure. All statistical analyses are reported at $P < 0.05$. In presenting the data in Table 1, only those affects, i.e., main, 2-order and 3-order interactions, that were significant were included in the model statement.

RESULTS AND DISCUSSION

Weed Data. Recycled waste paper pellets applied to a depth of 2.5 cm (1 inch) suppressed spurge germination, regardless of whether spurge seed were sown on top of the mulch or under the mulch (Table 1). In contrast, recycled crumble provided poor spurge control at both depths and when spurge was sown on top of the mulch,

Table 1. Mulch control of prostrate spurge in container grown plants.

			Before repotting			After repotting[Z]		
			Spurge #/pot	Spurge #pot	Spurge fresh wt(g)	Spurge #/pot	Spurge #/pot	Spurge fresh wt (g)
Treatment[Y]	Depth (mm)	P-level[X] (mg liter^{-1})	30 DAT[W]	75 DAT	75 DAT	30 DAT	60 DAT	60 DAT
Pellet/su[V]	12.5	0	1.0	3.3	2.6	0.25	2.3	3.1
Pellets/su	12.5	7.5	0.8	0.8	12.9	0.37	1.4	10.6
Pellet/su	25	0	0.0	0.0	0.0	0.0	0.0	0.0
Pellet/su	25	7.5	0.0	0.7	1.3	0.0	0.25	0.03
Crumble/su	12.5	0	10.1	18.8	22.7	1.9	4.0	5.6
Crumble/su	12.5	7.5	4.7	9.8	51.7	5.5	5.5	23.0
Crumble/su	25	0	2.5	8.5	9.2	1.4-	2.0	3.5
Crumble/su	25	7.5	2.6	6.8	36.8	2.5	3.6	56.2
Pellet/st[U]	25	0	0.0	0.3	0.0	---[T]	---	---
Pellet/st	25	7.5	0.0	0.2	0.0	---	---	---
Crumble/st	25	0	9.2	21.6	12.7	---	---	---
Crumble/st	25	7.5	8.0	17.3	46.2	---	---	---
mulch		***	***	****	***	***	**	
depth		***	**	**	NS	**	NS	
seed placement		***	***	NS	---	---	---	
phosphorus		*	**	***	*	NS	**	
mulch × depth		**	NS	NS	NS	NS	NS	
mulch × seed[S]		***	***	NS	---	---	---	
mulch × P		NS	*	***	*	NS	*	

Fabric disk/su	0.3	9.5	3.5	---	---	---	
Fabric disk/st	5.8	8.3	25.3	---	---	---	
Fabric disk+spin out/su	0.8	1.3	7.1	---	---	---	
Fabric disk+spin out/st	2.6	4.6	11.3	---	---	---	
fabric disk	NS	**	NS	---	---	---	
seed placement	**	NS	**	---	---	---	
fabric disk*seed	**	NS	**	---	---	---	
Rout[R]		0.0	3.5	0.0	0.25	1.6	9.5
Control[Q]		12.0	20.5	26.8	5.3	8.1	59.1
LSD[P]		3.1	6.0	11.4	2.2	2.8	27.4

[Z]Plants were repotted 7 May 1996 and retreated.
[Y]Only significant affects were included in the statistical model statement.
[X]P source was triple superphosphate; mg liter^{-1} (ppm) based on pounds of recycled paper per pot.
[W]DAT = days after treatment.
[V]su = seed applied under the mulch.
[U]st = seed applied on top of the mulch.
[T]Treatment not included.
[S]Mulch × seed interaction based on 25 mm depth only.
[R]Rout 3G herbicide applied at 3.5 kg ha^{-1} (3 lb ai A^{-1}).
[Q]Non-mulched control.
[P]Overall experimental LSD; 5% level.

there was increased spurge growth compared to when the seed were sown under the crumble mulch (significant mulch × seed) at both 30 and 75 DAT. There was a mulch × phosphorus (P) interaction at 75 DAT with spurge number where pellets with and without P had 0.6 and 1.2 spurge per container respectively, while the crumbled formulation with and without P had 11.3 and 16.3 spurge, respectively.

Spurge fresh weight was less with 2.5 cm (1 inch) compared to 1.3 cm (0.5 inches) (11.8 vs. 22.5 g). Also, there was a mulch × P interaction at 75 DAT with spurge fresh weight. When no P was added, spurge fresh weights were 0.9 and 14.8 g for the pelleted and crumbled formulations, respectively; however, with supplementary P, fresh weights were respectively 4.7 and 44.9 g. This greater spurge growth in the crumbled paper formulation with supplementary P is possibly due to improved fertility status. The crumbled paper formulation with supplementary P had fewer spurge numbers than without P, yet the fresh weights were about three times greater with P.

Better weed control from use of recycled pellets probably results from two factors. First, the pellets are three times the density of the crumbled product, thus creating a greater barrier for weed seed germination under the mulch. Secondly, the recycled waste paper pellets absorb approximately three times their weight in water within a few days after application. As water is absorbed the pellets swell, forming an interlocked mat of bonded pellets with a relatively smooth surface.

Results from the fabric disk showed limited spurge control was obtained with any treatment. There was a seed placement affect at 30 DAT with spurge number and at 75 DAT with fresh weight where seed placement under the fabric resulted in less growth than seed placed on top of the fabric (Table 1). Spurge also emerged around the container circumference and in the slit where the fabric disk fits around the plant. This observation concurs with those previously reported by Appleton and Derr (1990). There was a fabric disk × seed placement interaction at 30 DAT with spurge number and spurge fresh weight at 75 DAT with the greatest amount of spurge occurring when seed were placed on top of non-Spin Out™-treated fabric. Rout provided excellent spurge control.

Recycled pellets continued to provide excellent spurge control after the plants were repotted in May 1996 (Table 1). With 'Girard's Rose' at 60 DAT, recycled pellets provided greater spurge control (spurge number) than crumbled paper (1.0 vs. 3.8), and the 2.5 cm (1 inch) depth provided greater control than the 1.3 cm (0.5 inches) depth (1.5 vs. 3.3); data for 'Fashion' followed a similar trend.

Growth Indices. Both cultivars of azaleas grown with recycled waste paper mulch were generally similar in size to nontreated control plants and Rout-treated plants at 240 DAT (data not shown). No treatment produced a negative affect on plant growth when comparing effects of recycled paper treatments on 'Girard's Rose'. At 550 DAT all recycled paper treatment ehfl ã‰s!/'re similar with 'Girard's Rose' to plants grown with Rout and nontreated control plants.

'Fashion' showed a significant mulch × depth interaction with growth indices at 240 DAT. Plants grown in the crumbled paper mulch at a depth of 1.3 and 2.5 cm (0.5 and 1 inch) were similar with growth indices of 22.4 vs. 23.6, respectively. Plants grown with a pelleted mulch of 2.5 cm (1 inch) were smaller than those grown at 1.3 cm (0.5 inch) (19.5 vs. 24.3 growth index). We observed that the pelleted mulch appeared to retain greater water than the crumbled paper mulch. Since all treatments were watered similarly with overhead irrigation, the growth suppression with recycled pellets may be related to excessive moisture.

At 550 DAT, 'Fashion' growth indices were affected by mulch, depth, and P (data not presented). Plants in the pelleted mulch had smaller growth indices compared to crumbled material (53.9 vs. 56.2 growth index). Plants in the 1.3 cm (0.5 inch) depth were larger than those grown in the 2.5 cm (1 inch) (56.3 vs. 53.7 growth index), as were plants without supplementary P (56.3 vs. 53.7 growth index).

Salts and pH. The pH of the waste pellets is 6.8 and crumble is 7.0. Medium solution pH gradually became more acidic with all treatments over the course of the study; ranging from 5.6 to 6.6 at 7 DAT to 4.9 to 6.0 at 240 DAT (data not shown). These levels are within acceptable ranges for container-grown nursery crops (Wright, 1987).

Soluble salts (7 and 30 DAT) were affected by additional P and mulch (mulch × P interaction). At 7 DAT plants with pelleted mulch and supplementary P had medium solution soluble salt levels of about 2.0 dS m^{-1}, whereas pelleted mulch without supplementary P, and crumbled paper mulch with and without supplementary P, had soluble salts of 0.87, 0.88, and 0.46 dS m^{-1}, respectively. A similar trend occurred at 30 DAT; however, medium solution salt levels had dropped; ranging from 0.43 to 0.26 dS m^{-1}.

Our research shows that recycled waste paper in the pelletted form provides superior weed control compared to the crumbled form. The 2.5 cm (1 inch) depth is necessary to provide adequate weed control. Repotting and reapplying the mulch to the 3-gal, container-grown azaleas had no negative effect on azalea growth at any time during the study. While plant quality was not rated, plant appearance for all plants was reflected in good foliar color.

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Propagating and Growing Camellias

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INTRODUCTION

Not only is the camellia the most beautiful and desirable of all shrubs, it is also one of the most versatile This evergreen shrub responds well to pruning, or can develop into a small tree

DESIRABLE FLORAL CHARACTERISTICS OF CAMELLIAS

The spring-blooming *Camellia japonica* has a great range of flower sizes from miniature blooms of 5.1 cm (2 inch) to very large 15-cm (6 inch) flowers The range of bloom types is hard to match *Camellia japonica* can have blooms of semidouble, anemone, peony, formal double, or rose forms — sometimes more than one bloom type occurs on a single shrub! Bloom form is surpassed only by the variety of colors. *Camellia japonica* comes in every imaginable shade of white, pink, and red, some having all three colors on a single bloom! Recent color advancements have been the development of creamy shades of yellow and the introduction of sweetly scented blooms

Camellia sasanqua fills in the color void that most gardens suffer in the fall and it more than makes up for its lack of size in its abundance of blooms that can literally cover the bush The sasanqua blooms can have single, semidouble, anemone, and peony forms, as well as new advancements in formal double forms and larger sized flowers Colors are just as rich and varied as *C. japonica*. Your garden could have color from September through December and on into the new year with a careful selection of *C sasanqua*.

Chosen carefully, a selection of cultivars can provide continuous blooms throughout the entire blooming season from early fall to late spring

COLD HARDY CULTIVARS

The current excitement with camellias is caused by the successful introduction of cold-hardy cultivars *Camellia oleifera* 'Lu Shan Snow,' has been crossed with *C. sasanqua* and *C japonica* to produce a new division of camellias Most of the new *C. oleifera* hybrids are hardy to -24 C (-10 F), and some tolerate -26 C (-15 F) without injury. These cold-hardy cultivars have good bud set with moderate growth ranging from upright to spreading to semidwarf. Their blooms range through singles and semidoubles to anemones and peony forms with colors arrays from deep pink to white Zone 6 gardeners can now enjoy what was once considered a zone 8 and 9 plant.

Fall-blooming cold-hardy cultivars appropriate for Zone 6 include 24 cultivars with approximately 75% suited for commercial application They bloom from September to January, in anemone, semidouble, rose form and formal double forms. Colors vary from deep pink to white Plant form is upright, spreading, or semidwarf

Spring-blooming cold-hardy cultivars appropriate for zone 6, include approximately 18 cultivars, again with 75% being commercially viable. They bloom from January to April, in anemone, semidouble, rose form, and formal double forms.

Colors vary from red to variegated, to a broad range of pinks and whites. Plant form is upright, spreading or semi-dwarf.

PROPAGATION

Seasonal Timing and Condition of the Cutting Wood. Generally *C. japonica* and *C. sasanqua* and their hybrids are propagated similarly, except where we have experienced differences. Propagation in Greensboro, North Carolina begins about July 1st when the new growth starts turning golden brown or becomes semihardwood. Propagation continues into September.

Propagation Temperatures. Our propagation houses are maintained with 40% shade. The fans for each greenhouse are set to operate at 29C (85F) and the louvers turn on at 21C (70F). The minimum temperature maintained is 7C (45F).

Propagation Media. The propagation medium consists of fine pine bark, peat, and perlite (14 : 3 : 3, by volume). The medium is amended with 4.2 kg m^{-3} (7 lb yd^{-3}) dolomitic limestone and 3.6 kg m^{-3} (7 lb yd^{-3}) of the slow-release fertilizer, Osmocote 18N-6P-12K.

Fungal Control. We spray our propagation houses with fungicides once a month from July through November and then again February through May with a mixture of Cleary 3336 and Captan 50WP.

Rooting Hormone. The rooting hormone we use for the *C. japonica* is 8000 IBA and 2500 NAA. We use a slightly lower concentration for *C. sasanqua*: 6000 IBA and 2500 NAA. This year we started using Dip 'n Grow. We apply four parts Dip 'n Grow to two parts water for *C. japonica,* and three parts Dip 'n Grow to two parts water for *C. japonica.*

Cutting Preparation. Normally we take stem cuttings with two or three leaves, but if propagules are in short supply we take single leaf (single-node) cuttings. A sharp utility razor knife is used to make the cuttings, changing blades as soon as they become dull. The base of the cutting is sliced at a 45° angle approximately 19 mm (0.75 inches) from the lower leaf. Cuttings are then placed in a fungicidal bath of Cleary 3336 [2.3 ml $liter^{-1}$ (1.8 teaspoons gal^{-1})] for approximately 30 min. We start with a new batch of fungicidal bath every day. The cuttings are removed from the fungicide mixture and let drip dry before treatment with auxins. Cuttings are stuck into 5.7-cm (2.25 inch) or 8.3-cm (3.25 inch) rose cups under mist.

Mist Irrigation. Misting is done with Roberts Spray Head #2 under the following regime:

Frequency mist on (min)	Mist duration (sec)	Cycle length (days)	System on	System off
4	4	10	daylight	dusk
6	4	10	daylight	dusk
10	4	20	1 h after daylight	1 h before dusk
10	4	10	2 h after daylight	2 h before dusk
15	4	7	3 h after daylight	3 h before dusk

Agribrom, which is a brominating agent, is added to the mist water after 20 days of propagation through the duration of the rooting period. Rooting is completed in 57 days and the mist system is turned off. The rooted liners are watered only when needed with a Roberts Spray Head #5.

Rooting Success Rate. Our propagation success rate exceeds 90% when cuttings are taken from July through September.

Container Production System. We grow our older camellias under 35% shade and cover our greenhouses with plastic only during wintertime. Watering is done every other day with occasional light misting in extreme heat.

Year One. The first year the rooted liner camellias are potted up into 1-gal pots in May, using a container medium of pine bark and sand (17 : 3, v/v), amended with 6 kg m^{-3} (10 lb yd^{-3}) of dolomitic lime and 4.8 kg m^{-3} (8 lb yd^{-3}) of a slow-release fertilizer, Wilbro 20N-10P-10K. Plants are placed pot-to-pot and approximately 30% are budded and ready for Garden Center sales in the fall of the same year.

Year Two. A year later plants are spaced in the spring and either sold in the fall or the following spring, or used for shifting up into larger containers.

Post Year Two. After two growing seasons, plants are shifted up into 3-gal containers in October using the same container media formulation previously described. Plants are placed can tight (pot-to-pot) for the winter. They are spaced in May and sold the following fall and spring. After two more growing seasons, plants are shifted-up in October from 3-gal to 7-gal containers into the same container media formulation previously described. Containers are placed can-tight for winterization, then spaced in May and sold the following fall and spring.

Fertilizer Rate and Pot-In-Pot Production Influence Growth of River Birch

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A study was conducted to compare the effects of three fertilizer rates [High N-Southern Formula, 23N-1.7P-6.6K at 1.3, 1.7, and 2.0 kg N m-3 (2.2, 2.8, and 3.4 lb N yd-3)] and the pot-in-pot (PIP) system of production compared with a conventional above-ground (CAG) system on the growth of *Betula nigra* 'Cully' HeritageTM river birch. Plants grown PIP had greater shoot and root growth, total biomass, and increased root : shoot ratios. Fertilizer rate increased shoot dry weights, but decreased root : shoot ratios. Rate of fertilizer application influenced foliar Mg, Zn, and Fe, while the production system had no effect. Nutrient concentrations in the leachate were greater for plants grown CAG. Fertilizer longevity was increased when the PIP system was used, presumably due to lower substrate temperatures during the experimental period.

INTRODUCTION

Pot-in-pot production is increasing in popularity in the southeastern United States (Haydu, 1997; Montgomery et al., 1995; Ruter, 1997). This new production method is being adopted by in-field nurseries and producers of larger container-grown trees. Recent studies have shown that PIP production can be less costly than conventional above-ground (CAG) or in-field production methods (Haydu, 1997; Montgomery et al., 1995).

Fertilizer release from multicoated controlled-release fertilizers is regulated by substrate temperature. During the warmer production season, root-zone temperatures were consistently lower with plants grown PIP compared to CAG production systems (Parkerson, 1990; Ruter, 1993). To my knowledge, little research has been conducted on the effects of fertilizer rates on plants grown PIP. Therefore, the objectives of this study were to compare the growth of plants produced PIP and CAG with three rates of a controlled-release fertilizer.

MATERIALS AND METHODS

The experiment was conducted outdoors under full sun conditions at the University of Georgia Coastal Plain Experiment Station, Tifton. Uniform liners of *Betula nigra* 'Cully' Heritage™ river birch were transplanted from 2.8 L (#1) containers to 26 L (#7) containers in May, 1996. Potting substrate consisted of milled pine bark and sand (8 : 1, v/v) amended with micronutrients at 0.6 kg m^{-3} (1.0 lb yd^{-3}) and dolomitic limestone at 3.0 kg m^{-3} (5.0 lb yd^{-3}). Substrates were surface-incorporated to a depth of 2.5 cm (1.0 in) with 23N-1.7P-6.6K (23-4-8, High N - Southern Formula; The Scotts Company, Marysville, OH) at the rates of 1.3, 1.7, and 2.0 kg N m^{-3} (2.2, 2.8, and 3.4 lb N yd^{-3}) on 31 May, 1996. Holder pots (sleeve pots into which the containers are inserted) were placed in the ground with 2.5 cm (1 inch) at the top of the pot remaining above grade.

The experiment was a randomized complete block with two container production systems (PIP and CAG), three fertilizer rates, and six replications. Additional plants were grown at the 1.7 kg N m^{-3} (2.8 lb N yd^{-3}) fertilizer rate to collect fertilizer prill samples. Cyclic irrigation [~1033 ml (35 oz)] was applied three times per day at 8:00, 12:00, and 16:00. Irrigation was applied using 160° low-volume spray emitters (Roberts Irrigation, San Marcos, CA). All containers (PIP and CAG) had SpinOut™-treated landscape fabric placed beneath the bottom of the planted container to eliminate any problems with rooting-out into the surrounding soil.

On 29 Oct. 1996, final plant height and width measurements were taken. Growth indices were calculated as: [(height + width 1 + width 2 {perpendicular to width 1})/3]. Shoot dry weight and root dry weight were determined after drying in a forced-air oven for 72 h at 65.5 C (150 F). Substrate was removed from the root system before drying. Total biomass was calculated as the sum of shoot and root dry weights.

Foliage was removed after dry weight was determined, ground to 20 mesh, and duplicate 1-g samples were analyzed for N by macro-Kjeldal. Phosphorous was determined using a molybdovandate method while leaf K, Ca, Mg, Zn, Mn, Fe, and Cu were determined by atomic absorption spectrophotometry. At 15, 30, 60, and 120 days after fertilizer application (DAA), the pour-through method was used to collect container substrate leachate. Soluble salts (dS/m) and pH of leachate samples were determined using a conductivity meter and pH meter, respectively. Nitrate-N concentrations were determined with an ion-specific electrode. Nutrient charge remaining in the fertilizer prills was determined 180 and 300 DAA by crushing 2.5 g of oven-dried fertilizer prills in a mortar and pestle and adding the pulverized fertilizer to 250 ml of deionized water (n=4). Remaining nutrient charge was then determined by measuring the soluble salt concentration of the solution. Data analysis for all parameters were evaluated by analysis of variance and regression analysis where appropriate.

RESULTS

Growth indices of plants grown PIP were 7% larger compared to plants produced CAG, but production system had no effect on plant height. For PIP plants, shoot dry weight and root dry weight were 20% and 31% greater, respectively, than plants grown CAG. The increase in shoot and root dry weight resulted in a 27% increase in total biomass. The root : shoot ratio increased 12% when plants were grown PIP.

Fertilizer rate had no effect on growth indices, root dry weight or total biomass. Shoot dry weight increased linearly as fertilizer rate increased. At the highest rate of application 2.0 kg N m^{-3} (3.4 lb N yd^{-3}), shoot dry weight increased 34% compared to the lowest rate. The root : shoot ratio decreased linearly as rate of fertilizer application increased, ranging from 2.1 at the lowest rate to 1.6 at the highest rate.

The production system had no influence on the concentration of foliar nutrients. Fertilizer rate influenced foliar Mg, Zn, and Fe. Both Mg and Zn decreased linearly as rate of fertilizer increased while Fe showed a curvilinear response to rate of application. Production system had no effect on soluble salts or nitrate-N until 60 DAA when both parameters were greater for CAG plants compared to PIP. At 120 DAA, nitrate-N in the leachate was higher for the CAG plants. Soluble salt and nitrate-N levels increased linearly as rate of fertilizer increased at 15 and 60 DAA. The rate of fertilizer application had no affect on soluble salts and nitrate-N at 30 DAA and there was a curvilinear response to fertilizer rate for both parameters at

120 DAA. At 180 DAA, the remaining nutrient charge for fertilizer prills in the PIP system (6.3 dS m^{-1}) was greater than for CAG (4.7 dS m^{-1}). The same held true at 300 DAA as the values for PIP were 4.6 dS m^{-1} compared to 3.5 dS m^{-1} for CAG.

DISCUSSION

Plants grown PIP produced more biomass in terms of shoot and root growth compared to a CAG production system. Fertilizer rate had no effect on growth indices but did increase shoot dry weights, indicating that a denser canopy was produced. The production system and rate of fertilizer application had no effect on tree height. Trees in this study were allowed to grow with multiple trunks and results may have been different if they had been trained to a single leader.

Fertilizer rate had minimal affects on foliar nutrient concentrations. For both production system and fertilizer rate, soluble salt levels were below the recommended minimum of 0.2 dS/m at 30 and 120 DAA while nitrate-N concentrations were generally within or above the acceptable range of 15 to 25 mg/l for controlled-release fertilizers. The formulation of fertilizer used in this study has been rated to last 8 to 9 months at substrate temperatures of 32.2 C (90 F). After 10 months there were still substantial nutrient reserves in the fertilizer prills. Nutrient charge remaining after 10 months was greater for the PIP system compared to CAG, probably due to lower substrate temperatures during the experimental period. With the PIP system, slower fertilizer release rates coupled with increased nutrient uptake due to a larger root system should increase plant growth and fertilizer longevity as well as decreasing the potential for nutrient leaching.

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Winter Protection at Martin's Nursery

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INTRODUCTION

Martin's Nursery is located in Semmes, Alabama, which is just northwest of Mobile. The Semmes area has nearly a century-old history in the nursery industry. Cold weather and severe freezes have played key roles in our history. In fact, it was a devastating freeze that converted the earliest South Alabama nurserymen from citrus crops to ornamentals.

Protection from the elements is a state of mind for our business, as it should be for all ornamental nurseries. A big emphasis is placed on winter protection and we think about it 12 months out of the year. Daily decisions about what to pot and where to put it are partially based on how and if we plan to protect it during the winter. How we protect our azaleas (*Rhododendron*), hollies (*Ilex*), and cleyera (*Cleyera*) are in many ways standard in the industry, but we have some unique systems.

WINTER PROTECTION SYSTEMS

Our winter protection methods include some cultural conditioning, greenhouses, structureless winter coverings and also a "semi-structureless" method of covering.

Cultural. At the basic level, many of our cultural methods are geared towards preparing plants for the winter months. When possible, the timing of our production cycle maximizes the warmer months in order to finish the crops before the threat of cold weather. We plan the production cycle as well as the type of fertilizer around winter. Potting during the winter months can be challenging, but we do that by planning ahead. We prepare some azalea cuttings by toughening then up so we can pot an early crop during the winter. The cuttings are rooted during the summer and never given supplemental fertilizer. They are moved out of the propagation house in late summer and remain unfed. We encourage these plants to go dormant and rarely protect them during cold weather. This hardened-off cutting can then be potted up during the dead of winter.

Greenhouses. We physically protect plants with and without greenhouse structures. Currently, we have 44 greenhouses in use. We supplement some with heat, usually just keeping air temperatures above freezing. However, we will take advantage of the 4- to 6-week jump during early spring by increasing the greenhouse air temperature. We can use our greenhouses to manipulate dormancy and growth by opening and closing doors during certain weather conditions.

Structureless and Semi-Structureless Protection Systems. Our system of covering plants in the field is unique and may not actually qualify as structureless. We have boards permanently fixed in the ground and use them to attach winter cover. The idea behind installing these boards was to give us a surface to nail protective covers in place. This configuration is based on local greenhouse construction techniques — in fact it is exactly how we nail poly to our free-standing pipe houses. The blocks of plants we cover this way are set up with sprinklers on 12 m (40 ft) centers, with every fifth bed being a sprinkler bed. The boards run down both sides of the sprinkler bed stopping 3 m (10 ft) short of the end. Rough sawed, treated 1 inch × 6 inch lumber is used and is nailed and attached to 2.5-cm (1 inch) galvanized pipe. These pipes are on 2.4 ft centers. All are driven 0.6 to 0.8 m (2 to 2.5 ft) deep, and some set in concrete. Most covering is done with 6-mil white poly, but we will also use 4-mil white ploy, shade cloth or frost blankets. White poly is used not only because it has proven to conserve heat and protect, but also because it does little damage to plant foliage. The 6-mil white works much better than the 4-mil because it is stronger and lasts longer, in fact we have some pieces that have been reused for over 5 years.

By drilling holes in this poly, we can leave plants covered for extended periods of time. While still on the roll, we will drill 9.5-mm (3/8 inch) holes on 30 cm (12 inch) centers. These holes allow for rainwater drainage and limited ventilation. We can, and in fact have, leave this covering in place for over 2 months. Under the poly enough moisture is maintained to eliminate the need to irrigate.

Before we cover, we have to move the plants out of the sprinkler beds. We try not to move these very far, and usually fit them all into the walkways in nearby beds. When we are potting in the fall and jamming plants, we will simply skip the sprinkler beds and leave them empty for winter. Larger, finished-off plants are used when possible in the walkways and outside rows in order to hold the weight of the poly off of the younger plants. In most years, we begin covering greenhouses in October and place the poly in the field in November. We like to have all of our hollies and Cleyera either covered or ready to cover before the holidays. There are, of course, exceptions in years where we have early freezes.

In a typical year we will cover the block of plants with poly, then nail only the north end down. Greenhouse strips and double-headed nails are used. We then pull the poly to the north, uncovering the plants. The poly is bunched up on the north end with dirt buckets or peat moss bales sitting on it. If we know a freeze is coming we can quickly pull the poly back over the plants. Usually a stiff north wind assists us and we then nail the south side and secure the ends with dirt buckets or peat moss bales. We will also cover plants in blocks that have no boards. In that case, we secure the protective cover on all four sides with dirt buckets.

CONCLUSION

We've been served well for the past several years by our hybrid structureless system of covering for winter. We have benefited economically by both saving capital outlay and maintaining efficiency. Greenhouse construction can be financially prohibitive, especially during periods of cash-tight growth and expansion. Greenhouses can also reduce efficiency in nursery production systems, since workers can not always get directly to plants and must walk around obstacles. This increased daily walking mileage of workers decreases productivity in our very labor-intensive industry.

THE FUTURE

This structureless system is not perfect. Although it has saved us money and helped protect many plants during winter, we do have to work around it the rest of the year. The future at Martin's Nursery will see increased greenhouse construction and the removal of these boards from the fields. Our structureless system has been an outstanding interim method, but it's hard to beat a greenhouse. Many established nurserymen agree that a greenhouse will pay for itself quickly, sometimes in the first year. We will see!

New Releases From The U.S. National Arboretum

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Throughout its 70-year history, the U.S. National Arboretum has played a key role in the origination and dissemination of new and unique plant material through genetic research and through participation in various plant explorations. Over the past several years, the introduction of some especially exciting and noteworthy cultivars has taken place.

Ulmus americana

I'd like to begin my talk with a discussion of a classic, elegant tree from America's past, the American elm (*Ulmus americana*). Unfortunately, this species has all but disappeared from the landscape due to the ravages of Dutch elm disease. However, I am happy to report that there is hope for the American elm. After 20 years of research, two new cultivars of American elm have been released by the National Arboretum: 'Valley Forge' and 'New Harmony'. Although not immune to Dutch elm disease, 'Valley Forge' and 'New Harmony' have unusually high levels of disease tolerance and have demonstrated superior field resistance. Both cultivars are seedling selections made in Delaware, Ohio, by Dr. Denny Townsend and Dr. Larry Schreiber, who screened thousands of American elms for resistance by inoculation with both aggressive and non-aggressive strains of the Dutch elm disease fungus (*Ophiostoma ulmi*). Compared with the thousands of American elm selections and seedlings in the trials, 'Valley Forge' and 'New Harmony' showed significantly lower foliar symptoms and crown dieback after intensive inoculation with the fungus. The inoculation tests were rigorous: the elm bark beetle, the insect vector for Dutch elm disease, may introduce 10 to 100 spores of the deadly fungus, while the trees in the test were injected with at least a million spores. 'Valley Forge' was found to be the most tolerant with 'New Harmony' a close runner-up. As an interesting sidelight, an outbreak of elm yellows occurred in the Delaware, Ohio site while the new American elms were being tested. None of the 'Valley Forge' and 'New Harmony' trees came down with the disease while about 15% of the other American elms acquired it. Further testing is being carried out to determine if these two cultivars are also resistant or tolerant to elm yellows.

Both cultivars have the classic American elm shape, rapid growth rate, and the tolerance to air pollution, drought, and poor soil conditions of the species. 'New Harmony' has a broadly V-shaped crown with the main trunk dividing nearly 30 ft from the ground into several erect limbs that are strongly arched and terminate in numerous, slender, often drooping branches. The parent tree is 68 ft tall with an average crown spread of 72 ft. 'New Harmony' is reliably hardy in U.S.D.A. Zones 5 to 7 and possibly into Zone 4.

'Valley Forge' has an upright, arching, broadly V-shaped branching structure with a full, dense canopy of leaves. After 12 growing seasons in Ohio, cuttings from the parent tree are 26 ft tall with an average crown spread of 30 ft. It, too, is hardy in U.S.D.A. Zones 5 to 7.

Both cultivars root from softwood cuttings under mist, using 3000 to 8000 ppm IBA, in 3 to 6 weeks. Rooted cuttings that break bud will transplant successfully in the current year. Protection must be provided over winter the first year.

Acer rubrum

Another native American tree with much to offer in landscape potential is *Acer rubrum*, the red maple. The invasion of Norway maple seedlings into our native woodlands has led to the need to identify suitable alternatives for landscape plantings that will enhance the beauty of both the natural landscape and the designed garden.

Three new red maple cultivars, selected for their insect tolerance and the presence of several unique and desirable horticultural attributes, have been recently released by the National Arboretum. The three cultivars, 'Sun Valley', 'Somerset', and 'Brandywine', resulted from controlled crosses made in 1982 by Dr. Denny Townsend between several red maple cultivars and selections. These new cultivars produce only male flowers; no fruit are produced. Each one also has a significant level of tolerance to the potato leafhopper, an insect that can cause shortened internodes, bunching and distortion of new growth, and a general decline in vigor of the plant.

'Sun Valley' is a cross between 'Red Sunset' and 'Autumn Flame'. It has a symmetrical, ovate crown with leaves that show a brilliant red color in the autumn. In Washington, D.C., peak coloration usually occurs around mid-October. The original selection has reached a height of 21 ft with a crown spread of 10 ft after 12 growing seasons. It is adaptable for use in U.S.D.A. Hardiness Zones 4 to 7.

'Somerset' resulted from a cross of 'October Glory' with 'Autumn Flame'. Autumn coloration begins a little later than 'Sun Valley', late October in the Washington, D.C. area. 'Somerset' has outstanding red autumn color combined with an unusually broad range of adaptability. The crown shape is moderately ovate. At 12 years, it has attained a height of 23 ft with a crown spread of 11 ft. It is hardy in U.S.D.A. Zones 4 to 8.

'Brandywine' has the same parentage as 'Somerset'. Flamboyant in autumn, the vibrant red leaf color gradually turns to a brilliant purple red as the days grow shorter, thus providing 14 days or more of effective peak red autumn color. The crown is moderately columnar in form, and at 12 years 'Brandywine' can be expected to attain a height of 25 ft with a spread of 12 ft. It also is hardy in U.S.D.A. Zones 4 to 8.

'Sun Valley', 'Somerset', and 'Brandywine' are easy to propagate from softwood cuttings under mist, using 3000 to 6000 ppm IBA, with rooting generally occurring in less than 4 weeks. Cuttings should be left in place to overwinter.

Lagerstroemia

Lagerstroemia fauriei 'Kiowa' was officially released in 1994, but has not received the promotion and publicity it deserves. A unique source of *L. fauriei* germplasm arrived in the U.S. in 1968, sent to Dr. Donald Egolf at the U.S. National Arboretum by Dr. Y. Tachibana of the Botanical Garden of Osaka, Japan. After many years of evaluation of this germplasm, 'Kiowa' was selected as a superior representative of the species. 'Kiowa' has excellent vigor, fairly large flowers for a *L. fauriei*, and brilliant exfoliating, cinnamon brown bark. The winter beauty of these sinuous cinnamon trunks is a delight to behold. It has attained a height of 25 ft and makes an excellent single to multitrunked small flowering tree. It is reliably hardy to U.S.D.A. Zone 7. A test planting was recently established at a Zone 6 site in Kearneysville, West Virginia, so that the actual hardiness range of 'Kiowa' can be tested in the field under variable winter conditions.

Propagation of 'Kiowa' is not as easy as with other crapemyrtle cultivars. Rooted cuttings may be obtained from juvenile material with varying degrees of success. However, it has rooted very well using micropropagation techniques, and we now feel confident that significant numbers of 'Kiowa' can be made available to the retail trade.

The year 1997 has been a milestone year for the National Arboretum's crapemyrtle program with the introduction of 'Chickasaw', the first in a series of miniature hybrid crapemyrtles bred by Dr. Donald Egolf. This small, densely branched, compact plant is the answer to a gardener's dream. Clusters of lavender to pinkish-lavender flowers adorn the plant in mid-summer. The clusters of glossy, dark red flower buds provide several weeks of pre-season interest. New leaves have a dark reddish tinge and mature to a glossy dark green. Field resistance to powdery mildew is another plus. 'Chickasaw' grows as a compact mound and has reached a height of 2 ft with a width of $2^1/_2$ ft after 7 years of container culture. The exciting news is that this particular type of crapemyrtle lends itself to a variety of new uses for which the larger cultivars are unsuited. Reliably top-hardy in U.S.D.A. Zone 7B, the roots are hardy in U.S.D.A. Zone 6. The plant's unique habit may provide opportunities for growing and marketing the miniature 'Chickasaw' in areas of the country that do not currently grow crapemyrtle. For example, as a perennial plant, as an annual bedding plant, and definitely for use as a container plant or in the container garden, 'Chickasaw' could provide a "new look" for summer flower beds. Although slowgrowing, 'Chickasaw' roots easily from softwood to semihardwood cuttings taken before flowering. Rooting occurs in 2 to 3 weeks using 1000 ppm IBA, under mist.

Hemerocallis

Hemerocallis 'Chesapeake Belle' was named and released for propagation in 1996. This is a selection from the cross of 'Elfin Stella' with 'Shorty' made in 1989 by Dr. Robert Griesbach. 'Chesapeake Belle' is distinguished by its continuous flowering and dwarf habit. Most continuous flowering daylily cultivars produce small flowers on tall stems whereas 'Chesapeake Belle' produces its flowers on short stems. The plant is 8 to 10 inches tall and 10 to 12 inches wide, producing flowers 3 inches in diameter. A bright yellow-gold in color with a greenish gold throat, the flowers bring sunshine to the garden all summer long. This lovely small daylily will produce 4 to 6 inflorescences from May to October. It is suitable both as a container plant or in the garden as a border or rock garden plant.

With the expansion of the Floral and Nursery Plants Research Unit at the National Arboretum, the scope of plant material being investigated has widened considerably.

Future Releases

As an enticement to look to the future, I would like to mention three new proposed releases which have just been sent to our cooperators for stock increase this fall. As soon as their numbers are increased enough to make them commercially available, these plants will also join the elite roster of U.S. National Arboretum cultivars.

Lagerstroemia

Lagerstroemia hybrid (NA 62918) is the second in our series of miniature crapemyrtles. It will be released within the next 2 to 3 years. The foliage is an excellent dark green with a high tolerance to powdery mildew. The plant is a compact mound which has reached about the same overall size as 'Chickasaw'. Flower color is a deep rose pink. Like 'Chickasaw' propagation is extremely easy using 1000 ppm IBA, under mist. Semihardwood cuttings will root in 3 to 4 weeks.

Syringa

Syringa hybrid (NA 62973) will be the first lilac hybrid to be released by the Shrub Genetics Research Program at the National Arboretum. It is a floriferous, white-flowered, rounded shrub with high field tolerance to powdery mildew. The habit of the plant is compact and rounded, without the legginess associated with so many of the *S. vulgaris*-type lilacs. It has reached a height of approximately 6 ft in 15 years. Well suited for gardens as far south as U.S.D.A. Zone 8, this selection requires very little cold treatment to break flower bud dormancy. It has performed exceedingly well in the pollution, heat, humidity, and hotbed of powdery mildew in Washington D.C. Propagation by semihardwood cuttings is easily accomplished with 89% rooting in 4 to 5 weeks using 3000 ppm IBA, under mist. Unrooted cuttings were restuck after 5 weeks and the ultimate rooting percentage after 7 weeks was 95%.

Cercis chinensis

Cercis chinensis (NA 63877) is a selection much like the species except for the fact that it does not set fruit. Therefore, there are no unsightly pods hanging on during the winter. In addition, the plant has an excellent, compact growth habit and roots quite easily. One cooperator has reported rooting at 100% from semihardwood cuttings. Much the same results have been produced at the National Arboretum using semihardwood cuttings treated with 3000 ppm IBA, under mist.

The U.S. National Arboretum takes seriously its mission to conduct research, provide education, and conserve and display trees, shrubs, flowers, and other plants to enhance the environment. Committed to excellence, this institution will continue to develop superior plant material well into the next century and beyond.

New Clematis

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Clematis 'Błękitny Anioł'

Height: 2.5 to 4 m.
Flower: Diameter 10 to 15 cm; light blue, lighter in the middle of the sepals and darker on edges, very fine silky texture, ruffled sepals with curled edges, yellow-greenish stamens nicely contrast with blue sepals.
Flowering date: June to August.

A very freely flowering and long-blooming cultivar. At the same time a shoot can have flowers on seven nodes. It is a healthy plant, it can grow separately or in a group, also together with other plants, i.e., roses and other shrubs or conifers. It grows beautifully in a sunny, south-facing position, but a shadier, even a north location also suit it. 'Błękitny Anioł' flowers abundantly from the middle of June until the middle of August and its flowers look fresh for a very long time. If, however, blooming is weak, the plant can be cut back in the second part of July and it will flower nicely again in September. The blooms contrast well with a dark background from other plants or a wall. When flowers cover it densely, it looks like a downy angel. The cultivar is also suitable as a cut flower.

The cultivar was raised by Brother Stefan Franczak in 1989 and introduced to the market in 1990. In 1990 it received "Word of Recommendation" by the judging committee of the Royal Boskoop Horticultural Society in Holland. In 1992 it received the gold medal on "Plantarium" in Boskoop — the biggest ornamental nursery trade show in Europe.

Clematis 'Kardynał Wyszyński'

Height: 2.5 to 3 m .
Flower: Diameter 15 to 17 cm; broad sepals with lightly waved edges, glowing crimson sepals, stamens have dark crimson anthers and light pink filaments.
Flowering date: June to September.

This cultivar is very freely blooming and it has a very attractive bright color. It can be grown as a specimen or over other shrubs or conifers or as a good ground cover. The cultivar is also suitable as a cut flower.

The cultivar was raised by Brother Stefan Franczak in 1988 and introduced to the market in 1990. In 1990 it received "Word of Recommendation" by the judging committee of the Royal Boskoop Horticultural Society in Holland. In 1990 it received the gold medal on "Plantarium" in Boskoop — the biggest ornamental nursery trade show in Europe.

Clematis 'Jan Paweł II'

Height: 4 m.
Flower: Diameter 10 to 15 cm; creamy white with pink streaks which become more distinctive in the late summer as a pink bar, stamen has dark red anther and white filament.
Flowering date: July to October.

This cultivar is strong growing and very healthy. It has a very long flowering time and blooms freely. A changing color during the flowering season is a very interesting feature. Sepals are broad, overlapping, with a textured surface and a pretty satin sheen; pearly, almost translucent white with a hint of pink. Sepals have very light pink streaks at the start of the blooming period (July to August) and they become more distinctive by the end of the flowering season (September to October) as a pink bar. As the flowers age the bar on the surface fades, but on the reverse side still gives a hint of pink through the sepal. An additional attraction can be the very nice seed heads. The flowers and seed heads are suitable as cut flowers.

The cultivar was raised by Brother Stefan Franczak and introduced to the market in 1982.

***Clematis* 'Polish Spirit'**

Height: 3 to 4 m.

Flower: Diameter 7 to 8 cm; velvety, rich purple-blue, in the middle of sepals color is deeper; stamen has deep violet anther and light green filament.

Flowering date: July to September.

This cultivar is extremely free flowering with a long blooming period. It can be grown by itself but is also very good for growing over trees, large shrubs, or conifers, and it can be used as ground cover. It is suitable for cut flowers. The very nice small dark green leaves are also decorative. The cultivar was raised in 1984 by Brother Stefan Franczak. He gave it to Raymond Evison who named and introduced it to the market in 1990. The cultivar received Award of Garden Merit in England.

***Clematis* 'Emilia Plater'**

Height: 2.5 to 4 m.

Flower: Diameter 10 cm; light blue, crepe-like sepals with creamy-green stamens.

Flowering date: June to September.

Very free- and long-flowering cultivar from the viticella group. It is vigorous and very healthy cultivar, and especially good for sunny positions. It was raised by Brother Stefan Franczak in 1988.

***Clematis* 'Kacper'**

Height: 2.5 to 4 m.

Flower: Diameter 20 to 25 cm; very large, intensive violet with crenulated sepals and violet stamens.

Flowering date: June to September.

It was raised by Brother Stefan Franczak in 1988.

***Clematis* 'Matka Urszula Ledóchowska'**

Height: 2 to 2.5 m.

Flower: Diameter 14 to 18 cm; white with red stamens.

Flowering date: May to June and if cut back again in August to September.

A free-flowering culitvar from the bottom of the plant. It was raised by Brother Stefan Franczak in 1990.

***Clematis* 'Monte Cassino'**

Height: 2 to 2.5 m.

Flower: Diameter 13 to 15 cm, wine, velvet red, creamy stamens.

Flowering date: June to August.

It was raised by Brother Stefan Franczak in 1988.

***Clematis* 'Sympathia'**
Height: 2.5 to 4 m.
Flower: Diameter 15 to 18 cm; silky rosy-lilac, lightly wavy edges, deep brown stamens.
Flowering date: June to September.
It was raised by Brother Stefan Franczak in 1988.

***Clematis* 'Warszawska Nike'**
Height: 2.5 to 3 m.
Flower: Diameter 13 to 15 cm; a velvety violet color with golden stamens.
Flowering date: June to September.
A very free- and long-flowering cultivar even under a broad range of growing conditions. It was raised by Brother Stefan Franczak in 1988. In 1990 it received the silver medal on "Plantarium" in Boskoop, Holland.

***Clematis* 'Westerplatte'**
Height. 1.5 to 2 m.
Flower: diameter 13 to 15 cm, bright rich red with red stamens.
Flowering date: June to August.
It was raised by Brother Stefan Franczak in 1990.

***Clematis* 'Aljonushka'**
Height: 1.3 to 2 m; semiherbaceous, nonclimbing plant.
Flower: Flower does not open fully and remains as a hanging bell shape, slightly mauve-pink color.
Flowering date: July to September.
A hardy and free-flowering plant which was raised in 1963 by A.N. Volosenko-Valenis and M.A. Beskaravainaya in Yalta, Crimea (formerly part of the Soviet Union) from a cross of *C. integrifolia* and *C.* 'Nezhdamya'.

***Clematis* 'Paul Farges' (syn. *C.* 'Fargesioides')**
Height: 6 m.
Flower: Diameter 4 cm; white, open flowers.
Flowering date: July to September.
Vigorous, hardy, healthy, and very free flowering with attractive seed heads. It was raised by A.N. Volosenko-Valenis and M.A. Beskaravainaja in Yalta, Crimea from a cross between *C. potanini* Maxim. × *C. vitalba* L. Name synonym in use include 'Summer Snow'.

***Clematis* 'Asao'**
Height: 2 to 2.5 m.
Flower: Diameter 15 to 20 cm; light pink with rich deep pink margins and brown stamens; attractive seed heads; sometimes the flowers are semidouble.
Flowering date: The end of May to June and August to September.
It was raised in Japan.

***Clematis* 'Fuji-musume'**
Height: 2 to 2.5 m.
Flower: Diameter 12 to 15 cm, very clear color, sky blue, yellow anthers.
Flowering date: The end of May to August.
This cultivar is free flowering from the bottom of the plant. It was raised by Sejuru Arai in Japan in 1952 from a cross of 'Asgiri' and 'The President'. It was introduced into Europe in 1986.

***Clematis* 'Haku-oôkan'**
Height: 2 to 2.5 m.
Flower: Diameter 15 to 17 cm; the name in English means "The White Royal Crown" and was so named because the crown of white stamens surrounded by violet sepals makes its flowers look regal. Occasionally flowers are semidouble from old wood.
Flowering date: The end of May to August.

It was raised by Esio Kubota in Japan. It doesn't like a north growing condition.

***Clematis* 'Vino'**
Height: 2 to 3 m.
Flower: diameter 15 to 18 cm; magenta-red, with contrasting creamy-yellow stamens.
Flowering date: The end of May to June and August.

It was raised by D.T. Poulsen in Denmark and introduced in 1989.

***Clematis* 'Snow Queen'**
Height: 2 to 2.5 m.
Flower: Diameter 15 to 20 cm; bluish-white, changing to pure white as flowers ages.
Flowering date: The end of May to June and August to September.

It was raised by Alister Keay in New Zealand. Introduced to Europe in 1983.

***Clematis* 'Multi Blue'**
Height: 1.5 to 2.0 m.
Flower: Diameter 10 to 15 cm; sepals light French navy-blue, with a "multi" inner layer of sepals which forms an attractive spiky crown in the center of the bloom.
Flowering date: The end of May to August.

Very unusually looking clematis with double flowers from the young and the old wood. The cultivar is not genetically stable so there is some variation in flower shape with this free-flowering cultivar. It was selected by Bouter & Zoon in Holland as a sport from 'The President' in 1983 and it was introduced in 1986 . It received the silver medal on "Plantarium" in Boskoop, Holland in 1990

***Clematis* 'Helios'**
Height: 1 to 1.5 m.
Flower: Diameter 4 to 6 cm; yellow, open as they mature.
Flowering date: June to August.

A compact plant form in the *C. tangutica* group with open flowers. It was raised at the Research Station of Nursery Stock in Boskoop, Holland in 1988 as a cross of *C. tangutica* and *C. serratifolia* 'Golden Harvest'. It received an Award of Merit.

***Clematis montana* 'Freda'**
Height: 4 to 6 m.
Flower: Diameter 5 to 6 cm, sepals are deep cherry-pink, with paler pink bars and almost red margins — the darkest colored of all the montanas — golden stamens, and bronze foliage.
Flowering date: May to June.

A more compact plant and less vigorous than *C. montana* var. *rubens*. It was raised by Mrs. Freda Deacon of Woodbridge, Suffolk, England, and was introduced in 1985. It has an Award of Garden Merit in England.

Landscape Performance of Shade Trees Initially Grown in Above-ground Wire Basket Containers

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Trees of green ash [*Fraxinus pennsylvanica* var. *subintegerrima* (syn. *F. pennsylvanica* var. *lanceolata*)] grew equally well after 2 years in above-ground wire basket containers lined inside with tar paper, vinyl, or geotextile fabric. After an additional 7 years in the landscape, trees grown with both the basket and liner removed, or with the basket removed and the liner slashed, grew similarly and better than those with both the basket and liner intact. When the root ball was removed from the containers before planting in the landscape, trees initially grown in the tar-paper-lined containers grew the best. Trees initially grown in the fabric-lined containers grew the least.

INTRODUCTION

The introduction of the in-ground fabric container method of growing shade trees in the 1980s heightened interest in container tree culture (Reiger and Whitcomb, 1983). As an alternative tree culture system, the Ornamental Nursery Research Program at the Horticultural Research Institute of Ontario has been examining the use of inexpensive containers, custom-fabricated from wire baskets lined inside with various types of materials.

ABOVE-GROUND IN CONTAINERS

Through two growing seasons and two winters between May 1988 and June 1990, we evaluated and compared the production of green ash [*Fraxinus pennsylvanica* var. *subintegerrima* (syn. *F. pennsylvanica* var. *lanceolata*)] in three types of above-ground wire basket containers, fabricated by Braun Nurseries Ltd., Mount Hope, Ontario. The wire baskets (50 cm wide × 30 cm deep, normally used in conjunction with the burlapping of trees) were lined with: tar paper (similar in composition to roofing shingles); vinyl (grey on the outside and black on the inside); or geotextile fabric (the same material used in the construction of below-ground fabric containers). The linings fitted snugly inside the wire basket, and were composed of two parts (Fig. 1), either stitched together (vinyl and fabric) or unstitched (tar paper). Holes were punched in the bottom of the vinyl liner to allow drainage of water. Two specially-designed capes (Polyfoam or THERMAT) were also tested for their efficacy in moderating container soil temperatures during the winter and also during the growing season.

The trees survived without any winter injury and grew equally well in all the above-ground container treatments. A detailed report of this part of the trial was published (Chong et al., 1990). Further information about the subsequent performance of these trees in the landscape is provided below.

Fig. 1. The container liner, composed of two parts (circular bottom and sidewall), was designed to fit snuggly inside the wire basket.

LANDSCAPE PERFORMANCE

In early June 1990, the same trees (48-mm mean caliper) were planted into a silty clay loam soil to simulate a permanent landscape setting. Before planting, trees from each container type (tar paper, vinyl, and fabric) were treated (pre-plant treatments) as follows: (a) both wire basket and liner removed; (b) wire basket removed and vertical slashes made in the liner 15 to 20 cm apart around the root ball; or (c) both wire basket and liner left intact. There was a total of 45 trees (3 container types × 3 pre-plant treatments × 5 single-tree replications) planted at random in two rows 3 m apart and 2 m within rows.

Before planting and each spring thereafter, 112 kg N ha^{-1} was broadcast applied to the soil in the form of ammonium nitrate. The soil contained adequate quantities of P and K. Each year, mid-season leaf samples from each tree were analysed for N, P, K, Ca, Mg, Fe, Mn, and Zn, and end-of-season caliper and height were recorded. The trial was terminated at the end of the 1996 season, when trees began to crowd each other. At this time, the root ball of selected trees from each container type and pre-plant treatments were dug with a tree spade, loose soil was washed away, and the roots were inspected.

Growth Measurements. As illustrated by caliper and height data recorded in 1996 after 7 years in the landscape (Table 1), trees which had been planted with basket and liner intact grew less than those which had the basket removed and with liners either slashed or removed before planting. The same data showed that the types of liners used also influenced growth. Trees from the tar paper treatment grew best followed in order by those from the vinyl and the fabric containers (Table 1).

Table 1. Effects of container type and pre-plant treatments on performance of green ash (*Fraxinus pennsylvanica* var. *subintegerrima*) trees after 7 years in the landscape.

	Pre-plant treatments			
Container type	Basket and liner intact	Basket removed liner slashed	Basket and liner removed	Mean pre-plant effects
		Caliper (mm)		
Fabric	78	94	89	87 C
Vinyl	88	92	99	93 AB
Tar paper	96	101	105	101 A
Mean container type effects	87 b[Z]	96 a	98 a	
Height (cm)				
Fabric	545	604	610	586 C
Vinyl	588	618	623	610 AB
Tar paper	643	674	640	652 A
Mean container type effects	592 c	632 a	624 ab	

[Z]Means within columns (pre-plant treatment effects) or rows (container type effects) followed by the same letter are not significantly different according to LSD at 5% level of probability. There was no significant container type × pre-plant treatment interaction.

Root Ball Observations. Roots growing out of the intact containers invariably did so through the container side-walls, or through the stitches. Trees grown in tar paper liner only during the above-ground phase, showed no apparent restriction upon their root system (see basket and liner removed, Table 1). This result was observed also for trees which were planted in the landscape with the tar paper liner slashed (see basket removed, liner slashed, Table 1). In the two pre-plant treatments with tar paper liner intact or slashed, the tar paper had apparently been disintegrating during the landscape phase. When roots were dug, only remnants of the tar paper were visible in these treatments.

With the vinyl contained root ball, only a few larger roots emerged from the intact vinyl liner. Swellings at the points of root emergence were evidence of girdling (Chong et al., 1987; 1989; Remphrey et al., 1990). The fabric-contained root ball had numerous fibrous roots confined within the container (Reiger and Whitcomb, 1983). Many small, outer feeding or "nurse" roots, with knob-like swellings at the points of emergence indicated severe girdling. The nurse roots were loosely attached and easily broken off, as previously described (Chong et al., 1987; 1989).

Data from earlier years indicated that growth constraints by the intact fabric liner began to be manifested after the 2nd year in the landscape, and to a lesser extent and somewhat later by the vinyl liner. These differences were quite accentuated at the end of the landscape phase. Within the vinyl liner, there was substantial circling of medium-sized (1 to 2 cm diameter) or larger roots. This observation is consistent with description of "pot-bound" roots in regular nursery containers (Appleton, 1989). Within the fabric liner, many larger roots appeared to be abnormally swollen or deformed as previously described in "smaller-than-normal" experimental in-ground fabric containers (Chong et al., 1989). The occurrence also of less growth each year in landscape-grown trees with the fabric or vinyl liner removed or slashed was indicative of delayed manifestation or "latent effects" due solely to prior confinement (2 years) in these containers above-ground.

Chong et al. (1989) reported decreased foliar N and P contents in poplar trees grown in in-ground fabric containers. Throughout the landscape phase, we observed no differences in foliar nutrients due to container type or pre-plant treatments. Also the wire basket had little or no visible effect on the root system. Roots were not large enough for them to be restricted or girdled by the openings of the wire basket (Lumis and Struger, 1988).

CONCLUSIONS

The results of this study provide information about tree performance in various lined, wire basket containers and restrictions on the root system by these containers during nursery production above-ground and, subsequently, in the landscape. Reduction in tree growth varied with the type of container liner material and the extent of root ball confinement by the container. Slashing of the container liners was just as effective as complete removal (Fig. 2).

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Fig. 2. Slashing of the container liner did not restrict root growth and was just as effective as complete removal of the liner.

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Future Marketing Potential for Daylilies

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One of the few research studies available on the significance of daylilies in the market place was reported in the *Perennial Plants Quarterly* Journal of the Perennial Plant Association, Volume 3 (4), Autumn 1995. In an article "Views of Management", Tim Rhodus and James Haskin, Department of Horticulture, Ohio State University, reported that in their survey consisting of 441 respondent nursery managers, that they found *Hemerocallis* to be the second most frequently sold genus. *Hosta* was number one.

Their research also showed that few of the managers were growing a wide assortment of named daylilies. 'Stella de Oro' was grown more widely than any other cultivar, 75.4% mentioned this plant. The next most widely grown daylily was 'Hyperion' with 3.9%, and in third place 'Happy Returns' with 2.0%. Other daylilies mentioned were: 'Catherine Woodbery', 'Luxury Lace', 'Mary Todd', Trophytaker™ Series, 'Flying Saucer', 'Rebel Boy', 'Pardon Me', 'Penny's Worth', 'Aztec Gold', 'Brackle Red', 'American Craftsman', 'American Revolution', 'Hall's Pink', 'Dewey Fresh', and 'Hudson Valley'.

With this information as background I began to pursue my mission of looking at the potential future markets for daylilies in the I.P.P.S. Eastern Region. First I determined that the daylily markets directly to the public could be categorized into several groups:

1) Mailorder catalog companies with subgroups including:
   a) Bulb producers selling bareroot daylilies in various plastic packages out of cold storage.
   b) General garden plant catalog companies carrying a wide assortment of perennials and also sometimes woody plants selling daylilies bareroot.
   c) Daylily specialists mostly selling fresh bareroot plants during the growing season.
2) Mass marketing outlets, garden centers, and roadside markets.
3) Landscape contractors and re-wholesalers set up to service the landscape professional.

Then I selected firms representing these categories, and placed a phone call to managers and asked them a series of questions.

Many different questions were asked depending on the conversations. However a few standard questions were asked of each of the respondents.

One of these questions was, **"How important are mailorder firms, garden centers, and landscape contractors in the marketing of daylilies?"** Most interviewees felt that garden centers had the most profound impact on the market since buyers could see the plant in bloom and make decisions from direct observations.

Another question was, **"How important is micropropagation (tissue culture) for increasing numbers?** Here the answers were extremely variable. Most believe that micropropagation can play some role but that it also has had many limitations in the past.

A third question asked, **"Have you observed a color preference for daylilies?"** Landscape contractors answered stating their convictions for clear yellow and gold while the other groups generally put pink in first place, red second, and white third. There were very mixed feelings about daylilies with eyezones.

The next question was, **"What is more important, rebloom or a long season of bloom from plants with high bud counts?"** Most respondents feel that rebloom is a good selling point but in actuality has lots of limitations because of rest periods and the need for grooming. A few respondents were adamant that a 4- to 6-week bloom period on one set of scapes provided the best landscape effect.

The next question was, **"Is there a preference for size of flower?"** Almost all agree large flowers sell best but then attempt to explain why 'Stella de Oro' is so popular.

The final standard question asked was, **"Are there daylilies that do a disservice to future market development?"** One fairly new reblooming cultivar was frequently mentioned. Two respondents felt that evergreen daylilies from southern hybridizers were doing a great disservice to future purchases because they were giving gardeners the feeling that they were weak plants. And still another respondent said all of the old daylilies were a disservice to expanding the daylily market.

All of the respondents mentioned that the market is growing, there is a vast assortment of new types to sell, and there is an abundance of hybridizers insuring the availability of a new product. Generally daylilies are still considered one of the easiest perennial genera to cultivate and they offer color during the hottest part of the summer when many other plants fail.

Following is a smorgasbord of comments made in the telephone conversations:

- 'Stella de Oro' is the daylily market. The demand for this cultivar will continue to expand and will probably never be exceeded by any other new cultivar.
- I can sell any daylily if it is well grown and has a picture tag with hardiness zone and "how to" information.
- Daylilies are dependent on housing starts, the more open land the more daylilies will be sold, older subdivisions get shady quickly and require shade-tolerant plants.
- Contractors will never accept containers as a good source of plants, bareroot plants are less expensive and are much easier to take to the jobs.
- The concept of instant gratification is so great that garden centers can expect more and more purchases in 3- and even 5-gal containers.
- Most landscapes with mixed perennials will find clear colors their best choice. There will be a good market in garden centers for some of the new large-flowered daylilies with clear eyezones and popcorn edges.
- A comfortable price range for good new daylilies is between $7.95 and $14.95. Over $15.00, price resistance begins. Some specialists will be able to sell expensive daylilies but the number of sales for daylilies over $25.00 is small.
- More has to be done to make daylily sales quick and easy, people are time impoverished, they want well labeled plants with prices clearly stated and instant checkout. Sellers repeat when the

product is good and the garden center service excellent. Container plants have the best "shelf life" and can be left for planting later when gardening time is available.

- Daylilies have regional preferences: dormants for the north, evergreens for the south, and those that open after cold nights for the west coast. Markets will expand if the right selection is made for the right location.
- Large-flowered daylilies, those over 6 inches are easiest to sell.
- More education is needed to increase sales. There are 40,000 cultivars with only a couple of dozen plants with name recognition. Often landscape contractors select daylilies from a single wholesale catalog or rely totally on the nursery to select the plants for them.
- Many poorly chosen cultivar names limit the market potential for the plant.
- Presently numbers are difficult to build up so different firms can offer their own unique plants in smaller numbers.
- Recent advances in tissue culture techniques may provide rapid plant increases for new cultivars from foreign markets such as The Netherlands.

My summarizing remarks are that there is an excellent future market potential for daylilies. Growers and retailers, however, cannot expect sales unless they select the right plant for their region, spend adequate money on advertising and signage, price the plants competitively, and provide opportunities for convenient quick shopping.

New Plants for the 21st Century: The Sun Still Rises in the East

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As you have noted, my presentation is about new plants from Asia, specifically Japan. Asia is much too big a topic to cover in any talk. Everyone is still going to China so I will be contrary and talk about Japan because I believe that Japan is still the best source of preselected plants for the American nursery industry. I know that China has more wild species but when it comes to plants that you can plug into production, Japan is still number one. Japan's domestic horticultural tradition is the broadest, deepest, and richest in the world. I am sure that there are people who will disagree with me but I know people in Japan who collect one species of cactus depending on the curvature of the spines. In additon, I think that if you look at which plants are popular in the American nursery industry, you will find that the great majority of them are from Japan, or China via Japan. I get better Chinese plants out of Japan than most people get out of China because the Japanese have so many joint ventures in China.They have money, so the good plants get into Japan before anyone in the West can get a chance to see them. So, if you have good contacts in Japan, you can get the best from China with minimal trouble.

We have had horticultural contact with Japan for over 100 years, and yet it is amazing how little we know about Japanese horticulture. Americans, when they think of Japanese horticulture, think of bonsai, which has not been a strong horticultural tradition in Japan for very long. There are still so many layers of interest that we have not explored.

Most of us have a romantic image of Japan, this is set by scenes such as Mt. Fugi seeming to float majestically above the clouds. We think of the beautifully composed and manicured landscape gardens which were not open to the ordinary Japanese person until about 30 to 40 years ago. Such gardens were only for the very wealthy and highest ranking officials. These images are true and do exist in Japan, but to say they are typical is a misunderstanding.

The construction crane seems to be the national bird of Japan. For 90% of the Japanese people the city landscape is the natural landscape — overbuilt cities and lots of gray concrete. Even in these gray cities if you get onto street level and poke into the nooks and crannies you can see some extraordinarily beautiful things — things such as beautifully sculptured masses of Japanese azaleas and holly that soften the hard surfaces. Even in the more traditional urban situations you do not see traditional garden situations — because there aren't any spaces for gardens. It is only the very wealthy that can afford a garden such as a 10×10 ft^2 plot. If you are extremely wealthy you can have a walled-in garden but still with only simple imaginative uses of traditional Japanese plants. Most people in Japan have to garden in the street. You can walk down a residential street in Japan and see a horticultural display that is remarkable for its variety and ingenious use of plants in pots that you normally do not think of as pot plants. And speaking as a nurserymen, I think you would be highly educated it you walked these urban landscapes and saw the kinds of presentations they do with woody and herbaceous plants. There are a lot of ideas for presentation in American retail garden centers in these urban landscapes. People who are fortunate to have outside stairways and balconies, just take the plants up with them. It is interesting to see how people have brought plants into their lives when they do not have much space to do so. There is no place where you can not see plant displays: on the roofs, subways, fire escapes, stairs, any place were there is a bit of space left over.

You can also buy plants almost anywhere in Japan. There is more opportunity to buy plants in Japan than any place that I have been. You can buy orchids on a street from a vender. Department stores have some of the finest plant shops in Japan — at the entrance as well as in the store. A display of orchids in a dress shop in a department store is typical. It is common place for interesting displays of both native and exotic plants to be displayed and present in department stores. The Japanese are very fond of variegated plants and you can also find such displays in department stores. As American tastes have changed so that they are more open to variegated plants, this is an area of great opportunity. The Japanese have a perverse interest — which I share — in variegated weeds such as the variegated form of *Plantago lanceolata*. Other examples of variegated weeds include a variegated form of thistle, *Cirsium japonicum*, which is a popular cut flower in Japan. I have grown this variegated form and it grows quite well in Zone 6 in Pennsylvania. Another example of a white-variegated weed that I am growing is kudzu, *Pueraria montana* var. *lobata* which I call 'Sherman's Ghost'. Kudzu also has a yellow-splashed form that I call 'Old Yeller'. My favorite is the variegated form of Japanese poison ivy, *Toxicodendron radicans* ssp. *orientale,* which I have named 'Seven Year Itch'.

Some of the most interesting plant shops are on the roofs of stores. These urban plant shops on the roofs are often consignment shops. "Koten engei" plants, which are traditional Japanese pot plants, are examples of such displays. This type of display is to me one of the most interesting features of Japanese horticulture. Some of these plants are really bizarre. There are many contorted and variegated forms which have been grown for over 400 years. This is what I consider extreme horticulture, but as nurserymen we need to consider that what is extreme today may not be 10 years from now. I introduced plants in the 1970s that everybody laughed at but they are now standard nursery items because taste and sophistication have changed. Therefore, we need to keep in mind that some of these extremist expressions of horticulture might be the crops for tomorrow's nurseries, not only for the big plant factories, but the specialist growers.

One of the things that the Japanese nurseries do so well is display and presentation, and they offer a lot of ideas for people in this country. Plants are displayed with beautiful pictures containing good information on the tags. I can not say enough about the need of making it simple for people to get excited about plants and then take them home and know what to do with them. The displays are not limited to expensive plants but inexpensive types, such as *Viola*, are attractively displayed in 2-inch containers. This is a level that we should aspire to achieve, transmitting the interest in plants in a very small space.

I became aware of the virtues of Japanese woodland peonies through such a display where roots were packaged and displayed with photographs and information. I have come to believe that Japanese woodland peonies such as *Paeonia obovata* and *P. japonica* are plants of the future. They require shade and nothing eats them and they contrast well with ferns and hostas. They are extremely easy to grow and hardy from Zone 4b to 8. In addition to that they have beautiful flowers and foliage that is attractive through the season. Best of all they have seed pods that open to reveal red recepticals that split open and blue-black seeds — these remain ornamental for 4 to 5 weeks in the fall. If you are into shade plants you need these peonies. There are many things like this that are available — they are not new but often we overlook them because we are interested in sexier items.

We have been talking about roof-top stores with their enormous variety of plants. It is a lot of fun to wander around these stores and interesting to see that most customers are middle-aged men wandering around looking at plants. Almost all plants are grown in 2- to 3-inch pots, little is larger, therefore prices are low but because the quality is so high people are encouraged to buy a lot of different plants — I think there is a lesson in that. It is nice to visit the collectors and hobbyist but you can see an awful lot in places such as these stores. For those nurseries interested in specialty plants, plants not commonly found in the trade, this is a place to go — the holy grail.

The Japanese do autumn sales and displays better than anyone in the world. As a people they are very interested in what happens in the late summer and fall. Because of this interest the opportunities for fall-flowering plants are greater than anywhere else. This again may be a niche market for specialist nurseries because plant factories can not assemble plants to sell in the fall — there never will be much competition from plant factories in this area. Callicarpas are finally becoming popular in the U.S.A. and deservedly so. The Japanese have selected forms such as *Callicarpa dichotoma* 'Issai' because they display well in containers. There is a white-fruited form that is one of the most beautiful shrubs for autumn display — I originally found it in a department store. The fruits on the white form will remain attractive for 3 to 4 weeks after the leaves drop. Both the purple and white are fabulous plants for the cutting branch trade, and dry well too.

Another group that I think has a great future are the lespedezas, Japanese bush clovers. The Japanese have been cultivating them for hundreds of years for ornamental purposes. There are over 100 cultivars. Two great cultivars are *Lespedeza bicolor* 'Avalanche' and *L.* 'Samidare'. Lespedezas have two types of flower arrangements. Those with flowers arranged in clusters on the ends of stems tend to fall down in rain and never come back up. However, those with the flowers arranged on short side branches up and down the stem are ones to look for and these spring back up after they dry. *Lespedeza* 'Edo Shibori' is a bicolor with the wings white and the keel is a purplish-pink. All do well in poor soils — they "fix" nitrogen — and are one of the best covers for bulbs. You cut them back in the fall and they will arch out in the late spring when the bulb foliage is looking ratty. *Lespedeza bicolor* 'Island Dwarf' is a low-growing form that is great cover for small bulbs. One of my favorite dwarfs is 'Suzume'. There are also variegated forms.

Continuing with the theme of fall bloom I would like to mention a little-known Japanese perennial, *Keiskea japonica* var. *hondoensis*. This is far superior to *K. keiskea* because the flowers are pure white and it blooms for 4 to 5 weeks in mid to late fall. It tolerates shade and is extremely easy to grow. *Leucosceptrum stellipilum* has these really strange matte-finished yellow-green leaves that are a very interesting textural and color contrast in the summer garden in shade and then spikes of purple flowers in the fall that last until November — rarely seen in this country. The

Japanese have many different *Lycoris*, and *L. incarnata* with its striped flowers could not be easier and grows outdoors in Pennsylvania. *Rabdosia japonica*, with purple (species) and white forms flower in October and November — one of the most beautiful fall perennials for sun — best in Zones 6 to 8. Again little known in this country. There are many *Aster trinervius* ssp. *ageratoides* (syn. *A. ageratoides*) grown in Japan. One of my favorites is 'Ezo Murasaki' with its purple flowers. In semishade in Pennsylvania it comes into flower when the deciduous hollies are beginning to color up.

Another interesting place to find plants is at shrines. Some of the most interesting plant shows and sales are at shrines — and they are throughout Japan. Small nurseries that never sell in the big cities set up stalls at shrines; prices are low and presentation and quality are extraordinary.

There are also traditional garden centers (western style) in Japan and these are becoming more common as more and more Japanese have cars. They are smaller but tend to be clustered so you can visit many at one time. They tend to have a different cast on the market. The idea of clustering is becoming more common in the U.S. with auto dealers because it sells more cars and we should think about the same prospect with garden centers — everyone's sales would benefit. Because plants in Japan usually do not go into the garden but are tossed out after a couple years people are continually buying new plants. Displays such as citrus with a sample of fruit are a great selling idea and something we would be thinking about. How about moss. So many people have asked me for moss, but can you get it — no. It is certainly achievable here too.

The pinnacle of Japanese garden centers is the class of Japanese nurseries that go under the name "kozan shokubutsu" — nurseries for alpine plants. They are really not just for alpine plants but for all kinds of unusual plants. They are typically small and family owned, and they always have a specialty of some kind. If you are into weird plants this is the type of place you have to visit. One of the reasons these nurseries are so successful is because of the very successful Japanese overnight delivery system. Almost all these nurseries will take orders for delivery. These specialist nurseries are valuable for plant hunting and many of the plants you are familiar with in this country came from such sources. The selection of plants in just one such nursery is probably far greater than would be found in a large group of U.S. nursery. This is the place to find plants for the future, those that are outside of your comfort zone. An example of the potential is the three best current *Miscanthus sinensis*: var. *condensatus* 'Cabaret', var. *condensatus* 'Cosmopolitan', and Morning Light' — these three *Miscanthus* all came from specialist growers. A recent find is *M. sacchariflorus* with beautiful yellow-striped foliage. It does not flower, but just creeps and does not seed. *Carex* are finally becoming recognized. They are probably some of the best plants for shade. Plants such as *Carex morrowii* var. *temnolepis* 'Silk Tassel' which was collected in 1976 and is just now becoming appealing to nurseries. *Carex morrowii* var. *morrowii* 'Ice Dance' is similar to *Carex morrowii* 'Variegata' but creeps slowly so it knits together and is not lumpy, but does not run fast enough to cause trouble. Another one I introduced is *C. dolichostachya* 'Kaga-Nishiki' (renamed 'Gold Fountain' by a West Coast nursery). The *Hakonechloa* species, such as *H. macra* 'Aureola', are gaining attention. They tolerate shade and do not run too fast. There is a white striped form also and the green form is great for its texture. It is a good contrast for hostas and asarums. The Japanese consider the green form the epitome of elegance. 'Beni Kaze' turns bright red in late summer and early fall. There are also purple clones, and yellow forms, so there is great potential with this plant.

Angyo was one of the the traditional nursery centers is in Japan, but it is being consumed by Tokyo as the capital spreads. This is the place to see traditional woody plants. In distincts like Angyo you can find an infinite variety of woody plants such as *Quercus aliena* 'Ogon' in which the foliage opens bright lemon-yellow and remains so until mid summer and then turns green. *Salix integra* 'Hakuro', a small tree willow, has new foliage that is lemon yellow for about 6 weeks — like fall color in reverse. A common Japanese tree not seen often in the U.S. is *Euonymus hamiltonianus* ssp. *sieboldianus* a very cold-hardy species with beautiful fruits. It is reported a scale magnet but I do not find it's so. There are interesting forms with yellow margins, white margins, and white fruit.

One of the hottest group of plants today are the vines such as *Parthenocissus tricuspidata* 'Ginza Lights' with variegated foliage — the variegation is unique in that it is splashed with white and the older leaves turn green. The foliage is a beautiful pink in the spring. Variegation can be too much, so I look for those that change to green as the season goes on. A few more example of variegated foliage include *Juniperus rigida* 'Hikari' for dry cold areas. It is particularly tolerant of drought. New growth is bright yellow that turns green as the season wears on — yellow tips against a green background. *Juniperus conferta* 'Akebono' with splashes of variegation I feel would be accepted by the buying public.

One of the most interesting Chinese plants that I collected in Japan is *Loropetalum chinense* 'Hines Purpleleaf', Plum Delight™ fringe flower. This cultivar holds its color better than other purple-leafed cultivars.

Lots of interesting variegated trees are grown. With *Zelkova serrata* 'Goshiki' the variegation changes from pink to white. It is extremely vigorous and easy to grow. A rigid upright form is *Z. serrata* 'Iruma Sango'. *Diospyros rhombifolia*, a large shrub to small tree, is a very hardy persimmon with small edible fruits and extremely attractive foliage.

Mr. Fujino is an example of plant breeders in Japan. He is crossing *Spiraea thunbergii* with other spireas to get other colors into early spring-blooming spireas. He has developed some good pink forms. Examples include *S. thunbergii* 'Fujino Pink' with pink spring flowers, good foliage, and fall color. *Spiraea thunbergii* 'Ogon', Mellow Yellow™ spirea is an extreme attractive yellow-green color with flowers that are half again as large as the species — with both of these features it will really set you apart in the spring. *Spiraea japonica* 'Neon Flash' that I introduced in the late 1970s is now just becoming popular. It is a replacement for 'Anthony Waterer', without the albino shoots, and with richer flower and foliage color. *Prunus mume* is the most popular flowering tree in Japan. It is usually grown as a pot plant. They often flower in February and March and they will tolerate a frost to 25F. Flower buds are hardy to -10.

In conclusion I hope you have a sense that Japan is about the relationships between plants and people, and that the penetration of plants into their lives is extraordinary.

Propagation of Historically Significant Specimen Plants: The Historic Plant Nursery Program of the National Park Service and the Arnold Arboretum of Harvard University

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INTRODUCTION

Historic Plants. In 1863, Nathaniel Hawthorne planted two hawthorn trees in front of his home, The Wayside, in Concord, Massachusetts. He planted a pink one in honor of his daughter Rose and a white one for his daughter Una. More famous for his command of the written word than his talent in landscaping, Hawthorne apparently planted the two trees so close together that, as they grew, they grafted into one tree. A later occupant of the house, Louisa May Alcott wrote a poem about this tree in a letter to the Hawthornes, demonstrating the value she placed on it. This original, unified specimen still stands in front of The Wayside in 1997, now a National Park Service site. Blooming each spring, half in pink, half in white, the tree is a living legacy to Hawthorne and his daughters. Its presence helps tell the story of the site and also gives testament to the values of the people who once lived there.

Nathaniel Hawthorne's tree is a prime example of a landscape feature with great historic significance. All over the world, extreme measures are taken to protect and preserve buildings and homes with historic significance, but in the United States it is only within the past 20 years that attention has been given to preserving the landscapes that surround these historic structures. All too often it is assumed that the greatest value of the site belongs to the structures and their contents, when in fact the landscape and all its features may contribute just as much to the history of the place.

DEVELOPMENT OF THE HISTORIC PLANT NURSERY PROGRAM

In 1992, the National Park Service, recognizing the need for leadership in the area of historic landscape preservation, created the Olmsted Center for Landscape Preservation, located at the Frederick Law Olmsted National Historic Site in Brookline, Massachusetts. The mission of the Olmsted Center is to provide assistance with the preservation and ongoing management of historic landscapes at National Park Service sites in the northeastern U.S. The Olmsted Center conducts historical research, develops management plans, and organizes field projects, including hazard-stabilization tree work, hedge management, and pruning projects.

As part of the routine management of these historic landscapes, there is always the issue of what to do with the aging and declining specimens. Deteriorating specimens can be stabilized, but eventually will either die or become hazardous and need to be removed. Removal of these specimen plants can result not only in great change in the overall design intent of the landscape, but can also result in the loss of a specimen of historical significance.

The Olmsted Center wanted to develop a program geared specifically toward the conservation of these original, historically significant specimen plants. Through propagation of the original plant, a new specimen could be produced for in-field replacement which was a genetically authentic copy of the original. The Olmsted Center intended to use this program as a prototype for the National Park Service, with the hope that other Park Service regions in the United States might then establish their own propagation and nursery programs.

To develop this program, the Olmsted Center needed assistance from a botanical institution in the propagation and development of these replacement specimens. It was imperative that the collaborating institution not only have great expertise in propagation but also have an operational setup which could attend to the quality of each individual specimen. They turned to the Arnold Arboretum of Harvard University, a leading expert in woody plant propagation, which is located in Jamaica Plain, Massachusetts, about one mile from the Olmsted site. The two sites already share a significant historical connection, since the Arboretum's first director, Charles Sprague Sargent, worked with Frederick Law Olmsted Sr. to design the Arboretum grounds in 1872.

In 1991, the Olmsted Center and the Arnold Arboretum established a collaborative agreement, initiating two projects. The first project was the Historic Plant Inventory. The purpose of this 2-year program was to identify and inventory the woody plants at eight National Historic Sites. The plants were evaluated based on significance and existing condition, and recommendations were then made for propagation. The Historic Plant Nursery program was established as a follow up to the Historic Plant Inventory. In 1993 the first of the significant historic plants identified through the Inventory project were propagated at the Arboretum's Dana Greenhouse. The next year, the Arnold Arboretum offered use of their nursery space to the Olmsted Center in order to grow on these plants. In January 1995, I accepted a collaborative position, working with both organizations to develop the Historic Plant Nursery program.

PLANT SELECTION AND PRIORITIZING

One of the biggest challenges of this program was the establishment of guidelines for selecting and propagating these specimen plants. It was simply not possible to propagate every significant woody plant from every site within the National Park Service northeast field area. We needed criteria for prioritizing among many specimens, selecting those that were the most significant and in the most declining condition.

The first step was to clearly define what we considered significant. Plants are defined as historically significant based on their direct association with a historic figure or event, or that somehow help to tell the story of the site or its occupants, such as in the case of Nathaniel Hawthorne's tree. Plants which play a key role in a historic, designed landscape, often referred to as character-defining features, are also considered significant. One of the first specimens to be selected for propagation was the American elm at the Olmsted National Historic Site, chosen for its extreme importance to the site. This tree stands over 3 stories tall and is approximately 200 years old. Although this specimen was not planted by Frederick Law Olmsted, he prized it for its striking form and requested it be retained through all renovations and improvements to the landscape. This tree is a quintessential example of a character-defining feature within the landscape — its presence on the site is one of particular grandeur and elegance, and without it the site would be drastically different.

Other plants are chosen for their botanical or horticultural rarity or uniqueness, such as species or cultivars hard to find in today's commercial nurseries. Historic orchards often have many mature specimens that may no longer be fruiting, making identification of the exact variety remote. The Wick Orchard, located at Morristown National Historical Park in Morristown, New Jersey, is an example of just such an orchard. This orchard has great historical significance since General George Washington had established an encampment for his soldiers there one winter during the Revolutionary War. In 1993, Olmsted Center took scion material from the few remaining trees as the first step in an orchard restoration project. Most of the varieties could not be exactly identified due to their advanced age. In the spring of 1995, over 100 containerized replacement trees were returned to the park to be planted in the orchard.

How the Program Works. The Historic Plant Nursery program is designed to operate on a 3- to 5-year rotation, with everything from selecting the plants for propagation to the return of grown replacement plants back to the site occurring within this time frame. Approximately 20 original specimen plants are selected each year for propagation. Once propagated, the plants are grown in containers for 1 to 2 years, and then are planted into the nursery until they are large enough to be returned to their respective sites. Although only one replacement plant is needed for the in-field replacement, four propagules of each original plant are grown in the nursery, and the healthiest is then selected for return to the site.

Management of the program involves regular communication between the Olmsted Center, the staff at the Arboretum's Dana Greenhouse, and the participating National Park Service sites. An annual inventory is taken of all plants in the program, and each site receives a memo informing them of how the plants are doing and when they can anticipate their return. Monthly meetings are held between Olmsted Center and the Dana Greenhouse staff, to discuss nursery management issues. A database has been constructed to keep track of the plants in the program, and an operational manual has also been compiled which contains all information related to management of the program.

PROPAGATION AND NURSERY MANAGEMENT

Since the goal of this program is conservation of the original specimen plant's germplasm, we propagate primarily by vegetative means. If propagation by cuttings or grafting is not possible, we will then propagate by seed. Each fall, the Olmsted Center provides a list to the Dana Greenhouse staff of those plants to be propagated the following year. The greenhouse staff makes recommendations for method of propagation and also orders the understock needed for grafting. Once we decide on the plants to be propagated, cuttings and scion materials are collected from the sites by National Park Service staff and are shipped directly to the Dana Greenhouse.

During the first year of my appointment, I received training from the staff at the Dana Greenhouse 1 day per week in the skills of woody plant propagation and general nursery management. The Dana Greenhouse is equipped with excellent propagation facilities, including a fog room, mist benches, and open benches with bottom heat. There is a cold frame and shade areas outside, as well as a large full-sun area with irrigation for large container plants.

During the winter, the young container plants are kept in a cold storage facility at Minuteman National Historical Park in Concord, Massachusetts. The cold storage room is located in the basement of an old barn, and is equipped with lights, fans, heaters, an intake fan, and thermometers. The plants go into cold storage in early November and emerge in mid-April. The plants are monitored each week while in cold storage, to check for watering needs and also for rodent damage or fungal infection.

When the plants come out of cold storage in the spring, most are planted directly into the nursery. Those that are too small to be put into the ground at that time will spend another year in containers. Others, such as vines and shrubs, may be returned to their original sites, since some of these do not require any time in the nursery.

In April 1997, we had the first removal of specimen replacement plants from the nursery, marking the first completion of a nursery production cycle. A total of 78 plants were dug, balled and burlapped, and sent back to their original eight sites. These plants were propagated in 1993 and 1994. Although each site only needed one good specimen plant to be used as the in-field replacement, all of the sites were so enthusiastic about the plants they took all of the extra specimens.

CONCLUSION

Since the program began in 1993, 99 historic specimen plants have been propagated, from 15 National Park Service sites. What began as a 1-year trial program has continued for the past 3 years. Its success is directly related to the effectiveness of the collaborative agreement between the Arnold Arboretum and the Olmsted Center and also to the interest that exists in this type of conservation. It is extremely satisfying to be part of this program since we are able to see the complete cycle from the beginning to the end, as each plant returns to its site as a living piece of history.

There is a growing interest in conservation of historic plant material, creating potential for similar programs in conjunction with both private and public organizations. Conservation of historically significant specimen plants is an important aspect of historic preservation as it offers the unique opportunity to have a tangible connection to the past.

Introducing New Plants

Peggy Walsh Craig
Canadian Ornamental Plant Foundation, P.O. Box 21083, North Bay, Ontario P1B 7N8

This is an introduction to some plants new to the North American market. They've all been registered with the Canadian Ornamental Plant Foundation (COPF). We are a nonprofit foundation, established in 1964 to encourage new plant development by strengthening relations between growers and breeders for the benefit of the horticulture industry. Our main function is to collect royalties on new plants. We return 90% of the royalties collected to the plant originators. Last year we collected close to $1.2 million.

Our membership base is primarily in Canada, including the well-known Plant Introduction Scheme of the University of British Columbia and Agriculture Canada's Morden Research Station. Also, we are fortunate to count most of the major propagating nurseries in the United States as our members, and others in more than 10 overseas countries.

This morning I have two shrubs, four roses, and four perennials for you. I will name nurseries where you can get these plants. For contact information, please call the COPF office at 1-800-265-1629.

***Philadelphus lewisii* 'Blizzard'**

Botanical Name: *Philadelphus lewisii* 'Blizzard'.

Common Name: Blizzard mockorange.

Plant Type and Habit: Hardy shrub with a vigorous, upright habit, growing to 5 ft (150 cm) high by 3 ft (100 cm) width.

Description: An abundant bloomer (like a blizzard), with 2-inch (5 cm) white flowers which are about 1 inch (2 cm) larger than generally reported for the species (Fig. 1). Fragrant.

Special Features: The abundance and size of the blooms make this plant stand out.

Landscape Use: Well suited to many situations, particularly as accent plant. Blends well with other plants in a shrub border, especially where a fragrant plant is desired.

Rights & Trademarks: Registered with COPF.

Hardiness Zone: Canadian Zone 2.

Origin & Parentage: This species is native to southern British Columbia and Alberta. John Wallace of Beaverlodge Nursery made several cycles of selection from seed collected in southern Alberta.

Cultural Information: Similar to other mockoranges. Periodic renewal pruning is beneficial. Plants cut back to near the soil line recovered well in 2 years at Morden, Manitoba.

Propagation: Softwood cuttings taken in late June under traditional mist propagation average 90% success rate.

Testing: Tested at Morden Research Station since 1977.

Availability: Aubin Nurseries, Carman, MB.

Figure 1. Flowers of *Philadelphus lewisii* 'Blizzard'.

***Lonicera* 'Marble King'**
Botanical Name: *Lonicera* 'Marble King'.
Common Name: Marble king honeysuckle.
Plant Type and Habit: Hardy shrub with rounded habit.
Description: Has dense foliage with creamy-white or yellow spots and blotches irregularly displayed on dull green leaves. The variegation persists in shade or part shade, fades to all green in full sun. Flowers are creamy white turning yellow as they mature. Bears red fruit. 4 to 5 ft (120 to 150 cm) tall by 3 ft (100 cm) wide.
Special Features: The variegated foliage is uncommon in honeysuckles. An excellent container plant.
Landscape Use: In a shrub border in part or full shade, for a brighter contrast. The red fruits will attract birds.
Rights & Trademarks: Registered with COPF.
Hardiness Zone: Canadian Zone 3.
Origin & Parentage: Probably related to *Lonicera canadensis,* selected by Tony Huber, formerly of W.H. Perron, from plants in the wild.
Cultural Information: Tolerant of most soils, best in part shade.
Propagation: Softwood cuttings.
Testing: Done at Norseco in Boisbriand, Québec.
Availability: Contact Norseco in Laval, Québec.

***Rosa* 'Hope for Humanity'**
Botanical Name: *Rosa* 'Hope for Humanity'.
Common Name: Hope for Humanity rose.
Plant Type and Habit: A low-growing everblooming shrub rose.

Description: Plants are relatively open, 22 inches (56 cm) high by 24 inches (59 cm) wide. Flowers are intense dark red with about 25 petals. There are, on average, 4 to 5 flowers per inflorescence. They are slightly fragrant and bloom over a 10 to 14 week period in Manitoba. There is a moderate number of thorns, and hips are formed, but often do not fully ripen.
Special Features: The long bloom period, profuse flowers, and disease resistance to powdery mildew and rust are good. Resistance to black spot is fair to good.
Landscape Use: Wherever a low-maintenance, flowering shrub is useful.
Rights & Trademarks: Distribution rights have been assigned to the Canadian Red Cross until 1998. Aubin Nurseries and Bailey Nurseries have propagation rights until 1998. Available to COPF members after that.
Hardiness Zone: Canadian Zone 3
Origin & Parentage: Developed at Morden Research Station by Lynn Collicutt and Campbell Davidson. Part of the Parkland series of hardy roses. The complex parentage includes *R. arkansana*, *R. rugosa*, 'Prairie Princess', 'Morden Amorette', and 'Morden Cardinette'.
Cultural Information: Full sun, well drained soil.
Propagation: Softwood cuttings of 1 to 3 nodes, taken in late spring through to mid-summer, treated with 3000 to 5000 ppm IBA, placed under intermittent mist or fog will root with 85% or greater rates. Also can be budded or started in tissue culture.
Testing: Done at Morden Research Station.
Availability: Contact Bailey Nurseries or Aubin Nursery.

***Rosa* 'AC Marie Victorin'**
Botanical Name: *Rosa* 'AC Marie Victorin'.
Common Name: Explorer™ Marie Victorin rose.
Plant Type and Habit: Hardy shrub rose.
Description: The unopened bud is deep peach and the bloom is pale peach, fading to pink when fully open. The flowers average almost 4 inches (9 cm) in diameter, have 38 petals, and are borne in clusters of 1 to 7 blooms. The plant reaches 56 inches (140 cm) in height and 50 in. (125 cm) in width in southern Québec.
Special Features: The peach color is unique in hardy roses. Also it flowers abundantly and repeatedly. Highly resistant to blackspot and powdery mildew.
Landscape Use: Wherever a low-maintenance, flowering shrub is useful.
Rights & Trademarks: Will be introduced in 1998. U.S. Patent and Canadian Plant Breeders' Rights applied for. Distribution and propagation rights by special arrangement with the Agriculture Canada Research Station at St. Jean, Québec. Explorer™ name has been trademarked.
Hardiness Zone: Canadian Zone 3.
Origin & Parentage: A cross between the floribunda 'Arthur Bell' and a breeding line derived from a cross between *R. kordesii* and 'Applejack' done at the Central Experimental Farm in Ottawa, Ontario.
Cultural Information: Best in full sun and well drained soil.
Propagation: Softwood cuttings are best.
Testing: Was done for 2 years in Ottawa and 3 more years in Québec.
Availability: Several growers have paid for distribution and propagation rights, contact the COPF office for a list.

***Rosa* 'AC William Booth'**

Botanical Name: *Rosa* 'AC William Booth'.

Common Name: Explorer™ William Booth rose.

Plant Type and Habit: Hardy shrub rose with spreading to trailing growth.

Description: Deep red buds open to medium red, then fading to light red in the fully opened flower. The flowers average 2 inches (5 cm) in diameter, have 5 petals, and are borne in clusters of 8 to 10 blooms. Reaches a height of 5 ft (150 cm) and a spread of 9 ft (300 cm).

Special Features: The wide-spreading habit is worth noting, and the single flowers are charming for those who like the look of old roses. Excellent resistance to blackspot and powdery mildew.

Landscape Use: Good for low maintenance areas, especially because the wide spreading habit allows you to use fewer plants.

Rights & Trademarks: Will be introduced in 1999. U.S. Patent and Canadian Plant Breeders' Rights applied for. Distribution and propagation rights by special arrangement with the Agriculture Canada Research Station at St. Jean, Québec. Explorer™ name has been trademarked.

Hardiness Zone: Canadian Zone 3.

Origin & Parentage: Similar to 'Marie Victorin'.

Cultural Information: Full sun and well drained soil are best.

Propagation: Softwood cuttings.

Testing: Was done for 2 years in Ottawa and 3 more years in Québec.

Availability: Several growers have paid for distribution and propagation rights, contact the COPF office for a list.

***Rosa* 'AUSmum'**

Botanical Name: *Rosa* 'AUSmum', Pat Austin™ rose.

Common Name: Pat Austin rose.

Plant Type and Habit: Shrub rose growing 4 ft (120 cm) high by $3^1/_2$ ft (105 cm) wide.

Description: The flowers are bright copper on the inside of the petals, with pale copper-yellow on the outside, similar to Austrian copper rose (*R. foetida* var. *bicolor).* They are large and deeply cupped. Strongly fragrant. Dark green glossy foliage that starts out red.

Special Features: Brilliant and unique flower color; the only English rose of this color.

Landscape Use: Can brighten up any rose garden or border by contrasting with other flowers.

Rights & Trademarks: U.S. Patent and Canadian Plant Breeders' Rights applied for.

Hardiness Zone: On its own root, to Canadian Zone 3.

Origin & Parentage: David Austin prefers not to disclose this aspect of his breeding program.

Cultural Information: Grow like other roses, in full sun and well drained soil.

Propagation: Budding, softwood cuttings, and tissue culture.

Availability: In the U.S., contact Jackson & Perkins. In Canada, contact the COPF office. There are about 15 growers licensed by David Austin™ Roses in Canada.

Aster novae-angliae **'Bianca'**
Botanical Name: *Aster novae-angliae* 'Bianca'.
Common Name: Bianca aster.
Plant Type and Habit: Tall, hardy perennial.
Description: Has semidouble white flowers, $1^3/_4$ inch (4 cm) diameter, with yellow center, in late August to October. Grows 3 to 4 ft (90 to 120 cm) tall by 2 ft (60 cm) wide.
Special Features: Part of the Fall Fashion series, which were selected for their bright, vivid colors. 'Bianca' has larger and thicker flowers than the parent species.
Landscape Use: For the back of the perennial border, where you want lasting, fall color. Good cut flower and in mass plantings.
Rights & Trademarks: Registered with COPF.
Hardiness Zone: Canadian Zone 3.
Origin & Parentage: Selected by Tony Huber from Plants in the Wild.
Cultural Information: Best in full sun, well drained soil. For more compact plants, prune back to 18 inches (45 cm) height in July before flower buds appear. Divide every 3 years.
Propagation: By division or softwood cuttings.
Testing: Done by Norseco in Québec.
Availability: Contact Norseco.

Oenothera fremontii **'Lemon Silver'**
Botanical Name: *Oenothera fremontii* 'Lemon Silver'.
Common Name: Lemon silver evening primrose.
Plant Type and Habit: Hardy perennial with prostrate, spreading habit. Grows 8 to 10 inches (20 to 25 cm) high by 15 inches (40 cm) wide.
Description: Dense foliage is silvery green. The lance-shaped leaves have slightly wavy edges. Stems are green with rosy tips. Flowers are 3 in. (7.5 cm) wide, lemon yellow, and have a silky texture. As they fade, they turn orange. Seed caps are winged and attractive. Blooms from June to October.
Special Features: 'Lemon Silver' is more compact than the species, the foliage is more silvery, and it has a longer blooming period.
Landscape Use: Excellent for a sunny perennial border, rock garden, or landscape bed where a low-growing accent plant is desirable.
Rights & Trademarks: Registered with COPF.
Hardiness Zone: Canadian Zone 4.
Origin & Parentage: Selected from seedlings of the species by Tony Huber.
Cultural Information: Plant in full sun in a well drained location.
Propagation: By division or cuttings.
Testing: Evaluated at Norseco in Québec.
Availability: Contact Norseco

Geranium **'Janette'**
Botanical Name: *Geranium* 'Janette'.
Common Name: Janette geranium.
Plant Type and Habit: Low-growing hardy perennial.
Description: Striking magenta-pink flowers are borne at the top of the plant in early June for about 6 weeks. The foliage grows about 10 in. (25 cm) high by 18 in. (50 cm) wide.

Special Features: This is a showy, compact perennial that looks great in a pot over a long period. The flowers are more abundant and deeper colored than *Geranium cinereum* var. *subcaulescens*. Disease resistant. Can produce a second flowering in late August/September, especially if cut back after the first flowering. Sold 100,000 plants in England last year.
Landscape Use: In mass plantings, landscape beds, perennial borders, as a replacement for annuals.
Rights & Trademarks: U.S. Patent applied for. Has Plant Breeders' Rights in England and European Community Variety Rights.
Hardiness Zones: 3 to 7.
Origin & Parentage: Selected by C.M. Lowe of Border Alpines in England.
Cultural Information: Full sun and tolerant of different soil types.
Propagation: By division or cuttings.
Testing: Evaluated by the Plant Varieties Office in England.
Availability: In the U.S.: Monrovia, Sunny Border, Zelenka, Wight, and Willoway Nurseries. In Canada: Cannor and Mori Nurseries.

***Heuchera* 'Ebony & Ivory'**
Botanical Name: *Heuchera* 'Ebony & Ivory'.
Common Name: Ebony & ivory coralbells.
Plant Type and Habit: A vigorous, low-growing, hardy perennial. Spreads to an 18 inch (50 cm) wide mound. Flower stalks can go as tall as 20 inches
Description: Has extremely dark, ruffled leaves, which are evergreen in milder climates. The flowers are large, ivory colored, and profuse in June and July. Resistant to mildew, spider mite, and white fly.
Special Features: The very dark leaf color is unique, and it doesn't go woody like some *Heuchera* spp. The emerging leaves in spring are quite attractive. Does well in full sun.
Landscape Use: Excellent for borders, rock gardens, and crevices. The foliage stays remarkably neat all season. Try with gold-leaved plants, dwarf astilbes, or ferns.
Rights & Trademarks: U.S. Patent applied for. Registered with COPF.
Hardiness Zones: 4 - 9.
Origin & Parentage: [(*H. micrantha* × *H. americana*)(*H. villosa* var. *purpurea*)] × *H. sanguinea* 'June Bride'.
Cultural Information: Plant in sun or shade and well drained soil. Prefers soils rich in organic matter.
Propagation: By division or tissue culture.
Testing: Terra Nova Nurseries in Oregon.
Availability: Contact Terra Nova.

Spring Flora of Korea

Charles E. Tubesing
The Holden Arboretum, 9500 Sperry Road, Kirtland, Ohio 44094-5172

The slide presentation featured the following species:

Asarum sieboldii
Carpinus laxiflora
Caulophyllum robustum
Chrysoplenium sp.
Corydalis ambigua
C. speciosa
C. turtschaninovii
Fraxinus sieboldiana
Hepatica asiatica
Hylomecon hylomeconoides
Iris rossii
I. savatieri
Magnolia 'Darrell Dean'
M.'Elizabeth'
M. 'Galaxy'
M. liliiflora
M. sieboldii
Malus floribunda
Mukdenia rossii
(syn. *Aceriphyllum rossii*)
Paris sp.
Pinus bungeana
P. densiflora
Primula sieboldii
Prunus glandulosa 'Alba Plena'
P. persica (double pink)
P. triloba 'Multiplex'
Rhododendron schlippenbachii
Weigela subsessilis
Zelkova serrata

Finding New Plants for the Market

Tim Wood
Spring Meadow Nursery, Inc. 12601 120th Ave. Grand Haven, Michigan 49417

In a recent customer poll we found that 86% of our responding customers rely on new and unique plants to distinguish themselves from their competition and to improve their profit margins. As the Product Development Manager at Spring Meadow, my task is to find the new plants our customers demand. For me, no job could be as exciting. I love learning about plants. I appreciate the beauty they add to our lives. Finding a "diamond in the rough" plant that could someday be found in yards around the world, providing beauty and enjoyment, is the ultimate thrill. The plant hunting I do is more akin to detective work than exploration. Instead of touring China, I spend my time on the telephone, reading catalogs, thumbing through plant locators, attending seminars, visiting nurseries, hiking arboretums, and in front of a computer.

Reading nursery catalogs is my starting point for understanding what's in the market and for finding new plant leads. I read dozens of catalogs per week. I especially like foreign catalogs, specialty mail order catalogs, and plant listings of small nurseries. By shopping catalogs we've found some exciting plants like *Spiraea japonica* 'Neon Flash', *S. betulifolia* 'Tor', *Hypericum kalmianum* 'Ames', *Euonymus fortunei* BLONDY™ euonymus, and *Deutzia* 'Pink Minor'. A "new plant" need not be brand new. There are literally hundreds of outstanding plants out there but for whatever reason are not readily available in the trade. Obscure plants can find new life in today's market, if the timing is right and if they are properly marketed. Many of the hot "new" plants on the market today have been around for years. *Buddleja davidii* 'Dartmoor', *D.* ×*candida* var. *compacta, Hydrangea serrata* 'Bluebird', *Sambucus nigra* 'Pulverulenta', and *Caryopteris* ×*clandonensis* 'Worcester Gold' are all examples of older plants gaining new life.

Finding "brand new plants" is a different kind of plant hunting. These plants are often discovered by serious plant hounds, plant fanatics, or owners of small nurseries. Plant fanatics go crazy about a specific genus or a certain group of plants, like Jelena DeBelder who gave the world the wonderful plants *H. paniculata* 'Pink Diamond', 'Brussels Lace', and 'Kyushu', and many of our cultivars of *Hamamelis* too. These fun and exciting people often devote their lives to collecting, selecting, and hybridizing one genus. *Weigela florida* 'Alexandra' WINE & ROSES™ weigela came to us from Herman Geers. He's a Dutch nurserymen who has been hybridizing *Weigela* for nearly 20 years. His goal was to develop a truly dark purple-leaf cultivar. That's devotion!

Small nurseries are also great sources for new plants. Here the owner has direct contact with the plants. They do the weeding and pruning so the odds of finding a unique sport or seedling are better than at a larger nursery. *Itea virginica* 'Sprich' LITTLE HENRY™ sweetspire originated at just such a nursery. Rich Feist, the owner of Hummingbird Nursery discovered several sports of *I. virginica* on his stock plants. Fortunately he had the wherewithal to propagate and preserve these sports. The average nursery employee would have sheared them off, or shipped the plants out without even noticing the sport. Finding a plant with good commercial value is rare. It takes a person with a sharp eye, a keen knowledge of plants, and patience. It requires time, devotion, propagation skills, good record keeping, and good luck. We owe our respect to these people for the diversity of cultivars we enjoy today.

Finding these plant originators and their new plants is not an easy task and requires a lot of research. What we try to do is make it easy for them to find us. Our marketing, public relations, and advertising all focus on new flowering shrubs. We have had plant originators in Europe contact us based on one of our ads and/or catalog. We have let the word out that we are a good place to bring a new flowering shrub. That we will treat our originators fairly. We let them know that we have the focus, the facility, the capital, the customer base, the marketing tools, and the distribution system necessary to properly introduce flowering shrubs.

Whenever anyone brings us a plant we must objectively evaluate the chances of its success. The renown plantsmen J.C. Raulston once offered me the following criteria as a way to estimate the potential success of a new plant. When evaluating a new plant find, I ask myself the following questions:

- Is the plant truly ornamental?
- Does it have garden center appeal?
- Can it be economically propagated?
- Can it be economically grown?
- Is the plant an improvement over the cultivars currently being sold?
- Does the plant have multiple seasons of ornamental interest?
- Does the plant serve a new or unique function in the landscape?

If a new plant scores well against these criteria, we might consider protecting the plant. If the plant was discovered in a cultivated state it can be patented. If the plant was found in nature, it cannot be patented. The patenting and trademarking of plants remains controversial especially for woody plants and perennials. Some feel that serendipitous plant discoveries should not be protected. I don't understand this logic. Who faults DuPont for patenting nylon? Originators should be rewarded for their efforts by means of protection regardless if it is intentional or accidental. This provides incentive to develop new plants. The upsetting thing about plant protection is not the royalty per say. It's the exclusivity and/or the lack of value associated with these plants. Our philosophy is that licensing should be readily available. More nurseries growing and selling a plant benefits the originator, the industry, and the public. It also contributes to the overall success of the plant. A royalty should also add value to a plant. That's why we insist that a percentage of the royalty goes toward marketing and education. This too benefits the originator, the licensees, retailers, and the overall success of the plant.

Perhaps someday you are fortunate enough to discover a truly unique and marketable new plant. If so, you need to be very careful especially if you hope to protect your plant. The following list should provide help.

WHAT TO DO IF YOU DISCOVER A NEW PLANT

- Don't sell any plants! You only have 1 year from the date of the first U.S. sale to file for a patent.
- Don't distribute the plant without a signed trailing agreement. We never accept a plant without providing the originator with this basic and essential protection.

- Don't expect to get rich. Just look at the patent book and see how many plants you recognize. Very few I suspect. Greed will ruin friendships and make your life miserable.
- Consider partnering with a nursery with the means to properly evaluate, propagate, grow, distribute, and market your plant. Many good plants remain obscure because the originator did not have the means to properly introduce the plant. Properly introducing a new plant is expensive. For example, we've spent over $10,000 developing *W. florida* 'Alexandra' WINE & ROSES™ weigela and we haven't shipped a single plant as of yet.
- When looking for a partner, look for someone who specializes in the category of plant you have. We specialize in flowering shrubs and have the ability to properly introduce a new flowering shrub. If someone brings us a perennial, we tell the originator that its not in his or her best interest to have Spring Meadow introduce.We would try to put the originator in touch with a perennial specialist, even if we saw that the plant had great commercial potential.
- Consider partnering with a propagation nursery. Propagation nurseries have the ability to get plants to market quickly and to distribute across a wide geographic area. Finishing nurseries often want to keep new plant exclusive to themselves. This may limit the availability of your plant and your potential returns.
- Be patient and realistic. It takes many years for a new plant to come to market and few plants have what it takes to be a hit.

New plants are an important part of the nursery business. They're a fun, exciting, and profitable part of our business. New plants help keep garden centers exciting and profitable. Best of all, new plants keep our landscapes, gardens, and homes beautiful, fun, exciting, and ever-changing!

Medicinal Plants with a Potential Niche Market for Propagators

Jeanine M. Davis and Richard E. Bir
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INTRODUCTION

Herbal medicines and aromatherapy are one of the fastest growing U.S. markets. The companies producing medicinal herb products, such as capsules and tinctures found in health food stores and pharmacies, have traditionally purchased most of their raw herbs from India, China, and the Eastern European countries. A variable demand also exists for wild-collected native North American medicinal plants. In the past, the ultimate destination for many of these native medicinal plants has been Europe and the Orient.

As the medicinal herb industry has matured, the companies buying these plants have instituted new quality control efforts. These include testing for active compounds, purity, and bacterial contamination. Some plants that can be included in this group are purple coneflower (*Echinacea* sp.), ginseng (*Panax quinquefolius*), black cohosh (*Cimicifuga racemosa*), mayapple (*Podophyllum peltatum*), bloodroot (*Sanguinaria canadensis*), helonias (*Chamaelirium luteum*), skullcap (*Scutellaria lateriflora*), and goldenseal (*Hydrastis canadensis*). These plants are usually considered new or specialty crops within traditional agriculture with dependable research information unavailable or only gradually being developed.

GOLDENSEAL

Goldenseal Research. One of the plants in greatest demand is goldenseal, a shade loving herbaceous perennial. It is used for many purposes including as a treatment for AIDS, cancer, and various digestive disorders as well as to boost the immune system. The medicinal properties of goldenseal are attributed to the alkaloids hydrastine and berberine which are usually present in concentrations of 2% to 6%. Unfortunately, native populations have been seriously reduced by over collection and it is now an endangered species in North Carolina so wild collection is illegal. A permit from the North Carolina Department of Agriculture is required to cultivate or propagate goldenseal in North Carolina.

The following has been learned from Dr. J.M. Davis' research during the past 5 years. For grower information summarizing information about goldenseal and other medicinal plants, please check the following websites: www.ces.ncsu.edu/depts/hort/hil/spcrop-index.html or www.herbnet.com.

Propagation. Goldenseal produces a raspberry-like fruit which is full of small, round, black seeds. Seeds should not be allowed to dry out. Propagation by seed is difficult and unpredictable. However, best germination usually occurs when seed is sown immediately after being extracted from the fruit. Studies are currently underway looking at seed extraction, disinfection, and storage. So far, best germination has occurred by holding seeds at 70 F prior to sowing in late August or late October. Seeds will germinate the following spring or the second spring and may be subject to damping off if conditions are favorable. Good air circulation and lack of excessive irrigation during germination are essential. Seeds should be planted 0.5 inches deep at 3 to 4 seeds per ft in rows 6 inches apart. Harvestable roots can be grown from seed in 5 to 6 years.

Goldenseal spreads via a rhizome that can also be used for propagation. Currently, this is the preferred method of propagation. In fall or spring these rhizomes can be cut into pieces. Include an obvious bud on each propagation piece. Research indicates that it is also very important to have good roots on each piece. Do not cut roots off the rhizome piece! Root cuttings taken in late winter or early spring have also proven successful. Harvestable roots can be grown from rhizome pieces in 3 to 4 years.

Culture. Hardiness is not a problem in much of the United States since the native range is from Georgia to Vermont. Goldenseal should be planted in a rich, well-drained, moist loamy soil where goldenseal has not recently been grown (rotate crops!). Raised beds 2 to 6 inches tall and 3 to 5 ft across have worked well. Research has demonstrated the best emergence and subsequent growth occurred between soil pH 4.8 and 6.7 so beds are usually limed to a pH between 5.5 and 6.5. Supplemental nitrogen and phosphorus reduced emergence the first year but had little affect in subsequent years.

Plants grew best under a natural forest canopy or artifical 75% to 80% shade. While goldenseal can be successfully mulched with shredded leaves, pine needles, bark, sawdust, and chopped straw, our experience has been that straw mulch results in poor growth and severe slug damage. Goldenseal should only need irrigation during drought. If not irrigated during drought, plants will drop their foliage and go dormant earlier than normal.

Pests. Fortunately, goldenseal suffers few attacks from diseases or insects because labelled pesticides are not available. Slugs will eat the entire plant crown and fruit. Keeping mulch away from the crown of the plant and other common slug remedies seem to provide some control. Moles may damage beds and can be controlled by trapping or by bordering beds with wire mesh set 8 to 12 inches deep into soil. Rootknot nematodes are harmful to goldenseal. *Phytophthora cactorum*, a problem with ginseng, does not appear to harm goldenseal so crop rotation with ginseng is possible since both plants grow well under similar cultural conditions. In recent years, new plantings of goldenseal have been established in which plants are grown intensively and "pushed hard". In these plantings, some fungal diseases caused by *Fusarium* and *Alternaria* species are being found.

Harvest. When plants have fully occupied land either harvest the roots or divide plants. If you do not, the plants will start to crowd themselves out.

Dig roots in the fall after tops have died down. Remove all soil, breaking larger roots if necessary, but do not use a brush. Spread clean roots on screens and dry in a shaded, well-ventilated area or in a forced-air drier. Roots will lose about 70% of their weight during drying and should snap cleanly when at the proper moisture level. Dried roots should be packed loosely and stored in a cool, dry area secure from rodents. If a market exists for leaves and stems, harvest must be earlier such as in early September while foliage is still green. Dig carefully, keeping the many fibrous roots intact if harvesting leaves and stems for transplanting.

DISCUSSION

There is much remaining to be learned about goldenseal. However, the amount of scientific information that has been gained in the past few years demonstrates that commercial propagation and production of many medicinal herbs provides an opportunity for enterprising nurserymen. As selection is made for plants with higher concentrations of essential ingredients, clones will develop. Asexual propagation techniques have the potential to rapidly increase the production efficiency of the medicinal herb industry.

Medicinal Plants with a Potential Niche Market for Propagators

Ralph Shugert
Zelenka Nursery, Inc., Grand Haven, Michigan 49417

We shall be discussing the genus *Taxus* as one of many plant genera that produce anticancer compounds. Literature tells us that *T. baccata* produces a medicinal compound Docetaxel trademarked as Taxotere® by Rhone-Poulenc Rorer as an investigational drug. This evening our discussion will be relevant to Paclitaxel, which is sold as Taxol® by Bristol-Myers Squibb. Early on, in the mid 1980s, sadly the FDA only designated *T. brevifolia* our Pacific yew, as the only approved source of Taxol®. This dastardly act meant ripping the bark from 100-year plus trees thus killing the trees. Thankfully, this no longer is the case, since *T. brevifolia* is currently a threatened species. Today the only *Taxus* biomass source is from the nursery community. This biomass, which must be extracted and purified to obtain medical compounds, could be whole plants, roots (only), branches (only), or needles from current year's growth. We will briefly discuss the nursery role in each of the above and offer some suggestions to avoid pitfalls should you sign a contract with a pharmaceutical company.

I wish to caution all my nursery community friends that transactions with biotechnology companies are far different than dealing "with our own". Over the years, I have learned first hand that most of these people have never seen a nursery, never seen a taxus plant, generally have no agricultural knowledge, no knowledge of plant propagation, and the list goes on! If you are approached, ask many questions as to what type of biomass they are requiring, including cultivar (which is very, very important) as well as biomass condition (green or dry), and then have them submit a contract as to conditions. After you review the contract, have your attorney review same prior to signing. Sadly, a simple purchase order, which we deal with daily, will not suffice. My friends, I can't stress that point enough, it is extremely important! Do not sign a contract which only pays you on Taxol® percent of concentration, since this varies dependent upon time of year, nitrogen uptake levels, and cultivar, etc. Today, the cultivar of choice for Taxol® is *T.* ×*media* 'Hicksii', however, I am sure that not all *T.* ×*media* cultivars have been studied.

The various options we have as growers include the following:

- Entire plant (roots/tops) — contract, prior to planting, to grow close-spaced for 3 to 5 years, clean harvest, generally not dried but shipped as green biomass.

DISCUSSION

There is much remaining to be learned about goldenseal. However, the amount of scientific information that has been gained in the past few years demonstrates that commercial propagation and production of many medicinal herbs provides an opportunity for enterprising nurserymen. As selection is made for plants with higher concentrations of essential ingredients, clones will develop. Asexual propagation techniques have the potential to rapidly increase the production efficiency of the medicinal herb industry.

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We shall be discussing the genus *Taxus* as one of many plant genera that produce anticancer compounds. Literature tells us that *T. baccata* produces a medicinal compound Docetaxel trademarked as Taxotere® by Rhone-Poulenc Rorer as an investigational drug. This evening our discussion will be relevant to Paclitaxel, which is sold as Taxol® by Bristol-Myers Squibb. Early on, in the mid 1980s, sadly the FDA only designated *T. brevifolia* our Pacific yew, as the only approved source of Taxol®. This dastardly act meant ripping the bark from 100-year plus trees thus killing the trees. Thankfully, this no longer is the case, since *T. brevifolia* is currently a threatened species. Today the only *Taxus* biomass source is from the nursery community. This biomass, which must be extracted and purified to obtain medical compounds, could be whole plants, roots (only), branches (only), or needles from current year's growth. We will briefly discuss the nursery role in each of the above and offer some suggestions to avoid pitfalls should you sign a contract with a pharmaceutical company.

I wish to caution all my nursery community friends that transactions with biotechnology companies are far different than dealing "with our own". Over the years, I have learned first hand that most of these people have never seen a nursery, never seen a taxus plant, generally have no agricultural knowledge, no knowledge of plant propagation, and the list goes on! If you are approached, ask many questions as to what type of biomass they are requiring, including cultivar (which is very, very important) as well as biomass condition (green or dry), and then have them submit a contract as to conditions. After you review the contract, have your attorney review same prior to signing. Sadly, a simple purchase order, which we deal with daily, will not suffice. My friends, I can't stress that point enough, it is extremely important! Do not sign a contract which only pays you on Taxol® percent of concentration, since this varies dependent upon time of year, nitrogen uptake levels, and cultivar, etc. Today, the cultivar of choice for Taxol® is *T.* ×*media* 'Hicksii', however, I am sure that not all *T.* ×*media* cultivars have been studied.

The various options we have as growers include the following:

- Entire plant (roots/tops) — contract, prior to planting, to grow close-spaced for 3 to 5 years, clean harvest, generally not dried but shipped as green biomass.

- Roots only — from cull plants, fields ready to fallow. In our experience, this biomass must be dried (we use corn driers) and chipped prior to shipment. Certainly not a sustainable source of supply, but a viable means of cleaning a farm to fallow.
- "Tops" only — again from cull plants. Contract may stipulate branch caliper (no larger than 11/16 inches, etc). Contract may allow green biomass if stored in refrigerated storage with minimum/ maximum temperature and humidity regimes. Contract may call for dried tops at precise drying temperatures and durations.
- Needles — obviously a sustainable supply source. Contract may call for only current season's growth. We harvest with a combine built by the OARDC engineering department at Wooster, Ohio. If you are harvesting from salable or future salable plants, you should dictate time of harvest. In our nursery's program the only time frame we accept is 15 May to 15 June.
- Lease/Contract — This is simply leasing acres to the drug company, and you plant and maintain the crop for them. You must be careful on language to cover plant death, etc. Also all cultural activities must be detailed. You will definitely need an attorney to help you draw up this contract.

In all of the above, you set the price, not the drug company. Any of the above are very labor-intensive so it is mandated that you use a loaded labor rate. This figure will cover fringe benefits, depreciation, etc. Next step is to determine your gross margin. An example could be: calculating a 40% gross margin might mean marking up your loaded labor rate by 60% to 70%. We most certainly have a potential niche market with taxus. Once again, I do caution you to be very careful entering into an agreement with these drug companies. This is a new venture for the nursery community and no one should experience a not-for-profit venture.

In keeping with our society motto, if I personally can assist you, please ask!

Seed Propagation of *Trillium grandiflorum*

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Trillium is a predominantly North American genus of shade-tolerant herbs from deciduous forests. Many species are useful garden plants because of their large, showy flowers or attractively mottled leaves (Case and Case, 1997; Jacobs and Jacobs, 1997). Nearly all trillium plants in commerce are wild dug, often in large quantities, such as the 600,000 plants sold from Tennessee in 1989 (Sawkins, and McGough, 1993). Clearly a procedure for the practical horticultural production of trillium from seed would provide gardeners access to these plants without damage to native populations.

Often trillium seed takes 2 years to produce seedlings. It is said to be "doubly dormant" (Barton, 1944). However, there are reports of seedlings emerging outdoors after one winter (Jacobs and Jacobs, 1997; Gyer, 1997) or no germination after several cold cycles (Deno, 1993). The objective of my research is the development of a procedure that reliably produces significant germination the spring after the seed ripens. This paper reviews aspects of trillium seed physiology and development that relate to the proposed germination procedure. The research was possible because the Winterthur Garden Department graciously permitted me to study the large naturalized population of *T. grandiflorum* in the Azalea Woods area of Winterthur Museum, Garden and Library in Delaware.

SEED CHARACTERISTICS

At maturity trillium seed consists of a minute embryo, copious storage endosperm, a chalazal cap of two easily identified layers, and a complex funiculus and aril. The development of the endosperm and chalazal cap are relevant to trillium seed production, collection, and germination. Trillium endosperm is helobial (Berg, 1958), that is, the first division of the triploid endosperm nucleus forms a large and a small cell. The large cell produces storage endosperm after a series of divisions that do not immediately form cell walls. The small cell migrates to the chalazal cap area and forms a thin cellular layer. This layer is positioned to restrict the entry of photosynthate at ripening and help seal the endosperm after the seed is shed. The complex funiculus and aril are attractive to some ant species that distribute the seed throughout its environment (Berg, 1958).

The seed size variation between *Trillium* species is an adaptation to specific environments (Ohara, 1989). However, the embryo volumes I have observed are nearly constant across species. The typically *T. grandiflorum* embryo volume is 0.013 mm^3 and the typical endosperm/embryo volume ratio is 770.

POLLINATION

Trilliums are protandrous, that is, anthers shed pollen at anthesis before the stigma becomes receptive. The protandrous lag time between pollen production and stigma fertility depends on the species. *Trillium grandiflorum* has a protandrous lag of about a week.

Single plants in gardens where insect vectors are absent often fail to set seed because the protandrous lag time prevents automatic self pollination. These seed set failures have led some to the idea that *Trillium* species are self-incompatible. If protandry is considered in pollination experiments, the *Trillium* species I have examined are self-compatible and most can produce a heavy annual seed yield. An average *T. grandiflorum* berry contains about 40 seeds, but vigorous plants produce 90 or more seeds when fully pollinated.

SEED DEVELOPMENT

Trillium seed forms in an indehiscent berry that falls from the plant at ripening. Because the seed is quickly dispersed by insects, sometimes even before the berry falls, seed collection is best done before the berry is fully ripe. Because no literature related berry age to seed development and germination, I measured berry volume and seed germination as a function of time from pollination.

Berry volume was calculated as that of a prolate ellipsoid from the caliper measurement of the distance between the receptacle and the base of the style as the major axis and the width across the berry between the wings as the minor axis. In all species measured the berry volume followed the *T. grandiflorum* growth pattern in Fig. 1. The length of the initial slow growth induction time varied with species. During the induction time the plant grows new rhizome and bud tissue before seed production makes demands on its supply of photosynthate. In most cases the induction phase is followed by an essentially constant rate of volume growth until the berry falls.

The induction time reflects the very slow rate of pollen tube growth. Blain (1945) found that pollen tubes grew for about 2 weeks before they fertilized the ovules of *T. grandiflorum*. This slow growth rate and the asynchronous ovule development she observed suggests that not all ovules in a berry are fertilized at the same time and implies that a berry may contain a range of individual seed ages.

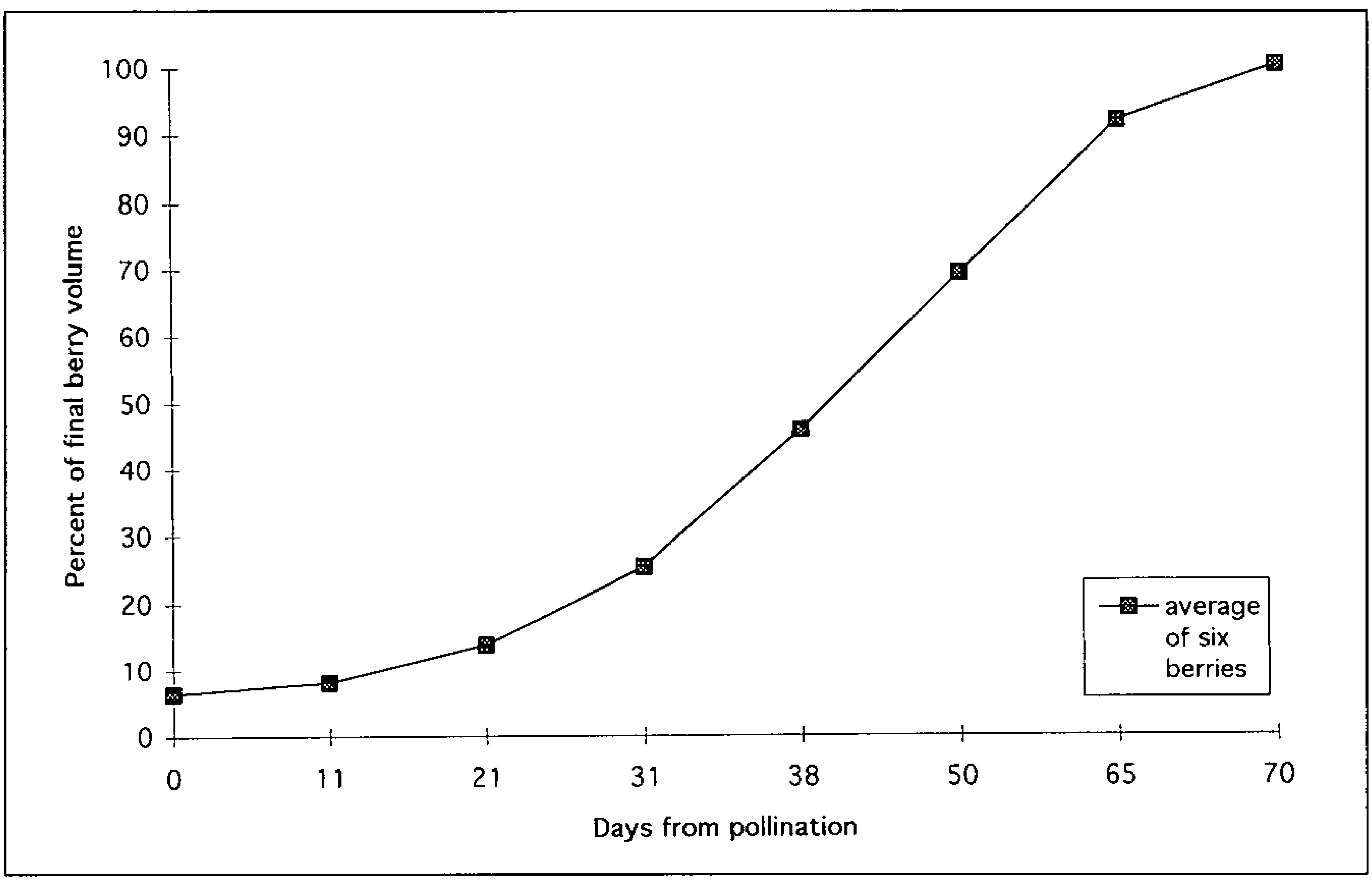

Figure 1. Berry growth rate, *T. grandiflorum*.

In Fig. 1 the slight growth rate increase at about 35 days probably reflects the end of free nuclear endosperm cell division, the onset of cell wall formation, and the initiation of food storage.

Table 1 shows the effect of age on aril and seed development. The aril or enlarged funiculus is relatively small until about 55 days post-pollination when the seed ceases to add food to its endosperm. At that time the photosynthate that has gone into endosperm tissue is stored in the aril. Because there is no change in the rate of photosynthate storage, only a change in the storage site, the berry volume continues to grow as observed in Fig. 1.

At 30X magnification the part of the chalazal cap derived from the first small endosperm cell becomes apparent about the time of this storage site shift. Because it lies between the storage endosperm and end of the vascular strand that delivers photosynthate to the seed, its position suggests that changes in this tissue have a role in seed ripening.

At about 40 days post-pollination seeds can germinate at 20 to 25C. The proportion of dormant seeds increases with age and reaches about 70% in the 66 day sample.

Table 1. Age effects on *Trillium grandiflorum* seed and germination.

Seed age[1]	Water %	Weight (mg) Seed	Aril	Embryo length (mm)	Germination at 21C (%)
32	---	4.0[2]	---	---	0
39	---	5.8[2]	---	---	0
46	67	8.2	0.9	0.15	>80
53	57	9.7	2.1	0.20	67[3]
60	---	10.7	2.9	0.25	48
66	51	10.6	5.9	0.25	35

[1] Days after hand pollination.
[2] Weight of seed + aril, seeds at these ages all decomposed.
[3] Calculated from a 30 seed dissection of a wild population between 50 and 55 days old.

EMBRYO GROWTH AND GERMINATION

Early germination stages are seen only by sectioning the seed and staining the cut surfaces with I_2/KI solution (Lugol, Sigma Chemical Co.); this turns starch in the embryonic rhizome blue-black. Trillium endosperm contains little or no starch. Embryo growth and germination occurs in warmth, 20 to 25C. The earliest evidence of embryo growth is an unstained halo around the embryo that suggests endosperm digestion. A suctorial cotyledon develops from the embryo apex, absorbs the digested endosperm, and deposits it as starch in the embryonic rhizome. After 40 to 60 days the cotyledon/rhizome axis grows to about 2 mm and the rhizome emerges from a collar of enlarged, starch-filled cells at the micropyle.

At soil temperatures above about 18C, endosperm digestion continues to drive root growth and starch storage in the young rhizome. Generally a good root system is produced by about 60 days growth after the rhizome emerges from the seed. A period of low soil temperature (5 to 12C) reduces root growth rate. The cold prepares the seedling for cotyledon elongation and emergence as a photosynthetic organ when soil temperature rises above about 15C. This cotyledon growth is driven by starch stored in the new rhizome and what little residual endosperm remains in the seed.

Table 2. *Trillium grandiflorum* embryo growth in culture[1].

Percent of embryos in each length group

Embryo length group (mm)	Time in culture	13 days		27 days		48 days		63 days	
	GA_3 conc. (ppm)	0	1000	0	1000	0	1000	0	1000
0 - 0.49		83	96	65	45	66	37	62	35
0.5 - 0.99		17	4	35	52	10	12	7	3
1.0 - 1.49		0	0	0	0	2	21	4	0
1.5 - 1.99		0	0	0	3	0	3	0	9
>= 2.0 Germination		0	0	0	0	22	27	27	53

[1]Agar medium as in Pence and Soukup (1986) maintained at 24C.

TRIGGERING EMBRYO GROWTH

A substantial fraction of most seed collections will be dormant because growers are averse to using "green" seed. In outdoor beds dormant seeds germinate the 2nd year after collection. Plants from these seeds will be a year behind those that grow from the 20% to 30% of the collection that germinates during the fall of the year they are produced. The dormant seeds produce a propagation bed of uneven age and increase by a year the time needed to go from seed to flowering rhizome.

To determine if the embryo is dormant in mature trillium seed, I excised embryos from seed in two berries collected at Winterthur 29 June 1993, and plated them onto half-strength MS agar medium supplemented with 3% sucrose (Pence and Soukup, 1986). Table 2 shows that about 30% "germinated" in 63 days at 24C. The similarity of this germination and that of the mature 66-day seeds in Table 1 suggests that the cultured embryo population responds like intact seeds. It also supports the idea that seeds in a single berry have different physiological ages. When 1 ppm GA_3 was included in the medium, the "germination" doubled indicating that GA_3 acts directly to trigger the growth of dormant embryos. The GA_3-treated excisions that did not grow represent errors in technique; endosperm explants or embryos injured by disinfectant or mechanical damage.

After 155 days in culture some embryos formed rhizomes from outgrowths of the cotyledons. Dr. Sherry Kitto at the University of Delaware, in whose laboratory this work was done, has grown the progeny of these proliferative embryo cultures into viable plants.

Moist storage at low temperature for about 90 days induces embryo growth after seed is moved to 25C. Germination follows in about 60 days (Stolt, 1996). I have seen no embryo growth at low temperature. In fact I have kept some seeds in moist storage for 15 months at 5C. The endosperms softened somewhat, but the seeds germinated in about 60 days at 25C and produced normal plants in outdoor beds.

Although Donovan (1995) has shown that low temperature can trigger the germination of sterile seeds, most of the germinating seeds that I have exhumed from outdoor beds or sectioned during indoor germination tests show signs of disease invasion at the chalazal end. Dormant seeds without embryo growth usually do not have chalazal infection. There are at least two explanations. One suggests that infections increase the permeability of the chalazal cap and expose the seed contents to growth stimulants either from the environment or the metabolism of the infecting agent. The other proposes that endosperm softens as it is digested by the growing embryo. Softening may cause some endosperm cell contents to leak out through the chalazal cap. Bacteria and fungus attracted to the exudate then grow to produce a pathological endosperm infection.

SEED DECOMPOSITION AND ROT

Soon after harvest the seed coat and chalazal cap darken. These changes, often accompanied by the formation of a brown exudate, appear to prepare the seed to resist attack by pathogens. During this time aril decomposition feeds the development of pathogens that can attack the seed before these protective changes are complete. Because of this, arils should be promptly removed, particularly when large numbers of seeds are germinated by the procedure in Note 1.

The endosperm cell walls of immature seed are permeable and can leak cell contents into the germination medium through the chalazal cap. This begins a process of decomposition that will kill the seed and contaminate the surrounding medium. Seeds that are undergoing decomposition should be periodically removed from the germinating mass by the sieve/wash process in Note 2.

SEEDLING PRODUCTION

The following protocol produces a significant stand of seedlings the spring of the year after the seed is collected. It primes the seed by inducing embryo growth before planting and improves the seedling stand by removing damaged or diseased seed.

- **Harvest the berries.** Berries can be harvested from about 50 days after pollination to just before they fall from the plant. Remove the seed from the berry and free it from placental tissue by the sieve/wash procedure of Note 2.
- **Remove the arils.** The bubbling action of the final peroxide rinse of Note 2 disrupts the aril tissue. If the seed is immature, use a shorter peroxide rinse because peroxide can more easily diffuse into and damage the endosperm of immature seed than that of mature seed. Rinse the seed and store it at room temperature in a moist environment, see Note 1. After 4 to 6 days, sieve and wash the seed to remove the decomposing aril tissue. Return it to moist 20C to 25C storage and repeat the process, if necessary, in another 4 to 6 days.
- **Controlled germination triggers embryo growth** in time for fall root establishment in outdoor beds. Good fall root growth assures early spring cotyledon emergence. There are three controlled germination options.

  1) ***Immature seed*** (50 to 55 days post-pollination) contains metabolically active embryos that will have 40% to 60% germination in about 60 days at 25C without further treatment. However, decomposing seed must be removed and the storage medium changed about every 2 weeks.

  2) ***Moist storage at 5C*** prepares mature seeds for embryo growth at 25C. In the Delaware Valley the combined times for stratification (about 90 days at 5C) and embryo growth (about 60 days at 25C) delay outdoor planting until the soil is too cold for fall root growth and early spring cotyledon emergence.

  3) ***Hormones such as*** GA_3 trigger embryo growth. After the aril is removed, soak the seed for 24 h in 1000 ppm GA_3 (0.2 g GA_3 dissolved in 2 ml dimethyl sulfoxide, DMSO, and diluted to 200 ml with distilled water). There is measurable embryo growth about 14 days after treatment. Micropyle rupture is apparent after 60 to 80 days of moist storage at about 25C. This allows time for root growth in outdoor beds before soil temperature falls below 12C. Expect some seed loss during embryo growth because GA_3 softens endosperm and may increase cell leakage or endosperm abnormalities. Every 2 weeks after the GA_3 treatment, remove decomposed seed with the sieve/wash procedure of Note 2, but omit the peroxide rinse.

  Although GA_3-induced embryo growth appears normal in most cases, experience with this hormone in trillium is limited. The effect of soak times and concentrations, for instance, remain to be investigated.

- **Plant the Seed** when micropyle rupture is apparent. Broadcast seed onto moist, but well drained compost/sand in outdoor propagation beds. For immature or GA_3 treated seed this will be early September in the Delaware Valley. Cover the bed with 1/2 to 3/4 inches of a mineral aggregate such as Turface or Axis. This reduces disturbance from rain, provides a disease-free substrate for foliage, and seems to reduce frost heaving damage. For me frost heaving and subsequent seedling desiccation is a major source of loss. The beds should be kept moist in the fall to promote good root growth.

  Although developed for *T. grandiflorum*, this protocol with the GA_3 embryo growth trigger has germinated species related to *T. erectum*, all the sessile species tested, some Asiatic species, and some species in the related genus *Paris*.

NOTE 1. All germinations mentioned in this paper were done with the technique used by Deno (1993). When modified to accommodate large numbers of seeds, his technique provides optimum conditions for embryo growth within the seed prior to planting. Paper towels or other inert, absorbent, smooth material surrounds the seed and is a reservoir of moisture that maintains 100% humidity in a closed plastic bag or other container. Sterile, boiled water is used, but no free water contacts the seed because it will increase rot. A single gallon-sized plastic bag can easily germinate 2000 seeds.

NOTE 2. Remove dead and decomposing seed about every 2 weeks. Wash the seeds into a sieve and gently rub under cool running water to remove decomposing aril tissue and break up decomposing seeds. Put the washed seeds into a beaker, stir, and pour off floating debris. Before aril removal, add some detergent to the wash water because fresh seed is hydrophobic and some will float. After aril removal most seed becomes hydrophilic and sound seed will sink. Disinfect by a brief rinse (about 1 to 3 min) in 3% hydrogen peroxide followed by washing with sterile (boiled and cooled) water and packaging into a clean germination bag moistened with sterile water. Do not use the peroxide rinse if there is any sign of micropyle rupture. It will damage the growing embryo.

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Propagation and Early Production of Bunchberry (*Cornus canadensis* L.)

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Bunchberry (*Cornus canadensis* L.) stem cuttings were rooted for 9 weeks in peat and perlite medium (1 : 3, v/v) under fine mist after a 7-sec quick dip treatment of 0, 1000, 3000, 5000, 7000, or 9000 ppm K-IBA water solutions. Rooting percentage (82% to 88%) was not influenced by K-IBA treatment but subsequent root development was enhanced by 3000 and 7000 ppm K-IBA. Rhizome initiation and extension was inhibited by 7000 and 9000 ppm K-IBA. Therefore, 3000 ppm K-IBA optimized root and rhizome development and was used as the cutting treatment to compare production of bunchberry from greenhouse-forced cuttings in April to field-collected cuttings in June. By the end of September, April-stuck cuttings had produced more shoots than had June-stuck cuttings; but in either case, rooted cuttings having rhizomes at transplant more consistently produced greater numbers of new shoots than those cuttings without rhizomes. Marketable 9-cm band pots of bunchberry can be produced in one season if cuttings are taken in April and have rhizomes at the time of transplant.

INTRODUCTION

Bunchberry (*Cornus canadensis* L.) is a perennial groundcover native to New England and has a circumpolar distribution. It is commonly found growing in the forest understory, on hummocks in bogs, and in open fields (Dirr, 1990). Bunchberry commonly colonizes open areas (Alaback, 1984) and has become a serious weed in commercial lowbush blueberry fields of New England and Canada (Hall and Sibley, 1976). Bunchberry is also a traditional food and medicinal plant used by Native Americans (Eastman, 1992).

Bunchberry possesses many characteristics that make it suitable for use as an ornamental plant. It produces showy white inflorescences above the foliage in spring and summer, similar to those of *Cornus florida* but smaller (Del Tredici, 1984). Bunchberry provides dense, dark green foliage cover throughout summer, and in late summer produces large terminal clusters of attractive bright red fruit. In autumn, the foliage of some individuals turns deep burgundy before dying back to the ground, while others retain this burgundy foliage throughout the winter. These features warrant greater use of bunchberry in the landscape.

Bunchberry spreads laterally by vigorous, perennial rhizomes extending up to 30 cm per year (Hall and Sibley, 1976). A clump or clone of bunchberry is actually a single plant consisting of a dense mat of individual stems connected by these underground rhizomes. This system of rhizomes is the portion of the plant that overwinters to produce new shoots the following spring. Each stem generally bears a terminal whorl of four or six leaves and one or more nodes bearing reduced leaves and lateral buds. Individual stems are usually 4 to 6 inches in length.

Bunchberry, though not grown commercially on a large scale, has traditionally been propagated by seed, division, or by transplanting sod pieces collected from the field (Dirr, 1990). Witt (1987) outlined his production of bunchberry for use as a holiday potted plant. He propagated bunchberry from divisions and stem cuttings, asserting that IBA application was unnecessary for rooting stem cuttings; however no data were provided. Our propagation studies focus mainly on producing bunchberry by rooting stem cuttings, a propagation practice not commonly used for this plant and one that has not been tested experimentally to date.

The purpose of the following studies was to provide propagation and cultural information to facilitate commercial production of bunchberry. Several other propagation and production studies are currently in progress, addressing such issues as IBA application, propagation method, time of propagation, and fertilization techniques and levels.

PROPAGATION STUDY

Materials and Methods. The objective of this study was to assess the effects of K-IBA concentration on rooting and rhizome production of bunchberry. Softwood cuttings were taken from three bunchberry clones growing in a commercial lowbush blueberry field (Ellsworth, Maine) on 18 June 1997. In a randomized complete block design, blocked by each of three clones, 120 cuttings (40 subsamples per clone) were treated with one of six K-IBA solutions: 0, 1000, 3000, 5000, 7000, and 9000 ppm. Cuttings were randomly assigned, within the blocks, to the six treatment groups and treated with K-IBA (dissolved in water) as a 7-sec quick dip. After air-drying, the cuttings were stuck in a poly rooting flat (40 cm × 40 cm × 12.7 cm) containing a medium of peat and perlite (1 : 3, v/v) and placed in a tunnel covered with 4-mil white polyethylene shaded with 40% shade cloth (120 to 140 $\mu E\ m^{-2}\ s^{-1}$, 23 to 29 C daytime temperature) for 9 weeks. Cuttings were physically blocked by clone within the mist tunnel to remove the variation due to position within the tunnel. A mist emitter (Floodjet TK-VS10, Spraying Systems Inc. Wheaton, IL, 47 psi) at one end of the poly tunnel propelled a fine mist over the cuttings periodically. Mist was controlled by a timer (45 sec every 10 min), which maintained a high level of humidity within the chamber during the day. Mist ran from sunrise to sunset. Cuttings remained under mist for 9 weeks until some had developed visible rhizome shoots, at which time they were evaluated for rooting percentage, root area, total number of rhizomes produced per cutting, and total length of rhizomes produced per cutting. Data analysis was performed on transformed data using the ANOVA and Fisher's LSD procedures of SAS.

Results. Rooting percentage ranged from 82% to 88% and was not affected by K-IBA concentration (Table 1). However, cuttings treated with 3000 or 7000 ppm K-IBA produced larger root systems than those in the control or any other treatment.

The average number of rhizomes produced per cutting was reduced by increasing K-IBA concentration. The 7000 and 9000 ppm treatments yielded significantly fewer rhizomes compared to the control and 1000 ppm K-IBA treatment. The two highest K-IBA concentrations reduced rhizome length compared to the 1000 ppm treatment. In this case, however, control cuttings produced similar rhizome lengths to those of 7000- and 9000-ppm-treated stems.

Table 1. *Cornus canadensis* L. percent rooting, root ball area, rhizome quantity,and rhizome length as affected by K-IBA concentration.

K-IBA concentration (ppm)	Rooting (%)[x,z]	Average root ball area (cm^2)[w]	Average number of rhizomes per cutting[y]	Average rhizome length (cm)
0	88.3 a[v]	22.5 b	0.67 a	1.58 ab
1000	85.8 a	31.0 b	0.76 a	2.05 a
3000	84.2 a	36.8 a	0.60 ab	1.26 ab
5000	87.5 a	32.0 b	0.62 ab	1.21 ab
7000	81.7 a	38.2 a	0.44 b	0.81 b
9000	81.7 a	34.5 b	0.26 b	0.52 b

[V] N = 120
[W] Root ball area calculated as the length of root ball (cm) multiplied by the width of root ball (cm).
[X] Analysis of variance performed on arc-sine transformed data.
[Y] Analysis of variance performed on log-transformed data.
[Z] Mean separation within columns by Fisher's Protected LSD ($p \leq 0.05$).

Discussion. Although rooting percentage was unaffected by K-IBA application compared to the control, as reported by Witt (1987), K-IBA application at levels of 3000 and 7000 ppm can increase root growth and the size of the root system produced. Based on this, K-IBA application may be recommended to enhance the growth and establishment of the root system. An additional consideration, however, is the effect of K-IBA on rhizome growth. Higher levels of K-IBA such as 7000 and 9000 ppm appear to be inhibitory to rhizome number and length. A concentration of 1000 or 3000 ppm K-IBA is therefore recommended to maximize root growth while minimizing inhibition of rhizome production and elongation.

PRODUCTION STUDY

Materials and Methods. The objective of this study was to compare production time for bunchberry plants propagated from greenhouse-forced material taken as stem cuttings in April to plants produced from cuttings taken from field-grown plants in June. Four bunchberry clones were identified in two lowbush blueberry fields. Portions of each clone were harvested as sod pieces in Oct. 1996 and placed in flats (10 cm × 50.8 cm × 38.1 cm) which were then overwintered in cold storage (90 days, dark, 2.8C) and subsequently moved to a heated greenhouse (set at 18C, ambient photoperiod) in Feb. 1997. The flats were irrigated as needed until new growth reached the softwood stage. Stem cuttings (2 to 3 nodes, cut to the soil line) were taken from this material on 10 April 1997. On 10 June 1997 cuttings were harvested from the same four clones from the portions left in the field.

Cuttings on both dates were treated with 3000 ppm K-IBA for 7 sec, stuck into a flat containing peat and perlite (1 : 3, v/v) and handled as described in the previous section. After 10 weeks under mist, cuttings were separated into categories based on root mass and rhizome status: cuttings with large root systems and above-ground rhizome shoots, below-ground rhizome shoots, or no rhizome shoots (rated 1, 2, and 3, respectively) and cuttings with small root systems and no rhizome shoots (rated 4).

Twenty cuttings from each collection date and rating (5 cuttings per clone) were transplanted into 9 cm × 9 cm × 10.8 cm band pots (16 to a flat) containing peat and perlite (1 : 1, v/v) (pH 3.5 to 4.0). In a randomized complete block design, blocked by each of four clones, the plants were grown under greenhouse conditions (470 to 570 $\mu E\ m^{-2}s^{-1}$, 40% shade cloth over the entire greenhouse) and fertilized twice weekly with 20 : 20 : 20 Peters General Purpose soluble fertilizer (Scotts-Sierra, Marysville, OH) at 300 ppm N until the end of September when they were assessed for mean number of shoots per cutting and number of cuttings producing new shoots. Because there was a significant interaction between collection date and initial rating, the effect of rating will be presented separately for each collection date.

For both studies, data were subjected to analysis of variance using the General Linear Model of SAS (Release 6.07, SAS Institute Inc., Cary, NC. 1992). Treatment effects were separated by Fisher's Protected LSD (Table 1) and Duncan's Multiple Range Test (Table 2). Percentage data in the first study were arc-sine transformed and count-based data in both studies were log transformed for statistical analysis, but are presented as the original data.

Results. Of cuttings taken in April, those with rhizomes, rated 1 or 2, produced more shoots by the end of the first season than those without rhizomes, rated 3 or 4 (Table 2). However, for cuttings without rhizomes, those possessing more extensive root systems (rated 3) produced more shoots than those with small root systems (rated 4). Cuttings taken in April produced more new shoots than did those taken in June.

For June cuttings, those rated 1 and 2 still produced more shoots than those rated 3 and 4. There was no difference, however, in new shoot production between cuttings with large root systems (rated 3) and cuttings with small root systems (rated 4). Thus, the advantage of a large root system to shoot production is lost when cuttings are taken later in the season.

Initial rhizome status also affects the number of cuttings producing new shoots by the end of the season. Cuttings with rhizomes at the end of rooting (rated 1 and 2) formed new shoots 90% to 100% of the time, regardless of cutting time (Table 2). For those without rhizomes, only 45% to 60% with good root systems and 30% to 45% with poor root systems produced new shoots by the end of September. Therefore, it may not be worthwhile to transplant rooted cuttings without rhizomes, since a low percentage of them produce rhizomes by the end of the first season.

Discussion. Production of new shoots during the first season is important because new shoots indicate the presence of rhizomes. If no rhizomes are produced in the first season, as was the case for some cuttings rated 3 and 4, the plants will fail to produce growth the following spring. Starting from single stem cuttings, the most successful plants (those produced from rooted cuttings rated 1 and 2) filled the majority of the band pot and would be marketable by the end of their first season. Production of new shoots on rooted cuttings of bunchberry during the first season is influenced by the time of propagation and the rhizome status of the cutting at the time of transplanting. The presence of rhizomes at the time of transplant increases mean shoot number and the percentage of cuttings producing new shoots.

Table 2. New shoot production as affected by cutting collection time and initial root/rhizome rating in *Cornus canadensis* L.[W]

Initial rating (1-4)	Root and rhizome status	Mean number of new shoots per cutting[Y]		Cuttings producing new shoots from rhizomes (%)	
		Collection time		Collection time	
		April[Z]	June	April	June
1	Heavy rooting, aboveground rhizomes	2.36 a[X]	1.40 a	100	100
2	Heavy rooting, belowground rhizomes	2.15 a	1.37 a	95	90
3	Heavy rooting, no rhizomes	1.43 b	0.81 b	60	45
4	Light rooting, no rhizomes	1.00 c	0.81 b	30	45

[W]Cuttings evaluated and transplanted on 20 June for April cuttings and 15 Aug. for June cuttings.
[X] N=20.
[Y] Analysis of variance performed on log-transformed data.
[Z] Mean separation within columns by Duncan's Multiple Range Test ($p \leq 0.05$).

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Superior Selections of Ilex

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Among the 1000 plus selections of American holly (*Ilex opaca*) given cultivar names, four recent introductions from the Woody Ornamentals Breeding Program at Rutgers University are worthy of mention. All have excellent foliage characteristics, high vigor and are fully winter hardy in U.S.D.A. Plant Hardiness Zone 6a (0 to -10F).

***Ilex opaca* Selections.**

- **'Jersey Princess'**. Selected from the progeny of an unnamed female × 'Jersey Knight', this red-fruited plant was introduced in 1976 as the Bicentennial Holly. The plants develop a conical form of moderate width and exhibit the darkest, glossy green leaves of any cultivar of *I. opaca* that this holly hybridizer has ever seen.
- **'Dan Fenton'.** A seedling among the progeny of a controlled cross of 'Maurice River' × an unnamed male, this red-fruited plant was selected for its excellent spiny, dark green leaves (almost squarish). 'Dan Fenton' was released at the 40th Anniversary meeting of the Holly Society of America, Inc. and named in honor of the now deceased Daniel G. Fenton, one of the greatest promoters ever of the value and uses of plants of *I. opaca*. Broadly conical in habit, the original seedling was 20 ft tall by 15 ft wide at 26 years. Plants of 'Dan Fenton' make up well in container production with a minimum of pruning and staking.
- **'Jersey Delight'.** This cultivar originated as a pistillate selection among the progeny of a controlled cross of 'Old Heavyberry' × 'Isaiah'. The plants develop a moderately narrow and compact, conical habit. The foliage is similar to that of 'Old Heavyberry' as the shiny leaves are dark green with deeply impressed veins above. The annual display of reddish orange fruit is very showy.
- **'Jersey Knight'.** Selected from the wild on the estate of the late Judge Thomas Brown, Locust, New Jersey by members of the Holly Research Committee of New Jersey, plants were propagated and placed under test at Rutgers University. After observing these plants for 6 years, I named this cultivar and introduced it to commerce in 1965. Thirty-two years later, I believe it safe to say that 'Jersey Knight' has received widespread acceptance as one of the best staminate cultivars of *I. opaca* for use in states of the Northeast, Mid Atlantic, and Midwest. The plants are dense and self-compacting, exhibit excellent dark green, semiglossy foliage and constitute an attractive pollinator for pistillate plants. Plants of 'Jersey Knight' are fully hardy in USDA Plant Hardiness Zone 5b (-10 to -15F.) and possibly colder areas if care is taken the first few years to get the plants well established.

Deciduous Holly Selections Introduced from my Breeding Program. My interest in deciduous hollies began my first year at Rutgers University (1960) when a cross of our native *I. verticillata* onto a plant of its Asiatic counterpart, *I. serrata*, yielded a large population of true F1 interspecific hybrids in early 1961. The two pistillate cultivars listed below were the first reported hybrids of these two species. These hybrids are smaller and more densely branched and foliaged close to the ground, and more refined in appearance with smaller leaves and fruit than plants of *I. verticillata*, which tend to be more coarsely textured and open at the base.

- ***Ilex* 'Harvest Red'.** Plants of this hybrid are very broadly vase shaped, being wider than tall, with dark green, glossy leaves. The abundant fruit become vivid red by September 1st in central New Jersey. The first heavy freeze (October 15-20) "knocks" the leaves off but the brilliant display of fruit remains into February, unless sub-zero temperatures (-0F.) occur before that. 'Harvest Red' received the Pennsylvania Horticultural Society's Gold Medal Plant Award in 1991.
- ***Ilex* 'Autumn Glow'.** Plants of 'Autumn Glow' are more erect and less spreading in habit than are plants of 'Harvest Red' but the dense branches and leaves still clothe the multistemmed nature of the plants. The leaves of this hybrid are lighter green, and the fruit on the South side bleach earlier, than is the case with 'Harvest Red'. Still, the plants provide 6 weeks of color with foliage and fruit plus the brilliant fruit display for another 10 to 11 weeks.
- ***Ilex* 'Raritan Chief'.** This staminate hybrid was selected from the progeny of a cross of a *I. serrata/I. verticillata* F1 hybrid (staminate) onto an unrelated plant of *I. verticillata*. The original plant of 'Raritan Chief' was selected for its very low, dense, compact, mounded habit and attractive summer foliage. Its unusually long flowering period is a distinct asset in its role as a pollinator as plants of both parental species and hybrids thereof flower at widely different times. The absence of staminate plants in flower at the appropriate time accounts for many of the reports, or complaints, one hears about poor fruit set with plants of various cultivars of these species and hybrids.

Other Deciduous Holly Selections

- ***Ilex verticillata* 'Red Sprite'.** One cultivar of our native *I. verticillata* that has been around for many years and has become very popular is 'Red Sprite' (previously sold as 'Nana' for many years). This cultivar originated as a chance seedling discovered by P. A. Siebaldi in the wild near Hampden Nursery, Hampden, Massachusetts and was named and registered as 'Red Sprite' in 1980 by P. A. Siebaldi (Galle,1997). Plants of this cultivar are dwarf, a mature plant being about 4 ft tall. The plants produce abundant bright red fruit that become exceptionally large on plants that are heavily fertilized.
- ***Ilex verticillata* 'Winter Red' and 'Winter Gold'.** Widespread interest in deciduous hollies began when the late Robert C. Simpson

of Simpson's Nursery Co., Vincennes, Indiana named, patented and introduced a pistillate selection in 1977 as 'Winter Red' (PP 4143; reissued PP 22912 in 1979). Plants of this cultivar are erect and multi-stemmed with a rounded shape (9 ft tall × 8 ft wide), flower at a young age and fruit abundantly. The foliage is dark green and the large fruit are vivid red, normally retaining good color unusually long. Mr. Simpson actively promoted 'Winter Red' and this cultivar was soon in heavy demand.

Mr. Simpson found a budsport on a plant of 'Winter Red' about 1983, the sport branch bearing lighter green leaves and yellow fruit with a tinge of pink. Plants propagated from this sport were similar in other horticultural characteristics to 'Winter Red' and this new clone was introduced as 'Winter Gold' in 1988.

Simpson's work in selecting, introducing and promoting deciduous hollies moved this group of plants from a level of relative obscurity to a position of prominence in the nursery industry.

- ***Ilex decidua* 'Council Fire'.** J. Bon Hartline of Anna, Illinois has made many selections of superior seedlings of our native *I. decidua*. His favorite is 'Council Fire', the original plant of which he selected in the wild and moved to his nursery. Plants of 'Council Fire' are small to medium size for plants of *I. decidua*, the original seedling being multistemmed and well branched, but of compact habit, attaining a size of 18 ft tall by 10 ft wide after 25 years. The leaves are dark green and rather narrow, and drop early in the fall to provide a good display of fruit. The fruit is a bright, dark red but smaller than typical for the species but this is of no consequence as the plants fruit heavily. Unlike *I. serrata* and *I. verticillata*, plants of *I. decidua* generally retain the fruit on the plant in good color throughout the winter.

  I maintained a replicated performance trial of many cultivars of *I. decidua*, along with other deciduous hollies, at the New Jersey Agricultural Experiment Station in central New Jersey for at least 20 years but I do not know of one nurseryman in New Jersey who showed any interest in plants of *I. decidua*.

***Ilex crenata* Selections.**

Two relatively new staminate cultivars of *I. crenata*, a species of widespread interest, have been introduced from Rutgers University and are gaining in popularity and availability. They are 'Beehive' and 'Jersey Pinnacle'.

- **'Beehive'.** Selected from a population of 21,000 seedlings resulting from a cross of 'Convexa' × 'Stokes'. Under test for 23 years prior to introduction, plants of 'Beehive' are dense and self-compacting, with attractive tiny, dark green leaves. The plants are much more winter hardy than plants of 'Stokes' and typically grow 3 ft tall by 4 ft wide in 12 to 14 years, and are fully winter hardy in Zone 6a.
- **'Jersey Pinnacle'.** This cultivar originated as a staminate selection from a controlled cross of 'Green Lustre' × 'John Nosal'. The original seedling was selected for its upright pyramidal habit and

dark green leaves that are highly resistant to winter scorch. Plants become uniformly wide (columnar) with age and are reliably winter hardy in Zone 6a.

Other Hybrids.

- ***Ilex* 'Rock Garden'.** One final *Ilex* selection I recommend for those who like truly dwarf plants is *Ilex* 'Rock Garden'. This selection resulted from a cross of *I. aquipernyi* × (*I. integra* × *I. pernyi* 'Accent'). An 18 year plant in a 7-gal container has attained a height of 10 inches with a spread of 12 to 14 inches and exhibits a good display of rather large, bright red fruit. This is the first good dwarf *Ilex* with a holly-type leaf for use in rock gardens.

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Breeding Maize as an Ornamental Annual Grass

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Ornamental grasses are firmly established as major components in the landscape and textbooks devoted exclusively to them are available (Grounds, 1989; Meyer, 1975). Perennial grasses are commonly used in mixed borders and as specimens, because of their attractive foliage, form, and/or ornamental inflorescences. Many are easily grown and reliably cold-hardy. They come in an assortment of heights, growth habits, and leaf shapes. Leaf color ranges from green [e.g. *Pennisetum alopecuroides* (fountain grass)], blue (e.g., *Festuca glauca* [blue fescue], red or purple (e.g., *Pennisetum setaceum* 'Rubrum' [red fountain grass], yellow (e.g., *Carex elata* 'Aurea' [yellow tufted sedge], brown (e.g., *Carex buchananii*, leather leaf sedge), and variegated (e.g., many *Miscanthus sinensis* [eulalia grass] cultivars and *Phalaris arundinacea* [ribbon grass] cultivars). With few exceptions, perennial grasses must be clonally propagated by division to maintain phenotypic integrity. Although many perennial grasses are quite cold-hardy, the red-leafed ones are not hardy above Zone 5 or 6, eliminating their use for a significant portion of the U.S. population. Some grasses (e.g., *Phalaris* and most bamboos) can be considered quite vegetatively invasive. There is also significant concern about the escape of non-native grasses via wind-blown seed (White et al., 1993).

In comparison to perennial grasses, annual ornamental grasses are not as impressive from a vegetative standpoint and are generally grown for their attractive seed heads which can be dried (sometimes dyed) and used in floral arrangements. Little selection has been done to improve annual grasses by developing cultivars with superior characteristics. Most can be considered species grasses. They include *Lagurus ovatus* (hare's tail), *Coix lacryma-jobi* (job's tears), and *Setaria italica* (foxtail millet).

Zea mays L. (maize) is an annual grass most commonly used as a food, forage, and seed oil crop. To date, its most popular use as an ornamental is its fruit (i.e., "ears") which can possess brightly colored seeds (i.e., kernels) in a variety of colors and patterns (see Vernon, 1997). When dried the ears are hung as an autumn ornamental. The use of maize as an ornamental landscape grass has not been fully exploited. There exist a few "heirloom" types developed decades, if not centuries, ago. A type called *Zea mays var. japonica* with white and green striped leaves is still listed in some seed catalogs. A cultivar called 'Quadricolor' is infrequently still available. We have field tested the plant and found it to possess leaves irregularly striped with cream, yellow and occasionally bright pink stripes, although the leaf surface is mostly green. In my trials, 'Quadricolor' was the type most susceptible to a fungal disease called smut. In addition, it grew over 7 ft tall, a height that limits its use in the home landscape. In the text *Variegated Leaves* (Conder, 1993), a maize cultivar called 'Gracillima Variegata' is pictured. The plant is short, well branched, and has wide white stripes on the leaves. We thoroughly investigated the source of this photograph (taken in England) and was informed that the photograph is decades old and the seed is apparently no longer available. If anyone knows otherwise, please inform me. In addition, Conder (1993) advises that with 'Gracillima Variegata' you should select the most variegated seedlings as it has been reported that some seedlings never develop white strips and remain dull green. The *Index of Garden Plants* (Griffiths, 1994) also lists a 'Harlequin' maize described as having green and red striped leaves, but we could locate no source for seed. In addition, many of the described plants in the literature appear to be the same plant with different names. Meyer (1975) claims that 'Variegata', Quadricolor' and 'Versicolor' are the same plant.

The lack of cultivated maize cultivars suitable as ornamental grasses inspired me to initiate a program to investigate the potential of maize as an ornamental grass. Maize has several advantages over many other annual grasses. It is a highly adaptable rapidly growing plant that is grown worldwide. It has a tolerance to a number of soil conditions and, being an annual, can be grown in extremely northern climates. Although the seed can be attacked by corn ear worm, the foliage is generally pest free. From a sentimental standpoint, maize holds a significant role in the agricultural heritage of the United States. Thanksgiving Day is a celebration that is largely the result of a gift of corn seed from native Americans to the first European settlers — a gift that allowed their survival through their first winter (Vernon, 1997).

One fact that we have taken advantage of in the breeding program to my knowledge is that, during the assemblage of linkage maps for maize breeding, geneticists used chemical mutagens and other methods to generate hundreds of maize mutants (Neuffer et al., 1997). Although most of these mutants have no agronomic use, they assist geneticists trying to map agronomically important maize traits to specific locations on each of the maize chromosomes. Mutant stocks are available to researchers and are the source of the unique traits that we will describe. Most are nuclear genes, which are transmissible by seed. Some cause variegation that mimics that of periclinal chimeras (pictured in Marcotrigiano, 1997). In addition, there are dwarfs as small as 18 inches at maturity, multi-tillering types, leaf shape variants, and plant architecture mutants. There are leaf color mutants that make foliage either red, yellow, mottled, or brown, and stem color variants that make stems red or white. Table 1 lists some mutants that potentially could be combined to produce many different ornamental maize cultivars.

The positive aspects of breeding maize include the reproductive anatomy of maize, which allows hybridization with relative ease. Maize has imperfect flowers (i.e., individual flowers do not possess male and female organs). The plant is monoecious (i.e., male and female flower on the same plant) with the male flowers on the terminal inflorescence (i.e., the tassel). All male flowers can be removed by manually detasselling the plant. Ear shoots, which develop the female flowers, arise in the leaf axils, well separated from the male flowers. Paper bags can be placed over ear shoots to prevent random pollination and paper bags can be placed over the tassels to collect desired pollen. It is thereby possible to make deliberate crosses even in the presence of wind-blown pollen from undesirable plants. In most lines, one cross can yield about 300 seed. To develop ornamental lines that "breed true" some difficulties must be overcome. Inbreeding depression, which is caused by the necessity of either self-pollinating plants or crossing related plants in order to fix a series of desirable traits, can weaken plants or result in poor seed set. Unrelated background genes can also affect the expression of the genes of interest, sometimes reducing their expression. So, for example, in some stocks, genes that are suppose to make a plant yellow in

Table 1. Mutations in maize with possible use in the development of maize as an ornamental grass.[1]

Trait name	Gene symbol	General phenotypic effect
albescent plant	al1	reduction in chlorophyll
booster	b1	distribution of anthocyanin pigments
bronze	bz1	yields brown plant when combined with B1 and Pl1
corngrass	cg1	shorter, more tillered, reduced fertility
dwarf	d1 to d10	all mutants are very short plants
delayed flowering	dlf1	delays flowering
iojap striping	ij1	variable white stripes on leaves
japonica striping	j1	white stripes on leaf and sheath but not on seedlings
lax midrib	lxm1	flattened broad flexible midrib making leaves appear limp
liguleless	lg1	leaves lack ligule and auricle and stand upright wrapping around the culm
oil yellow	oy1	plant color yellow
piebald	pb1	leaves yellow-green with irregular white crossbands
purple plant	pl1	sunlight-independent purple pigment enhanced when other genes are present
tillered	tlr1	tillers on non-tillered stocks, extra tillers on others
red color	r1	controls kernel and plant coloration by regulating genes responsible for anthocyanin biosynthesis
teopod	tp1,2,3	reduces leaf width, increases tillering, can lead to male-sterility
white sheath	ws3	white leaf sheath and culm

[1]Descriptions modified from Neuffer et al., 1997.

color will make the plant light green instead. In addition, the phenomenon of "paramutation" at the R locus (the R locus causes the expression of red pigment) can permanently stop the expression of the genes responsible for the red pigment in maize. Yet, given these technical difficulties the first 4 years of the breeding program has yielded maize lines with significant ornamental appeal. By combining several mutations into one line, we have created dwarf variegated plants, large variegated plants with deep red stems, intensely red plants with upright habit, dwarf plants with yellow leaves, and many highly tillered plants which, unlike the familiar maize of commerce, produce plants with dozens of shoots rather than one or two. Preliminary results from a local trial garden indicated public excitement over these new maize plants.

Most of the lines that have been developed have not been inbred enough to result in uniform populations. Yet, with a few more years of work it will be possible to release some new cultivars of ornamental maize that will integrate well into informal perennial borders and even formal beds. Truly a-maize-ing.

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Production of Epimediums by Division

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As of 1997 we have seven *Epimedium* cultivars in production as well as several new cultivars in the process of increasing quantities of stock plants.

Deb McCowen of Knight Hollow Nursery asked me if there were any unique plants I would like to suggest for short presentations on propagation for this meeting.

Since I had been working on epimediums and wanting to believe that someone had a better technique than mine, I suggested epimediums. She proceeded to ask me to speak about epimediums and my technique seeing as I was doing them already!! So, here we go.

Species such as *E.* x*rubrum, E. grandiflorum, E.* x*versicolor* 'Sulphureum', and the cultivar 'Frohnleiten' are simply divided by brute force pulling the rhizomes apart. The unique ability of the rhizomes to break free of the parent is akin to the loosening felt as you work *Hemerocallis* apart in your hands to separate fans of that plant. We grow the stock plants in 1-gal containers and upon removing the container and with a light shaking of the bark mix the location of the rhizomes is apparent. The rhizomes can be seen radiating out from the center crown of the mature plant.

The divisions can be as short as 1 inch and as long as 3 inches dependant on the age, species and cultivar of the species you are working with. The divisions will resemble cigarette butts to small whole cigarettes in this form. We do not remove any roots remaining since we find the plant hard enough to grow on without a further challenge.

The main body of the original plant will have several very short "nubs" of rhizomes containing buds similar to those that appear on the divided segments. If sufficient quantities of buds exist a Felco-type pruner is used to snip the basel crown in 2 to 3 half-moon to pie-shaped pieces.

We replant all of these segments one to a 1-gal container. These divisions will yield a four- to eight-leaf plant that same season and will be dividable again in $1^1/_2$ to 2 seasons of growth after potting.

We have never removed any live leaves or existing foliage when we are dividing. We have in the past done all divisions as soon as or prior to resumption of the spring bud break. As we produce more stock plants (10,000+) we have begun dividing "in leaf" epimediums. We have found that the plants do fine if kept from excessive drying conditions. We repot all fresh divided plants within 48 h and have begun placing late divisions in a fog house which is shaded with 50% white poly vented at 88F. Although I must say the initial idea of this "in leaf" potting occurred out of the duress of a 4-day Chicago spring season before the onset of 85F temperatures, the results have been quite good. We have potted plants in nearly full new foliage and these plants have done as well as dormant potted divisions. We make every effort to keep the young plants moist without creating a wet soil medium. We use aged pine bark mix as well as a polymer water retention agent to accomplish this somewhat daunting task.

I have recently learned that other propagators find "in leaf" divisions as their choice for epimedium cultivation.

The species that form somewhat "woody crowns", such as *E.* ×*youngianum* 'Niveum' and 'Roseum', are divided in a manner similar to that described for the center body of the above types. A Felco-type pruner is used to cut sections of the mother plant about the size of a large thumb leaving all roots on the division attached.

This form of division can be expected to yield 6 to 13 divisions from a 1-gal plant of the rhizomatous types and 3 to 5 divisions of the *E.* ×*youngianum* types. I cannot stress enough the need for fresh divisions that are not allowed to dry excessively as is often the case in plants imported and or stored in a cooler for extended periods, as well as, a polymer water retention agent to accomplish this somewhat daunting task.

Native Herbaceous Wetland Plants Used for Wetland Mitigation

Dale Pierson
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INTRODUCTION

A growing awareness of the value and sensitivity of our wetlands prompted requests for low-cost, native, herbaceous plants for the mitigation, restoration, and enhancement of impacted wetlands. As the demand became apparent we looked at the potential for growing particular plants in areas that were unsuitable for conventional nursery production.

What follows is a look at the ongoing process of keeping production cost low and meeting the constantly changing demands in the market for this narrow group of plant materials.

METHODS

Our intent was to market bareroot, herbaceous wetland plants to the growing mitigation market. We identified and harvested existing plant materials on the site to be developed. This enabled us to keep the startup cost of plant material low. The first site used for production was a runoff ditch from an existing container facility with overhead irrigation. This required no additional application of water, and helped deal with runoff and nutrient issues.

At the end of 1 year we reviewed the results of our first attempt and modified the size of the swale to a width of 8 to 10 ft with length limited only by the individual site. Native loam was used in the base of the swale as a planting medium.

In an area where there was no irrigation runoff, a spring was tiled and allowed to run continuously into an enlarged roadside ditch. A silt growing medium was used in place of the native soil to ease the harvesting process. It did not limit growth of most taxa.

After grading the bottom of a swale and seeding any disturbed areas the base is planted with one or more taxa of plant material conducive to the hydrology of that specific site. The swale would remain for one growing season and could be harvested

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METHODS

Our intent was to market bareroot, herbaceous wetland plants to the growing mitigation market. We identified and harvested existing plant materials on the site to be developed. This enabled us to keep the startup cost of plant material low. The first site used for production was a runoff ditch from an existing container facility with overhead irrigation. This required no additional application of water, and helped deal with runoff and nutrient issues.

At the end of 1 year we reviewed the results of our first attempt and modified the size of the swale to a width of 8 to 10 ft with length limited only by the individual site. Native loam was used in the base of the swale as a planting medium.

In an area where there was no irrigation runoff, a spring was tiled and allowed to run continuously into an enlarged roadside ditch. A silt growing medium was used in place of the native soil to ease the harvesting process. It did not limit growth of most taxa.

After grading the bottom of a swale and seeding any disturbed areas the base is planted with one or more taxa of plant material conducive to the hydrology of that specific site. The swale would remain for one growing season and could be harvested for the next 2 to 4 years with 1 to 2 weedings per season.

After a complete harvest or when undesirable growth occurred the swale is harrowed, graded, and replanted. Several species of saltwater marsh plants are grown in the same manner.

Since some taxa are extremely difficult to harvest due to the nature of their root system, a fabric has been added in some swales to restrict root growth and allow for a more efficient harvest and processing procedure.

When an order is received or there is need for divisions for a new planting, plants are harvested and brought to the root cellar. They are processed on a six-person work bench with counting bays and pallet box for removal of unwanted soil and top growth. They are stored on shelving until shipping or planting.

Containerized plants, ranging from 1.5 inches to 2 gal are contract grown. Bareroot plants are harvested, processed, potted, and placed in a stone-dust lined depression in the existing container facility.

Several of our species are now also being grown from seed. As the demand for particular plants increases seed can be collected from the swales to be used in seed propagation to supplement plant propagation from division.

In order to extend the shipping season some plants, such as *Typha latifolia*, can be harvested, processed, and stored in a holding swale or the root cellar for shipment to customers with a longer planting season.

In another attempt to extend the planting season, plants grown from a late seeding are lined out in a swale and covered with used poly to encourage extra rooting before going dormant.

SOME OF THE PLANTS WE HAVE UNDER PRODUCTION

Carex lupulina	hop sedge
C. vulpinoidea	fox sedge
Juncus canadensis	Canadian rush
J. effusus	soft rush
Peltandra virginica	arrow arum
Pontederia cordata	pickerelweed
Scirpus cyperinus	woolgrass
S. microcarpus	redtinged bulrush
S. lacustris subsp. *tabernaemontani*	softstem bulrush
Sparganium (syn. *S. angustifolium*)	American bur reed
Sparganium eurycarpum	giant bur reed

PLANTS UNDER EVALUATION FOR CHANGES IN PRODUCTION TECHNIQUES

We are amending our approach to the production of *Sagitaria latifolia*. It emerges late and can only be harvested as a live plant from early June to late July. It must not be disturbed later or the corms that are produced for next year's plants will not have time to grow and harden off. In mid October the corms can be harvested and sold or overwintered for spring sales. The size of the plant's leaves and corms varies greatly. Currently demand outweighs supply and for us production cost are at or above the market price. In the spring of 1998 we will move all of the plants in production to a fabric-lined swale with a compost-based planting medium. It is our hope that this will give maximum production and ease of harvest of the corms.

Typha latifolia demand varies widely from season to season. In order to maintain a cost-effective production method we are seeding into plugs that help to slow the aggressive growth of this plant and enable us to have a stable supply. After 1 full year any remaining plants can be composted before they become too large.

Peltandra virginica has a very deep root system. In order to be able to harvest it we are seeding into plug trays and growing on for one season. The following year we will plant into a fabric-lined swale with a compost medium. It is our hope this will allow us to produce a healthy, cost-effective plant.

CONCLUSION

The line of native herbaceous wetland plants we currently produce is a low-end product. In order for it to be successful for us it is imperative that we keep cost low. Our swales enable us to increase quantities of plants for several years while waiting for the right opportunity to market the crop. This helps us weather the plant of the month syndrome that we all are subject to. Each year several new species are added in an effort to adapt to the market needs and expand our product line.

Micropropagation of Native Plants or Multiplying Some of Mother Nature's Really Good Stuff

Sherry Kitto
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What do I consider to be native plants? By my definition, and I will grant you it is very narrow by design, native plants are herbaceous perennials that are indigenous to the northeastern United States. How do I select the native plants I work with? I make plant lists based on talking with people who propagate, grow, and sell plants for a living. I also talk with people who love plants and gardening in general and have a special interest/knowledge in native plants. I compare the two lists and see what plants come up as "double" hits and then I research these plants. There also has to be some "chemistry" between the plant and me for me to work with it. There has to be a need for the plant to be micropropagated, and there must be a problem using conventional propagation techniques. Chemistry takes the form of leaf color or shape, unique seasonal interest, flower size, shape, or color. Part of the chemistry is the ease with which the plant can be reestablished in urban settings, if the plant has very narrow, specific environmental needs, then there is a good chance I will not work with it.

Micropropagation is propagation on a very small scale. Conventional propagators obtain cuttings and divisions from stock plants grown and maintained outdoors. Micropropagation relies on stock plants too; however, the stock plants are diminutive and maintained in glass or plastic containers under sterile conditions in a sold or overwintered for spring sales. The size of the plant's leaves and corms varies greatly. Currently demand outweighs supply and for us production cost are at or above the market price. In the spring of 1998 we will move all of the plants in production to a fabric-lined swale with a compost-based planting medium. It is our hope that this will give maximum production and ease of harvest of the corms.

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Micropropagation is propagation on a very small scale. Conventional propagators obtain cuttings and divisions from stock plants grown and maintained outdoors. Micropropagation relies on stock plants too; however, the stock plants are diminutive and maintained in glass or plastic containers under sterile conditions in a laboratory. Instead of going to the field to collect cuttings or divisions, the propagator goes to a laboratory and, with the aid of some low-tech equipment, collects microcuttings or microdivisions. These micropropagules are rooted using conventional techniques and acclimated to a post-laboratory environment. Rooting can take place in vitro or ex vitro. It is advantageous to root ex vitro due to the economics of 1 less month of laboratory maintenance and due to the fact that the acclimation process starts sooner; however, it is not economical, due to plant loss, to root some plants ex vitro, i.e., *Aconitum uncinatum*.

Micropropagation is a relatively young industry having been commercially entrenched only 15 to 20 years. During this time period, there have been many micropropagation successes. Most foliage plants, many orchids, some fruits, and ornamentals (e.g., azaleas) presently available on the market are derived from commercial micropropagation. In this same vein, there have been some less-than-successful micropropagation enterprises. In most cases, micropropagation is categorized as less-than-successful if it is less economical compared to conventional propagation. Micropropagation is not for every plant.

For micropropagation to be successful, it must meet a number of criteria. The bottom line is that the protocols developed must be economical. To be economical, the plants produced must be clonally identical and exhibit uniform growth habits. Micropropagation must produce plants quicker than if using conventional protocols, quicker to the point that enough plants are produced to make them available for sale at a price that people are willing to pay. Plants produced need to be pathogen free.

For simplicity, I like to divide micropropagation into two stages, a laboratory stage and a greenhouse/field stage. In the laboratory stage, plants are proliferated (axillary shoots are produced) and, in some cases, the microcuttings are rooted. In the greenhouse/field stage, microcuttings are rooted and acclimated. Each of these stages is critical to successful micropropagation. Each step needs to have a high success rate. There needs to be a relatively large number of microcuttings produced that are capable of rooting and acclimating at a high percentage. Native plants are no different than exotics, if there is one difficult step in the process it can be the economical determinant. Some plants are very difficult to establish in vitro, some plants are very slow proliferators while with others the real problem step is root initiation. Some plants need a cold treatment, during or after rooting, prior to moving to the greenhouse/field environment. Proliferation, rooting, and acclimation protocols need to be determined for each plant species and, in some cases, for each cultivar.

Many times plants that are easy to propagate in nature are easy to work with in vitro; however, usually plants that are easy to propagate conventionally are not chosen for in vitro research. Exceptions to this would be newly developed/discovered plants that have a high potential market; micropropagation makes these plants available en masse sooner. It should be no surprise then that many of the plants that micropropagation could really help are difficult to propagate conventionally. It is the hard to propagate plants, for whatever reason: poor or slow seed germination, few divisions per growing season, that frequently get passed on to the tissue culturists. Culturing a plant in vitro does not necessarily transform it from difficult to propagate into easy to propagate. Right? Tissue culturists are many times starting out behind the eight ball.

Just as each plant is a different entity so is each person who works in the field of micropropagation. What one person can successfully micropropagate does not necessarily translate universally to every other person. I have had very poor success with some plants, e.g., *Dodecatheon pulchellum* (syn. *D. amethystinum*). There are plants that I have worked with for years and have not been able to clone using micropropagation protocols.

I categorize the plants I have worked with as being easy, moderate, challenging, or impossible (for me) to micropropagate. Examples of plants I consider easy to micropropagate include *Asarum* spp., *Lilium canadense*, *Heuchera americana*, native ferns, *Sanguinaria canadensis*, *Sarracenia* spp., *Tiarella cordifolia*, *Trillium grandiflorum*, and *Viola pedata*. I consider these plants to be easy because at no stage in the micropropagation process is there a difficulty. They proliferate freely in vitro, microcuttings root with ease, and the resulting plants require little acclimation time. I would rate *Pachysandra procumbens* as being moderately easy due solely to the time it takes for microcuttings to root and acclimate. It takes about 6 weeks for microcuttings of *P. procumbens* to root and then another 8 weeks for the first new, fully acclimated shoot to appear. During this 14 week time frame, the microcutting must not be neglected. More challenging plants include *Spigelia marilandica* and *A. uncinatum*. These plants are easy to proliferate but have special needs during the rooting and acclimation stages. *Spigelia marilandica* has photoperiod requirements while *A. uncinatum* requires a chilling period after in vitro rooting. Plants that have proved impossible for me to micropropagate include *D. pulchellum* and *Galax urceolata*. I was unable to root microcuttings of these two plants. But what is impossible for me is easy for another, and there are plenty of wonderful native herbaceous perennials out there that are, as yet, undiscovered in any commercial sense.

Horticultural Applications of *Agrobacterium rhizogenes* ("Hairy-Root"): Enhanced Rooting of Difficult-to-Root Woody Plants

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INTRODUCTION

These studies tested the influence of *Agrobacterium rhizogenes* ("hairy root") dip-treatments on rooting of stem cuttings of difficult-to-root woody ornamentals. Prior work has shown that treatment of some woody plants with *A. rhizogenes* ("hairy root") resulted in root proliferation, as well as improved growth and performance in field and controlled environments (Han et al., 1993, Stomp, 1995; Strobel et al., 1988; Strobel and Nachmias 1985).

Rooting of woody plant cuttings by treatment with *A. rhizogenes* may make it possible to more profitably propagate difficult-to-root woody plants which are now grafted, or which are now expensive to produce from cuttings because of low rooting percentages. Woody plants propagated from stem cuttings induced to root with *A.rhizogenes* ("hairy root") may also show improved transplant recovery (Strobel et al., 1988). Positive results could lead to increased profitability and simplified production for growers of difficult-to-root woody ornamentals by enhancing rooting of stem cuttings. This work could therefore also positively affect consumer access and retail marketability of these plants.

Possible utility for *Agrobacterium*-treated, "extra-rooty" plants, in diverse arenas, has been discussed by Stomp, et al., 1993. However, little information exists regarding any potential uses for "extra-rooty" plants in horticultural applications—like improvement of vegetative propagation. We, therefore, screened a small number of commercially significant woody ornamentals for their susceptibility to *A. rhizogenes*, including botanical relatives of plants that have already shown enhanced rooting following treatment with *A. rhizogenes*.

Robinia pseudoacacia (Han et al., 1993) and *Prunus amygdalus* (Strobel and Nachmias, 1985) were reported to be successfully affected by *A. rhizogenes*. *Cercis* is a botanical relative of *Robinia*. *Prunus sargentii* and *P.* 'Kwanzan' are botanical relatives of *P. amygdalus* and therefore *C. canadensis, C. chinensis, P. sargentii,* and *P.* 'Kwanzan' were included in this study. In addition, two difficult- or slow-to-root conifers were included in a second study: *Abies fraseri* and *Cephalotaxus sinensis*. *Thuja plicata* was also included with the two conifers as an easy-to-root comparison species.

MATERIALS AND METHODS

Two propagation trials were conducted comparing percent rooting, number of roots greater than 1 cm, and length of longest root in stem cuttings of numerous difficult-to-root woody ornamental taxa when treated with standard rooting compounds and with two strains of wild-type ('hairy root') *A. rhizogenes*. The 'hairy-root' dip treatment was used in an analogous manner to that of an additional rooting hormone in the trials.

All trials were conducted in 1996 and 1997 using propagation facilities and plants from the living collections of the Arnold Arboretum of Harvard University, Jamaica Plain, Massachusetts. Stomp prepared and shipped to Tripp wild-type, bacterial cultures and the solutions necessary for dipping cuttings. Work with wild type *A. rhizogenes* strains is exempt from regulations governing genetically engineered plants (wild type strains are easily controlled with routine sanitary horticultural procedures such as cleaning all surfaces and implements with bleach solution).

In June 1996, Tripp collected and treated softwood stem cuttings of *Alnus hirsuta, A. maximowiczii, C. canadensis, C. chinensis, P. cyclamina, P.* 'Okame', *P. sargentii*, and *P.* 'Kwanzan'. Cuttings were treated with one of the following treatments: water, 8000 ppm KIBA (potassium salt of indole-butyric acid), *A. rhizogenes* strain A-4, *A. rhizogenes* strain R-1600, or combined treatments of *A. rhizogenes* strains A-4 or R-1600 with 8000 ppm KIBA. KIBA solution was prepared by dissolving KIBA salt in tap water at room temperature.

In December 1996, Tripp collected and treated hardwood stem cuttings of *A. fraseri, C. sinensis,* and *T. plicata,* with 95% ethanol:tap water (1 : 5, v/v) as a control, 5000 ppm NAA (naphthalene acetic acid), 8000 ppm KIBA, strains A-4 or R-1600 of *A. rhizogenes*, or combined treatments of *A. rhizogenes* strains A-4 or R-1600 with 8000 ppm KIBA, or with 5000 ppm NAA. KIBA and NAA solutions were prepared by dissolving the hormone powder in a solution of 95% ethanol and tap water (1 : 5, v/v).

All trials were conducted using a randomized complete block design with two replications of 10 cuttings each per treatment and plant (20 cuttings per treatment per plant combination for 960 total softwoods and 540 total hardwoods). Cuttings were collected, treated, and installed on the same day by replication. Cuttings were trimmed to about 5 inches long and all foliage was removed from the lower 2 inches of each cutting before treatment application. Control, NAA, and KIBA treatments were applied as 8-sec quick-dips. *Agrobacterium* treatments were applied by dragging the cutting bases through the appropriate culture plates. Treatments combining both standard hormone and *Agrobacterium* treatments were done by applying the quick-dip treatment first, allowing cuttings to air dry for 1 min, and then dragging the cutting base through the culture plate. Cuttings were rooted in 4 inch × 12 inch × 6 inch deep plastic rooting trays filled with a pre-moistened medium of peat and perlite (1 : 2, v/v).

Cuttings were maintained in the Arnold Arboretum Dana Greenhouses, Jamaica Plain, Massachusetts under intermittent mist for 6 sec every 6 min for softwoods, or 6 sec every 15 min for hardwoods (with periodic reductions in mist frequency in response to prolonged cloud cover). Bottom heat was applied at 65F to the conifer cuttings only for the duration of that trial. Mist was applied for 10 h day^{-1} to softwood cuttings and for 7 h day^{-1} to conifer cuttings. Greenhouse temperatures were maintained at 80F maximum day and 55F minimum night for the softwood cuttings, and at 55F maximum day and 40F minimum night for the conifer cuttings.

All cuttings were harvested after 12 weeks in both trials. Root fresh weights, length of longest root, and number of roots greater than 1 cm were recorded for all individual cuttings in all treatments. Percent rooting per replication for each plant and treatment were calculated from these data. Cuttings were counted as rooted if they showed at least 2 roots $\geq$ 1 cm. All data were analyzed for statistically significant treatment effects using the General Linear Means procedure for analysis of variance as performed by Statistical Analysis Software (SAS, SAS Institute, Inc., Cary, North Carolina). Analysis of variance was performed on arcsin transformations of percentage data but for clarity actual percentages were presented in Tables 2 and 3. Treatments and plant taxa treated for both the softwood and conifer trials are summarized below in Table 1.

Table 1. Summary of treatments and plants used in two trials testing rooting response of ornamental woody plant cuttings treated with standard rooting compounds and exposure to two strains of wild type *Agrobacterium rhizogenes* ("hairy root" bacteria). The softwood trial was conducted for 12 weeks in summer 1996 and the conifer trial was conducted for 12 weeks in winter 1996-97. *Agro.*=*Agrobacterium rhizogenes.*

Softwoods		Conifers	
Treatments	Plants	Treatments	Plants
Control	*Alnus hirsuta*	Control	*Abies fraseri*
8000 ppm KIBA	*A. maximowiczii*	8000 ppm KIBA	*Cephalotaxus sinensis*
Agro. strain A-4	*Cercis canadensis*	5000 ppm NAA	*Thuja plicata*
Agro. strain R-1600	*C. chinensis*	*Agro.* strain A-4	
KIBA + *Agro.*A-4	*Prunus cyclamina*	*Agro.* strain R-1600	
KIBA + *Agro.*R-1600	*P.* 'Kwanzan'	KIBA + *Agro.* A-4	
	P. 'Okame'	KIBA + *Agro.* R-1600	
	P. sargentii	NAA + *Agro.* A-4	
		NAA + *Agro.* R-1600	

RESULTS AND DISCUSSION

Results for overall percent rooting and rooting characteristics for all plants are presented in Tables 2 through 5. *Agrobacterium* treatments had varying effects on percent rooting and rooting characteristics depending on the plant and the *Agrobacterium* strain. In general, treatments combining KIBA with *Agrobacterium* significantly enhanced percent rooting and rooting characteristics for some of the difficult-to-root plants but not others.

A strong, positive *Agrobacterium*-related response for increased percent rooting, enhanced rooting characteristics, or both (compared to controls and traditional hormone treatments), was observed in the difficult-to-root plants *A. fraseri, C. sinensis, A. hirsuta, C. chinensis,* and *P. sargentii.* The more readily rooted plants *P.* 'Kwanzan', *P.* 'Okame', and *T. plicata* showed little or no *Agrobacterium*-related response for enhancement of percent rooting or rooting characteristics. No roots were formed on any *A. maximowiczii, C. canadensis,* or *P. cyclamina* cuttings (although there was significant callus formation on some treatments) therefore no results were reported for these taxa.

There was no apparent relationship between enhancement of percent rooting and rooting characteristics in taxa that responded to *Agrobacterium* treatments compared to traditional hormone and control treatments. In some plants both percent rooting and rooting characteristics were enhanced by *Agrobacterium* treatments relative to traditional hormone and control treatments (*Abies, Cephalotaxus*). In some plants, percent rooting only was enhanced by *Agrobacterium* treatments relative to traditional hormone and control treatments (*C. chinensis*). In some plants, rooting characteristics only were enhanced by *Agrobacterium* treatments relative to traditional hormone and control treatments (*A. hirsuta, P. sargentii*).

Softwoods.

Effect of Treatments on Mean Percent Rooting of Softwoods (see Table 2). There were no effects of treatments on mean percent rooting of *A. hirsuta, P.* 'Okame' or *P. sargentii.* For *P.* 'Kwanzan', all KIBA treatments showed significantly greater percent rooting compared to all other treatments. KIBA alone and combined with either *Agrobacterium* strain showed 100% rooting, while controls and *Agrobacterium* strains alone showed significantly lower rooting at only 55% to 65%. For *C. chinensis*, KIBA combined with *Agrobacterium* A-4 gave significantly increased percent rooting compared to all other treatments (100%). *Agrobacterium* A-4 alone gave intermediate results (90%) and all other treatments were significantly lower ($\leq$ 80%).

Table 2. Mean percent rooting of softwood stem cuttings of five different ornamental trees following treatment of cuttings with one of five rooting promoters or control after 12 weeks of standard intermittent mist treatment in a medium of perlite and peat medium (2 : 1, v/v). *Agro.*=*Agrobacterium rhizogenes.*

	Percent rooting of five ornamental trees[x]				
Treatment	*Alnus hirsuta*	*Cercis chinensis*	*Prunus* 'Kwanzan'	*Prunus* 'Okame'	*Prunus sargentii*
Control	30	75[a]	65[a]	85	45
8000 ppm KIBA	15	80[a]	100[b]	100	70
Agro. A-4	65	90[ab]	55[a]	65	45
Agro. R-1600	35	70[a]	65[a]	80	55
KIBA + *Agro.* A-4	45	100[b]	100[b]	90	75
KIBA + *Agro.* R-1600	5	50[a]	100[b]	90	85
	NS	*	**	NS	NS

NS=No statistically significant differences among column means.
*Statistically significant differences at $p \leq 0.05$ among column means.
**Statistically significant differences at $p \leq 0.01$ among column means.
[a,b,c] Column means with different letter designations are significantly different as per indicated p value.
[x]Statistical analysis was performed on arcsin transformations of percentages. Actual percentages are presented here for clarity. Statistically significant differences indicated apply to transformed data.

Effect of Treatments on Rooting Characteristics of Softwoods (see Table 3). Treatments had no significant effects on rooting characteristics of *C. chinensis* or *P.* 'Okame'. For *P.* 'Kwanzan', KIBA treatments alone, or in combination with either *Agrobacterium* strain, significantly improved all rooting characteristics (length of longest root, root number, root fresh weight) compared to all other treatments, but the addition of *Agrobacterium* did not enhance results compared to KIBA alone. For *P. sargentii*, KIBA treatments alone, or in combination with either *Agrobacterium* strain, significantly improved rooting characteristics compared to all other treatments. The combination of KIBA with *Agrobacterium* R-1600 increased mean root fresh weight only compared to all other treatments, however, the combination of KIBA with *Agrobacterium* A-4 increased mean root number and mean root fresh weight compared to all other treatments. *Prunus sargentii* cuttings showed enhanced rooting characteristics when treated with KIBA combined with *Agrobacterium* A-4. These root systems were more highly branched and more fully developed than those of other treatments. *Agrobacterium* strain treatments alone, in contrast, had no effect on rooting characteristics.

For *A. hirsuta*, combined treatment with KIBA and *Agrobacterium* A-4 significantly enhanced all rooting characteristics. These cuttings had more highly branched and fully developed root systems. Treatment with KIBA alone increased mean root fresh weight but did not effect mean length of longest root or mean root number. There were no other treatment effects.

Summary of Effects of Treatments on Softwoods (see Tables 2 and 3). Use of *Agrobacterium* combined with KIBA produced significantly enhanced results in some difficult-to-root softwoods in this trial (*A. hirsuta, C. chinensis, P. sargentii*). Use of *Agrobacterium* alone, however, had no effect on percent rooting or rooting characteristics of softwoods tested. There were significant treatment effects on mean percent rooting of *C. chinensis* and *P.* 'Kwanzan'. There were no treatment effects on mean percent rooting in *A. hirsuta, P.* 'Okame', or *P. sargentii*. Any KIBA treatment (alone or combined with either *Agrobacterium* strain) increased mean percent rooting of *P.* 'Kwanzan'. Use of *Agrobacterium* A-4 combined with KIBA, however, significantly enhanced percent rooting in *C. chinensis* compared with the control and traditional KIBA treatments. These results show promise for further study and application to *Cercis* cutting propagation. There were significant treatment effects on rooting characteristics of *A. hirsuta, P. sargentii,* and *P.* 'Kwanzan'. Potassium indolebutyric acid combined with *Agrobacterium* A-4 enhanced all rooting characteristics of *A. hirsuta* such that cuttings had more highly branched and fully developed root systems compared to those of control and traditional hormone treatments. KIBA alone enhanced rooting characteristics of *Prunus sargentii* but root fresh weight and root number were further increased when KIBA was combined with *Agrobacterium* A-4, and root fresh weight was also further increased when KIBA was combined with *Agrobacterium* R-1600. Any KIBA treatment enhanced all rooting characteristics of *P.* 'Kwanzan'. There were no treatment effects on rooting characteristics of *P.* 'Okame' or *C. chinensis.*

Conifers.

Effect of Treatments on Mean Percent Rooting of Conifers (see Table 4). For *A. fraseri*, KIBA combined with either strain of *Agrobacterium* significantly increased percent rooting compared with all other treatments. *Agrobacterium* A-4 alone gave intermediate results and there were no differences between all other treatments. For *C. sinensis*, KIBA combined with either strain of *Agrobacterium* significantly increased percent rooting compared with all other treatments. KIBA alone and either *Agrobacterium* strain alone all gave intermediate results and there were no differ-

Table 3. Mean length of longest root (cm) (LN), mean number of roots ≥ 1 cm long (NM), and mean fresh weight of roots (g) (FW), per cutting, for softwood stem cuttings of 5 different ornamental trees following treatment of cuttings with one of 5 rooting promoters or control after 12 weeks of standard intermittent mist treatment in a medium of perlite and peat (2:1, v/v). *Agro.*=*Agrobacterium rhizogenes.*

	Rooting characteristics for each of 5 ornamental trees														
	Alnus hirsuta			*Cercis chinensis*			*Prunus* 'Kwanzan'			*Prunus* 'Okame'			*Prunus sargentii*		
Treatment	LN	NM	FW	LN	NM	FW	LN	NM	FW	LN	NM	FW	LN	NM	FW
Control	7.60[a]	34.6[a]	0.52[a]	10.8	20.8	0.41	12.3[a]	43.2[a]	1.96[a]	19.6	79.4	0.62	11.3[a]	22.3[a]	1.13[a]
8000ppm KIBA	4.70[a]	43.2[a]	0.83[b]	10.9	25.1	0.37	20.9[b]	108.8[b]	4.29[c]	21.8	101.4	0.77	19.8[b]	81.5[b]	2.14[b]
Agro. A-4	5.60[a]	15.1[a]	0.32[a]	11.3	30.6	0.41	9.81[a]	26.8[a]	1.63[a]	14.8	60.8	0.54	8.42[a]	21.6[a]	0.86[a]
Agro. R-1600	7.52[a]	24.1[a]	0.42[a]	11.6	21.2	0.36	12.7[a]	39.5[a]	1.78[a]	13.5	50.5	0.43	11.4[a]	29.2[a]	0.98 [a]
KIBA+ *Agro*A-4	11.1[b]	102.2[b]	1.99[c]	10.7	22.7	0.42	20.4[b]	94.5[b]	3.31[b]	16.3	82.9	0.60	26.8[b]	146.0[c]	3.56[c]
KIBA + *Agro.* R-1600	12.1[y]	44.0[y]	1.09[y]	9.54	21.5	0.48	19.5[b]	97.9[b]	3.19[b]	17.7	77.2	0.69	25.1[b]	102.8[b]	3.18[c]
	*	**	**	NS	NS	NS	**	**	**	NS	NS	NS	**	**	**

NS=No statistically significant differences among column means.
*Statistically significant differences at $p \leq 0.05$ among column means.
**Statistically significant differences at $p \leq 0.01$ among column means.
[a,b,c] Column means with different letter designations are significantly different as per indicated p value.
[y]These data were included for observational comparison only and were not included in any statistical analyses because they are the means of only 2 surviving cuttings in this treatment group.

ences between all other treatments. Using combined treatments of *Agrobacterium* with IBA significantly increased percent rooting in both of the difficult-to-root conifers compared to traditional hormone treatments. There were no significant treatment effects on percent rooting of *T. plicata* which roots readily under most conditions and treatments.

Table 4. Mean percent rooting of hardwood stem cuttings of three different ornamental conifers following treatment of cuttings with one of eight rooting promoters or control after 12 weeks of standard intermittent mist treatment in a medium of perlite and peat (2 : 1, v/v). *Agro.=Agrobacterium rhizogenes.*

	Percent Rooting of Three Ornamental Conifers[x]		
Treatment	*Abies fraseri*	*Cephalotaxus sinensis*	*Thuja plicata*
Control	5[a]	30[a]	75
8000 ppm KIBA	20[a]	60[ab]	90
5000 ppm NAA	10[a]	20[a]	75
Agro. A-4	30[b]	60[ab]	95
Agro. R-1600	10[a]	65[bc]	75
KIBA + *Agro.* A-4	70[c]	100[c]	80
KIBA + *Agro.* R-1600	60[bc]	95[c]	95
NAA + *Agro.* A-4	10[a]	45[a]	90
NAA + *Agro.* R-1600	15[a]	30[a]	55
	*	*	NS

NS=No statistically significant differences among column means.
*Statistically significant differences at $p \leq 0.05$ among column means.
**Statistically significant differences at $p \leq 0.01$ among column means.
[a,b,c]Column means with different letter designations are significantly different as per indicated p value.
[x]Statistical analysis was performed on arcsin transformations of percentages. Actual percentages are presented here for clarity. Statistically significant differences indicated apply to transformed data.

Effect of Treatments on Rooting Characteristics of Conifers (see Table 5). For *A. fraseri*, combined treatments of KIBA with either strain of *Agrobacterium* significantly increased all rooting characteristics in comparison to all other treatments. Root systems from these treatments showed strongly enhanced branching and development. For *C. sinensis*, combined treatments of either *Agrobacterium* strain with KIBA significantly increased all rooting characteristics compared to all other treatments. Root systems from these treatments showed enhanced branching and development. Either strain of *Agrobacterium* alone, KIBA alone or NAA in combination with either strain of *Agrobacterium* gave intermediate results compared to controls and NAA alone. For *T. plicata* there were no treatment effects on root number. KIBA combined with *Agrobacterium* R-1600 increased the length of longest root compared to all other treatments and all NAA treatments reduced length of longest root compared to the control. All treatments using KIBA, NAA or *Agrobacterium* A-4

Table 5. Mean length of longest root (cm) (LN), mean number of roots $\geq$ 1 cm long (NM), and mean fresh weight of roots (g) (FW), per cutting, for hardwood stem cuttings of three different ornamental conifers following treatment of cuttings with one of eight rooting promoters or control after 12 weeks of standard intermittent mist treatment in a medium of perlite and peat (2 : 1, v/v). *Agro.=Agrobacterium rhizogenes.*

	Rooting characteristics for each of three ornamental conifers								
	Abies fraseri			*Cephalotaxus sinensis*			*Thuja plicata*		
Treatment	LN	NM	FW	LN	NM	FW	LN	NM	FW
Control	0.86^{a}	1.45^{a}	0.15^{a}	1.98^{a}	3.40^{a}	0.24^{a}	7.81^{bc}	13.0	0.55^{a}
8000 ppm KIBA	2.50^{a}	1.70^{a}	0.36^{a}	5.37^{b}	13.9^{ab}	0.77^{ab}	7.42^{bc}	30.8	1.15^{b}
5000 ppm NAA	2.13^{a}	4.01^{a}	0.49^{a}	1.29^{a}	3.02^{a}	0.23^{a}	5.41^{ab}	14.7	0.69^{ab}
Agro. A-4	2.65^{a}	4.19^{a}	0.40^{a}	7.41^{b}	22.8^{b}	0.95^{b}	10.2^{bc}	37.1	1.24^{b}
Agro. R-1600	0.95^{a}	1.45^{a}	0.07^{a}	10.0^{b}	32.2^{b}	1.56^{b}	6.52^{b}	9.84	0.48^{a}
KIBA+*Agro.*A-4	10.0^{b}	31.2^{c}	1.97^{b}	14.5^{c}	60.0^{c}	2.69^{c}	8.02^{bc}	46.5	1.27^{b}
KIBA+*Agro.*R-1600	8.56^{b}	16.3^{b}	1.33^{b}	15.9^{c}	58.1^{c}	2.19^{c}	11.6^{c}	35.0	1.29^{b}
NAA+*Agro.*A-4	2.00^{a}	1.99^{a}	0.28^{a}	3.97^{ab}	8.59^{a}	0.60^{ab}	5.00^{ab}	24.0	1.21^{b}
NAA+*Agro.*R-1600	3.05^{a}	2.24^{a}	0.29^{a}	3.52^{ab}	11.2^{ab}	0.64^{ab}	1.84^{a}	7.36	0.32^{a}
	**	**	**	**	**	**	*	NS	*

NS=No statistically significant differences among column means.
*Statistically significant differences at $p \leq 0.05$ among column means.
**Statistically significant differences at $p \leq 0.01$ among column means.
^{a,b,c} Column means with different letter designations are significantly different as per indicated p value.

increased root fresh weight compared to the control, but did not differ in other respects, while all treatments using *Agrobacterium* R-1600 reduced root fresh weight compared to all other treatments.

Summary of Effects of Treatments on Conifers (see Tables 4 and 5). Use of *Agrobacterium* combined with IBA significantly enhanced results in the difficult-to-root conifers (*A. fraseri, C. sinensis*) but not the readily rooted conifer (*T. plicata*). Use of *Agrobacterium* alone enhanced some results in comparison to controls, but not in comparison to traditional hormone treatments. *Agrobacterium* combined with KIBA strongly increased percent rooting and enhanced rooting characteristics in both of the difficult-to-root conifers compared to traditional hormone treatments and controls, but did not result in a strong response in the readily rooted conifer. These results show promise for further study and application to *Abies* and *Cephalotaxus* cutting propagation.

CONCLUSIONS

Use of *A. rhizogenes* wild type strains in combination with KIBA as a rooting promoter shows good promise for some difficult-to-root woody ornamentals — particularly conifers in these trials. There were large differences in response among the taxa tested. Significantly more work clearly needs to be done to elucidate which species and cultivars could benefit from such treatment.

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Plant Growth Regulators on *Kalmia latifolia*

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INTRODUCTION

Mountain laurel (*Kalmia latifolia*) is a popular ericaceous shrub with showy buds and flowers in the spring. However, it is slow to begin flower bud development during container production, often taking 3 or more years to produce a significant floral display. I became interested in the potential for growth regulators to induce earlier flowering when I heard of previous experiments done with *Rhododendron* and *Kalmia* by Tom Ranney and Dick Bir at North Carolina State University (Ranney et al., 1994) and by Martin Gent at the Connecticut Agricultural Experiment Station (Gent, 1993).

FIRST EXPERIMENT

In 1994, I did an experiment comparing spray concentrations of Bonzi (paclobutrazol) at 0, 10, 50, 100, 200, 400, and 600 ppm, and of Sumagic (uniconazole) at 0, 10, 50, 100, 200, and 300 ppm on three cultivars of *Kalmia*: 'Freckles', 'Carol', and 'Bullseye'. The 'Freckles' and 'Carol' plants were in 1-gal containers beginning their second season of growth. The 'Bullseye' plants were in 3-gal containers beginning their third season of growth. The experiment was conducted at Historyland Nursery in Montross, Virginia, on plants that were part of their regular production stock. The treatments were applied on 20 May 1994, following the first growth flush. Five plants per treatment of each cultivar were utilized in a completely randomized design. The sprays were applied with a CO_2-pressurized sprayer set at 34 psi, to wet the foliage and young stems. On 6 Oct 1994, the flower bud clusters were counted and shoot growth was measured. On 15 May 1995 another measurement was made of new shoot growth following the first growth flush for the subsequent spring.

The Bonzi treatments were generally less effective, and less consistent than the Sumagic treatments. Bonzi promoted a slight increase in flowering on 'Freckles' and 'Bullseye', but no increase for 'Carol' (Fig. 1). With Sumagic, there was a slight increase in flowering for 'Carol' and 'Freckles', and a dramatic increase in flower buds for the older 'Bullseye' plants, especially at rates of 50 ppm and above (Fig. 2). Shoot growth decreased correspondingly with increasing concentrations of both Bonzi and Sumagic (Figs. 1 and 2). Sumagic rates of 50 ppm and above also decreased shoot growth for the first flush the following spring (data not shown).

SECOND EXPERIMENT

In the first experiment, application of treatments after the first growth flush retarded growth of the second flush, more or less, depending upon concentrations. It was speculated that if growth regulator treatments could be delayed until after the second growth flush, the benefit of two growth flushes could be obtained prior to initiating flower buds. Therefore, in 1995, the effectiveness of treatments applied after the first and after the second growth flushes were compared. I also compared treatments to plants both 1 year in production and 2 years in production. The plants used were *K. latifolia* 'Nipmuck', 'Olympic Fire', and 'Bullseye'. These were con-

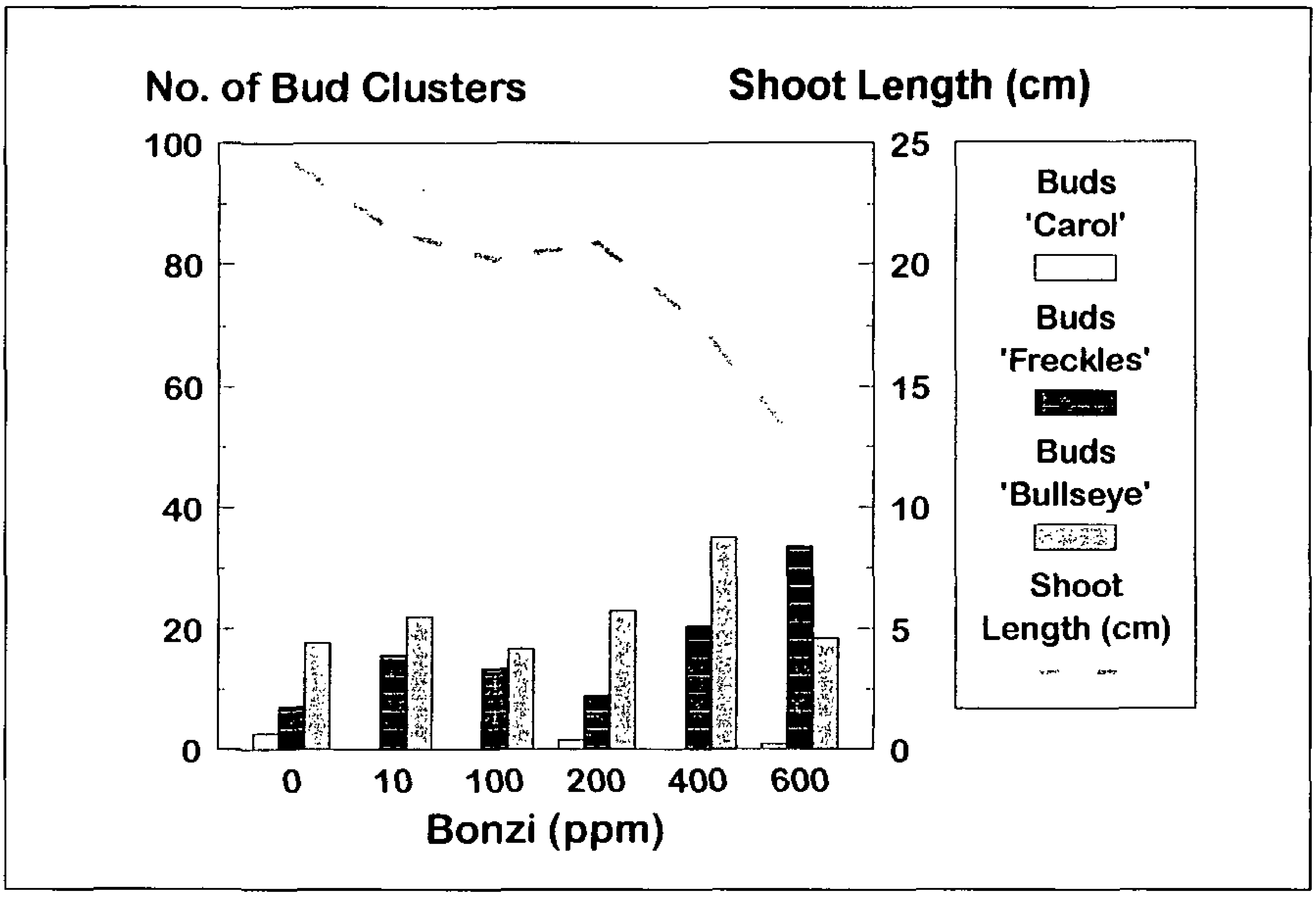

Figure 1. The effect of Bonzi (paclobutrazole) on flower bud initiation and shoot growth of three *Kalmia* cultivars.

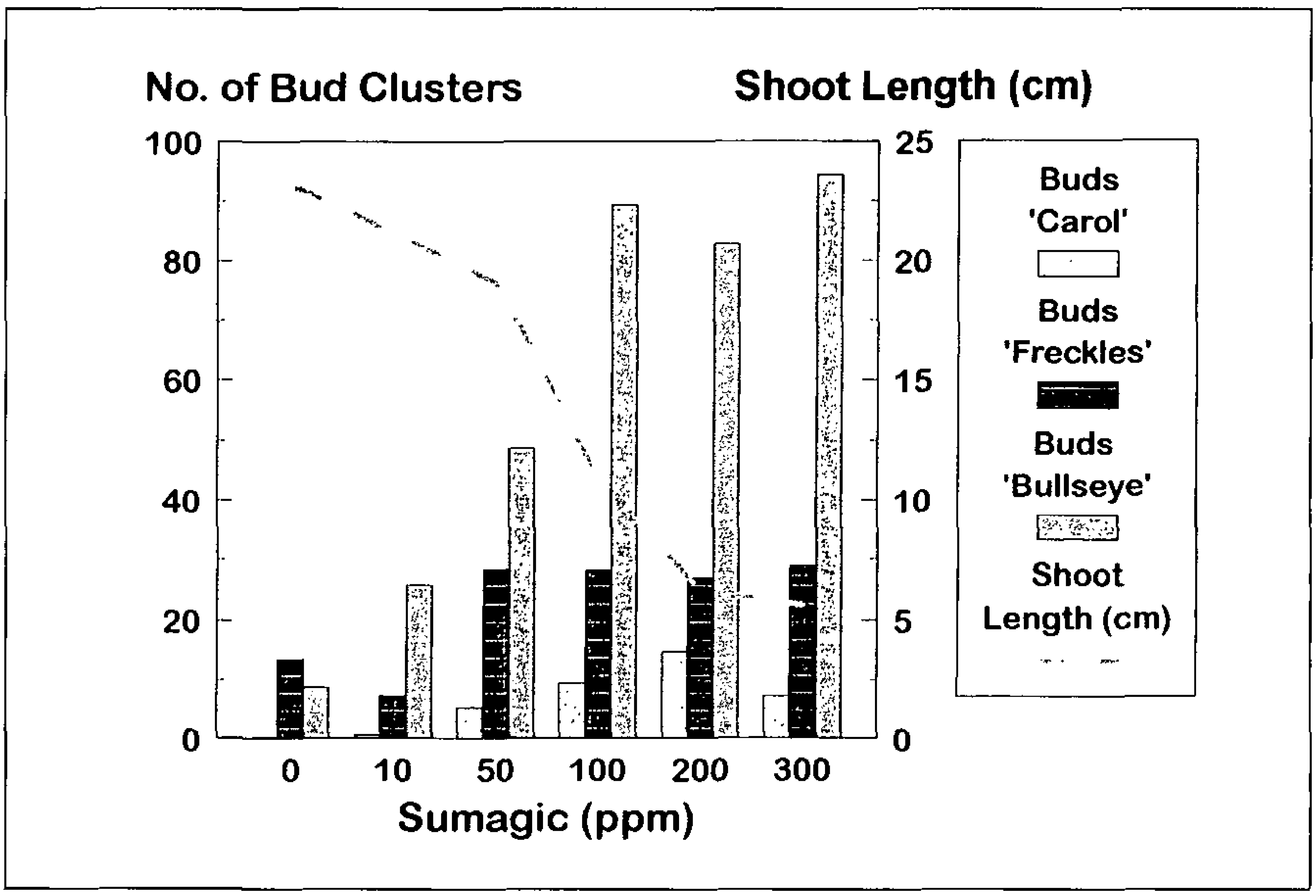

Figure 2. The effect of Sumagic (uniconazole) on flower bud initiation and shoot growth of three *Kalmia* cultivars.

tainer-grown plants in production at Historyland Nursery. Two-gallon (1 year, beginning their second season) and 5-gal (2 year, beginning their third season) plants of each cultivar were used.

On 26 May 1995, following the first growth flush of the season, spray treatments of Sumagic (uniconazole) at concentrations of 0, 25, 50, 100, 150, and 200 ppm were applied as in the first experiment. A completely randomized design was used with five plants per treatment per cultivar for each of the two container sizes. On 20 July 1995, after the second growth flush of the season, the same spray treatments were applied to an additional set of plants of the same age and cultivars as used on 26 May. On 8 Nov. 1995, flower bud set and plant heights were evaluated.

Applications of Sumagic to the first growth flush on the 2-gal plants provided no significant increase in flower buds for any of the three cultivars evaluated (data not shown). However, when applications were made to the second growth flush, there were increases in flower bud initiation for both 'Olympic Fire' and 'Bullseye'. Maximum flowering increase occurred at 50 to 100 ppm depending on the cultivar (Fig. 3). Application of Sumagic to the second flush also resulted in larger plants at the end of the season than application to the first flush (Fig. 3).

When Sumagic was applied to the 5-gal plants, there were large increases in flower buds with increasing rates of Sumagic for both first and second flush applications (Fig. 4). There were no significant differences in bud numbers between the two application times for the 5-gal plants of both 'Nipmuck' and 'Olympic Fire'. However, the size of the plants treated after the second flush were larger when compared with corresponding treatments applied after the first flush (Fig. 4). The 'Bullseye' plants could not be evaluated because of losses apparently due to *Phytophthora*.

THIRD EXPERIMENT

This experiment, conducted in 1996, was very similar to the previous (1995) experiment with slight modifications in the concentrations of Sumagic applied. The cultivars 'Nipmuck', 'Olympic Fire', and 'Bullseye' were again used, both 2-gal and 5-gal sizes. On 6 June 1996, following the first growth flush of the season, spray treatments of Sumagic at active ingredient concentrations of 0, 50, 75, 100, and 150 ppm were applied to wet the leaves and young stems. These same treatment concentrations were again applied on 2 Aug. following the second flush of the season. There were five plants per treatment for each application time and each plant size, in a completely randomized design. On 15 Oct. 1996, flower bud set and plant size were evaluated. The plants were again evaluated on 6 May 1997, to confirm the flower bud set numbers, and to measure the first growth flush for the year following treatment application.

In 1996, none of the second season (2-gal) plants, of any of the cultivars evaluated, produced flower buds regardless of application time. With the third season (5-gal) plants, there was a large increase in flower buds with increasing concentrations of Sumagic when the application was made following the first growth flush. Unlike the previous experiment, there was only a slight increase in flower buds when application was made following the second growth flush (Fig. 5). As with the previous experiment, the plants were larger at the end of the season when applications were made to the second flush rather than the first (Fig. 5), however, there was more growth retardation to the first flush of the season following treatments if the treatments were made after the second flush (Fig. 6).

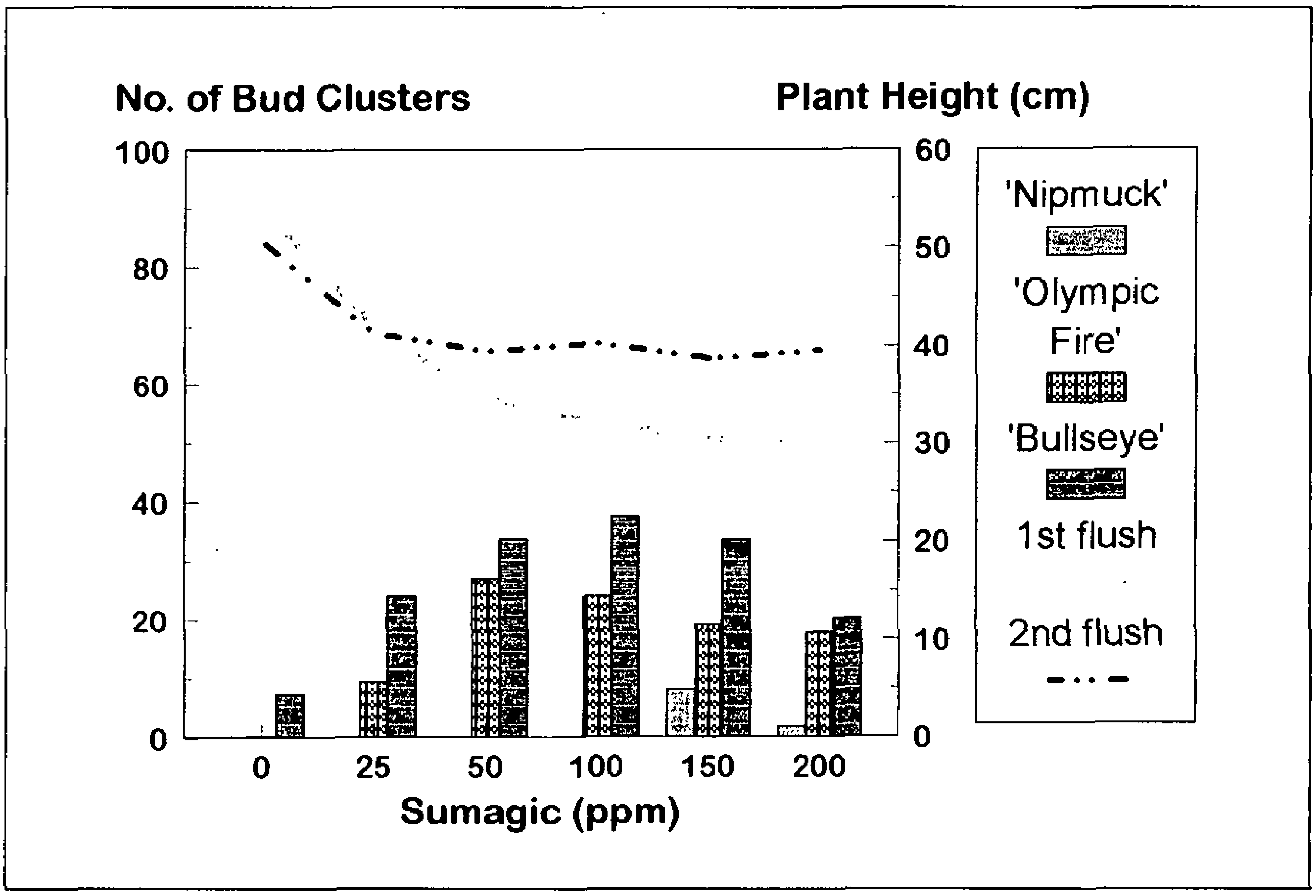

Figure 3. The effect of Sumagic on flower bud initiation when applied to the 2nd growth flush on 2-gal *Kalmia* and on plant height when applied to the 1st or 2nd flush.

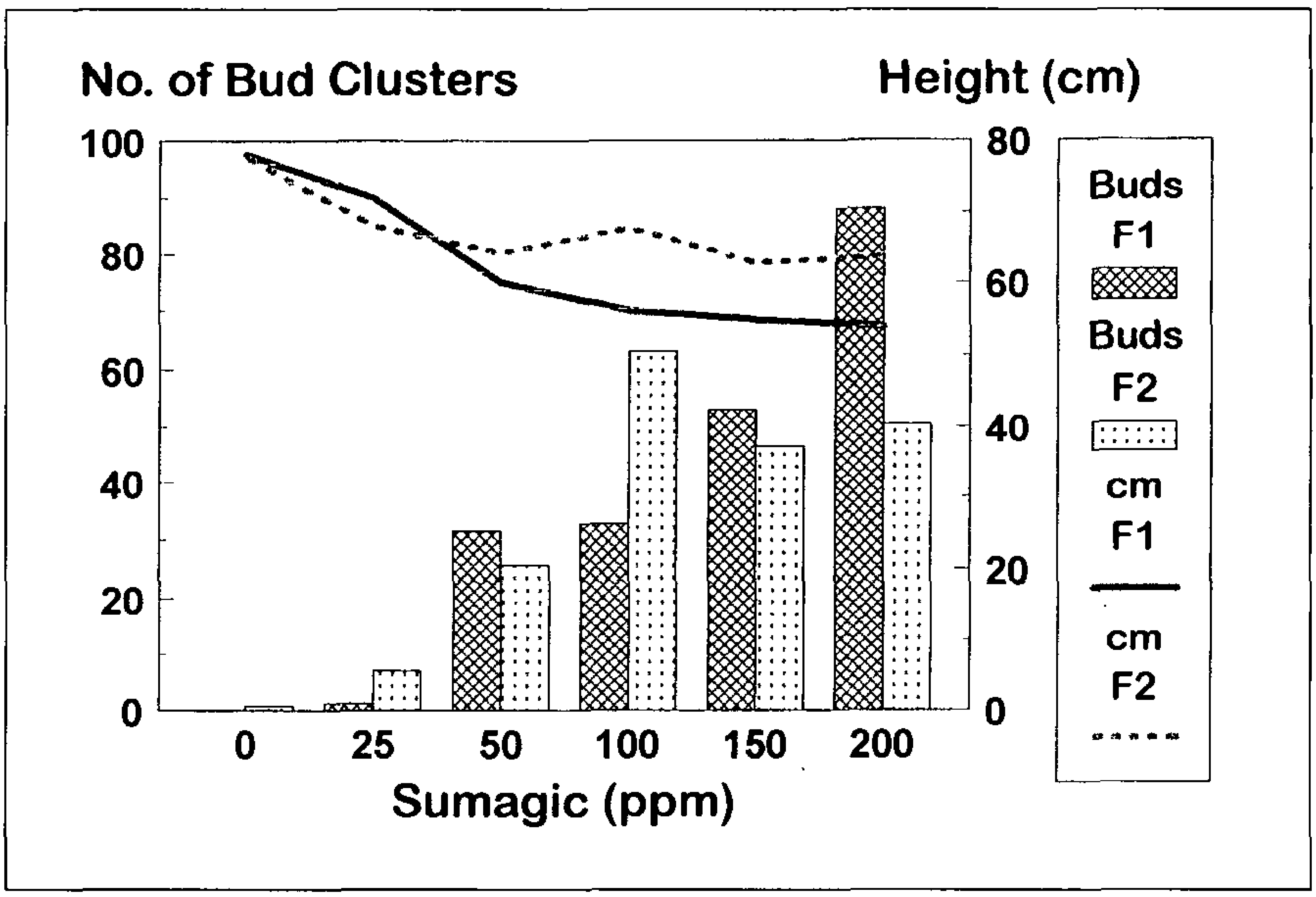

Figure 4. The effect of Sumagic on flower bud initiation and plant height when applied to the 1st (F1) or 2nd (F2) growth flush of *Kalmia* (means of 'Nipmuck' and 'Olympic Fire'.

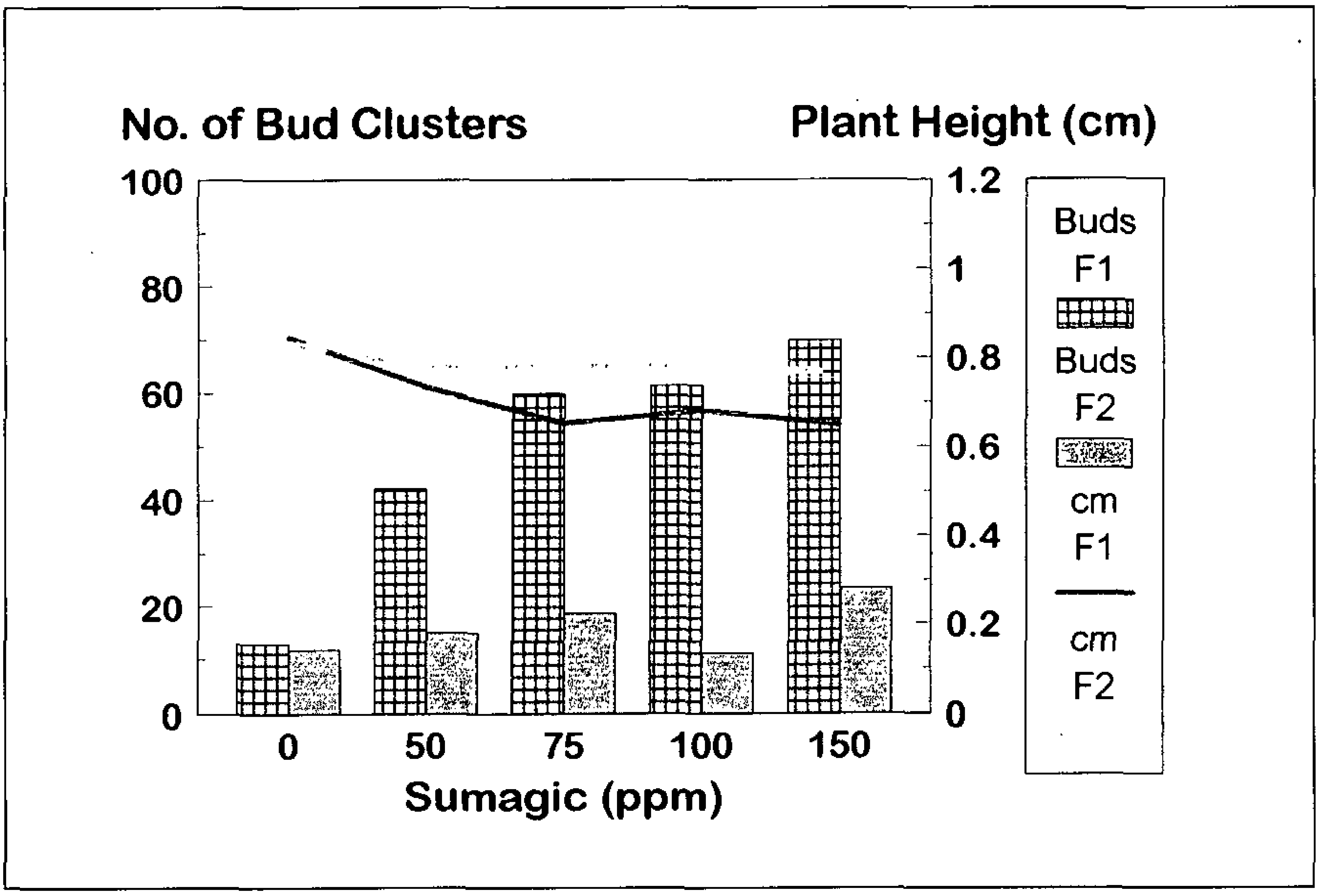

Figure 5. The effect of Sumagic on flower bud initiation and plant height when applied to the first (F1) or second (F2) growth flush of 5-gal *Kalmia* (means of 'Nipmuck', Olympic Fire', and 'Bullseye' (Experiment 3).

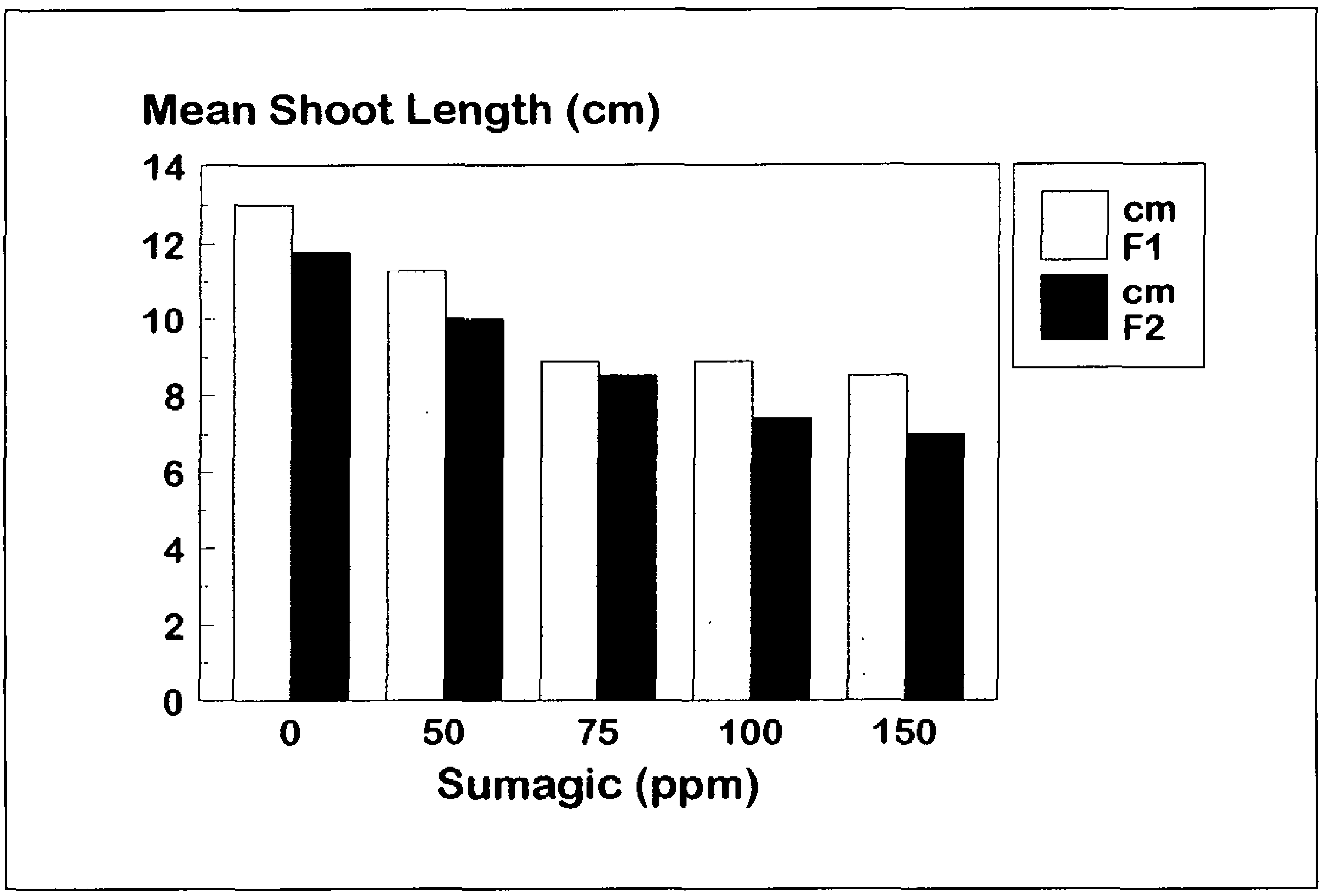

Figure 6. The effect of Sumagic on shoot length of the 1st growth flush of the year when treatments were made to the first flush (F1) or the second flush (F2) of 5-gal *Kalmia* the previous year (mean of 3 cultivars) (Experiment 3).

CONCLUSIONS

Spray applications of Sumagic (uniconazole) may be used to substantially increase flower bud initiation during container production of *K. latifolia*. Bonzi (paclobutrazol) also increased flower bud initiation to a lesser extent. A significant increase in flower buds was obtained with Sumagic on plants as early as the second season of growth following propagation. However, these results on plants this young could not be repeated in one of the three experiments. Consistent increases in flower buds were obtained, however, on plants in their third season of growth when uniconazole was applied at 50 ppm or above. The most consistently satisfactory results were obtained when applications were made following the first growth flush of the season, with uniconazole at 50 to 100 ppm, on plants that were in their third season. There is some reduction in plant growth, however, especially at rates above 50 ppm. These growth reductions may also carry over to the following season, especially at the higher rates.

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Subirrigation of Rhododendron as an Alternative to Mist

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The success of softwood or semihardwood stem cutting propagation requires optimal conditions of the plant and the rooting environment, such that new roots may be initiated on a severed stem. Perhaps most important in the rooting process is the control of water loss. If water loss from the cutting exceeds the ability of the stem to take up water, either through the leaves or cutting base, it will experience water stress, and may die. In either case rooting success is greatly reduced or prevented altogether. The development of intermittent mist in the early 1950s was a great aid to plant propagators (Hartmann et al., 1997). The mist reduces transpiration stress by cooling the leaf surface, and reduces evaporation of water from the leaf. However, mist propagation is not without its problems. Mist has been shown to promote leaf chlorosis, mineral nutrient leaching, necrosis, and algal growth (Hartmann et al., 1997). As well, the propagator must be vigilant against waterlogging of the rooting medium, salt build-up or clogged nozzles, and other maintenance requirements. Fog may be a promising alternative to intermittent mist for stem cutting propagation because it does not lead to many of the problems associated with intermittent mist. Unfortunately fog is comparatively expensive to install, and also requires regular maintenance (Hartmann et al., 1997).

The use of subirrigation technology has been proposed as an inexpensive substitute to intermittent mist for softwood and semihardwood stem cutting propagation (Mezitt, 1978; Zhang and Graves, 1995; Cuny, 1996). In subirrigation, stem cuttings are inserted into perforated propagation flats filled with perlite. These propagation flats are placed in a reservoir of water, with the water level maintained about 1 inch (2.4 cm) below the base of the cuttings. Water moves through the rooting medium from the reservoir to the cutting base by capillary action. This method of propagation keeps the leaf surface of the cutting dry, thereby reducing disease and nutrient leaching, and requires no automated equipment.

A key to the success of subirrigation seems to be the use of perlite as the rooting medium (Mezitt, 1978; Zhang and Graves, 1995). Historically, perlite, produced from crushed aluminum-silica volcanic rock, has been used as an amendment to propagation media because it increases drainage and aeration (Dirr and Heuser, 1987). Though perlite is essentially inert and has no cation exchange capacity or nutritional value, each particle of perlite contains micropores that make excellent capillary channels. The capillarity of perlite exceeds that of most other rooting media, including sand (Cooke and Dunsby, 1978; Moore, 1987). Cuttings also benefit from the ease in which they are able to take up water contained in perlite, that does not bind water as tightly as other propagation media, such as peat which is highly organic and contains negative charges that attract water. It is intriguing that perlite holds very little water (3 to 4 times dry weight), but readily passes it to the cutting, while peat, which holds lots of water (up to 15 times dry weight), actually makes less water available to the cutting (Grange and Loach, 1983).

Subirrigation has been used successfully to propagate a range of species by stem cuttings including *Acer, Berberis, Betula, Cornus, Cotinus, Hamamelis, Magnolia, Prunus, Syringa,* and *Viburnum*, as well as many herbaceous species (Mezitt, 1978;

Zhang and Graves, 1995; Cuny, 1996). However, poor success has been reported for rooting cuttings of rhododendron by this method (Cuny, 1996). We noted that most propagation literature suggests rooting rhododendron cultivars in an acidic medium of either peat/perlite or peat/vermiculite. However, the perlite used in subirrigation systems typically runs between pH 6 to 8 (Hartmann et al., 1997) and the tap water used in the subirrigation reservoir also is usually neutral to alkaline. We suspected that the pH of the typical subirrigation system would not be optimal for rooting ericaceous plants. In the studies reported herein we investigated the effects of subirrigation and medium pH on the rooting of several rhododendron cultivars.

Terminal stem cuttings of the rhododendron cultivars P.J.M. Group, 'Purple Gem', and 'Catawbiense Album' were collected from stock blocks in early August. Cuttings were stripped to 6 or 7 leaves and the 'Catawbiense Album' leaves were trimmed in half. Cuttings were wounded on one side and treated with a 1 : 10 (v/v) aqueous dilution of Dip 'n Grow (1.0% IBA, 0.5% NAA, Astoria-Pacific, Clackamas, OR). The propagation system was set up in a greenhouse under about 90% shade. For each treatment, three replicate reservoirs were set up, each containing 1 inches of water. The first treatment used tap water (pH=7.5; lime added at the water plant to reduce pipe corrosion). The second treatment used tap water titrated to a pH of 4.5 with weak sulfuric acid. The third treatment used tap water mixed with peat moss at a 4 : 1 (v/v) ratio to form a peat slurry (pH=4.1). Perforated propagation flats filled with perlite were placed in the reservoir the day before the cuttings were inserted to allow time for the equilibration of the reservoir solution with the perlite. The cuttings were inserted into the perlite so that the base of the cutting was approximately 1 inch above the water table.

Table 1. Rooting response and root volume displacement of rhododendron cuttings rooted in a subirrigation system at two solution pH levels (rooting time 63 days), n=40 values.

	Rooting percentage			Root volume displacement (ml)		
Cultivar	pH 4.5	pH 7.5	Peat slurry	pH 4.5	pH 7.5	Peat slurry
Catawbiense Album	87.5	72.5	-	12.4	2.5	n/a
P.J.M.	85	37.5	87.5	2.8	0.8	3.9
Purple Gem	97.5	80	95	3.5	0.3	3.2

At no time were the top of the propagation flats or the cuttings misted. The solution pH was monitored weekly, and water was added to bring the subirrigation solution back to its original level. The pH of the 4.5 treatment had a tendency to rise over time, and was adjusted biweekly with weak sulfuric acid. The pH of the peat slurry was more stable and never needed to be adjusted over the course of the experiment (9 weeks). However, the peat slurry treatment was more susceptible to evaporation due to increased surface area and water had to be added more often. After several weeks the peat settled to the bottom of the reservoir and evaporation decreased.

The cuttings were harvested after 9 weeks and rooting percentages recorded along with rootball volume displacement. The solution pH of the subirrigation system had a dramatic effect on rooting of all cultivars whether pH was brought down by sulfuric acid or by peat (Table 1). It is deceiving to examine rooting percentages alone without also examining root ball displacement. Although 'Purple Gem' and 'Catawbiense Album' rooted 80% and 73%, respectively, in the pH 7.5 treatment, almost all of the rootballs were commercially unacceptable. Cuttings rooted in high percentages in the low pH treatments, and also produced root balls 5 ('Catawbiense Album') to 10 times ('P.J.M.' and 'Purple Gem') greater than in the high pH treatment. The large-leaved 'Catawbiense Album' yielded larger cuttings then the small-leaved 'P.J.M.' and 'Purple Gem' and consequentially had a larger root ball volumes.

In additional trials, we mixed peat with perlite in the propagation medium in ratios of 1 : 2 (v/v) and 1 : 4 (v/v). These mixes resulted in inferior rooting, well below 50% (data not shown). Stem rot also was apparent in most of the unrooted stems, most likely due to waterlogging of the rooting medium.

Though we were able to successfully root all three cultivars of rhododendron without intermittent mist, rooting percentages and time of root formation lagged behind that of intermittent mist. Cuttings of 'P.J.M.', 'Purple Gem', and 'Catawbiense Album' rooted at 100%, 100%, and 95%, respectfully, under intermittent mist (data not shown). These cuttings were propagated in a medium consisting of peat and perlite (1 : 2, v/v). When the root balls of the cuttings propagated under intermittent mist were gently washed, most of the peat washed away leaving only the perlite. This resulted in a root ball that could not be directly compared to that of a root ball propagated in 100% perlite. However the rootballs from the rhododendrons rooted under intermittent mist appeared to be slightly larger then those produced in subirrigation. This increase in size may be due to greater water stress experienced by subirrigated cuttings. However, for those who wish to root rhododendrons without mist, subirrigation with low pH solutions works quite well.

There may be potential in combining subirrigation with mist for hard-to-root cuttings that do not tolerate excess water on their foliage or which are susceptible to disease, salt-buildup, or leaching. Cuttings that normally need to be misted once every 8 or 16 min may require mist only once or twice an hour, or less, if subirrigation is used.

Presently, we are researching the use of sand as an alternative, or amendment, to perlite medium in subirrigation propagation. Sand is less expensive then perlite and might help promote the development of a more fibrous root system. We also are studying the grade of perlite used, and its effect on the moisture content of the rooting medium. Easy-to-root plants and plants that are considered "heavy feeders" may also benefit from subirrigation propagation. Once cuttings have formed roots, fertilizer might be added to the subirrigation reservoir to speed the growth and development of the newly rooted cuttings (Zhang and Graves, 1995). With further refinement, cutting propagation using subirrigation promises to be a viable and economical alternative to intermittent mist for the commercial cutting propagation of many plant species.

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Ericaceous Plants from Seeds

H.William Barnes

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There is undoubtedly thousands upon thousands of ericaceous plants that are grown annually from cuttings. In many cases these plants are named clones and as a part of the natural selection process the ability to root from cuttings is an integral part of the success of the plant in the market place. However, many individual species of ericaceous plants such as *Rhododendron maximum,* can only be rooted with marginal to poor results and certain plants, such as *Pieris floribunda* and wild forms of *Kalmia latifolia,* can not be rooted at all. Aside from collection from the wild the only feasible source of some *Rhododendron* species and related plants is via seed.

NURSERY PRACTICE

Several key ingredients are essential for good nursery production of ericaceous seedlings.

Of utmost importance is fresh seed. Since many ericaceous plants have seeds ranging in the neighborhood of 300,000 to the ounce the likely hood of seed degradation over time is to be expected. Dirr and Heuser (1987) suggest that seed will remain viable with a moisture level of 4% to 9% for about 2 years if kept in cold storage. However, work done at Lorax Farms has shown seed of *P. japonica* and *Leucothoe axillaris* to degradate after 1 year in cold storage. The importance of fresh seed can not be over emphasized.

Second in line to fresh seed is the need for light. Work done by Blazich et al. (1991) and Duncan and Bilderback (1982) showed that for *Rhododendron maximum, R. catawbiense, and K. latifolia* light was absolutely essential for good germination percentages. Both groups of researchers found that while a minimum photoperiod is needed for good germination (> 4 h) once this level is achieved there is an upper limit of about 12 h with little or no appreciable gain past that point. In practice it

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Ericaceous seed does not need to be cold stratified and, therefore, it can be directly be surface sowed without stratification. This can be facilitated for proper spacing by mixing the seed with fine silica and or as has been suggested by Hamernik (per comm.) sugar. To do this mix 5 to 6X the amount of substrate with 1X amount of seed Mix thoroughly and sprinkle the resultant mixture with a salt shaker over the medium-filled tray (with or without dividing cells). Afterwards the seed should misted thoroughly so as to wet both the seed and the medium.

The selection of media is important as too coarse of a mix will result in the seed being washed down into the crevices and consequently be hidden from the light. While milled sphagnum is an appropriate choice, it is inconvenient to use and there are numerous brands of commercial bag propagation mix that readily fill the bill Caution should be exercised in choosing a mix that has a uniform texture and not one that is more suited as a potting mix Two excellent mixes are Grace Sierra Vegetable Plug mix and Grace Sierra 300 or 310 mix

Damping-off fungi can sometimes be a problem and this can be readily corrected by watering the soil prior to seed sowing with either Manzate at 1 tsp gal^{-1} or a benlate derivative. If Manzate is used it has the dual purpose function of stopping the spore germination of both mosses and liverworts These weed-like pests can rapidly overcome the tiny seedlings making further growth and transplanting virtually impossible.

It should be noted that the fungicide must be applied before the seed is sown and may need to be applied at regular intervals afterwards if the mosses or liverworts become noticeable.

Once seed is sown the trays can be placed under intermittent mist or hand misted on a regular basis Duncan and Bilderback (1982) had over 90% germination of *K. latifolia* and 88% germination of *R maximum* when the seed trays were placed under intermittent mist

Once seedlings are quite evident it is best to remove the trays from the mist and institute a regular hand watering or misting to provide adequate moisture When in a greenhouse environment care must be exercised to prevent the seedlings from becoming too hot High temperatures can lead to cessation of growth prematurely and will often give rise to the occurrence of damping-off fungi

When the seedlings are around 4 or 5 mm high and have true leaves they can be successfully transplanted. The tiny seedlings are often too small to be handled by human fingers and the transplanting can be facilitated by using 15-cm (6-inch) forceps. The tip of the forceps are excellent for teasing apart the very tender seedling and for grabbing the very small roots and dragging them down into contact with the new potting medium. Once transplanted seedling trays are finished they should be watered in with the Manzate mixture as described above They then should be placed under intermittent mist for 5 days and at the end of that time they should be removed to a regular greenhouse or nursery bench and treated as normal seedlings

TIPS FOR TRANSPLANTING ERICACEOUS SEEDLINGS

1) Soil Use fine-grained material such as Grace Sierra 300 or Vegetable Plug Mix.
2) Pretreat soil before sowing of seed with Manzate- or Benlate-

derivative-type fungicides to prevent damping off. Mazate has additional benefits of preventing mosses and liverwort.

3) Mix seed with fine silica sand and/or sugar. Sprinkle on with a salt shaker to achieve uniform distribution of seed.
4) Transplant seedlings after true leaves have formed. Usually seedlings are 5 mm in height. Use long forceps as a transplant tool. Be sure to treat transplant soil with fungicide prior to insertion of seedlings.
5) Place transplanted seedlings under mist for 5 days, then remove and treat as normal seedlings. Avoid high light and high heat conditions. Begin fertilization starting with 100 ppm N.

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Rhododendron maximum for the Next Millennium

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INTRODUCTION

Rhododendron maximum is locally known as great laurel, great rhododendron, rosebay, or max depending upon where it is encountered. Despite an extensive native range from Georgia into Ontario, Quebec, and Nova Scotia, it is only locally abundant to the point of being a dominant understory species in and near the Appalachian mountain range of North America. *Rhododendron maximum* is a much sought after plant for landscaping where a bold evergreen shrub is needed in shady locations. Full sun is tolerated only in the coolest parts of the native range.

The most common current use of *R. maximum* is for screening in shady areas or to enhance natural landscapes, particularly those involving stonework. Since plants 30 ft or more tall and 20 ft across exist, it can provide a formidable screen with time. Trusses composed of 20 to 30 flowers are most often about 4 inches across and white with yellow spots at the base of the corolla but pink-flowered forms are common in the Appalachian highlands. The most distinctive feature is narrow, dark green leaves from 4 to 12 inches long and 2 to 3 inches wide (Bir, 1992; Leach, 1961).

PRODUCTION PRACTICES

Wild Collecting. In states, such as North Carolina, where it is currently legal to collect wild rhododendrons, by far the largest numbers of plants entering commerce are wild collected from either private or public lands. A permit for collecting plants in some National Forests can be obtained from the U.S. Forest Service. *Rhododendron maximum* is not a currently endangered or threatened plant in the southern Appalachians.

Collecting is typically done by independent contractors who dig "pans" (shallow rootballs), tying up branches while balling and burlapping root systems. Plants are harvested from a few weeks after first frost in the fall until new growth starts in late spring. At the highest elevations, this can be an 8-month harvest season. "Pans" are harvested because roots typically do not extend deeper than a few inches into native soils. Plants are most often harvested from areas where they are locally abundant and often are threatened by residential and road development or timber harvesting. Many of these plants would be destroyed if not harvested for ultimate landscape use. Collected plants are almost always sold to rewholesalers who act as brokers. These plants are often 4 ft or more tall.

Cut-offs. Often the most luxuriant collected plants shipped to market are the result of either timber production or land clearing for some other purpose. These plants are pruned to the ground then multiple sprouts are allowed to develop for a few years before plants are balled and burlapped for shipping to market. In this system of production, most of the root system remains in North Carolina soils when the vigorous new tops of plants go to market. Despite this, survival rate, if plants are only moderately well cared for, is high. Cut-off plants are usually about 3 ft tall when marketed and possess many vigorous stems with little branching of individual stems near the earth.

Cutbacks or Stock. In this system of production, the tops of plants are removed, rootballs dug and transported to a field nursery then replanted at the same depth as they were originally growing in the wild (Bir, 1981). Soil in production fields is prepared ahead of time; pest management, pruning, and fertilization are practiced. These are truly nursery-grown plants with rootstock being the propagules collected from the wild. Generally, 4 years are required to produce 2-ft tall plants which are harvested over the following 3 to 5 years due to plant-to-plant variation in growth rate. Since both root systems and tops of plants are regenerated at the same time, they are in balance. These plants have an excellent survival rate in the landscape when provided any reasonable care. I estimate that these plants account for no more than 10% of *R. maximum* available for sale in most years.

Seedlings. Seed may be harvested in fall. These seeds have no stratification or scarification requirement but are tiny with seed counts reported in excess of 100,000 per ounce. Light is required for seed germination (Blazich et al., 1991; Duncan and Bilderback, 1982). A few growers are sowing seeds either under lights indoors or in outdoor seedbeds under shade similar to practices used in conifer seedling production (Bir, 1985). Plants from indoor production are pricked out of seed flats and transplanted into containers where they are grown for 1 to 2 years. Plants in outdoor beds are generally allowed to develop in germination beds for 2 to 3 years.

From both methods of seed propagation, plants are most often transplanted into beds or into the field. The best quality plants are produced under shade below 3000 ft. in elevation in North Carolina or in sun on north- or east-facing slopes with protection from wind at elevations greater than 3000 ft. Proper site selection for good air and soil drainage as well as soil preparation to remove obstacles and provide proper preplant nutrition based on soil analysis prior to planting is essential for high quality plant production. While excellent plants can be produced by this method, obtaining an adequate price for a 6- to 8-year-old plant grown from seeds that is 24 to 30 inches tall has been difficult. I estimate that less than 5% of plants available in any year are produced by this method.

Cuttings and Micropropagation. To my knowledge there is no commercially significant production of *R. maximum* by either of these methods. Experiments in cutting propagation have shown promise (Williams and Bilderback, 1980) but have not been pursued.

DISCUSSION

Rhododendron maximum is a desirable landscape species that may become nearly impossible to purchase in commercially reasonable numbers if current trends continue. Approximately 95% of plants currently sold have their origins as wild plants. We are mining the existing resource with no knowledge of whether such production is sustainable yet *R. maximum* does not appear to be threatened or endangered in the southern Appalachians. Current production appears to be a very slowly renewable resource via wild collection, cut-off, or cutback production.

With increased land development in areas where *R. maximum* is abundant, increased social and political pressure to preserve existing populations on public lands, and a reduction in independent contractors willing to do the hard work of digging plants from the wild for relatively low wages, true nursery production rather than wild harvest of this valuable landscape plant is being encouraged. The technology for some production practices already exists. However, until there is economic incentive to nursery propagate and grow this species little true nursery production and development of superior commercial production technology can be expected to occur.

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Ledum groenlandicum and *Chamaedaphne calyculata*

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Ledum groenlandicum and *Chamaedaphne calyculata* are plants native to North America in damp, boggy situations. Although, in my experience, I find that *Ledum* tends to like areas that are not quite as wet as those where *Chamaedaphne* can thrive. Both of these plants are little known to most nurserymen. I'm sure quite a few nurserymen know them only as weeds in container mixes containing Canadian peat. *Ledum groenlandicum* (Labrador tea) tends to stay further North than *Chamaedaphne*. It is primarily native from Greenland across Canada, south into Washington State, and on the East Coast down into the mountains of Pennsylvania. It will, however, tolerate warmer climates if given enough moisture and does quite well in our nursery in Connecticut. Labrador tea gets about 2 to 4 ft high and about the same size in width. The leaves are evergreen; however, in some winters they can be damaged to the point where we might only call it persistent leaved. The flowers are perfect white corymbs covering the plant in late June in most northern areas — perhaps late May in the southern borders of its range. Propagation in the nursery is quite simple. At Summer Hill we take the cuttings in late January, wound them, treat them with Dip 'n Grow (1 : 15, v/v) and stick them in a peat and perlite (1 : 1, v/v) mixture with bottom heat and minimal mist. They root quite readily for hardwood cuttings, and you can expect very close to 100% rooting. After the cuttings are rooted, we flat them in a peat and perlite mix, and they produce the first flush of growth in the greenhouse. After shearing this back a bit, they are planted in 1-gal containers in June. We consider the plants salable after two summers, and those that are not sold at that point are kicked up into 2-gal containers to be grown on for 1 more year. The market for *Ledum* is not great as most people do not know the plant; however, it is quite an effective plant for damp areas. Although it is not of great ornamental value, it is quite a pretty thing when it is in bloom. As far as I know, there are no named selections of *Ledum* in the trade. The plants we grow originate from cuttings I took along Route 16 in northern Maine, not far from the New Hampshire border.

Chamaedaphne calyculata, leatherleaf, is a plant that is very valuable for wet, boggy areas. However, at least in my estimation, it is an uglier plant than *Ledum* — small evergreen leaves that are a poor green in the summer and turn brown in the winter with a plant habit that can be rather open, scraggly, and unappealing. It does have white bell-shaped flowers in the spring, somewhat similar to blueberries, and at the time of blooming, can be quite an attractive plant. Its range goes much further south than *Ledum*, probably as far as Georgia in the cool areas of the state. I have observed a rather good-looking specimen only about 50 ft from a salt pond in Rhode Island which leads me to believe that, at least, some members of the species are quite salt tolerant.

At Summer Hill, we propagate leatherleaf about the same time as Labrador tea and treat them about the same way. However, you must be careful to take cuttings with plenty of vegetative buds below the flower buds at the end of the stem. We take cuttings the end of January, wound the cuttings, treat them with Dip 'n Grow (1 : 15, v/v), and stick them in a peat and perlite mix (1 : 1, v/v) with minimal mist. The rooted cuttings are put into flats of peat and perlite. Their first growth, and perhaps the second, in the greenhouse are sheared, and they are planted into 1-gal containers in early June. They grow to a salable size in 2 years, being sheared several times in the process. Even with shearing, however, it is difficult to produce a nice, full *Chamaedaphne*. As with Ledum, some plants are kicked up into 2-gal containers for another year.

Now comes the interesting and, I believe, valuable part of my talk. A few years ago, Tom Dilatush, who I'm sure most of you know, sent me seed and some cuttings of *C. calyculata* from a population in Dare County, North Carolina on the Virginia border. This area has a rather large population of *Chamaedaphne* that is far more compact than the type plant. While some of the seedlings show some promise, we have not yet selected any of them for propagation; however, four of the cuttings have produced plants that are very interesting to us — tight, full, beautiful little plants that could be valuable additions to moist or wet areas in the landscape. These produce plants that are as full, tidy, and as aesthetically pleasing as many small leaf rhododendrons; however, they are not susceptible to *Phytophthora cinnamomi* (rhododendron root rot). Three of these selections bloom profusely, giving the plants a dwarf *Pieris japonica*-type aspect when blooming in late May and early June. Tom and I feel that these selections, and perhaps one or two more from the seedling group, have great promise for ornamental plantings in damp areas unsuitable for azalea or rhododendrons. We haven't named them yet; however, if anyone is interested, please write to me and we will be more than glad to send you some cuttingwood after we've made our final selections and have given them names.

Calluna Propagation

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Propagation is a lot like cooking. My father's Aunt Margaret was a very good cook, but when my mother tried to duplicate one of her recipes, it never worked. Mother privately accused her of omitting some necessary ingredient on purpose, but in my kinder moments I want to think that it was just a matter of individual differences that regulated the outcome.

Individual differences play a big part in propagation. One person's technique in making cuttings is different from another's. Everyone varies somewhat from the norm, no matter how hard we strive for uniformity in our procedures. We each bring our own set of habits and experiences to the propagating table. At Sylvan Nursery we propagate thousands of heathers annually. Our procedures are simple and straightforward, but even these are sometimes difficult for others to duplicate.

We take semihardwood cuttings from our stock plants in January. We do this at that time of year because it fits our schedule. I don't need to tell you why this is sometimes difficult. Snow can be a factor. This past spring we put up two new greenhouses to aid in the situation. We have planted stock plants in the floor of the houses. The houses will be covered with poly in the late fall so that the plants will be accessible, yet still dormant, when the time comes to take cuttings.

Winter is the ideal time to take cuttings for the summer-flowering heathers and heath, such as *Bruckenthalia*, but probably not the best time for the winter-flowering heaths. To somewhat compensate for the plants being in flower, we remove the blossoms on the winter heath before sticking to lessen the stress on the plants caused by transpiration.

Juvenile tissue is best to use, but really the general health and vigor of the cutting is of greater importance. The wood must be such that the ratio of stored sugars to nitrogen in the tissue approaches one to insure good adventitious rooting. Too much nitrogen and cuttings will rot, too much sugar and cuttings will not root. Fresh material is taken each day for the next day's work. Rarely, do we use anything older than 24 h.

Cuttings are made with sharp knives or shears which are periodically dipped in fungicide. Crews work together doing one cultivar at a time. Because of these "individual differences" which are inherent in the process, it is easy to identify the crew member when the cuttings do not measure up to the supervisor's standards. Corrections can then be made quickly.

Before sticking, the cuttings are first dipped into Hormodin #2, a talcum-powder-based indolebutyric acid product. They are then laid in rows in flats and covered with newspaper. Next they are taken into the greenhouse to be promptly placed into the bench. Cuttings are not allowed to dry out for any length of time.

Our propagation benches are filled with #2 washed builder's sand, watered well, and then pounded to remove any air spaces in the sand. The tools of the trade are simple: pounders, hammers, linolium knives and a 1 inch × 1 inch strip of wood, the length of which is the width of the table. Benches are as wide as two people can reach, one from either side.

After re-pounding the sand, the stick is laid across the sand and hammered into place to mark the line. The slice is made with the linoleum knife and the cuttings are lined up in the groove. Once the line is filled, the stick is placed against the line of cuttings and hammered in again for the dual purpose of securing the first line of cuttings and of marking the next. Several times during the day, the cutting blocks are watered in. At the end of the day, they are drenched with fungicide. Last year we began using bottom heat beneath the bench. The greenhouse is kept at 65F during the day and at 55F at night. However, on very sunny days, the temperature in the house can climb to 70 or 80F.

As soon as the cuttings are stuck, they are misted several times a day manually in addition to the automatic misters which are set to spray the bench every hour for 10 seconds. When the weather warms, more frequent mistings are necessary to assure that the cuttings do not dry out. It is most imperative that they are never allowed to dry out. Callunas need an acid medium to root adequately, as well as for growing. The fact that our water supply registers a pH of 5.8 is undoubtedly beneficial to their growth.

Rooting will occur in 2 months or so. Very good results are achieved with *Calluna* or heathers, but only good results are found with *Erica* or heath. The latter is an indication of the relative hardiness of heather to heath. The quality of the cutting wood on heathers is often superior to heath if our weather has had many sudden temperature plunges before the wood is taken. Heath stems will split lengthwise if temperatures vary widely. It is best to pot the cuttings as early in the spring as possible. However, with spring being as busy as it is at Sylvan, that means June.

We use an automatic flat filler to fill the pots and a board dibble to hollow out a potting circle in the soil. The cuttings are potted into Nu Pots using a sandy potting mix of peat, perlite, and sand with gypsum and micronutrients added. In the following year, if not sold, they will be shifted up to 4-inch square pots and eventually into 1-gal containers. Since this is a soilless mix, periodic feedings with a balanced fertilizer improves growth. When necessary, Cleary's or Funginex are acceptable fungicides to use.

After the first year the 3-inch plants are sometimes planted directly into the field for growing on. In 1 year's time we can field pot into 1-gal containers, or sometimes even into 2-gal containers, if the growing season has been good.

Herbicides are not recommended. We have found that herbicides are very destructive to heathers and heath. Hand weeding, although labor intensive, is necessary. In the same field with flourishing plants disasterous results occurred when we used the herbicide, Rout, on one section. The plants showed poor color, lack of vigor, and general plant decline. Similar results were found when herbicides were used in our container production.

Winter protection is a prudent practice on newly planted beds. We have used both straw and Remay cloth to shield the plants from extreme weather. Either covering can be held in place by snow fences. Once plants are established, they can withstand more exposure. In the spring they should be cut back and fertilized lightly.

Heathers offer unlimited variety to the garden. Even one or two plants mixed with dwarf conifers or other shrubs can give a garden winter color, summer bloom, and foliage interest. Foliage can be gold, green, copper, gray, orange, or red. Flowers vary from pink, lavender, fuschia, white, to purple. They all require an acid soil and good drainage. Although they will withstand some drought once established, they should not be allowed to dry out. They are hardy to Zone 5 and sometimes to Zone 4 with good snow coverage. They do not thrive well in hot, humid conditions. The southern zone of their hardiness has not yet been established.

Occasionally new cultivars will spring up in a garden. One such happy event occurred at Sylvan Nursery about 15 years ago when we were collecting cuttings of *C.* 'Sister Anne'. The plant we found was taller and not quite as velvety gray as 'Sister Anne'. It appeared to be very vigorous, so we collected it. Later when we realized that this was a new sport, Neil Van Sloun named the cultivar after a wonderful lady who was on the crew, Mary Ferreira. We have propagated 'Mary Ferreira' for over 15 years and it is still growing well. It is grayish green in color and has a purple bloom. It has been reliable and true to its own characteristics, growing to 15 inches in size and becoming grayer in the winter. The growth habit is upright and the plant forms a dense mound.

Other less well known heathers are 'Kinlochruel', a double white variety which is similar to 'County Wicklow' in growth habit, and a beautiful new cultivar for us 'Dark Beauty'. The latter is the first red-flowered heather that we have found. We hope to introduce 'Dark Beauty' into our line soon. 'Wickwar Flame' also has a bright future. Gold to bright red foliage with a spreading growth habit makes it everyone's first choice.

Heathers deserve greater use. It is rewarding to see that this is beginning to occur. Although they have been widely used in their native areas of the British Isles and South Africa, they have not been used extensively in the United States. The fact that heathers are being featured in national magazine articles and planted in many of the large botanical gardens, such as Longwood Gardens, attest to the renewed interest gardeners are giving them. Heather societies now flourish on both the east and west coasts of the U.S.

It is indicative of the interest in heathers which we are seeing that you have asked me to speak on them this morning. Thank you for the chance to spread the word about these useful plants. White heather has always symbolized good luck. So, we wish you all good luck and may you be blessed with many heathers in your gardens.

In Vitro Propagation and Selection of Superior Wetland Plants for Habitat Restoration[1]

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Increased restrictions on field collection of wetland plants used for restoration and creation have promoted efforts to develop more efficient nursery production practices including the use of in vitro propagation (micropropagation). Selection and in vitro propagation of wetland plant genotypes from populations adapted to particular site conditions could enhance wetland restoration or creation success. In this preliminary study, comparison was made of the early ex vitro growth responses of in vitro propagated *Pontederia cordata* L. genotypes collected from five Florida populations. Significant differences in plant height, leaf production, and flowering between genotypes were observed. Correlation of these early growth differences with capacity for adaptation to specific site conditions will require evaluation of the survival and growth of these genotypes under field conditions.

INTRODUCTION

Once thought of as wastelands, wetlands are now considered important for maintaining water quality, recharging groundwater, providing unique wildlife habitats, and storing flood waters. Federal and state statutes require restoration of degraded wetlands, or replacement of destroyed wetlands (mitigation), through extensive planting and successful establishment of herbaceous and woody wetland species. Requirements for 100,000 plants for a single restoration project are not uncommon. Many wetland species are also used for ornamental purposes in water gardens and aquascaping of retention ponds. Consequently, these markets combined have resulted in rapid expansion of the wetland plant industry (Pategas, 1992).

Herbaceous and woody wetland plants used for habitat restoration are obtained from several sources: (1) bareroot transplants collected from natural populations; (2) seeds and vegetative propagules in mulch or peat from donor wetlands; and (3) nursery-grown seedlings and vegetatively propagated plants. Collection of bareroot transplants from donor wetlands has lead to over-collection in and subsequent damage to donor sites in some areas. Increased restrictions on field collection have promoted efforts to develop more efficient nursery production practices for wetland plants including the use of in vitro propagation (Brumback, 1990; Kane, 1996; Street, 1994; Sutton, 1990).

Nursery production for restoration/mitigation often raises two ecologically important concerns: (1) the lack of knowledge and maintenance of genetic diversity within vegetatively propagated species and (2) the potential negative results following introduction of plants genetically "mismatched" to wetland site conditions. Some

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regulatory agencies have attempted to set guidelines that restrict collections of either bareroot transplants or propagules for nursery production from only local provenance plants within a limited radial distance from a planting site. However, the relationship between geographical source distance and wetland plant adaptability is not known. The practice of selecting and propagating wetland plant ecological varieties (ecotypes) from populations adapted to particular site conditions may more effectively ensure wetland restoration or creation success. Application of micropropagation could facilitate genetic selection, production, and storage of wetland plant ecotypes exhibiting superior adaptation to specific site conditions (Kane, 1996). *Pontederia cordata* L. (pickerelweed), a perennial emergent herbaceous wetland plant, is one of the most frequently used plants in wetland restoration projects in the southeastern U.S. (Brown, 1988). In the present study, the early ex vitro growth responses of in vitro propagated *P. cordata* genotypes collected from five Florida populations were compared.

MATERIALS AND METHODS

Plant Source and Micropropagation. Single plants of *Pontederia cordata* were collected from five Florida populations: (1) shallow marsh, Steinhatchee, FL (**NWCF**); (2) deep-water site, Lake Kanapaha, Gainesville, FL (**NCF1**); (3) shallow retention pond, Gainesville, FL (**NCF2**); (4) white-flower variety, Paynes Prairie, Gainesville, FL (**NCF3**); and (5) shallow marsh, Tampa, FL (**WCF**). Collected plants were established in commercial soilless potting mix (Metro-Mix 500) contained in 1-gal plastic containers and maintained under greenhouse conditions prior to culture establishment. Specimens were verified as being genetically different using random amplified polymorphic DNA (RAPD) analysis (results not shown). Two *Pontederia* varieties, *P. cordata* var. *cordata* and *P. cordata* var. *lancifolia*, are recognized and separated by differences in flower characteristics and leaf morphology (Godfrey and Wooten, 1979). *Pontederia cordata* var. *cordata* and *P. cordata* var. *lancifolia* produce lobed ovate- and lanceolate-shaped leaves, respectively. With the exception of WCF, the genotypes screened were *P. cordata* var. *cordata*.

Each genotype was in vitro propagated by shoot culture and rooted in vitro using previously described methods (Kane et al., 1991). On 21 June 1993, rooted microcuttings were planted into 38-cell trays containing Metro-Mix 500 and acclimatized under mist (5 sec every 10 min) in partial shade for 7 days. Trays were then moved to a 50% shade house when initial measurements were made. After 7 days, 10 plants of each genotype were transplanted into individual 6-inch azalea plastic pots containing Metro-Mix 500. On 6 July, pots were placed in full sun in an outdoor vinyl-lined trough (119 cm × 734 cm) with a water depth of 7.5 cm containing 20-20-20 liquid Peters fertilizer (300 mg liter^{-1} N). A completely randomized block design was used. Plant height, leaf, shoot, and flower number were recorded weekly. However, with the exception of flowering data, only the 9th week data collection is shown. At the end of the Week 9 study (31 Aug. 1993) the area of two of the newest fully expanded leaves from each plant was determined with a Li-Cor Model LI-3000A area meter. Shoot and root dry weights were also determined. Data were statistically analyzed using the General Linear Model (GLM) procedure (SAS, 1985). Where appropriate, significant ($p \leq 0.05$) mean separation was achieved using Duncan's Multiple Range Test.

RESULTS

The *Pontederia* genotypes screened exhibited significant differences in growth and shoot regeneration during the 9-week growth study. By Week 9, the white-flowered genotype NCF3 exhibited significantly greater shoot and leaf production than the other genotypes evaluated (Fig. 1). Both NCF1 and NWCF were significantly taller than the other genotypes (Fig. 1). The WCF genotype exhibited the shortest plant height and lowest shoot and leaf production (Fig. 1). Genotype had a significant effect on leaf area (Fig. 2). Not surprisingly, the smallest leaf area was observed in WCF, a specimen of the narrow-leaf *P. cordata* var. *lancifolia* (Fig. 2).

Patterns of flowering also differed between genotypes. Flowering was first observed by Week 5 in NCF1 and NCF3 (Fig. 3). By the Week 7 all genotypes were flowering. However, by the Week 9 both NCF1 and WCF ceased flowering. Among the genotypes, flowering was significantly greater (3 flowers/plant) in NCF3. Enhanced flowering in NCF3 may be the result of greater shoot production (Fig. 1). Shoot and root dry weights for NWCF, NCF1, NCF2 and NCF3 were not significantly different. Both shoot and root dry weights were significantly lower in WCF. There were no significant differences in root : shoot dry weight ratios between genotypes.

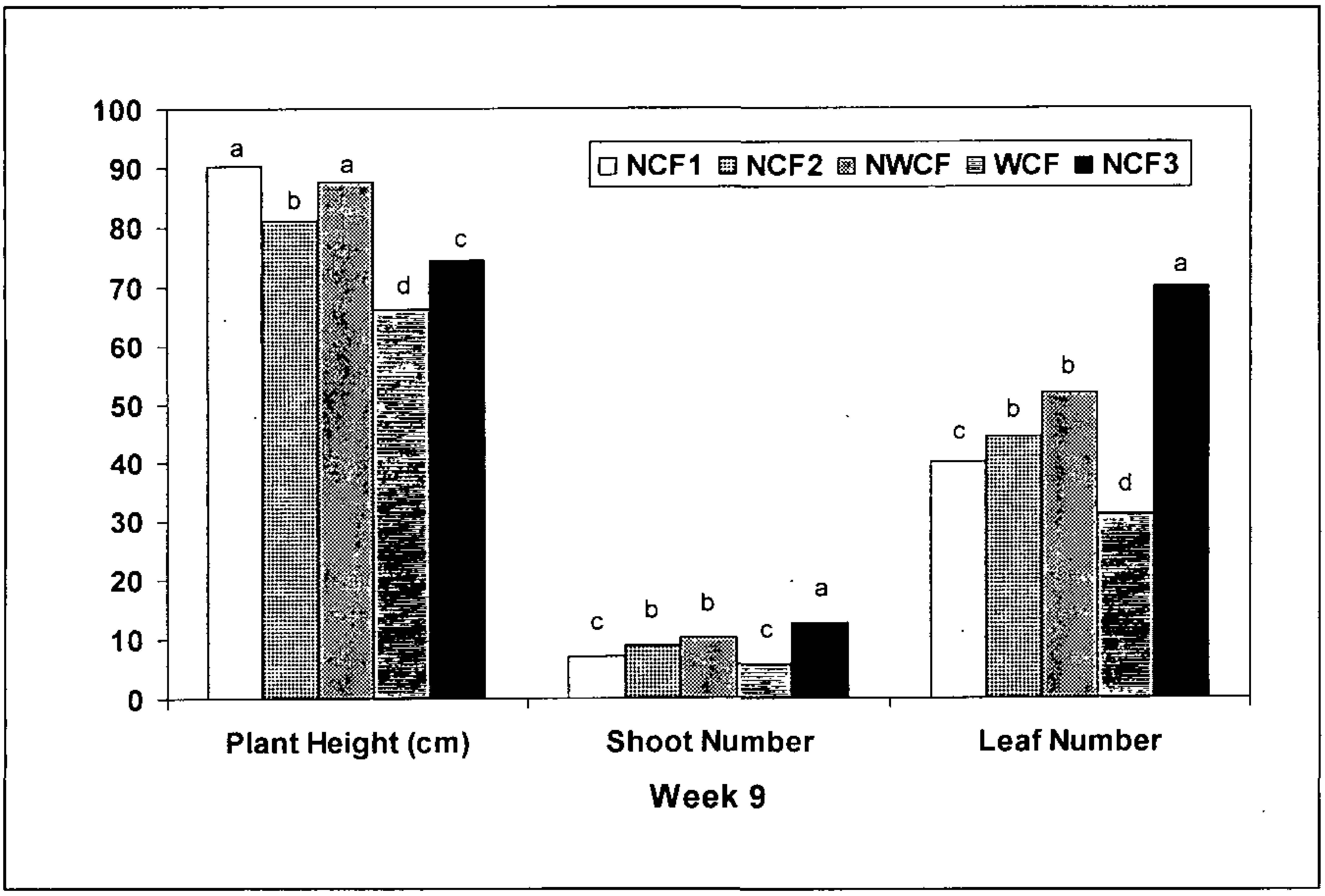

Figure 1. Comparison of plant height, and shoot and leaf production by five *Pontederia cordata* genotypes after 9 weeks growth. Each histobar represents the mean response of 10 plants. Histobars with the same letter are not significantly different at the 5% level.

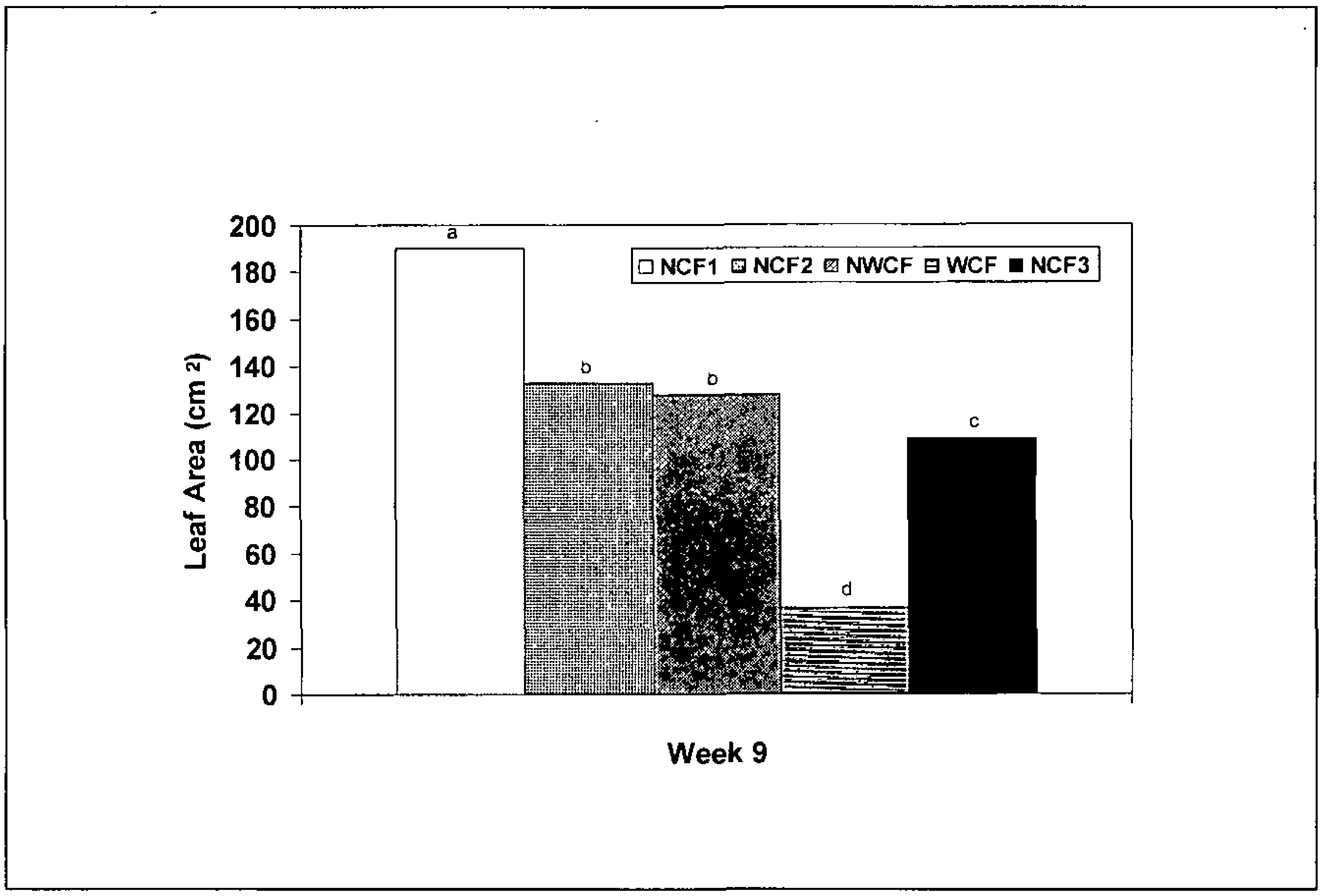

Figure 2. Comparison of leaf area of five *Pontederia cordata* genotypes after 9 weeks growth. Each histobar represents the mean area of the two newest fully expanded leaves from 10 plants. Histobars with the same letter are not significantly different at the 5% level.

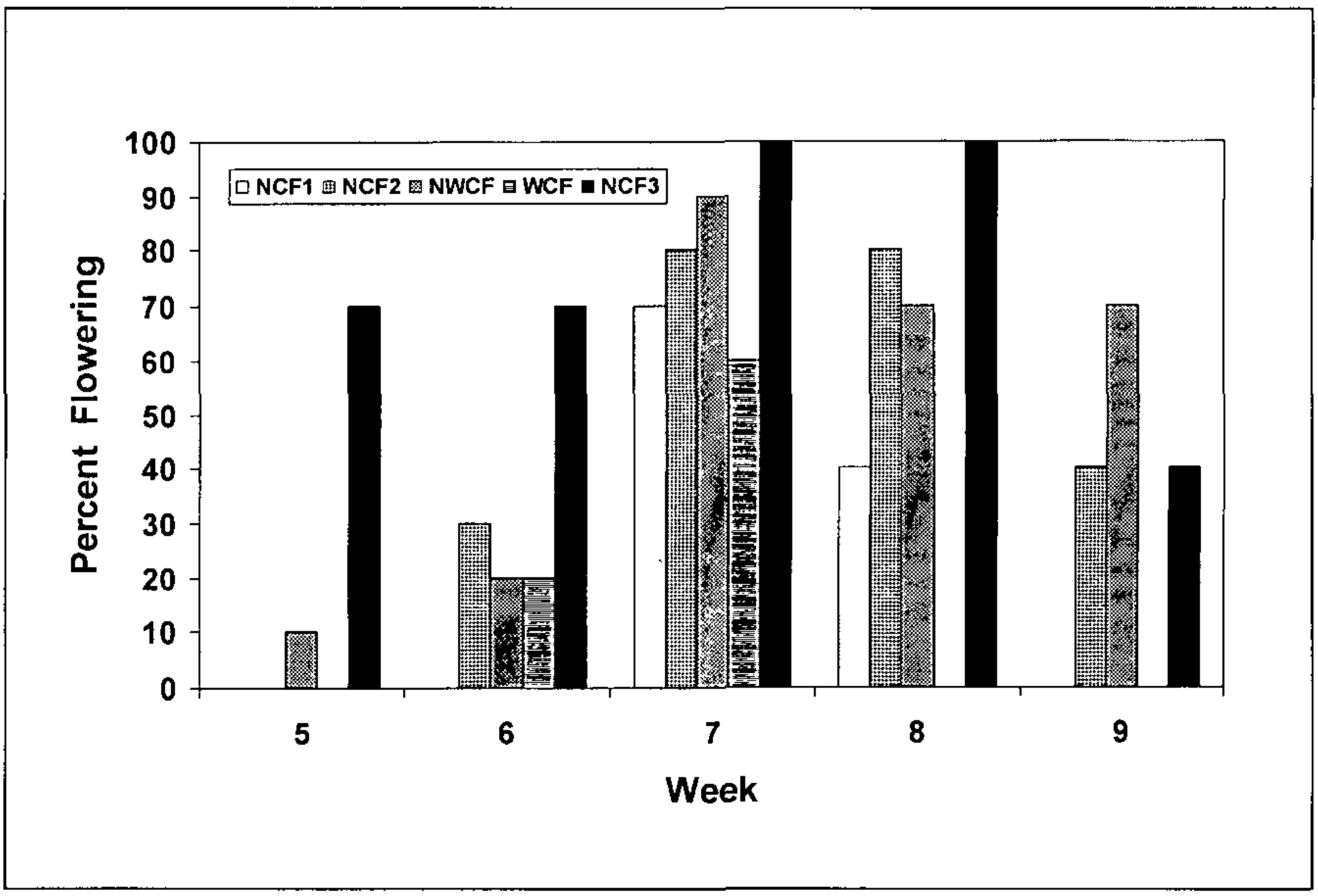

Figure 3. Comparison of flowering response of five *Pontederia cordata* genotypes during 9 weeks growth. No plants flowered prior to Week 5. Each histobar represents the percent flowering of 10 plants.

DISCUSSION

The RAPD analysis revealed that the *P. cordata* specimens collected from the five Florida wetland populations exhibited a high degree of genetic divergence. This is not surprising since *P. cordata* possesses a breeding system in which populations contain individual plants producing one of three floral types (tristyly). Tristyly promotes outcrossing and enhancement of genetic diversity (Price and Barrett, 1982). Apparently, this genetic variation can be observed as differences in the early ex vitro growth and development of in vitro propagated plants.

Presumably genetic variation is beneficial for most species since it allows populations to adapt to changing conditions. Environmental conditions at the donor sites possibly play a role in genetic selection in natural *Pontederia* populations. For example, NCF1 plants, in vitro propagated from a tall large leaf specimen growing in deep water, exhibited similar morphological traits when grown under controlled conditions. Conceivably, these early growth and morphological differences can be correlated with capacity for adaptation to specific site conditions.

Although plants in this study were grown under nonflooded conditions, this screening procedure could be modified to evaluate responses to different hydrologic conditions and soil types. Validation of this procedure would require subsequent field evaluation of the screened wetland genotypes. Survival and growth of four *Pontederia* genotypes screened in this study have been examined under field conditions and results will be reported elsewhere. Selecting and micropropagation of multiple wetland plant genotypes from populations physiologically adaptable to particular site conditions may prove both commercially valuable and useful in ensuring wetland restoration/mitigation project success.

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Cranberries as a Ground Cover

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INTRODUCTION

Most everyone is familiar with the fruit of *Vaccinium macrocarpon*. Cranberries are a traditional fruit with our Thanksgiving and Christmas dinners. Very few people are aware of the potential of this plant as an attractive groundcover.

The American cranberry (*V. macrocarpon*) has all of the attributes of a great groundcover. It is a native North American evergreen vine, wetland adapted, and hardy in U.S.D.A. Zones 2 to 6 (Dirr, 1990). Cranberries have four seasons of appeal with flowers, fruit, and summer and winter foliage. The cranberry is more American than apple pie.

Vaccinium macrocarpon is indigenous to the North American continent. When colonists arrived they found cranberries growing on the peat bogs of Cape Cod and surrounding areas in Massachusetts. Native cranberries were found south in the Pine Barrens in New Jersey, to the North in the Maritime Provinces of Canada, in isolated areas in the Allegheny Mountains in Pennsylvania, and in the peat swamps in Virginia. As the westward migration of settlers continued, cranberries were found growing in the wetlands of Indiana, Michigan, Wisconsin, and Minnesota (Eck, 1990).

The American cranberry is a low-growing perennial vine that spreads by runners or stolons. The cranberry flowers in early to late June with inflorescence resembling the neck, head, and bill of a crane (Eck, 1990). Thus the name crane berry evolved to cranberry. The fruit begins to ripen and turn red in September and is picked in October. The leaves turn a reddish purple in the fall and winter and lustrous dark green in spring and summer (Dirr, 1990).

In the spring of 1992 Degrandchamp Farms Inc. decided to diversify our operation by including cranberry production to our existing 150-acre blueberry farm and nursery. Vines of several named cultivars from Wisconsin were obtained and propagated for a stock block. During the first growing season, some of our garden center and landscape customers wanted to know what that beautiful groundcover was. They were amazed when they learned the plants were cranberries. They thought that they only grew in water. Most peoples' knowledge of cranberries are of ripe berries floating in commercial farm bogs or marshes during harvest. Cranberries can tolerate flooding during dormant periods, but they don't grow in water.

GROWING

Planting Procedures and Sites. *Vaccinium macrocarpon* is an ericaceous plant and needs acidic well drained soils. They will grow anywhere rhododendrons and other acid-loving plants thrive. Planting cranberries in the landscape requires the same soil preparation as would be done for rhododendron. The use of peat moss incorporated in the soil and planting in raised beds in clay soils is essential. Small 4-inch pots can be planted 12 inches to 18 inches apart and will fill in within a year. Mulching with fine pinebark when first planted will help the runners root. Full sun will increase flowering and fruit set, but they can tolerate some shade. Because cranberries are an evergreen vine, windswept exposed sites should be avoided unless winter protection of snow or straw mulch can be provided. In more protected sites no winter protection is needed. In our nursery, cranberries are grown in 4 inch and 1-gal pots and overwintered outside above ground with only normal snowcover during winter. Planting in large tubs or planters is very sucessful by using an acid mix of peat and pine bark (1 : 1, v/v).

Water and Fertilizer. Adequate soil moisture needs to be maintained because the plants are shallow rooted.

Good drainage needs to be maintained during the growing season. Avoid excess nitrogen fertilizers after plants have become established. This will promote upright fruiting growth instead of vegatative runner growth.

Maintenance. Cranberries are relatively pest free and form a dense mat that suppresses weed problems. Excess vine overgrowth should be trimmed off to promote better fruit ripening and development. Pick the fruit when dark red and store in your refrigerator until Thanksgiving.

Vaccinium macrocarpon makes an excellent alternative to many evergreen groundcovers. It is a native wetland plant, with excellent four-season appeal. The beauty and versitility of cranberries makes them ideal for increased use in northern gardens.

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Growing *Pieris* to Landscape Size

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There are many nice selections of *Pieris* and except for *P. floribunda* they are easy to propagate and grow. Most of our emphasis is on *P.* 'Brouwer's Beauty' which is a cross between *P. floribunda* and *P. japonica*. It is bushier and lower growing than *P. japonica* and seems to have inherited resistance to lacewing fly from *P. floribunda*. We have adopted a no-spray policy in the nursery for the last 3 years and it seems to be working. The flower buds of 'Brouwer's Beauty' have a nice maroon winter color which is very effective in the landscape.

Our greenhouse propagation year starts about 1 August. The rooting operation begins after washing down the greenhouse with a Clorox solution. Vegetative cuttings 3 inches to 4 inches long are best, although flowering shoots can be used by removing the flower buds. Cuttings from young plants and shaded plants are better than from older plants growing in full sun. Cuttings are stripped of leaves except for the top 4 or 5, lightly wounded on both sides, dipped in Hormodin No. 3 or, Dip 'n Grow, or Woods solution diluted 1 : 7 (v/v). We then stick in 4-inch deep flats or greenhouse benches in a mixture of peat and pine bark (1 : 1, v/v) with the fine bark particles graded out. By the middle of October they are well rooted. We then cut them out of the flats , transplant them about 4 inches apart, and place them in a cool greenhouse maintained at a 55F night temperature during the winter. The planting mixture in the cool house is peat and ungraded pine bark (1 : 1, v/v). Approximately every other time we water during the winter we soak the benches with a half-rate Peters starter fertilizer solution. We let the benches become quite dry between watering, this eliminates our need to use fungicides. Watering is done in the morning on sunny days so we can turn the fans on and dry off the foliage quickly. We think this does slow down the growth somewhat, even so by spring the plants come out of the benches with a good firm 4 inch × 4 inch rootball.

The liner beds are plowed as deep as possible the previous fall and left open. Around 1 May when the ground has dried out we add 2 inches of peat to our lighter soils and 3 inches of ungraded pine bark to our heavier soils. At this time a light dressing of urea is also rototilled into the beds. The spring transplants have 1 or 2 flushes of growth and are planted at a 10 inch × 10 inch spacing and shaded with snow fence. Before bringing to the liner beds the plants are soaked in a starter solution in the greenhouse.

Pieris floribunda is a more connoisseur-type plant and certainly not the money maker of *P. japonica* selections. Due to the fact that *P. floribunda* is difficult to root from cuttings, we collect our seed from a native stand in West Virginia. The seed is sown in flats of peat and pine bark medium (1 : 1, v/v) topped with a 1/8-inch layer of sphagnum moss and placed under intermittent mist. During the winter the seedlings are transplanted to 4 inch deep flats so they can be moved to the shade house for the summer. They are set out in liner beds the 2nd spring after germination. *Pieris floribunda* is more difficult to establish in the landscape. It prefers overhead shade with a well drained high organic soil. A north slope is also best.

Prior to transplanting the bed-grown liners to the field, the ground in late April is sown with Sudan grass which is mowed and fertilized during the summer. Around the end of July the Sudan grass is plowed under. After growing 2 years in the liner beds, we start field planting around mid-August and on into October. The green manure Sudan grass is rototilled in as we plant each row. We do no spring transplanting of liners because we are busier and the ground is usually too wet. In addition, the watering needs are more critical during the summer.

The liners are dug out of the beds and soaked in tubs of starter fertilizer prior to planting. High phosphorus fertilizer enhances the root growth of both transplants and seedlings. The soaking meets the watering needs of the new transplants in the field for 2 weeks or more. Even in this present dry fall, we have not had to do any additional watering. In the middle of September, oats are sewn over the top of the transplants to provide winter protection and keep the ground from washing away. The oats are killed by hard frost.

After 2 years in the field the *Pieris* should be excellent, full, 18-inch to 24–inch plants with a good root system, which will thrive in the landscape.

Native Azaleas – Beautiful, Versatile, Dependable[1]

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INTRODUCTION

Thank you for inviting me. I feel most unqualified to be here talking to an international group of professional propagators when I probably should have followed my friend, Jim Cross', advice and spent more of my time writing verse than trying to be a propagator. But by way of introducing you to myself and to CARLSON'S GARDENS, where we grow over 2000 cultivars and species of azaleas and rhododendrons and ship them all over the country, I'll read to you from one of the mailing pieces we've been sending to our customers with a color photo of 'Carlson's Coral Flameboyant' azalea. The verse on it is called,

"Buy Big & Save"
Buy yourself some politicians
But don't neglect your yard.
Azalea costs are not recurring –
No future bills for each dance card.
Buying Bill may buy Bill time,
But big azaleas are no crime,
And unlike time for politicians,
The time you'll buy will not be hard.

For nearly 30 years I've been collecting, hybridizing, propagating, growing, and marketing native azaleas. So I'm hoping that some of my enthusiasm for them will rub off on some of you. We grow many other types of azaleas and rhododendrons, such as 'Gable Walk', but native azaleas were my first love — initially because of the intense fragrance of some of them — and secondly because of the ease with which a novice nurseryman could propagate the species from seed.

But to put our discussion in the proper geographical perspective, let me first explain that CARLSON'S GARDENS is located 50 miles north of New York City in Zone 6a. So the third reason for my enthusiasm for native azaleas concerns their hardiness. These deciduous plants don't object to the fact that CARLSON'S GARDENS is a container nursery that operates in this inhospitable climate without any wintering-over structures. The only winter protection our containers receive is a mulch of wood chips. If a plant doesn't like that treatment, it ends up on the compost pile. As a result we market our plants as being "northern grown and acclimated".

Fragrance was what started me growing azaleas many years ago, and the azalea 'Hot Ginger & Dynamite' is the one which motivated me and has also influenced many of my customers including:

Mrs. Jeremiah Aloysius Withington III
Always leaves for Maine each year about June 23rd
With several cats and dogs, the cook, and just a maid or two –
"It's still a trifle chilly, but one does what one must do!"
A single day of summer south of Maine is quite unheard
Of, when you have a pedigree like 'Withington III'.

[1]Copyright 1997 Bob Carlson

Meanwhile back in Upper Crust her garden scene is quiet,
Since plants are only authorized to hold a Springtime riot.
"What's the use of summer blooms that I'm not there to see?"
But can you guess whose gardener left behind did not agree?
Who after many bloomless summers went June 24th
And bought azaleas that would bloom while Withington was North?

But it so happens that he chose some fragrant *arborescens*,
Which proved to be the source of one of Nature's harsher lessons –
That trips are less precise than blooms, he hadn't fully reckoned,
For *arborescens* in full bloom on June the 22nd
Not only got the trip to Maine historically deferred,
But gets him three more weeks each year of Withington III.

Rhododendron arborescens, the sweet azalea.

Rhododendron arborescens is commonly known as the sweet azalea. 'Hot Ginger & Dynamite' is our selected clone of *R. arborescens* that was introduced nationally a number of years ago in both *Horticulture* and *Flower & Garden* magazines. It is extremely fragrant and the original plant has been a long time favorite of visitors to our gardens.

Like most of the native azaleas, *R. arborescens* is native to the eastern United States. It makes a gorgeous large shrub, typically 6 to 8 ft in 20 years in our gardens. Give it lots of room because it will be fully as wide as it is tall. The stock plants from which we take our seed all tend to form a lovely umbrella shape as they mature. Whether this is true of all populations of the species, I can't say. But we're very pleased with that attribute in ours.

Rhododendron arborescens is intensely fragrant and capable of perfuming the air for a considerable distance – probably 20 ft or more. Just as important, they bloom in late June into July after most other azaleas have finished. The deciduous foliage is a shiny deep green that remains attractive and trouble free throughout the growing season. The flowers are typically a clear white with pink stamens that are apparent only as you get up close.

But there can be some variation in flower color, and as a hybridizer and collector, it is those variations that I have been looking for and selecting for future propagation.

- **'Fringe on Top'.** This is another fragrant selection with a decided fringe to the upper petal. Our original plant is at least 7 ft tall by 7 ft across in about 20 or so years. In its maturity it is mounding over to form the handsome umbrella shape.
- **'Summer Parasol'.** 'Summer Parasol' is the exception that proves the rule. It started forming its parasol shape at a height of about 3 ft — all without any pruning to help it.

Next, I'll discuss some our newer *R. arborescens* selections. Most of these are in shades other than white.

- **'Deed I Do'.** This is a large light salmon pink with a light gold flare framed in lighter pink. It is very fragrant and blooms in early July.
- **'Intermission Riff'.** A selection that usually blooms in late June during the intermission between *R. atlanticum* and *R. arborescens* with a delicate pale pink with a faint yellow blotch or flare. It, too, has a delightful fragrance.

- **'Sweet & Lovely'**. A white flower with a faint pink blush, red stamens, and distinctive golden yellow flare characterizes this cultivar. It is very fragrant and appears to be more compact than most. It blooms from late June into July.
- **'Bronze Age Beauty'.** This cultivar is another blush pink. Each year's new leaves open with a bronze color that concentrates towards the tip and outer edges of the leaves as they mature, while the inner portion becomes a nice bright green. The striped effect of green down the center of the bronze leaves is very striking.

***Rhododendron atlanticum*, the coast azalea.**

This species is native to the eastern United States coastal plain. It is typically a smaller and twiggier plant than *R. arborescens* staying in the neighborhood of 3 to 4 ft in our gardens. Another characteristic is its lovely soft gray-green foliage. Normally it is white. If you want fragrance, but don't have room for *R. arborescens*, then some form of *R. atlanticum* is probably your best choice.

- **'White Heat'.** This cultivar is as generous with its fragrance as *R. arborescens*. However, it blooms in late May and early June with white blooms while we are still anxiously awaiting *R. arborescens*.
- **'High Society'.** This has a touch of pink at the base of the corolla.
- **'S Nice Like This'.** A large fragrant white flower with a flush of pink on the upper petals is the feature of this selection.
- **'Milenberg Joys'.** This is a delicate pink with a hint of gold in the throat; add a touch of yellow and you have 'Oh, Baby', add ruffles to a soft pink and you have 'Anything for You'.
- **'Easy To Love'.** Peachy yellow buds opening to a creamy yellow with peach edging.
- **'Somebody Loves Me'.** Similar to 'Easy To Love' but 5 days later with a touch more yellow and slightly more fragrance.

Choptank River Azaleas.

The original Choptanks were natural hybrids of *R. atlanticum* mixed with a bit of *R. periclymenoides* that were found growing wild in the vicinity of the Choptank River by Polly Hill of North Tisbury Azalea fame. She originally described them as follows:

"The flowers have a wider flare than the pure white species and the clusters are showier. The glandular hairs, stamens, and pistils are a sparkling deep pink against white petals. The fragrance is intense and delightful, especially on a damp day or in the evening. They bloom directly after the lilacs (either side of Decoration Day into June for 2 or 3 weeks) and cover our 'farm', just as the lilacs do, with a wind born spring fragrance."

She continues: "The color comes from hybridizing with *R. periclymenoides*, I am told; and the plant is a stabilized wild hybrid, but basically *R. atlanticum*, coming true from seed. The plants grow 2 or 3 ft only, or to 4 ft or better in partial shade. They will take much exposure and are drought tolerant to an astonishing degree. Being very stoloniferous, beds quickly fill in, and mulched by oak leaves from above, they need no better food. I strongly recommend them for natural-looking mass planting."

She convinced us that we'd better try them. So we planted the seed she sent us, and have been growing Choptank River azaleas ever since. Over the years we have continued to propagate Choptanks from the seed of one of her original named selection which she calls 'Marydel'. We also have made some selections of our own.

- **'Choptank River Belle'.** This was our first Choptank selection. It is similar in its coloring to 'Marydel' but seems to be a bit more vigorous, having grown a foot or more taller over the years.
- **'Choptank River Doll'.** A cultivar having a fragrant light yellow with a deeper yellow flare and a reddish tube.
- **'Choptank River Queen'.** This selection with pink striped buds opens to a fragrant white with rose tips at the ends of the petals.
- **'Choptank River Sweet'.** 'Choptank River Sweet' is a very fragrant buff yellow flushed with peach accented by red stamens, an orange-red tube, and a light golden flare.

Before I continue my discussion of what the flowers of some of the native azaleas look like, let me call your attention to the fact that some of these native azaleas have been designated as either threatened or endangered somewhere in their native habitat. So if you, too, are concerned with preserving our native flora, you'll want to remember that while:

We mourn the long gone dinosaur –
Except for bones, he is no more.
Wooly mammoth – same sad plight:
Only tusks still come to light.
When whooping cranes have flown the coop;
Their missing whoop won't be from croup.
So let's make sure we've given room
To wild azaleas and their bloom.
We can't do much for tusk and bone,
But natives can be grown at home!

Rhododendron cumberlandense (syn. _R. bakeri_), the Cumberland azalea.

Rhododendron cumberlandense is native to the Southeastern United States. It blooms in combination with our Kousa dogwoods in late June into July. We particularly like it in the garden for its horizontal branching habit, much like our native dogwoods. In addition it seems to be even more shade tolerant than most other native azaleas. We initially considered them to be relatively low growing, but now have some in our own gardens that are at least 6 ft or more in 20 years. The strains we are growing are predominantly in the orange-red shades like 'Baker's Dozen'.

- **'Baker's Dozen'.** This is a particularly floriferous orange with exceptionally large trusses.
- **Bakeri 88-1.** Bakeri 88-1 has not yet been named. It has a deeper pink ribbing down the center of each petal, and a frosted look to the edges of the petals.
- **'When You're Smiling'.** This is a soft golden yellow with peach-pink edging to the petals.
- **'So Ready'.** This is our deepest red to date.

A number of years ago we swapped seed with a gentleman who had collected seed from a native stand of *R. cumberlandense* on Gregory Bald. The plants from that seed have proved to be quite similar to the strains we had previously been growing, but we have continued to propagate them separately.

- **'Yellow Gregory Bald'.** A selection that we saved for ourselves back in 1988. It proved to be a lovely soft yellow with a large deep golden flare.
- **'Wait A Minute'.** This cultivar is called 'Wait A Minute' for its ability to change colors as it matures and to display multiple colors all at the same time, a characteristic of *R. cumberlandense* that occurs more frequently than we once thought.

***Rhododendron calendulaceum*, the flame azalea.**
This species is also native to the Eastern United States. It can flower in a remarkable range of bright yellows, oranges, and reds, and in-between combinations, from late May well into June. It can become very tall in time, at least 6 to 8 ft and often higher. The strains we are growing tend towards the oranges, although some are gorgeous soft yellows with deeper golden flares.

- **'Jazz'.** This is one of our favorite clones of the flame azalea.

"The shrub's aflame!" the gardener said –
"Fiery blooms of orange-red;
Blazing yellow; smokey rose –
So get your Kodak, not the hose."

- **'Ruffles & Flourishes'.** 'Ruffles & Flourishes' is a rather spectacular pink.
- **'Carlson's Coral Flameboyant'.** Our nurseries earlier blooming form of *R. calendulaceum* with large flowers in bright shades of coral that blooms for us in mid-May. We find that it carries spectacularly in the garden. I have color postcards of it here for any of you who would like one.

***Rhododendron periclymenoides*, pinxterbloom azalea.**
This azalea which someone with a marvelous sense of humor has renamed from *R. nudiflorum* to *R. periclymenoides*; perhaps just to make it more difficult for those of us who like to write verse. In any case it called for some mild form of retaliation. So with a tip of my hat to Mr. W.S. Gilbert of Gilbert and Sullivan I offer you a verse entitled:

"Azalea buttercup"
I'm called *schlippenbachi*,
Named for Mr. Schlippenbach,
Although he was not my first choice –
Far too rarely taxonomists,
Historical botanists,
Give namesakes that much of a voice.
Do you think *nudiflorum*
Was furnished a forum
When renamers revised the last time?
Was my naming an omen
That they'd find a cognomen
That folks can't pronounce, spell or rhyme?
Some day some revisionist,

Ambitious taxonomist
May learn who first gave me the eye –
'Twas poor Mrs. Buttercup,
Sweet Mrs. Buttercup,
Who showed Mr. Schlippenbach I!

We call the pinxterbloom azalea pincushion because of its long showy stamens. The sweetly fragrant white to pale pink flowers appear in tight clusters in mid-May. In 20 years or so ours reached 5 to 6 ft, and is now even taller. This is the native azalea that you are most likely to find growing wild in the Northeast.

Rhododendron austrinum **(syns. *R. prinophyllum, R. roseusm*), the roseshell azalea.**

Rhododendron periclymenoides is sometimes confused with the roseshell azalea (*R. austrinum*). Usually, but not always, *R. austrinum*, is a deeper pink with a spicy clove fragrance rather than the sweeter perfume of *R. periclymenoides*.

Roseshell azalea always delights us with its very pronounced fragrance. But it has also surprised and delighted us with some of its variations. We started with a bright rose-colored clone that we obtained years ago from Weston Nurseries. It was selected for both its color and its fragrance. Some of its offspring include:

- **'Opus One'.** 'Opus One' has bright pink buds that open into fragrant large blush pink flowers with deeper pink on the upper petals. It produces a very large truss.
- **'Stop, Look & Listen'.** This cultivar has soft pale pink flowers with sharply contrasting rose-red stamens and tube.
- **'Yes, Indeed'.** A selection with flowers having a blush pink color with deeper pink edges to the petals and a hint of a yellow flare.
- **'Marie Hoffman'.** This is a lovely, fragrant, deep pink from Mike Johnson at Summer Hill Nursery. Its flowers are much larger than the species, but are considerably smaller than our own 'Opus One'.

***Rhododendron prunifolium*, the plumleaf azalea.**

The plumleaf azalea is one of the last native azaleas to bloom. It is native to southwestern Georgia and eastern Alabama, yet it has proved hardy in our gardens for years. Our plants that Henry Skinner sent us, nearly 30 years ago from the National Arboretum, are the selection 'Hohman' which are more than 6 to 8 ft tall and wide.

They normally start to bloom in our gardens about the middle of July. In our light woodland shade that gives them some afternoon protection, they continue blooming for a month or more, at least into mid-August, and this past cool summer into September. In full sun they open all at once and last for a 7 to 10 days. Our seedling-grown plants of *R. prunifolium* are predominantly in shades of red and orange-red. But we do get some variation in both flower color and time of bloom.

- **'Plumb Lovely'.** A selection that is considerably lighter in color than 'Hohman', but seems to vary in color from one year to the next. I have notes indicating that it was a lovely soft coral-pink one year. In the year I took this picture it was obviously more of a buff yellow with shadings of peach or apricot. It is 'Plumb Lovely' in any case.
- **'Plumb Later'.** This cultivar blooms even later, opening as it does in late August, or the beginning of September, and continuing to bloom through much of that month. It is a soft orange.

***Rhododendron vaseyi*, the pinkshell azalea.**

Jekyll cautioned Mr. Hyde:
"Vatch out vat you do –
Ve don't vant dem vondering
Vich is me and vich is you.
"Vitnesses of homicide
Makes tough de alibi
Ven dat jury's vondering
Vas 'e you or vaseyi?

This species is native to the mountains of North Carolina. Its soft pink and rose flowers are an absolute delight, blooming as they do in early to mid-May before their leaves appear. Most become very tall plants of 6 to 8 ft and more. A delicate soft coloring of the blossom is typical and the fall color can be exceptional.

- **'Pinkerbell'.** This cultivar is a gorgeous strain with considerably deeper pink flowers.
- **'White Find'.** This is an example of one of several white forms that we grow.

***Rhododendron viscosum*, the swamp azalea.**

Mike Johnson selected a clone of *R. viscosum* that is called 'Pink Mist'. This species is native to the Eastern United States but in my opinion it is not as desirable a garden plant as *R. arborescens*. It seems to bloom a little later than *R. arborescens*; but I don't find the flowers as showy, nor the plant and its foliage as attractive. It is reputed to be able to tolerate wetter growing conditions than most other azaleas, and perhaps it can when growing in the wild, but we grow it in containers under the same conditions as we grow our other azaleas. Whether the fact that it has not been acclimated to wetter conditions in the nursery makes it any less tolerant of them I can't say. But it is a consideration I take pains to point out to customers contemplating them for wetter areas.

- **'Bob's Bayou Beauty'.** Here is a pretty good argument for continuing to grow some of these natives from seed. This selection is an open pollinated seedling of 'Pink Mist'. Blooming for the first time this summer, it opens as a deeper brighter pink and matures to a soft light pink. It blooms about 5 days later than 'Pink Mist' and is intensely fragrant.

Before I continue let me remind you of a couple of selling points for persuading gardeners to include native azaleas in their home landscapes. They should take advantage of their fragrances. By using the species *periclymenoides, austrinum, atlanticum, arborescens*, and *viscosum,* in that sequence, they can have a nearly continuous succession of fragrances from mid-May well into July.

Secondly they can enjoy an extended blooming season. *Rhododendron vaseyi* starts off our native azalea blooming season in early May. But by using the later-blooming species as well, they can have azaleas in bloom in June, July and August — even into September with Jim Cross's 'Sweet September'. They can plan a nearly continuous sequence of bloom with the species *cumberlandense*, *arborescens*, *viscosum*, and *prunifolium*. Then expand their color palette with some of our summer blooming natives. That way they'll be enjoying "next" spring along about the first day of "this" summer.

So Let's Look at Some More Late-Blooming Natives.

As many of you are no doubt aware, from having either seen or read about them, native azaleas frequently grow in the wild in extensive colonies. And one of the nicest aspects of these swarms, as they are called, is that they don't believe in ethnic cleansing. They are absolutely delighted to interbreed and hybridize with other azalea species. This of course gives straight-laced purists and taxonomists fits, but gives gardeners and collectors in search of diversity a wealth of material to landscape with.

Having gotten myself tied down to my nursery, much the same way that a dairy farmer does to his cows, I've had to create my own swarms, albeit on a considerably more modest scale. To some, including my ever-patient wife, it seemed that I've tried to grow every azalea in existence that would be hardy. But I really have attempted to specialize.

Now it just so happens that my specializing has addressed a concern of one of our favorite customers. And possibly it's a concern that your customers may share too. We usually receive a number of orders from him each year, each being sent as the inspiration strikes him. Writing to add to his first fall order on the third day of July, he wrote: "Nostalgia (already?): Monet's apple trees (which were pictured on his note paper) prompt this question from Old Dribbler: Why can't we have another spring each year, say, about July 1?"

And lo and behold, we do. Not just with the species I've been showing you this morning, but with my hybrid swarms. Fortunately they're made up of the crosses I've been growing for years of the late blooming natives, *R. cumberlandense* and *R. arborescens*. We call them Carlson's Postscripts.

So I was able to advise Old Dribbler that:

Azaleas in June and July!
Need no longer seem pie in the sky –
Carlson's Postscripts will bring
You an encore to Spring
When the usual kinds have gone by.

We've been selecting and naming representative colors and forms of them for a number of years now. Many are described in the revised and enlarged edition of Fred Galle's marvelous book *Azaleas*. A few of these include:

- **'Salmon Chanted Evening'.** This is a nicely veined light salmon-pink with a large golden yellow flare that was still opening on July 4th.
- **'Dream Lover'.** 'Dream Lover' is a slightly deeper shade of salmon pink with a less conspicuous golden orange flare.
- **'Let's Dance'.** This one was named shortly after we lost Benny Goodman. 'Let's Dance' is a very showy fragrant pale pink with a light yellow upper petal.
- **'Summer Bouquet'.** In 'Summer Bouquet' the flower is striped pink with a hint of a yellow flare that blooms in early July.
- **'Moonlight Serenade'.** A selection that is a fragrant, soft salmon-pink with creamy yellow undertones and a soft yellow flare in late June.
- **'Lady Marmalade'.** 'Lady Marmalade' is a lovely light yellow with a brighter yellow flare in July.
- **'Thou Swell'.** This is a bright pink with deeper rose striping down the center of each petal and a hint of gold in the throat. It was still in full bloom on the 10th of July.

Before I continue I'm going to offer you a few words of caution to pass along to anyone who might be thinking of acquiring some late-blooming beauties. They should think long and hard whether they should keep them and plant them for themselves, or whether they should give them to a friend or neighbor, because:

Who would have thought
Nosy Myrtle McWhirtle,
Who grew pachysandra
And nothing much more
Till her neighbors chipped in and
Bought her some POSTSCRIPTS,
Would summer at home
Instead of next-door?

- **'Exactly Like You'.** 'Exactly Like You' is a bright rose-red with an orange flare over much of the upper petal.
- **'That Certain Feeling'.** 'That Certain Feeling' has very large light pink flowers with a very soft yellow flare. Its blooms last an exceptionally long time, well into mid-July.
- **'I Remember Apri'.** This selection blooms with the Old Dribbler's request in mind – in early July in varying shades of pink with a light yellow flare and showy red stamens. Not only that, but it's also fragrant!
- **'Fine & Dandy'.** 'Fine & Dandy' is a well veined medium pink with a contrasting very pale pink upper petal in early July.
- **'Glad Rag Doll'.** This is a large bright salmon-pink with a golden orange flare in late June.
- **'Later Than You Pink'.** A few of them got sillier names than others. Despite the name it is a nicely veined bright pink with a golden yellow flare framed in a lighter pink.
- **'Sing, Sing, Sing'.** We are back honoring the memory of Benny Goodman with this one. 'Sing, Sing, Sing' is a festive salmon-pink with a golden yellow upper petal in late June.
- **'Such A Night'.** Dr. John's 'Such A Night' has many large light pink flowers with a yellow flare and contrasting red stamens in late June.
- **'Lovey Mine'.** This is a beautifully veined fragrant pink with a golden throat.

I'm going to close with a short salute to my favorite nurseryman, Jim Cross. Jim and my wife, Jan, shared their cancer fight and hoped for cures for nearly a year. They both lost the fight, and were both always so supportive. And Jim repeatedly said that the following verse was one of his favorites.

So for Jim, and for Jan, I give you:

Protocol for royal balls
Calls for first unmasking
Common folk from royalty
Courteously asking:
"Vot's yore nomber, name and rank?
Iss you a king or lackey?
Lackeys has to schtand in line
Vile kings can schlippenbachi"

The Little Laurels

Richard A. Jaynes
Broken Arrow Nursery, 13 Broken Arrow Rd., Hamden, Connecticut 06518

Never mind that the native mountain laurel (*Kalmia latifolia*) has been described as our most beautiful evergreen shrub, there are still people around who keep trying to change and "improve" it! Over 100 years ago someone found an unusual small-leafed variant. It is so uncommon that it has been observed in the wild less than six times. These semidwarf or myrtle-leafed laurels are usually referred to as miniature mountain laurels and, at least when found in the wild, belong to the botanical form *myrtifolia* of *Kalmia latifolia*.

The few plants found and propagated from the wild have flowers that are light pink in bud and open near white, much like flowers of the species. Hilliers in England was one of the few nurseries to offer these plants in the 1960s. The first plants I received (1963) came from nurseryman Hay Reid of Osterville, Massachusetts, and were just seedlings grown from seed of a *K. latifolia* f. *myrtifolia* plant and looked like our native mountain laurel. However, I made crosses between these seedlings and one fourth of the offspring were small-leafed semidwarfs, that is the form *myrtifolia*. That was the first evidence that this unique plant form was under the control of a single recessive gene — one of those Mendelian traits that segregates independently — or put another way, there were no intermediate types or blending of the normal and myrtifolia types.

By crossing the myrtifolia seedlings among themselves I obtained 100% myrtifolia types, but if one was crossed with red-budded, rich pink, or banded laurel the offspring had the typical foliage and growth habit of regular mountain laurel. In 1976, I placed several of the myrtifolia seedlings in a screened cage before the flowers opened. When the flowers began to open a bumble bee was introduced into the cage to cross-pollinate the flowers. I harvested a lot of seed and almost 100% of the seedlings grown have been *K. latifolia* f. *myrtifolia* types. I selected one of the seedlings and named it 'Elf' and that was the first myrtifolia selection to be named. I have kept that seed from 1976 in an envelope in a refrigerator and grow a few seedlings from it almost every year. The seed was still viable after 20 years and in that time the original 'Elf' plant was 3-1/2 ft × 3-1/2 ft.

With appropriate crosses and by going through two or more generations it has been possible to combine several of the striking flower color selections of normal growing laurel into plants of the *myrtifolia* form.

Two cultivars that have flowers rich pink in bud and medium pink open are 'Tiddlywinks' and 'Tinkerbell'. 'Tiddlywinks' is a bit tighter and slower growing. The flowers of the more vigorous 'Tinkerbell' have more substance and appear to last longer. After 20 years the original 'Tiddlywinks' was 32 inches high and 42 inches across, whereas 'Tinkerbell' was 4 ft high and 5 ft across.

'Minuet' has dark, glossy pointed leaves and the open flowers are rich cinnamon maroon trimmed in white. A 10-year-old plant in a landscape planting would be about 30 inches × 30 inches. The original plant after 20 years was only 40 inches × 40 inches.

'Little Linda' is the fifth miniature I have named. It is characterized by red flower buds that open nearly white and then turn pink — a typical sequence for many of the larger-leafed, red-budded laurels. Foliage of 'Little Linda' is glossy and the leaves relatively broad. The original plant was 3 1/2 ft × 3 1/2 ft in 15 years.

One nice attribute of all the *K. latifolia* f. *myrtifolia* selections is that they are vigorous when young and grow almost as fast as the large-leaf selections. It is not until they begin to flower or get into the landscape that they become slow growing. Their special merit as garden plants is that their mature height is roughly half that of normal mountain laurel, 4 to 5 ft versus 8 to 10 ft in 20 to 25 years, and thus they fit better in some of today's smaller gardens and landscapes. Like other laurel and many rhododendrons, pruning at a young age is usually necessary to get a dense, multibranched plant. Best branching occurs if plants are pruned when dormant. They appear to be less shade tolerant than the larger-leaf selections.

These small leafed cultivars need to be vegetatively propagated; they do not come true to type from seed. Like most mountain laurel, cuttings are difficult to root so that tissue culture (micropropagated) plants are the preferred starting point for most nurseries. A few nurseries have in-house labs but most growers purchase their plants from independent labs (For a list of labs and more info on all aspects of propagating and growing *Kalmia*, see the book by the author). The culture of these small-leafed laurels is the same as that for other laurels. In containers that means a well drained, well aerated mix. Many successful growers use aged pine bark as a major component of the media.

If you haven't grown *Kalmia* before, beware it is not an easy crop. At least not nearly as easy to grow as Mother Nature would lead you to believe. She has millions of acres of plants growing beautifully on apparently terrible sites from soggy swamps to rocky outcrops. But, as Dick Bir has pointed out, if you put them in a rich garden loam they don't have the grace to die quickly; they just linger on looking ever worse — if it was easy there would be no challenge. *Kalmia* can and is being grown successfully in nurseries. Yet the consumer demand for mountain laurel is not being met, especially in the Northeastern U.S. Plants of any kind over 24 inches are in very short supply. Anyone growing quality plants is able to sell them at a reasonable price. We need more growers of both the small-leafed and regular mountain laurels. There are approximately 80 cultivars now and more will be named. Likely candidates include miniatures with red budded/banded flowers or with near-petaled flowers.

[Note: the author requests a breeders fee of 15 cents for each plant propagated and sold of the four small leafed cultivars most recently named: 'Little Linda', 'Minuet', 'Tiddlywinks', and 'Tinkerbell'. These fees have helped support additional breeding and selection of *Kalmia*.]

LITERATURE CITED

Jaynes, R.A. 1997. *Kalmia,* mountain laurel and related species. Timber Press, Portland, Oregon.

QUESTION BOX

MODERATED BY RALPH SHUGERT AND BRUCE BRIGGS

RALPH SHUGERT: Question for Dick Bir or Peter del Tredici. What is aroma therapy?

DICK BIR: Aromas can affect you in different ways. They can make you more tranquil or excited or any of that sort of thing, and that is what it is all about. You buy little capsules or salts put them in hot water or incense burners and it is suppose to change your whole way of looking at the world. That is all I know.

RALPH SHUGERT: Question for Bill Barnes. How do you heat treat manzate? How do you treat fine seed with manzate? How much manzate per flat, per gallon, rates? How long is manzate good for?

BILL BARNES: You do not heat treat manzate. I would never heat treat manzate. I do not recall mentioning the heat treatment of manzate but did mention that you should avoid heat with the seedlings because damping-off fungus could move in and they do not like heat treatment — if you get above 90F they will stop growing. You want to use manzate because it has the heavy metallic ion manganese (not magnesium). This ion prevents the germination of spores — ferns, mosses, liverworts, and fungi—with broad spectrum capability. Compounds, such as benlate, are more specific to fungal spores. Heavy metal pesticides containing zinc, copper, and manganese have a much broader spectrum. Teaspoon per gallon and it is drenched into the soil before liverwort gets started.

RALPH SHUGERT: Question for Ralph Shugert. You stated that *Taxus* ×*media* 'Hicksii' had a high rate of Taxol. What other *Taxus* cultivars are rated average to high?

RALPH SHUGERT: When we formed the alliance (*Taxus* growers), Ken Cockran who is the curator for the Secrest Arboretum and in charge of the Chadwick's *Taxus* collection collected samples from various cultivars of taxus and tested them. Bruce Vanicek also had some testing done from a different lab. Bruce, would you comment on your results?

BRUCE VANICEK: *Taxus* ×*media* 'Dark Green Spreader', 'Hicksii', 'Nigra', and 'Taunton' are high in Taxol content. There appears to be a relationship between dark green color and higher Taxol content. All the faster growing types, such as *T.* ×*media* 'Densiformis and 'Brownii', are very low in Taxol. It takes a lot of taxus plant material to get any Taxol. One reason the drug companies like 'Hicksii' is because it is fairly uniform throughout the industry. Many of the other cultivars are mixed in the trade and misnamed.

RALPH SHUGERT: I would just like to caution everyone in the room that Taxol testing is much like soil testing. You can often get different results from different labs.

BRIAN MAYNARD: I think that production methods need to be looked at as they relate to Taxol production. In addition, stress (temperature and drought) needs to be examined as a stimulator of Taxol production.

RALPH SHUGERT: Question for Tom Kimmel. What is the hardiness (zone) of the Polish clematis cultivars and which are the hardiest? Does the U.S.D.A. require plants to be soil free? Pesticide dipped? Quarantined?

TOM KIMMEL: I am not sure but assume that they are hardy to Minneapolis because I sell them that far north. Poland has a climate similar to our midwest climate so on that basis I assume they are as hardy. Yes they are soil free. They are inspected in New York City which results in a 2- to 3-day delay. We do not give them any fungicide dip. There is no quarantine on the clematis. The name of the peach-colored cultivar is *Clematis montana* 'Freda'.

BRUCE BRIGGS: What herbicide works best for field-grown boxwood?

DICK BIR: What is used and is labeled for it is Casoron put on in the winter. Roundup Pro to knock it down and Surflan to keep it down. We are not seeing yellowing as long as we do not have nutrient deficiency problems.

RALPH SHUGERT: In containers we are using Rout at the label rate.

JOHN MARSHALL: We use Casoron successfully for several years on Japanese hollies, not boxwood, until one year when we got 4 inches of rain in the middle of the summer and cooked the roots. Be careful if you have large amounts of rain. We have a silty-loam soil.

VOICE: The best thing I have ever found is Goal and Surflan.

ED LOSELY: We have a problem with the older leaves of 'Green Velvet' showing a golden margin. Does anyone else have this problem and is it related to an herbicide?

GIACOMO MULÉ: We had that problem and sprayed it with micronutrients and solved the problem on that particular cultivar and believe it is a nutritional problem.

TED KIEFER: I had the gold margins from simazine applied in the spring. With simazine the leaves were variegated.

VOICE: From our experience it could be a boron deficiency, salt problem, or herbicide toxicity.

KEN ROE: We grow a lot of boxwood without herbicide and get the problem and I am led to believe that it is a micronutrient problem.

BRUCE BRIGGS: I have been unsuccessful in finding a herbicide to use on *Phlox paniculata* that will not cause phytotoxicity. Can anyone help?

BILL BARNES: I have used water soluble Treflan and pendimethalin combined on perennials after they have broken bud and grown out 3 to 4 inches but not before in the spring. Surflan is big trouble and should not be used.

BRUCE BRIGGS: What can we use to control liverwort? Where in the U.S. can we buy Mogeton a chemical used to control liverworts from Japan?

BRUCE BRIGGS: We presented a paper at the Southern Region meeting this year from the results of a large study. Cinnamic aldehyde gave good results.

RALPH SHUGERT: Just straight vinegar made from apples with no additives I saw on a tour.

BILL BARNES: Ronstar G, although it is not on the product label, will control liverworts.

MARK SUTCLIFFE: I was speaking to Charlotte Smith and she mentioned that they use buckwheat hulls 1/4 inch to 1/2 inch for control of liverworts.

BRUCE BRIGGS: If you have something in your area that can be used as a mulch it will give you control if the surface is allowed to dry out.

RALPH SHUGERT: Will male *Ilex opaca* pollinate *I. verticillata* or *I. verticillata* × *I. serrata* female forms? Will *I.* ×*meserveae* males pollinate any deciduous females? If not, is it timing of flowering or compatibility of pollen?

DAVE THOMPSON: I have heard that it may pollinate *I. decidua* but not *I. verticillata*.

RALPH SHUGERT: On Elwin Orton's hybrid hollies. How are the dwarf hollies (*Ilex crenata* 'Beehive' and 'Jersey Pinnacle') doing?

DAVE THOMPSON: 'Beehive' has done well for us and is hardy as indicated. With 'Jersey Pinnacle' I have had no experience.

VOICE: As with many *I. crenata* it really depends on climatic factors. You can see winter problems after a cold winter if you have had a dry summer.

GIACOMO MULÉ: We have overwintered 'Jersey Pinnacle' in a polyhut with no heat without problems.

RALPH SHUGERT: In Michigan we have tested them from material Dr. Orton sent and found them to be slower growing and we are not going to grow them.

BRUCE BRIGGS: In don't understand why but in the west we have great color on 'Jersey Pinnacle' but poor on 'Beehive' which is the opposite of your results.

RALPH SHUGERT: Question on flowering in *Kalmia*. Has anyone thought of treatments including extra light or shading (short days) to increase flowering?

DICK JAYNES: Yes it does have an effect. A lot of people think that *Kalmia* is a deep shade plant. It barely flowers in deep shade. It flowers best along the edge of woods. They need light to flower.

BRUCE BRIGGS: Does anyone know if the form of *Cornus canadensis* found in the east is different from the west?

BILL BARNES: The one that grows in the Rocky Mountains is the same as the one that grows here. I am not sure about the Cascade Mountains. Such a wide growing range would lead to ecotypes.

NEW PLANT FORUM

Compiled and Moderated by Jack Alexander

PRESENTERS:

Jack Alexander, The Arnold Arboretum, Jamaica Plain, Massachusetts 02130
Syringa ×chinensis 'Lilac Sunday'

Mark Brand, University of Connecticut, Storrs, Connecticut 06269
Halesia carolina 'UConn Wedding Bells'

Tim Brotzman, Brotzman's Nursery, Madison, Ohio 44057
Cercis canadensis 'Covey'

Steve Cotta, Portsmouth Nursery, Portsmouth, Rhode Island
Rhododendron 'Amy Cotta'

Alan Jones, Manor View Farm, Monkton, Maryland 21111
Thuja 'Green Giant'
Cornus kousa 'Wolf Eye'

Phill King, Greenwood Propagation, Hebron, Illinois 60034
Hamamelis vernalis 'Autumn Embers'
Fothergilla gardenii 'Beaver Creek'

Kevin Parris, Gilbert's Nursery, Chesnee, South Carolina 29323
Cryptomeria japonica var. *sinensis* 'Green Grissly'
Prunus incisa 'Snow Cloud'

Cercis canadensis 'Covey'

This is a unique weeping form which grew in northwest New York for over 30 years before its recognition by Brotzman's Nursery in 1991. In 6 years of observations, 'Covey' has exhibited moderate to rapid growth, hardiness to -23F, larger than normal leaves, and lavender flowers borne profusely on young and old plants. When left untrained this plant will mound and twist back over itself producing a large arching form. When trained upright and single stemmed, a striking, small weeping tree is possible in 3 to 4 years. Leaves are so large and dense that trees appear to be shingled. First commercial release of 'Covey' will be in 1998 from licensed growers.

Cornus kousa 'Wolf Eye'

A variegated form of *C. kousa* selected at Manor View Farm a few years ago. The variegation is very consistent with no reversion occurring. The habit is similar to regular *C. kousa*. An added bonus is that the bracts are also variegated adding an unusual quality to the plant. No leaf burn has been reported with this selection, but it does require some shade to reduce leaf curl during extreme summer heat.

Cryptomeria japonica var. *sinensis* 'Green Grissly'

In August 1991 Gilbert's Nursery received seven distribution bags at the NCAN Short Course and Trade Fair. Each bag contained a seedling of *C. japonica* var. *sinensis* (syn. *C. fortunei*). After two growing seasons we evaluated the plants and selected one clone to propagate. This clone was darker green than its six siblings were in the month of January when cryptomeria typically shows signs of winter foliage discoloration. It was also two-thirds the height of the others with a more compact habit. The branch tips have same pendulous nature as other specimens of *C. japonica* var. *sinensis*, which separates it from most *C. japonica* selections. It is easily rooted from winter hardwood cuttings under mist with bottom heat. We think this selection will satisfy those who are looking for a slightly pendulous conifer with good winter foliage appearance. It will likely be faster in production than *Cedrus deodara* but achieve a similar function in the landscape. Despite little marketing, the plant has received interest from our local landscape and garden center customers. Two-gal and 10-gal sizes are available for those interested.

***Fothergilla gardenii* 'Beaver Creek'**

This excellent selection is from Mr. Roy Klehm of Beaver Creek Nursery.

He selected this clone from a single plant and has rooted all further generations from this selection. The uniformity and superior form of this selection is unsurpassed in the selections of *F. gardenii* presently available.

The growth form is that of a full, low-growing mound about 35% wider than tall in youth.

Field-grown specimens are "cookie cutter" in form with no variation in shape. This makes choosing of finished nursery plants easy and a delight. Other selections of *F. gardenii* that we have seen vary from upright to wide spreading in shape within the same field. This variation is probably due to the fact that most *F. gardenii* being rooted use seeding-grown mother plants as stock sources.

'Beaver Creek' also exhibits flower bud hardiness not often seen in fothergilla in northern climates. Unlike most *F. gardenii*, flowering occurs evenly over the entire plant, not the one-sided flowering most often seen in our cold climate.

Fall coloration is a rich red/purple/gold with yellows and oranges intermixed.

The plant is a good grower and will tolerate up to 50% shade quite easily.

Softwoods are rooted late June and overwintered without disturbance of the root system.

It took much cajoling to get Mr. Klehm to name this selection which we can now use as a standard for *F. gardenii* future selections.

***Halesia carolina* 'UConn Wedding Bells'**

USDA hardiness Zones: 4b to 8.

Origin: Discovered as an outstanding specimen in Columbus, OH. Observed, propagated, and named by Mark Brand.

Landscape niche: A small flowering tree with multiseason interest. Excellent for smaller properties where bloom is important.

Ornamental features: Displays white, bell-shaped flowers in early May. Profuse flower production occurs annually and young plants flower precociously, making them readily marketable at small sizes. Flowers open wider than typical for the species so they are showier. Foliage is somewhat shiny. Interesting four-winged fruits are conspicuous in the fall and persist into early winter. Bark is a striking steel-gray, streaked vertically with cream.

Habit and growth rate: A rounded, deciduous small tree reaching 15 to 20 ft height, with an equal crown spread. Can be grown as a single- or multistemmed form. Growth rate is moderate when young, slowing with maturity.

Culture: An understory tree naturally, so it is tolerant of light/moderate shade to full sun. Prefers a moist, well rained, slightly acidic soil, but has proven adaptable to most soils that are not excessively alkaline.

Pest/disease problems: No significant problems.
Propagation methods: Summer softwood cuttings treated with IBA/NAA will root >90% in fog or mist. In a single season, 24- to 30-inch plants can be obtained from rooted cuttings. 'UConn Wedding Bells' has also proven to be easy to micropropagate.
Patent/royalty information: The University of Connecticut is requesting a $0.25 per plant royalty, with funds returning to the ornamental plant development and evaluation program in the Department of Plant Science.
Availability/distribution: Softwood cuttings and tissue cultures are available from Mark Brand.

Hamamelis vernalis 'Autumn Embers'

Mr. Roy Klehm of the Beaver Creek Nursery in Poplar Grove, Illinois, made this selection of vernal witchhazel.

Mr. Klehm first noticed the impressive fall coloration in a large block of *H. vernalis* seedlings. He at first felt that the plant was perhaps another species or cultivar mistakenly mixed in with its more common sisters. The fall coloration is a rich red with overtones of purple, yellow, and orange. The breathtaking effect is that of a glowing campfire on a crisp fall evening.

Best fall coloration is triggered with the hard frosts of colder climates and the plant is at its best there.

The flowers are colored in shades of ripe grain and are quite fragrant.

A national mailorder nursery firm has sought this plant as its "cover girl" and many have been quite surprised that Mr. Klehm did not wish to patent the plant.

Unlike other witchhazels this cultivar roots quite well in June-July.

Perhaps the best selection of witchhazel to date within the realm of fall color, 'Autumn Embers' is the equal of fothergillas in the north.

Prunus incisa 'Snow Cloud'

This tree was personally selected and named by Dr. John Creech, formerly of the National Arboretum. Dr. Creech shared cuttings with us in 1994 from the parent tree growing in his personal garden. This cherry is ideally suited for the small garden, having a more compact growth habit than the typical species. You could describe this tree as a diminutive white-flowering *Prunus* ×*incam* 'Okame'. Softwood cuttings root easily under mist with 1000 ppm IBA or KIBA. A small quantity of 2 gal-sized plants is available for those interested.

Rhododendron 'Amy Cotta'

Named in honor of Amy Cotta who through her endless generosity allowed Portsmouth Nursery to exist and succeed as a wholesale growing operation. This plant serves as a reminder of her love of all plants

Rhododendron 'Amy Cotta' can best be described as a dwarf 'P.J.M.' Developed as a mutation of *R.* 'P.J.M' this plant features dense azalea-like foliage that is somewhat darker than the *R.* 'P.J.M' and less than half the size. A dwarf growth habit assures a tightly rounded form that matures at 3 ft high with a wider spread. Plentiful blooms cover the plant in early spring and are the same lavender pink as the *R.* 'P.J.M'. Hardy to Zone 4.

Propagation methods used for *R.* 'P.J.M' have proven to be equally effective for 'Amy Cotta'. However, no micropropagation has yet been attempted. This plant can be classified as one that is easy to root.

***Syringa ×chinensis* 'Lilac Sunday'**

This new lilac cultivar is named in honor of the Arnold Arboretum's annual lilac celebration. It is an open pollinated seedling, that I grew and selected from seed that we obtained in 1979 from the Botanical Garden of the Chinese Botanical Academy, Beijing, Peoples Republic of China.

'Lilac Sunday' produces a great abundance of fragrant, light purple (78-C on the RHS color chart) flowers. Flower buds form along the stems for a distance of 2 or more feet from the terminal and come into bloom with the earlier cultivars of common lilac. When in bloom, the weight of the flowers causes the thin branches to arch some almost touching the ground. The late summer and autumn foliage has shown little affect of mildew or leaf-roll necrosis.

Softwood cuttings of 'Lilac Sunday' root readily when treated with 5000 ppm K-IBA. These rooted cuttings, at just 1 and 2 years of age, produce flowers. Plants have also been produced by micropropagation and are now becoming commercially available.

It is estimated that plants will attain a height of 8 to 10 ft and a width of 10 to 12 ft. and to be hardy to USDA Zone 3. For a more complete description see Arnoldia 57 (Spring 1997): 12-13.

***Thuja* 'Green Giant'**

This hybrid between *Thuja plicata* and *T. standishii* grows as fast as Leyland cypress. Relaxed dark green foliage adds to the elegance of this fast-growing pyramidal conifer. A growth rate of 3 to 5 ft can be expected once established, making this plant very useful for screening. Is considered by many as a replacement for Leyland cypress. It is deer resistant. Ultimate height unpruned is 30 to 50 ft.

POSTER SESSIONS

Involvement of Cytokinins in Tissue Proliferation of *Rhododendron* 'Montego'

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Tissue proliferation (TP) of rhododendrons is an unusual morphological variant characterized by tumorous growths at the crown with or without abnormal shoots. In many cultivars, TP occurs in plants produced by tissue culture within 1 to 3 years after initial propagation. However, in *Rhododendron* 'Montego', TP occurs in tissue culture as shoots [TP(+)] that produce nodal tumors with many compressed lateral shoots and small leaves, unlike tissue-cultured normal [TP(-)] shoots. Tumors develop from abnormal axillary buds with a bulbous structure that forms at the base of the growing axillary shoot. Growth of the tumor is dominated either by continued growth of the single shoot or by proliferation of the bulbous structure with many de novo meristems on the tumor surface.

Another difference between TP(+) and TP(-) shoots is their plant hormone requirement for in vitro growth. Tissue proliferation(+) shoot cultures appear to be habituated since they grow and multiply rapidly on hormone-free medium. Tissue proliferation(-) shoot cultures, however, require the cytokinin isopentenyladenine (iP) for multiplication. When the growth of TP(-) axillary buds was compared to the growth of TP tumors on woody plant medium with iP (WP-iP) or without iP (WP-None), TP(+) tumors cultured on WP-None had the highest growth rate. Growth of these TP(+) tumors was characterized by the formation of TP(+) shoots. Although iP was necessary for growth to occur [as TP(-) shoots] from TP(-) axillary buds, TP(+) tumors cultured on WP-iP had a lower growth rate than the tumors cultured on WP-None. The high growth rate of TP tumors on WP-None indicated that tumors, like TP(+) shoots, are habituated. The slower growth rate of TP(+) tumors cultured on WP-iP suggested that exogenous cytokinin creates supraoptimal levels which inhibit growth.

The effect of exogenous cytokinin on the formation of TP(+) shoots from TP(-) tissues was also studied. Since abnormal shoots are proposed to be more readily formed from *de novo* buds than from organized axillary buds, we studied the ability of TP(-) leaves to produce adventitious TP(+) shoots. Mature TP(-) leaf blades were cultured for 10 weeks on adventitious shoot regeneration (ASR) medium with 3 cytokinin treatments (WP medium with 1 mM indolebutyric acid and 15, 30, or 60 mM iP). After transfer to WP-None medium, leaf explants were evaluated for death and for abnormal, TP(+), and TP(-) shoots present 5 and 10 weeks later. Abnormal shoots had unusual leaf morphology and/or were freely branching but did not have nodal tumors. When the level of iP was increased from 15 to 30 mM, more TP(-) leaf explants survived, but the number of leaves with TP(+) and abnormal shoots increased significantly after transfer to WP-None medium. In the case of 30 and 60 mM iP, leaf explants generated more abnormal shoots after 5 weeks. These results not only suggest that exogenous iP induces the adventitious formation of TP(+) and abnormal shoots, but also that the cytokinin affects shoot morphology long after transfer to hormone-free medium. Above 30 mM iP, no increase in leaf death or leaf explants with TP(+) shoots was observed.

Because exogenous iP influences the growth of TP tumors and induces adventitious TP(+) shoots to develop, the uptake and metabolism of exogenous iP was studied by using radioactively-labeled iP ([3H]iP) as a tracer. The [3H]iP (specific activity 6.6 × 104 dpm $pmol^{-1}$) was combined with cold iP to provide a final concentration of 10 mM iP in liquid WP medium. Excised TP(-) and TP(+) shoot tips were placed separately in the medium, and the percent uptake of [3H]iP was calculated from counted aliquots of the medium over 7 days of culture. After 7 days, cytokinins were extracted and prepared for HPLC. Samples were analyzed for cytokinin and adenine nucleotides by anion exchange HPLC. Fractions corresponding to free base and conjugated cytokinins were collected, and prepared for analysis by reverse-phase HPLC. Radioactive peaks were quantified by an IN/US on-line liquid scintillation counter. Our results showed that the percent uptake of [3H]iP increased greatly between 1 and 3 days of culture, with 85% to 90% uptake by the 7^{th} day of culture. Analysis after extraction did not show significant differences in the uptake of iP between TP(-) and TP(+) shoots. The cytokinin metabolites adenosine 5' monophosphate, a glucoside conjugate of iP (IP9G), and iP were identified in both TP(+) and TP(-) shoots. However, only iP levels were significantly different between the two shoot types. In both shoots, greater than 50% of the iP was conjugated to IP9G, resulting in inactivation. Overall, TP(+) shoots appear to metabolize iP faster than TP(-) shoots by 7 days of culture.

The differences in the growth of TP(-) of TP(+) tissues in response to exogenous iP and differences in the metabolism of iP between TP(-) of TP(+) shoots suggest that changes in endogenous cytokinins could be producing the tumorous morphology in *R.* 'Montego'. Currently, we are measuring endogenous cytokinins in TP(-) and TP(+) tissues using an ELISA method.

Long-Term Inhibition of Stem Elongation of *Rhododendron* and *Kalmia* by Triazole Growth Retardants

Martin P. N. Gent
Department of Forestry and Horticulture, Connecticut Agricultural Experiment Station, New Haven, Connecticut 06504

That a growth retardant chemical, in combination with a cold- and day-length forcing treatment, could induced *Rhododendron* to flower a year after propagation, was first shown by Stuart (1960). The triazole growth regulators more effectively reduce stem elongation than the chemicals used previously (Davis et al., 1988). Two of these, paclobutrazol and uniconazole, promoted flowering of field-grown *Rhododendron* and *Kalmia* (Gent, 1995a, Ranney et al., 1994; Wilkinson and Richards, 1991), where other chemicals had inconsistent effects. However, paclobutrazol inhibited stem elongation a year after application when applied to *Rhododendron* (Ranney et al., 1994; Wilkinson and Richards, 1991) and *Vitis* (Reynolds and Wardle, 1990), and for 2 years when applied to *Malus* (Williams 1984). This not only suggest that exogenous iP induces the adventitious formation of TP(+) and abnormal shoots, but also that the cytokinin affects shoot morphology long after transfer to hormone-free medium. Above 30 mM iP, no increase in leaf death or leaf explants with TP(+) shoots was observed.

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Why does the effect of triazole growth retardant persist for several years in woody plants? Inhibition of stem elongation in herbaceous plants, such as *Dendranthema* (syn. *Chrysanthemum*), *Euphorbia pulcherrima* (poinsettia), and annual bedding plants, persisted only for a few weeks after growth retardant was applied. The normal rate of stem elongation in *Dendranthema* was restored as the concentration of growth regulator chemical in plant tissue was diluted by plant growth and increase in biomass (Dicks and Edwards, 1973). Growth of herbaceous plants is rapid and thus the effect of growth retardant would be rapidly diluted. Because woody plants grow more slowly, the effect of growth retardant could persist for a much longer time.

Inhibition of stem elongation is proportional to dose when growth retardant is applied at a low dose, but it is almost completely inhibited at a high dose, and additional growth retardant has little effect. More generally, stem elongation is inversely related to concentration of growth retardant, decreasing to a limiting value as the concentration increases. *Rhododendron* and *Kalmia* responded to triazole growth regulators at doses on the order of 1 mg per plant (Gent, 1995a). Consequently, doses of 10 to 100 mg per plant would completely inhibit stem elongation. When applied at these rates, it would take several doublings in size, e.g., several years, before the chemicals were diluted into the range where stem elongation was only moderately inhibited.

Model. The following equation related the length of stem elongation to the dose of growth retardant applied and the year after application:

$$\text{Growth (dose , year)} = \text{initial growth} + \frac{\text{Growth(dose} = 0\text{ , year)}}{1 + K_c \cdot \text{dose} \cdot \exp(-K_t \cdot \text{year})}$$

In the year of application, year = 0, some initial growth was not affected by growth regulator. In the years following application, the initial growth was not significantly different than zero.

Growth (dose=0 , year) was the maximum stem elongation in each year, that of untreated plants. A dose-response coefficient was K_c, in units of mg^{-1} plant, specific to the growth retardant chemical, the plant species and cultivar, and the size of the plant. K_t was a time constant, in units of $year^{-1}$, for the exponential decrease in effect of growth retardant. The time constant should only depend on growth rate. Figure 1 shows the predictions for stem elongation, as a percentage of growth of untreated plants, for each of several years after application of a single dose of growth retardant. The prediction used coefficients of $K_C = 2\ mg^{-1}$ plant (e.g., 0.5 mg inhibits half of stem elongation in the year of application) and $K_t = 2\ year^{-1}$ (e.g., the dose response decreases seven fold per year, and a dose of 3.5 mg is required to inhibit half of stem elongation in the year after application).

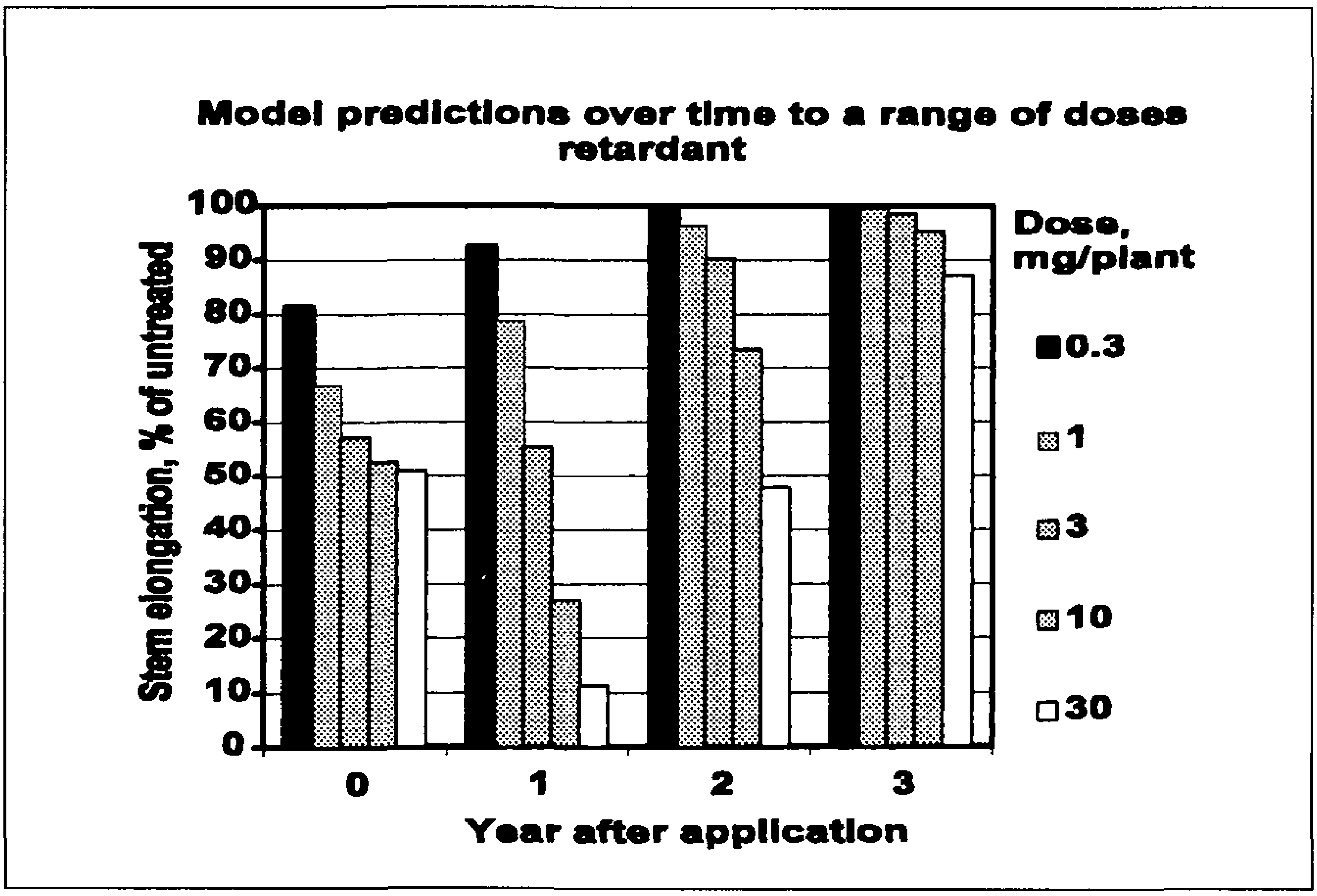

Figure 1. Model predictions over time to a range of doses retardent.

MATERIALS AND METHODS

Plant Material and Growth Conditions. The large-leaf *R. catawbiense* Michx. cultivars 'Boursault' and 'Roseum Elegans', and the *K. latifolia* L. cultivars 'Carousel' and 'Yankee Doodle' were propagated and potted in 8-liter pots at Prides Corner Farm, Lebanon, Connecticut, a commercial nursery. Plants were treated and grown at Lockwood Farm, Hamden Connecticut, the experimental farm of the Connecticut Agricultural Experiment Station. The plants were spaced two-pot diameters apart in full sun, and watered at regular intervals during the growing season, protected over the winter in hoop houses that were covered with white polyethylene film, and transplanted into a field in spring of the year following application of growth retardant. The field was plowed, and 10 : 4 : 8 (N : P_2O_5 : K_2O, by volume) fertilizer and powdered sulfur were incorporated to give high fertility and adjust the pH to 5.0. Plants were set in rows with 0.6 m between plants in the row and 1 m between rows. The soil surface was covered with a layer of wood chips. Insecticides, fungicides, and herbicides were applied according to normal production practices.

Application of Growth Regulators. The growth regulators used were paclobutrazol, (2RS,3RS-1-[4-chlorophenyl]-4,4-dimethyl-2-[1,2,4-triazol-l-yl]-pentan-3-ol in the BONZI formulation (Uniroyal Chemical Co., Naugatuck, CT), and uniconazole, (E-1-[4-chlorophenyl]-4,4-dimethyl-2-[1,2,4-triazol-1-yl]-1-penten-3-ol in the SUMAGIC formulation (Valent Chemical Co., Walnut Creek, CA). The plants were treated in the 2nd year after propagation, except the *Kalmia* 'Carousel' treated in April 1992 were in the 3rd year. Each plant received just one dose of growth retardant. In each year, a batch of solution was applied in its entirety to a group of plants. The solution was applied to leaves and stems as a timed, directed spray, with repeated applications, to equalize the volume applied to each plant and to reduce runoff to a minimum. Six or more plants of each cultivar were not sprayed to serve as controls.

Measurements. In April, three to five stems on each plant were marked with white paint just below the terminal bud. In October, the length of the annual growth was measured for three stems of each plant. Typically, the growth was measured for the longest leader on each of three different branches resulting from pruning in the 1st year of propagation. If there were only two branches, a side shoot was measured. This procedure was repeated in each year following application of growth regulator.

RESULTS

Application in 1991. After a spray application of paclobutrazol in August 1991, stem elongation of *R.* 'Roseum Elegans' in 1991 was inhibited to a similar extent by doses of 5 and 20 mg. In 1992, stem growth was inhibited more by a dose of 20 than 5 mg. In 1993, there was still a significant response to 20 mg paclobutrazol applied in 1991.

In the years following application, stem elongation of *K.* 'Yankee Doodle' was more severely inhibited than that of *Rhododendron.* Stem elongation was inhibited in 1994, 3 years after application of a 20 mg dose of paclobutrazol. This was the only combination of treatment and cultivar that also resulted in smaller leaves than the controls. This illustrated that triazole growth retardant could inhibit stem elongation for at least 3 years after a spray application.

Application in 1992. When growth retardant was applied on three dates in 1992, the initial growth, that growth of stems not inhibited by growth retardant, depended on the date of application. These results have been reported previously (Gent, 1995a). Across application dates, a single coefficient was sufficient to predict the dose response of that part of stem elongation sensitive to growth retardant. Half the maximum inhibition of stem elongation in 1992 was achieved with a dose per plant of less than 0.7 mg paclobutrazol or 0.04 mg uniconazole, except for *K.* 'Carousel'. For all cultivars, and for both chemicals, there was a significant response of stem elongation in 1993 to application of growth regulator in 1992. Because all stem growth was sensitive to growth retardant in the year following application, the inhibition as a percent of total stem elongation of untreated plants was greater than in the year of application. In 1993, stem elongation was inhibited to half that of untreated plants by the residual effect of less than 5.0 mg paclobutrazol and 0.4 mg uniconazole, with the exception of *K.* 'Carousel'. The *K.* 'Carousel' were 3 years after propagation when treated in April 1992, and these larger plants had the lowest dose response. In contrast, *K.* 'Yankee Doodle' was the cultivar most affected by both chemicals, and it grew very little in the year after application, even at low doses.

When the year after application was included in regression to determine the time constant, K_t, for the decrease in the dose response, the time constant for an exponential decrease was 1.3 to 2.7 $year^{-1}$. This corresponded to an apparent decrease in the dose response coefficient, K_C, of 4 to 15 fold per year. In general, the effect of growth retardant persisted for a shorter time in *Rhododendron* than in *Kalmia*. The K_c for uniconazole was 4 to 20 times that for paclobutrazol, but the decrease over time in the dose response was similar for the two chemicals.

Application in 1995. The inverse response of stem elongation to concentration of growth retardant was clearly seen when six doses over a 40- or 50-fold range were applied in 1995. A 0.12 mg dose of uniconazole gave half the maximum inhibition of stem elongation of *R*. 'Boursault' in the year of application. However, only about 5 cm of the total of 15 cm of stem elongation in 1995 was sensitive to application of growth retardant. An inverse response to the dose of growth retardant was also seen in the year following application, but 3.0 mg of uniconazole was required to reduce stem elongation to half that of the control.

In 1995, *K*. 'Carousel' was more responsive to paclobutrazol and uniconazole than was *R*. 'Boursault'. A 0.07 mg dose of uniconazole gave half the maximum inhibition of stem elongation of *K*. 'Carousel', and all but 4 cm of the total of 19 cm of stem elongation in 1995 was sensitive to growth retardant. In 1996, about 0.6 mg uniconazole was required to inhibit half of the stem elongation relative to untreated plants. For both *Rhododendron* and *Kalmia*, the response to a given dose of paclobutrazol was much less than for uniconazole. The effect of paclobutrazol on *R*. 'Boursault' was not significant in the year following application.

DISCUSSION

On average, the apparent response to a particular dose of growth retardant decreased by a factor of seven in each year following application, equivalent to $\mathbf{K}_t$ = 2 year^{-1}. Using this coefficient, the model predicted that a dose inhibiting half of stem elongation in the year of application would only inhibit 12% of the stem elongation in the following year. Practically speaking, the effect of growth retardant would persist for less than a year, if it was applied at this dose. However, a dose 10-fold greater than that required to reduce stem elongation to half that of controls would inhibit stem elongation to less than half that of untreated plants in the following year. This persistent inhibition of stem elongation was nearly always seen after application of a high dose of paclobutrazol or uniconazole. The model predicted a 55-fold decrease in the dose response coefficient by 2 years after application. Spray application of growth retardant had few significant effects in the 2nd year after application, except when high doses were applied to the most sensitive cultivars.

Even for untreated plants, stem elongation was less in the year after application, when plants grew in the field, than in the year of application, when they grew in pots. In part, this difference in growth was due to greater water stress in field-grown than potted plants. This stress would slow the growth in biomass and dilution of growth retardant, and prolong the inhibition of stem elongation. However, stress also decreased the maximum stem elongation and the response to low doses of growth retardant. Thus, the growth conditions in the field did not necessarily emphasize the persistence of effects of triazole growth retardants. In part, growth differed between the year of application and the following years because flowering affected vegetative growth. Vegetative shoots often failed to initiate at stem apices that flowered. All plants were strictly vegetative when growth retardants were applied, but in the following years, many stems terminated in a flower raceme. Often, there was no new vegetative growth on one or two of the three stems selected for measurement. Thus, the average stem elongation was reduced by stems that did not grow at all.

The responses to paclobutrazol and uniconazole were qualitatively similar, but uniconazole was effective at lower doses than paclobutrazol. Based on the regression analysis of the *Rhododendron* treated in 1992 and 1995, the efficacy of uniconazole was 10 to 20 fold that of paclobutrazol. *Kalmia* differed less in response to the two chemicals. For *Kalmia*, the efficacy of uniconazole was 4 to 8 fold that of paclobutrazol.

Whereas stem elongation showed an inverse relation to dose of growth retardant, the number of flowers per plant generally showed a linear response. After application in April or June 1992, the response of stem elongation to paclobutrazol or uniconazole was non-linear (inverse) in 8 of 16 comparisons, while the number of flowers per plant showed a nonlinear response in only 3 of 16 comparisons (Gent, 1995a). Thus, nearly complete inhibition of stem elongation was achieved more easily than complete expression of flowering. After application in 1995, the number of flowers was not significantly increased for *R.* 'Boursault', and flowering of *K.* 'Carousel' was increased only with high doses of paclobutrazol and uniconazole (Gent, 1995b). In part, plants did not respond in 1995 because untreated plants flowered, which was not the case in 1991 and 1992. In 1992, some flowering was induced by a dose of growth retardant that inhibited less than or equal to half the stem elongation of untreated plants. This dose would have little effect of stem elongation in the following year. Thus, there is a dose of paclobutrazol or uniconazole that can induce flowering when untreated plants would normally not flower, but that will not severely inhibit stem elongation in the following year.

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The Greening of Poland's Nursery Industry

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In the 8 years since the collapse of Communism, Poland's nursery industry has made a turnabout and is gaining recognition and status. A recent study (Sept. 1997) involving contacts, observations, and personal visits to Poland's nurseries, arboretums, botanical gardens, and garden centers reveals a positive pattern of growth. Polish nursery operators have realized the importance of plant differentiation, crop specialization, marketing techniques, nursery exhibits for the trade, and public and customer service.

PREFACE

Current observations and studies indicate that Poland's nursery industry is growing and its production is of fine quality.

RESULTS AND DISCUSSION

Collegial Poland's Plant Propagators' Society came into being in 1997 with the cooperation of the Great Britain and Ireland Region. The one-day conference was attended by approximately 100 people representing nurseries, students, and academia from Poland. Presentations included 12 technical sessions and three poster sessions with participation from Poland, Ireland, Germany, and England.

Innovative. Production and marketing are two areas in which Poland's nurseries are making a difference — whether it is marketing "oversized" crabapples for eating, developing practical tools for carrying plants, overwintering nursery stock with layers of reusable mesh, or offering imaginative standards for limited garden space, the greening of Poland's nurseries shows innovation.

Distinctive. Poland' s nurseries specialize in specific crops and then market them through distribution centers. This remarkable change from a production-driven infrastructure is distinctive. Domestic and export markets are growing at the rate of 30% annually.

Trendsetting. Over 30 taxa of top-grafted willows are marketed by Polish nurseries. These culitvars are used in small and large landscapes, rock gardens, patios, and balconies. The trend started 6 years ago with the pendulous form of willow, *Salix caprea* 'Kilmarnock'.

Blossoming. Annual international nursery shows are the industry's most powerful communications program. These professional exhibitions are unusual in the sense that they enable both the trade and public to participate. While star billing goes to the plants, the exhibition includes the following: a plant doctor clinic, children's activities, seminars, plant sales, and show gardens displayed by the industry.

CONCLUSION
There is an opportunity and a need for the exchange of horticultural ideas, plants, and practices. We (trade associations, nurseries, academia, and government personnel in both countries) desire to create a horticultural exchange.

Use of Ethephon Treatments to Reduce Seed Set and Stimulate Shoot Production in *Kalmia latifolia*

Richard K. Kiyomoto
Department of Forestry and Horticulture, Connecticut Agricultural Experiment Station, PO Box 1106, New Haven, Connecticut 06504-1106

INTRODUCTION
Nursery production of mountain laurel (*Kalmia latifolia* L.) often involves labor-intensive, manual deadheading of flower clusters immediately after flowering to stimulate the formation of new shoots. A chemical method of deadheading that encourages shoot production would save time and labor costs while maintaining current production schedules. Perry and Lagarbo (1994) used ethephon sprays to eliminate fruit formation in flowering pear (*Pyrus calleryana*) and American sweet gum (*Liquidambar styraciflua*). They found that 1000 ppm ethephon applied to runoff at full bloom eliminated 95.3% and 99% of fruit in flowering pear and American sweet gum, respectively. Proper timing of ethephon application was crucial for these results. On the basis of these studies I tested the effectiveness of ethephon in reducing seed set and stimulating shoot production and growth in *K. latifolia*. Since blossoms in mountain laurel open over an extended period of time and since nursery production may involve many cultivars which bloom at different times, the current experiment made no adjustment for bloom stage. I wished to answer the following questions: (1) does ethephon have any potential in chemical deadheading of mountain laurel; (2) what are the appropriate rates of application; (3) is shoot production and growth stimulated; (4) does ethephon have any phytotoxic effects?

MATERIAL AND METHODS
Experiments were conducted on field-grown mountain laurel cultivars at Broken Arrow Nursery, Hamden, Connecticut, in the spring and summer of 1995 and 1996. Treatments were applied on cultivars 'Snowdrift', 'Hoffman's Pink', and 'Angel' in 1995 and 'Snowdrift', 'Hoffman's Pink', and 'Tinkerbell' in 1996. In each year plants in different populations of each cultivar were treated in a completely randomized design.

Single applications containing 0 (water), 500, 1000, and 2000 ppm ethephon were made on 9 June 1995 and 5 June 1996. In 1995 seed set was estimated by counting the number of nonsenescent seed capsules out of the total number of blossoms (= % viable seed capsules), and new shoot production was scored as the total number of new shoots per plant. In 1996 seed set was estimated by counting the number of flower clusters which were completely senescent out of the total number of flower

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Single applications containing 0 (water), 500, 1000, and 2000 ppm ethephon were made on 9 June 1995 and 5 June 1996. In 1995 seed set was estimated by counting the number of nonsenescent seed capsules out of the total number of blossoms (= % viable seed capsules), and new shoot production was scored as the total number of new shoots per plant. In 1996 seed set was estimated by counting the number of flower clusters which were completely senescent out of the total number of flower clusters per plant; new shoot production was recorded as the number of new shoots produced below a flower cluster; and new shoot growth was determined by measuring the shoot length. Data were collected at weekly intervals after ethephon treatment, but are reported here only at 30 and 32 days after ethephon application in 1995 and 1996, respectively.

RESULTS AND DISCUSSION

Treatments with 500, 1000, and 2000 ppm ethephon significantly reduced seed set when compared to the control treatment containing no ethephon. Although the differences between the 500 ppm and the higher concentration ethephon treatments were not always significant, in all populations, higher ethephon concentration resulted in greater reduction in seed set.

Table 1. Effects of ethephon treatments applied on 9 June 1995 on seed set and new shoot production in field populations of *Kalmia latifolia* cultivars Angel, Snowdrift, and Hofman's Pink.

		19 July 1995	
Cultivar	Ethephon treatment (ppm)	Viable seed capsules(%)	New shoots/ plant
Angel (N = 41; 52.9% open flowers at start)			
	0	20.1	2.8
	500	9.0	27.8
	1000	4.2	65.4
	2000	2.2	57.2
	$LSD_{0.05}$	9.1	20.0
Snowdrift (N = 17; 53.4% flowers open at start)			
	0	28.3	2.2
	500	12.2	16.8
	1000	9.8	26.2
	2000	6.9	31.6
	$LSD_{0.05}$	2.4	1.4
Hoffman's Pink (N = 37; 27.3% flowers open at start)			
	0	20.1	2.8
	500	9.0	27.8
	1000	4.2	65.4
	2000	2.2	57.2
	$LSD_{0.05}$	6.4	21.5

All treatments with ethephon significantly increased shoots produced per plant. The 1000 and 2000 ppm ethephon treatments resulted in significantly more shoots than the 500 ppm treatment, but the effects of the 1000 and 2000 ppm treatments on shoot production were not significantly different in two of the three populations.

The 1995 experiments suggest that application of 1000 ppm ethephon is sufficient to reduce seed set and stimulate shoot production in *K. latifolia* even when blossoms were not fully open. No phytotoxic effects were observed. These experiments were repeated in 1996 on different populations of 'Snowdrift' and 'Tinkerbell' and on untreated 'Hoffman's Pink' from the 1995 population. In 1996 an additional control was included. In populations of 'Hoffman's Pink' and 'Tinkerbell', plants were also manually deadheaded in order to test if ethephon treatments stimulated shoot growth to the same extent.

Table 2. Effects of ethephon treatments applied 5 June 1996 on field populations of *Kalmia latifolia* cultivars Hoffman's Pink, Snowdrift, and Tinkerbell.

		New shoots	
Cultivar/ethephon treatment (ppm)	Flower cluster abscission (%)	per flower cluster	Mean length (cm)
Hoffman's Pink (N = 39; 66.7% blossoms open at start)			
Deadhead control	Removed	2.6	1.58
Water control	0.0	0.0	0.0
500	79.4	2.0	1.63
1000	98.4	2.7	2.17
2000	100.0	2.7	2.41
$LSD_{0.05}$	12.4	0.4	0.40
Tinkerbell (N = 73; 94.7% blossoms open at start)			
Deadhead control	Removed	2.3	8.18
Water control	0.0	0.1	2.56
500	79.4	2.2	5.71
1000	88.9	2.4	6.23
2000	100.0	2.5	6.22
$LSD_{0.05}$	8.6	0.5	1.55
Snowdrift (N = 21; 22.8% blossoms open at start)			
Water control	5.6	0.1	1.00
500	83.7	2.1	5.94
1000	100.0	3.0	6.94
2000	100.0	2.9	5.73
$LSD_{0.05}$	6.3	0.4	1.73

The 1996 results confirmed the 1995 observations. The 500, 1000, and 2000 ppm ethephon treatments significantly reduced seed set and stimulated shoot production and length when compared to treatment with water only. In most cases the 1000 and 2000 ppm ethephon treatments stimulated the production of significantly more shoots per flower cluster than the 500 ppm treatment, but significant differences in shoot length were more difficult to detect. In 'Hoffman's Pink', treatment with ethephon stimulated shoot growth equal to or in excess of that seen in the deadhead controls. However, in 'Tinkerbell' the deadhead control produced significantly longer shoots than the 1000 and 2000 ppm ethephon treatments. Phytotoxic effects indicated by premature leaf yellowing and drop was observed in the 2000 ppm ethephon treatment of 'Snowdrift'. The leaves affected were those just beneath the flower cluster.

The results of 2 years of study on six populations of *K. latifolia* show that application of 1000 ppm ethephon is effective in reducing seed set and stimulating shoot production and growth without phytotoxicity. Further studies will be required to determine if these observations are true for all cultivars and environmental conditions.

LITERATURE CITED

Perry, E. and **A. Lagarbo.** 1994. Ethephon sprays eliminate the messy, hazardous fruits of flowering pear and liquidambar. California Agriculture, March-April, pp. 21-24.

Elements of a Winning Proposal for an I.P.P.S. — Eastern Region Research Grant

Cameron Smith
The Oxboro Technologies Group, Inc., 10120 Pleasant Ave. S., Bloomington, Minnesota 55420-4708

The International Plant Propagators' Society — Eastern Region offers an annual grant to assist an individual or group to plan, complete, and report on a research project which is intended to advance the art, science, or teaching of plant propagation as they are defined in the Society's constitution and by-laws. The 1997 grant offer is for up to $5,000. This opportunity is open to practicing propagators, teachers, researchers, and others. Good proposal "grantsmanship" often makes the difference between winners and losers. Adopting the following suggestions in your proposal preparation might help to level the competitive playing field.

1) Read and follow all directions carefully. This is the single most important part of the process. Ignoring trivial items such as proposal length, number of copies required, or a submission deadline could disqualify an otherwise winning proposal.
2) State the question that your research is aimed at resolving. Do not assume that the evaluators are experts on your particular topic.
3) Describe your expected results and the impact that they can have on the plant propagation community. This includes both breadth and depth that your findings may have on commercial, research, and/or educational plant propagation activities.

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4) Explain how you will perform your proposed research. This action plan should include the "whats" and "hows" of both your research and its analysis.
5) Demonstrate that your proposed research is within your capabilities and can be completed in less than 1 year. Professional researchers do not have an advantage over practicing propagators or teachers; all applicants must show that they have enough knowledge, facilities, equipment, and time to do the proposed job properly.
6) Tell how you intend to communicate your results to others. It is important to give other propagators, teachers, and/or researchers access to the results of your work. Venues, e.g., the *North American Plant Propagator* or a presentation at an I.P.P.S. conference, are among the many available. The I.P.P.S. motto is "TO SEEK AND TO SHARE."
7) Present a realistic dollar budget for your proposed research. This should name other funding source(s) if needed to complete this project. Using this I.P.P.S. grant to leverage equal or greater funding from other sources is desirable. No I.P.P.S. grant funds should be used to pay for multipurpose capital equipment, overhead, management, supervision or any other indirect costs.
8) Present a realistic time schedule for your proposed research. Good schedules have some elasticity to accommodate real-world delays.
9) Structure and prepare your proposal to be neat, readable, and logical.
10) Allow enough time to prepare a well crafted proposal. It is a harder to write a short, crisp, informative and compelling proposal than a long one loaded with references and unnecessary detail.
11) Certify that each of the following requirements will be met:
    - The proposed or substantially similar research has not been done in whole or part by, with, or for the proposers.
    - To the best of the proposers' knowledge and/or belief the proposed or substantially similar research has not been done and/or reported on at any conference or published in any book, scientific, trade, or general readership publication nor do the proposers have reason to expect such publication before completion and publication of the proposed research results.
    - Details of the proposed research and findings will be published in a venue(s) available to all who may be interested. Every such disclosure or publication shall acknowledge that "The International Plant Propagators' Society - Eastern Region has financially supported in whole (or part) this research."
    - Contemporaneous written technical and expense records of the proposed research will be maintained and preserved for a period of 2 years after first publication of final results of the proposed research. These will be available to the I.P.P.S.
    - None of the proposed I.P.P.S. funding will be used for the acquisition of multipurpose capital equipment or will be used for overhead, supervision, management, or other indirect expenses.

- The name, address, and telephone number of the principal investigator will be provided.

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ONE SUCCESS STORY - STILL IN THE MAKING

A few years ago the I.P.P.S. - Eastern Region research grant was awarded to assist a small commercial propagator in developing key parts of an automated cutting preparation and sticking system. That grant provided the credibility and leverage needed to receive an additional $249,000 in phase 1 and 2 SBIR (Small Business Innovation Research) grants from the USDA. The findings of that research have verified that it is practical to automate the rooted cutting production process. Speed of rooted cutting production will rise while the associated costs and tedious labor decline.

This effort was proposed by someone who saw a need which affected cut flower, pot plant, bedding plant, woody landscape, and forest products producers. The applicant developed a feasible solution concept, did a careful cost analysis, and recruited key technical people. They then wrote a convincing proposal. It applied the best of technology to a broad-based need. In another year or so you may see the fruits of that original grant as commercially available systems which will allow an ordinary assistant propagator to prepare and stick up to 7200 cuttings per hour with a system which pays for itself in a couple of years of normal use.

Taxus Response to Differential Concentration and Timing of Pendimethalin Application

Robert E. McNiel, Kimberly Collins, and Mark Czarnota

Dept. of Horticulture and Landscape Architecture, University of Kentucky, Lexington, Kentucky 40546

Suspected herbicide phytotoxicity injury in the nursery industry initiated our interest in this project. Industry reports indicated that phytotoxicity damage had occurred when pendimethalin was used for weed control in the production of *Taxus*. Initial reports stated foliar death occurred where herbicide application had resulted in foliage contact. Reports have indicated plant injury occurred, but not total plant loss. Our interest was to determine if pendimethalin application was the cause of *Taxus* injury and if so, was it due to application at early growth stage or rate or formulation of material applied.

An established field planting of 24- to 30-inch *T.* ×*media* 'Densiformis' was used for this experiment. Treatment plots measured 12 ft × 7 ft, with three plants per plot. Five treatments were used on three spray dates, for a total of 15 treatments

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Table 1. Phytotoxicity ratings on *Taxus* after treatment with pendimethalin.

Treatment	Form	Rate and unit	Application date	May 12 rating	June 3 rating	June 18 rating	Aug. 28 rating	Sept. 30 rating
Pendulum	3.3 EC	2.0 lb AIA	April 28	0.0 b	0.1 b	0.4 abc	0.6 fg	1.1 e
Pendulum	3.3 EC	4.0 lb AIA	April 28	0.1 ab	0.1 b	0.5 ab	1.1 def	1.4 de
Pendulum	3.3 EC	8.0 lb AIA	April 28	0.3 ab	0.1 b	0.5 ab	1.9 cd	2.3 c
Pendulum	60 WG	4.0 lb AIA	April 28	0.4 a	0.4 a	0.7 a	1.0 def	1.1 e
Control			Aril 28	0.0 b	0.0 b	0.0 e	0.0 g	0.0 f
Pendulum	3.3 EC	2.0 lb AIA	May 13		0.1 b	0.1 de	1.9 cd	2.1 cd
Pendulum	3.3 EC	4.0 lb AIA	May 13		0.1 b	0.2 bcde	3.3 a	3.9 ab
Pendulum	3.3 EC	8.0 lb AIA	May 13		0.2 ab	0.2 bcde	3.0 ab	4.3 ab
Pendulum	60 WG	4.0 lb AIA	May 13		0.2 ab	0.4 abc	1.2 cdef	1.1 e
Control			May 13		0.0 b	0.0 e	0.0 g	0.0 f
Pendulum	3.3 EC	2.0 lb AIA	May 30			0.3 bcd	1.2 cdef	1.9 cd
Pendulum	3.3 EC	4.0 lb AIA	May 30			0.2 cde	1.7 cde	3.7 b
Pendulum	3.3 EC	8.0 lb AIA	May 30			0.4 abc	2.1 bc	4.7 a
Pendulum	60 WG	4.0 lb AIA	May 30			0.3 bcde	0.8 efg	1.0 e
Control			May 30			0.0 e	0.0 g	0.0 f

Column means followed by different letters are significantly different (P=0.05; ANOVA)

Table 2. Weather data for Lexinton, Kentucky for the seven day period following herbicide application

Treatment time	Date	Air temperature Max.	Air temperature Min.	Precipitation
Date of Treatment 1	April 28	56	47	T
	April 29	67	40	
	April 30	78	46	0.32
	May 1	57	47	0.04
	May 2	76	46	0.19
	May 3	61	47	1.03
	May 4	64	41	
Date of Treatment 2	May 13	61	41	T
	May 14	71	46	0.09
	May 15	61	42	0.06
	May 16	60	33	
	May 17	73	48	0.08
	May 18	84	61	0.02
	May 19	82	64	0.37
Date of Treatment 3	May 30	75	54	0.06
	May 31	66	63	2.85
	June 1	70	62	0.53
	June 2	79	52	0.07
	June 3	72	57	0.01
	June 4	65	53	
	June 5	67	53	T

T = trace.

replicated three times. The treatments were: pendimethalin (Pendulum) 3.3 EC at 2, 4, and 8 lb active ingredient per acre (AIA); pendimethalin (Pendulum) 60WG at 4 lb AIA; and a control. The spray dates were: 28 April, 13 May, and 30 May 1997. Treatments were applied over the top of the plants using a CO_2-pressurized backpack sprayer calibrated to 26 GPA using 8004 nozzles at 30 psi at the boom. New growth on the *Taxus* was approximately 1 inch in length on 28 April 1997.

Plant phytotoxicity was measured on a scale from 0 to 10 (0 representing no phytotoxicity and 10 representing plant death). Spray date one was evaluated on May 12; spray date one and two were evaluated on 3 June; spray dates one, two, and three were evaluated on 18 June. Evaluation on 7 July was not performed because no visible change in foliage was observed. Once dead foliage was observed, evaluations were continued for all three spray dates on 28 Aug. and 30 Sept. 1997.

Phytotoxicity during the 12 May, 3 June, and 18 June ratings consisted of slight foliar discoloration. No change had occurred by 7 July and the plot was not rated.

This was different from what was reported in the nursery industry where foliar death was reportedly occurring within weeks. By mid August, foliar injury had become more pronounced and ratings were resumed on 28 Aug. and 30 Sept. Phytotoxicity increased in intensity as the season progressed. Final level of damage was still unknown on 30 Sept. With the EC formulation, phytotoxicity increased as the rate increased from 2 to 8 lb (Table 1). Although the WG formulation initially caused more severe discoloration during the first ratings, by the Sept. rating damage was less than that of the EC formulation. Besides causing foliar discoloration, the most severely affected plants also exhibited stunted growth of newly emerged shoot tissue.

This class of herbicides is known to influence root system growth and has strong adsorption to soil. Little information is available on foliar uptake or injury associated with woody landscape plants. For turfgrass, pendimethalin will be retained on and within the foliage (Stahnke, 1991). Exposure to sunlight and high temperatures are thought to contribute to initial pendimethalin dissipation (Stahnke, et al., 1991). Temperatures were below normal for Lexington, Kentucky, during our initial treatment. Varying levels of rainfall occurred immediately after application on each treatment date (Table 2). Rainfall apparently had limited influence on *Taxus* injury and growth; however, the influence of mild temperatures is unknown. Mild temperatures may contribute to the slow development of severe phytotoxicity. Photos were taken 16 September 1997.

Pendimethalin, at levels of 2 to 8 lb acre^{-1}, may inhibit new shoot development for cutting propagation in *Taxus*. The slow rate of phytotoxicity symptom development could mean that cuttings taken from treated plants may fail after entering the propagation cycle.

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Eastern Redbud (*Cercis canadensis*) Toxicity with Increasing Rates of Sulfentrazone

Kimberly B. Collins, Robert McNiel, and Leslie A. Weston
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Sulfentrazone, an experimental herbicide from the FMC Corporation, has shown promising results for long-term weed control in field trials with ornamentals by controlling weeds such as morningglory and yellow nutsedge that are difficult to manage with currently labeled products (Collins et al., 1996). This compound has recently been labeled for use in both soybeans and tobacco. A possible hindrance to the labeling of sulfentrazone for use in ornamentals is the phytotoxicity that occurs in certain sensitive ornamental species.

Sulfentrazone works by inhibiting protoporphyrinogen oxidase in the chlorophyll biosynthetic pathway in susceptible plants. As a result, a phytodynamic toxicant (protoporphyrin IX) builds up, leading to membrane disruption. Sulfentrazone is absorbed by both the roots and shoots of plants, which turn necrotic and die shortly after exposure to light. Postemergence application of sulfentrazone, resulting in foliar contact of weeds, can cause rapid desiccation and necrosis in affected species, particularly smaller ones (Theodoridis et al., 1992; Van Saun et al., 1991).

In a field trial using sulfentrazone during 1996, *Cercis canadensis* exhibited foliar damage, but phytotoxicity ratings were not noted because the damage resembled *Botryosphaeria* canker, a common disease of redbuds in this area. After much discussion about that trial, an experiment was designed to determine if sulfentrazone had detrimental effects on *C. canadensis*, and if increasing rates were related to increased phytotoxicity.

Cercis canadensis liners measuring 18 to 24 inches were planted in 3-gal containers in April 1997 using a medium consisting of pine bark and expanded shale (2 : 1, v/v). The plants were allowed to leaf out completely and establish new roots. Sulfentrazone 80WP was applied in May 1997 at increasing rates for a total of six treatments (0.125, 0.25, 0.375, 0.5, and 0.625 lb ai acre^{-1}, plus a control). Ten single plant reps were used for each treatment, arranged in a completely randomized design of 60 plants. Plants were watered using trickle irrigation. Treatments were applied using a CO_2-pressurized backpack sprayer calibrated to 26 GPA using 8004 nozzles at 30 lb psi at the boom. Plant phytotoxicity ratings were taken weekly after herbicide application, measured on a scale from 0 to 10 (0 representing no phytotoxicity and 10 representing plant death). Plants were harvested 6 weeks after treatment (WAT). At that time, a visual root rating was taken on a scale from 0 to 10 (0 representing no root damage compared to the control and 10 representing plant death). Shoot and root dry weights were determined after drying for 2 days in a 40C oven.

Phytotoxicity ratings are reported in Table 1 and Fig. 1. Phytotoxicity appeared as a reddish-brown necrotic area around the leaf margin, eventually spreading throughout the whole leaf. A more severe form of phytotoxicity was exhibited as current season stem death in some plants. At 1 WAT, phytotoxicity increased with increasing sulfentrazone rates as expected. At 2 WAT, we observed increasing

Table 1. Phytotoxicity ratings.

Treatment	Rate	1 WAT	2 WAT	3 WAT	4 WAT	5 WAT	6 WAT
Sulfentrazone 80WP	0.125	2.9 c	2.2 c	2.7 c	3.6 b	2.9 a	3.2 a
Sulfentrazone 80WP	0.250	3.1 c	3.1 c	3.7 bc	4.2 ab	3.0 a	3.6 a
Sulfentrazone 80WP	0.375	4.7 b	3.2 bc	3.9 abc	4.1 ab	3.2 a	3.5 a
Sulfentrazone 80WP	0.500	5.7 ab	4.4 ab	4.7 ab	4.7 a	3.5 a	3.6 a
Sulfentrazone 80WP	0.625	6.6 a	5.2a	5.1 a	4.8 a	3.7 a	3.7 a
Control	0.000	0.0 d	0.0 d	0.0 d	0.0 c	0.0 b	0.0 b
LSD at $P < 0.05$	--	1.54	1.29	1.28	0.95	1.04	0.92

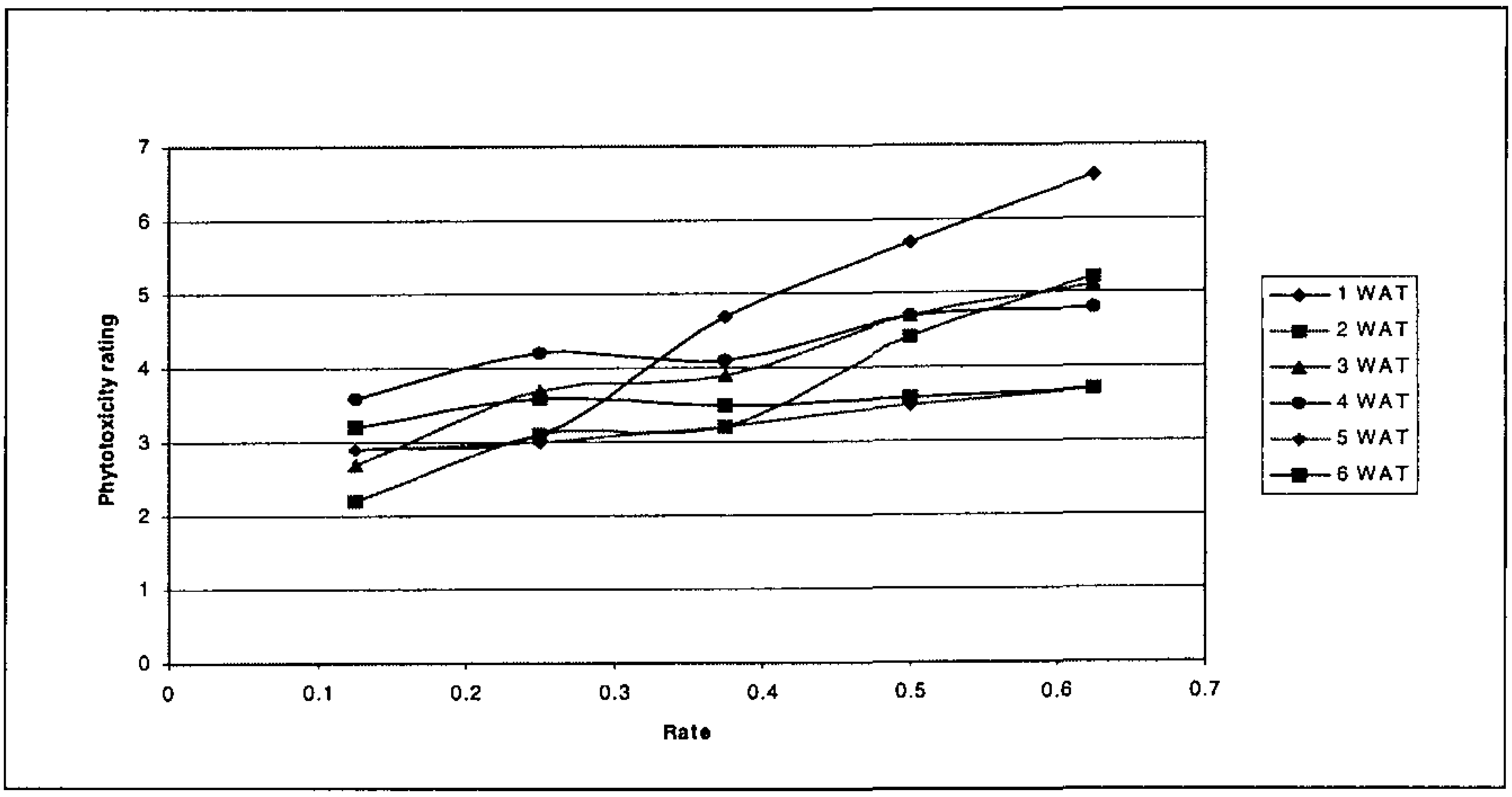

Figure 1. Sulfentrazone toxicity on *Cercis canadensis*.

phytotoxicity with increasing rates, but this response was not as linear or exponential with increasing rate. This phenomenon was due to the fact that the more severely damaged plants were producing new growth which was undamaged, while the plants that initially had less damage were exhibiting increasing toxicity. By 4 WAT, response was similar among all treatment combinations, with a difference of only 1.2 between the lowest and highest rates. The higher rates had a considerable amount of new growth by this time, thereby negating some of the initial negative effects of sulfentrazone. An explanation for the continued decline of the plants sprayed with lower rates could be that the higher rate effects were initially so severe that the stressed plants temporarily shut down growth and translocation processes, no longer absorbing the herbicide, while the plants sprayed with lower rates continued to absorb the herbicide readily, allowing continued translocation throughout the plant. By 5 and 6 WAT, there were no significant differences among the rates of sulfentrazone. The phytotoxicity ratings were slightly higher at 6 WAT, due to abnormal growth noticed on the new leaves of plants in all treatments, indicating sulfentrazone phytotoxicity persisted 6 WAT from visual analysis.

Table 2. Root and shoot evaluation.

Treatment	Rate	Root rating	Root dry weight(g)	Shoot dry weight(g)
Sulfentrazone 80WP	0.125	5.4 c	7.86 b	13.76 ab
Sulfentrazone 80WP	0.250	6.0 bc	7.86 b	11.19 bc
Sulfentrazone 80WP	0.375	7.3 ab	4.65 b	7.85 cd
Sulfentrazone 80WP	0.500	7.7 a	3.88 b	6.02 d
Sulfentrazone 80WP	0.625	6.4 abc	6.75 b	9.17 bcd
Control	0.000	0.0 d	13.88 a	17.97 a
LSD at $P < 0.05$	-	1.64	4.40	4.87

At 6 WAT, plants were harvested and a visual root rating was given to each plant (Table 2). Roots were then separated from shoots and placed in a drying oven for 2 days. At this time, root and shoot dry weights were measured in grams (Table 2). The visual root rating increased with increasing sulfentrazone rates, but dropped at the highest rate. The shoot dry weight followed a similar trend, decreasing with increasing sulfentrazone rates, but increased again at the highest rate. These observations could be attributed to the fact that the plants sprayed with the highest rate of sulfentrazone started to show new growth earliest after the initial treatment, and had the most time to regenerate. The root dry weights showed no significant difference among sulfentrazone treatments, although there were differences visually. Future experiments could utilize more replications to evaluate treatment effects.

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Yankee Nursery Online: Your Future on the Web

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Over the last 10 to 15 years, colleges of agriculture in New England and other parts of the U.S. have experienced a significant reduction in their resources available and committed to landscape horticulture and nursery crops. At the same time, there has been a dramatic increase in the need for high quality teaching and learning in these areas to meet the demand for well trained graduates generated by the tremendous and continued growth in the ornamental plant industries. One of the most essential skills needed by individuals entering the landscape and nursery industries is a solid and broad knowledge of landscape plant materials.

Students, educators, and landscape professionals need visual materials to help learn, teach, and sell plants. Adequate and cost-effective visual materials do not exist in the form of books or CD-ROM programs. Existing media lacks sufficient breadth and depth to serve the needs of baccalaureate degree teaching and learning. Outdoor campus plant walk laboratories are commonly used at all universities, but are limited by the plant specimens present, weather conditions and the inability to see the many seasonal plant features at one point in time. A multimedia database is being developed on the World Wide Web (WWW) (http://www.canr.uconn.edu/plsci/mbrand) which will contain descriptive text, thousands of photographs of over 1000 landscape trees, shrubs, and vines used in U.S.D.A. Zone 6 or colder, as well as a sound library of pronunciations. This database will provide users with a single body of information on plant species, cultivars and varieties, and their characteristics, the breadth and depth of which is not available elsewhere. It will include information and pictures of habitat, habit and form, summer foliage, autumn foliage, flowers, fruit, bark, culture, landscape uses, liabilities, identification features, propagation, and varieties and cultivars.

In conjunction with the plant material database, "Virtual Campus Plant Walks" are being developed for all of the New England Land Grant University campuses, and one private college campus, which will enable undergraduate and associate degree students to repeat on-campus plant walks from their dormitory room or from any capable computer connected to the WWW. "Virtual Campus Plant Walks" will be specific to each laboratory walk, and each campus, and will be comprised of a series of image-mapped photographs of each stop along the route taken by the instructor. Students using the program will be able to move their mouse cursor over an image-mapped photograph and click on the plant covered during the walk, as indicated by the cursor changing to a hand with a pointing finger. By clicking on the image-mapped plant, students will then seamlessly access the plant material database and its textual, visual, and audio information on all plant characteristics, rather than just those characteristics visible during an outdoor campus plant walk laboratory. The plant material database will also serve as a free reference and instructional aid for the nursery and landscape industry, agricultural consultants, extension personnel, landscape architects, and the gardening public.

In addition to the plant material sections, Yankee Nursery Online also has a section on nursery and landscape extension personnel. For each employee with ornamental horticulture extension responsibilities, information is provided that tells the web visitor the expertise of each person, where they are located and how to reach them for assistance. A photograph is also provided of each person so growers and landscapers can recognize the people they have contacted.

Horticultural fact sheets are available at the web site in Adobe Acrobat PDF file format and other Extension publications will also be added. The PDF file format allows the web site user to view and print the fact sheets exactly as they are in the hardcopy versions by using free Acrobat Reader software and any internet-capable computer with a laser printer. Similarly, back issues of Yankee Nursery Quarterly, a regional Extension Nursery publication produced by the University of Connecticut, are available in PDF file format.

Effect of Division Size on Direct-potted Ornamental Grasses

Mark H. Brand
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INTRODUCTION

In many nursery operations, ornamental grasses are potted in May using established plugs. These plugs are started in October/November (cool season grasses) or in February (warm season grasses) from very small divisions made from the previous year's container crop. Although this system makes efficient use of a small number of stock plants to yield a large quantity of small divisions, it adds an extra step to the production process. This extra step has the potential to add cost to the process in the form of additional labor-hours, additional skills needed by laborers, and fuel to at least minimally heat greenhouses. Typical production methods also require that a grower is set up to efficiently deal with a plug production system that uses a different set of pots, potting medium, materials handling equipment, and so on, than are used for 1- and 2-gal production.

Of course, when stock plants are limited in number, such as for new cultivars and species or for slow-to-increase selections, this method makes the most sense, allowing one to gain the greatest number of plants from a minimal amount of stock materials. However, for more common plant material and those that increase rapidly, we don't have to be as concerned about conserving plant material and dividing the plants down to the smallest propagule that is possible. In these cases, a method where a larger division is potted directly into the container size that the plant will be marketed in may be another approach worth considering. The advantage of this type of system is the elimination of the entire plug production step, which, as was discussed earlier, can be resource intensive.

MATERIALS AND METHODS

A study was conducted during the 1995 growing season to look at the performance of two division sizes of several common ornamental grasses when used in a direct potting system that eliminates the plug production step. The research was conornamental horticulture extension responsibilities, information is provided that tells the web visitor the expertise of each person, where they are located and how to reach them for assistance. A photograph is also provided of each person so growers and landscapers can recognize the people they have contacted.

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MATERIALS AND METHODS

A study was conducted during the 1995 growing season to look at the performance of two division sizes of several common ornamental grasses when used in a direct potting system that eliminates the plug production step. The research was conducted at the Department of Plant Science Research Farm, University of Connecticut, Storrs, Connecticut. The ornamental grasses used in the study are listed below. For each grass, divisions of two sizes, large and small, were made on 9 May 1995 as follows: *Miscanthus sinensis* 'Graziella' (small = 4 to 6 tillers, 2 inch × 2 inch clump, large = 15 to 20 tillers, 4 inch × 4 inch clump); *M. sinensis* var. *purpurascens* (small = 12 to 15 tillers, 3 in. × 3 inch clump, large = 50 tillers, 5 inch × 5 inch clump); *M. sinensis* 'Silberfeder' (small = 3 to 5 tillers, 2 inch × 2 inch or 3 inch × 5 inch clump, large = 8 to 12 tillers, 5 inch × 5 inch clump); *M. sinensis* 'Strictus' (small = 3 to 5 tillers, 2 inch × 2 inch clump, large = 9 to 11 tillers, 4 inch × 5 inch clump); *M. sinensis* 'Variegatus' (small=4 to 6 tillers, 2 inch × 3 inch clump, large = 12 to 15 tillers, 4 inch × 4 inch clump); *Calamagrostis ×acutiflora* 'Karl Foerster' (small = 15 to 20 tillers, 1 inch × 2 inch clump, large = 35 to 40 tillers, 2 inch × 4 inch clump); *Panicum virgatum* (small = undetermined number tillers, 2 inch × 2 inch clump, large = undetermined number tillers, 4 inch × 4 inch clump); *Pennisetum alopecuroides* (Small = 12 to 15 tillers, 1.5 inch × 1.5 inch clump, large = 25 to 30 tillers, 2 inch × 3 inch clump). All divisions were potted directly into 2-gal containers (Nursery Supplies Classic 600 containers). The potting medium used was an aged pine bark, peat moss, and sand mix (3 : 2 : 1, by volume) to which 7 lb of dolomitic lime was added per cubic yard of mix. Each container was top dressed with 40 g of Sierra 17-6-10 controlled release fertilizer, 8- to 9-month formulation, plus minor nutrients. Plants were grown in an outdoor gravel container nursery and received irrigation through a trickle system (0.5 gal per pot, 3 times daily). For each ornamental grass type, 10 pots were used per division size. At the end of the growing season (27 Sept.), data were collected to determine and compare how well small and large divisions performed in a direct pot system. The following measures of plant performance were evaluated: foliage height, flower height, number of flowers per plant, number of tillers per plant, plant fresh weight, and plant dry weight.

RESULTS AND DISCUSSION

All of the grasses tested in this study did well in a direct pot system, producing salable 2-gal plants by the end of the growing season or earlier. Although I was concerned that uniformity of the plants produced by direct potting of divisions might not match that of those produced by potting plugs, the mature plants were no more variable than plants grown from plugs that I have observed at commercial nurseries. For the *M. sinensis* cultivars used in the study, larger divisions produced plants with significantly more tillers and greater fresh and dry weight (Table 1). The only exception was 'Silberfeder', which showed no differences in fresh and dry weight between plants from large and small divisions. In general, division size did not affect the foliage height or flower height of *M. sinensis* cultivars. However, 'Silberfeder' large divisions were again the exception, producing taller flowers than small divisions. Number of flowers per plant was greatest for large divisions of 'Graziella' and 'Purpurascens', but 'Silberfeder', 'Strictus', and 'Variegatus' showed no differences in flower number between large and small divisions. I should point out that evaluating flower number, and especially ultimate flower height, was challenging on 'Strictus' and 'Variegatus' because both cultivars bloom late in the fall and often fail to fully complete the blooming process before the first hard frost.

Larger divisions were important for the production of flowers on *C. ×acutiflora* 'Karl Foerster' (Table 1). Large divisions produced over double the number of flowers

Table 1. The response of small and large divisions of eight ornamental grasses to direct potting. Where significant differences exist between division sizes (Tukey-HSD at $P \leq 0.05$), the first value given is for small divisions and the second value is for large divisions. NS indicates no significant differences between small and large divisions

Grass cultivar	Foliage height (cm)	Flower height (cm)	Flower number	Tiller number number	Fresh weight (g)	Dry weight (g)
Calamagrostis ×acutiflora 'Karl Foerster'	NS	131, 141	8.4, 19.0	NS	NS	82, 102
Miscanthus sinensis 'Graziella'	NS	NS	20.6, 26.6	39.0, 61.6	533, 606	202, 229
M. sinensis var. *purpurascens*	NS	NS	15.5, 29.0	60.1, 92.7	397, 480	163, 209
M. sinensis 'Silberfeder'	NS	149, 184	NS	35.6, 42.7	NS	NS
M. sinensis 'Strictus'	NS	NS	NS	33.0, 42.7	378, 507	118, 171
M. sinensis 'Variegatus'	NS	NS	NS	31.7, 45.4	423, 541	134, 180
Panicum virgatum	NS	NS	NS	140.1, 188.7	NS	NS
Pennisetum alopecuroides	93, 86	NS	35.7, 44.3	88.6, 112.8	NS	NS

of small divisions and the flowers were also taller. A difference was also detected between small and large divisions of *C. xacutiflora* 'Karl Foerster' for dry weight, but not for fresh weight. This is probably due to the fact that *Calamagrostis* flowers dry to tan early in the season and were already dry prior to the harvest date. Therefore, plants from large divisions had under-represented fresh weights in comparison to plants from small divisions, because a greater percentage of what was weighed for fresh weight was flowers that were already dry.

Switchgrass (*P. virgatum*) was simply too vigorous for a 2-gal container when large divisions were potted. Plants from the large divisions rapidly filled the pots and exhibited signs of growing under nutrient and possibly moisture deficiencies. The data bear out this empirical observation. Although large-division plants produced 40 to 50 more tillers per plant than small-division plants, there were no differences in fresh and dry weight, number of flowers, foliage height, or flower height (Table 1). This indicates that large-division plants had a greater number of thin, wiry tillers that failed to flower and were not particularly lush.

Fountain grass (*P. alopecuroides*) responded somewhat similarly to switchgrass. Large divisions seemed to be too much plant to start with, causing plants to become nutrient and/or water starved during the season. Large divisions had shorter foliage than small divisions, a greater number of flowers and a greater number of tillers (Table 1). However, the extra tillers and flowers may not compensate for the slightly anemic appearance of the plants.

Propagation of *Weigela florida* 'Alexandra', WINE & ROSES™ Weigela

Gail Billingsley
Spring Meadow Nursery, 12601 - 120 Ave. Grand Haven, Michigan 49417

Spring Meadow Nursery is a wholesale grower of woody shrub liners or starter plants. Many of our plants, like *W. florida* 'Alexandra', WINE & ROSES™ weigela, are direct rooted in pots that have a thin coating of SpinOut™. SpinOut™ is a root growth regulator containing 7.1% copper hydroxide that is sprayed on the interior portions of the pots to prevent circling roots. One cutting is stuck per $2^1/_4$-inch pot. The medium is composed of perlite, pine bark, and peat moss (55 : 35 : 10, by volume). The medium is amended with the following materials per cubic yard:

- 2 lb potassium nitrate 13.75-0-44.50
- 2 lb triple phosphate 0-46-0
- 4.5 lb Nutricote type 140 18-6-8
- 10 lb limestone

Weigela florida 'Alexandra', WINE & ROSES™ weigela is an easily rooted plant taken as softwood cuttings spring through mid-summer. The cuttings are ready to be taken when the stem is firm enough to snap rather than bend. A two-node cutting is taken just above the second node.

To improve efficiency, the cuttings are bundled in groups of 50 which are held together with a small rubber band. Unless there is access to a cooler or refrigerator, the cuttings should be stuck within 6 h. Application of Woods hormone in 1 : 20

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dilution (500 ppm IBA), as a quick dip, is applied to the basal portion of the bundled cuttings. Although rooting would occur without the use of hormone, its use provides more consistent rooting.

Following sticking the cutting, the flat moves through a watering tunnel that thoroughly waters the medium and prevents desiccation before being placed under mist or in a fog environment. The flats containing *W. florida* WINE & ROSES™ weigela are placed on the concrete floor of Stuppy gutter connected greenhouses. Two systems for rooting are used. One method is under a traveling irrigator from Growing Systems with misting frequencies dependant on the time of day and light intensity controlled by a PRIVA environmental computer system. The other method is in a high humidity environment (90% to 95%) provided by a high pressure Mee Fog system. Traveling irrigators are used once or twice per hour on hot, sunny days to prevent overheating of the unrooted cutting.

Root initials appear within 7 to 10 days in both environments and after 4 weeks are rooted sufficiently to undergo hardening off by reducing mist frequency to 0 to 10 times per day or being moved out of the fog environment. Rooting percentages have been 90% to 95% in either environment with few disease problems noted.

Chionanthus virginicus: Embryo Culture vs. Traditional Germination

Charlotte R. Chan and Robert D. Marquard
The Holden Arboretum, 9500 Sperry Road, Kirtland, Ohio 44094-5172

INTRODUCTION

Chionanthus virginicus is traditionally propagated by seed sown outdoors, with germination taking 2 years to break double dormancy. Cuttings have not been as successful (Dirr,1987; Nicholson,1990), and grafting to *Fraxinus excelsior* rootstock (Dirr,1994) or *F. ornus* (Fagan,1980; Young,1992) has met with limited success. Work with embryos cultured on a gibberellic-acid-enhanced medium (Redcay and Frett, 1990) and with removal of the epidermis, pericarp, and endocarp to accelerate germination (Carpenter et.al.,1991) suggested a possible method to overcome the dormancy and to compress the time to obtain marketable plants. The objective of this investigation was to compare traditionally propagated and embryo-cultured *C. virginicus* for percent germination, plant size, and vigor over a duration of 2 years.

MATERIALS AND METHODS

Embryo Culture. Fruit (still green) of *C. virginicus* were collected 9 Aug., 16 Aug., and 23 Aug. 1995. The fruits were surface sterilized with 95% ethanol for 30 sec, then in 20% household bleach and 0.1% Tween with agitation for 20 min, rinsed 3 times for 4 min each in sterile distilled water, then left in the final rinse until excision. Ninety embryos were excised for each collection date and placed three per baby food jar for a total of 90 jars with 270 embryos.

Andersons rhododendron medium (Anderson,1978) was prepared a day in advance and included: 3.0% sucrose, 0.7% Difco-bacto agar, M.S. vitamins, and brought to pH dilution (500 ppm IBA), as a quick dip, is applied to the basal portion of the bundled cuttings. Although rooting would occur without the use of hormone, its use provides more consistent rooting.

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Andersons rhododendron medium (Anderson,1978) was prepared a day in advance and included: 3.0% sucrose, 0.7% Difco-bacto agar, M.S. vitamins, and brought to pH

5.8 with 1M KOH. Medium was melted in a microwave (15 min for 2 liters of medium) to evenly distribute the agar. Thirty milliliters of medium was distributed to each jar, with the jars loosely capped, and autoclaved for 15 min at 121 C.

The embryos were excised under sterile conditions in a laminar flow hood. The radicle end of the embryo is at the distal end of the fruit. To excise, the fruit was held laterally with forceps, while the stem end was cut off just enough to remove part of the endocarp. The fruit was placed cut surface down, held in place with forceps, and cut again along the side only enough to expose the endosperm. By carefully running the scalpel between the endocarp and endosperm, the embryo dislodged and generally lay along the side of the scalpel blade. The embryo was then placed with radicle in the sterile medium and cotyledons above the medium surface. After capping the jars tightly, the lids were sealed with parafilm. On average, 30 embryos could be excised per hour.

Cultures were placed in growth chambers at 25C with 16-h illumination (40 watt cool white fluorescent bulbs). After 4 weeks incubation, the germinated embryos were transferred to flats that contained a sterile perlite and peat mix, watered-in, covered with plastic, and placed in a greenhouse (high humidity at 18 to 24C). Plastic was removed after 1 week. Flats were moved to cold storage (4C) on 12 Jan. 1996 for 2 months. On 8 March 96 the flats were moved out of cold storage to a greenhouse at 18 to 24C. The seedlings were transplanted to pots 12 June 96 into a standard potting mix and returned to the greenhouse. The pots were moved into cold storage (0 to 4C) 4 Nov. 96, then out again 7 May 1997, and transplanted to 1-gal bags 27 June 1997.

Traditional Germination. Fruit (158) from the same seed source were collected on 20 Sept. 1995, pulped and cleaned, then stratified 79 seeds per seed pan in sterile germination medium (peat and perlite). The pots were placed in a greenhouse at 21 to 27C with mist for 5 months.

The pots were moved to 4C on 20 Feb. 96 for one month, then returned to the greenhouse. Carpenter et.al. (1992) reported on the ineffectiveness of additional cold treatments as a means of shortening the germination period. Therefore, pots remained in the greenhouse until the appearance of cotyledons. On 21 April 1997 the seedlings were transplanted from the seed pans to individual pots.

Data including germination, seedling heights, numbers of leaves, and stem calipers were collected at regular intervals for all seedlings. In Oct. 1997, 10% of each of the two groups of seedlings were randomly selected, cleaned of all soil, thoroughly dried in a 95C oven for 24 h and weighed (roots, stems, and leaves) for mass comparison.

RESULTS AND DISCUSSION

Excised embryos started to expand and grow within 3 days. One month after initiation on sterile medium, most of the embryos had true leaves and radicles over 4 cm in length and were transplanted to sterile soil. Mortality occurred due to contamination in culture, as well as during the seedling stage. By Oct. 1997, the survivorship was 6% (for excision on 9 Aug.), 18% (16 Aug.), 21% (23 Aug.), and 44% for traditionally grown seedlings.

On 15 May 1997, measurements were made of seedling heights and numbers of leaves for both groups and averages calculated: average height for embryo cultured was 12.7 cm and 2.7 cm for traditional, and average number of leaves was 8.8 for embryo cultured and 2.8 for traditional. Stem caliper measurements made at root collar level compared as follows: embryo cultured seedlings averaged 7.9 mm and traditional averaged 2.6 mm.

Dry weight data, collected Oct. 1997 demonstrated an overall increase for the embryo-cultured group of 13.4-fold over that of the traditionally germinated group of seedlings.

In conclusion, additional time and labor were required for the embryo-cultured seedlings and the rate of germination success was lower than for the traditionally-germinated seedlings. However, a comparison of culture methods showed a remarkable difference in both size and vigor, suggesting embryo-culture to be a viable alternative to traditional propagation.

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American Wild Celery (*Vallisneria americana* Michx.): Propagation of Revegetation Transplants from Seed

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INTRODUCTION

American wild celery (*Vallisneria americana* Michx., family Hydrocharitaceae) is a submerged grass-like aquatic perennial that grows in fresh or slightly brackish water from Canada to Florida, west to the Dakotas (in the north) and to Arizona and New Mexico (in the south).

Reproduction commonly occurs by vegetative means, either by stolons during the summer, or in the spring from overwintering buds (known as turions) formed at the end of stolons. Sexual reproduction also occurs in the wild, but there have been very few documented observations of seedlings. Wild celery plants are dioecious, and flowering occurs in the upper Chesapeake Bay during August and September. On male plants, flowers develop in a spathe at the base of the plant, breaking free and floating on the water surface to release pollen upon maturation. The flowers of female plants are tubular and sit atop long peduncles (basally attached) that grow to the water surface. Once the female flowers are fertilized at the surface by floating pollen, the peduncles coil to pull the immature fruits underwater. Mature fruits are long capsules that resemble green beans; each capsule contains 150 to 300 seeds (dark brown when ripe) in a gelatinous substance. Capsules split to release seeds and gel into the water.

Wild celery is a particularly valuable submerged aquatic vegetation (SAV) species, since it provides food and habitat for a variety of fish, invertebrates, and waterfowl. The canvasback duck, *Aythya valisineria*, is even named because of its association with wild celery. Wild celery is able to colonize areas that other SAV cannot — it can grow in fairly turbid water and tolerates high nutrient levels as well as nutrient-poor water; it can also tolerate lower light levels than other SAV species. It acts as a shoreline erosion control and a nutrient buffer.

SEEDLING PROPAGATION

The National Plant Materials Center (NPMC) is cooperating with the U.S. Army Environmental Center (USAEC) at Aberdeen Proving Grounds, Maryland and Anne Arundel Community College (AACC) in Arnold, Maryland on this project. The USAEC is attempting to restore wild celery beds in the Gunpowder River, an upper Chesapeake Bay tributary. Studies were initiated at the NPMC to investigate production of revegetation transplants from seed and at AACC to examine micropropagation techniques. Using nursery-grown wild celery would be an alternative to the current method of disturbing existing celery beds for transplant material, and seedlings would provide greater genetic variability than clonal transplants in the restored areas.

The NPMC is currently in the process of developing a propagation / production protocol and has summarized the information gathered for each step of the process:

Seed Collection. Seed pods were collected from the lower Gunpowder River in the first week of Oct. 1996. Proportion of light-colored (immature) to dark brown (mature) seeds was approximately 1 : 1. Pods were collected before they could be scavenged by waterfowl. The NPMC obtained the seeds in Dec. 1996.

Seed Storage. Seed pods were stored whole in tap water at 4C in the dark. Seed pods and mucilage began to fall away from the seeds after 4 months.

Germination. The literature is mixed regarding the need for a cold treatment prior to sowing. Seeds collected in 1996 stored wet and cold for 3 months (and longer) germinated readily in the greenhouse. The NPMC is testing seeds collected in 1997 for a stratification requirement. From observations at the NPMC, seeds do not require light for germination. In fact, seeds can be lightly covered with medium when sown since uncovered seeds have a tendency to float after germinating. An experiment was carried out in Aug. 1997 on a range of temperatures to determine which resulted in the greatest germination. Four 10-gal aquaria were heated to 20, 25, 30, and 35C, respectively. Three pots of sand, each containing 100 celery seeds (sown 5 mm deep) were placed in each aquarium. Germination was counted over a period of 1 month and seedlings were removed as they were counted. An incubation temperature of 20 C resulted in 7.7% germination, 25C in 25.0%, 30C in 21.7%, and 35C in 3.0%.

Seedling Production. The NPMC is currently investigating growing conditions and media most effective for generating transplant material in a reasonable amount of time. Three growing methods were evaluated in 1997: peat pots, plastic pots, and coconut fiber mats.

Seed Propagation And Production of *Trillium grandiflorum*

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INTRODUCTION

The genus *Trillium* is widely known and long recognized as one of the most beautiful components of the spring woodland wildflower garden. There are approximately 35 species native to the eastern U.S. Of these, roughly 10 species are offered for sale by wholesale nurseries. In recent years conservationists have raised concerns about the source of these plants. Reports indicate that nursery propagation by seed is rare, most trillium rhizomes are wild collected.

Research Goals at Mt. Cuba Include:

- Recognizing the need for and benefits of propagating native species in the nursery.
- Determining the most cost effective and labor efficient methods of doing so.
- Selecting exceptionally attractive, easily cultivated species.

Supporting Marketing Strategies Might Include:

- Emphasizing the desirability of purchasing healthy, vigorous, flowering-sized plants that have been established in containers and are well adapted for survival in the landscape.
- Promoting the conservation benefits of nursery grown plants.
- Promoting the image of difficult-to-propagate native plants as garden perennials with appropriate market value.

MATERIALS AND METHODS

Trillium grandiflorum berries (approximately 10,000 seeds) were collected on 8 July 1991 from the G. Richard Thompson Wildlife Management Area near Linden, Virginia with permission from the Commonwealth of Virginia Department of Game and Inland Fisheries. They were cleaned and planted in a 5 ft × 10 ft bed filled with sterilized soil and Promix BX (1 : 1, v/v) on July 10, 1991. The bed was watered, covered with a 1-inch layer of pine straw followed by landscape fabric to conserve moisture and discourage the establishment of weeds. The landscape fabric was removed the following spring; by early May approximately 50 seedlings had appeared. The bed was watered and weeded as necessary until November when the landscape fabric was reapplied. By early April 1993 additional seedlings had emerged bring the total number to approximately 2000. Shadecloth (30%) was added due to early seedling dieback from excessive sunlight. Subsequent care included the yearly removal of landscape fabric in March and it reapplication in November. The bed was fertilized in April 1994, 1995, and 1996 with Agriform 14-4-6 at the lowest recommended rate. The bed was checked weekly for watering and weeding needs.

In early September 1996 all plants were lifted: the foliage was removed and their rhizomes were weighed and 1000 plants were planted into individual 3-5/8 × 5-1/2-

inch tree bands, 25 bands per flat. There was a total of 40 flats, subdivided into groups of 10 flats. In Weight Class 1 the rhizomes weighed .10 to 1.25 g, in Weight Class 2 the rhizomes weighed 1,26 to 2.99 g, in Weight Class 3 the rhizomes weighed 3.00 to 5.30 g and in Weight Class 4 the rhizomes weighed 5.31 to 14.62 g. Five flats of each weight class received Agriform 14-4-6 fertilizer in March 1997 at the rate of 3 oz per band. Data was collected on stem number, leaf number, and flower number for each plant.

RESULTS

Approximately 50 seedlings germinated 11 months after sowing (April 1992). By 23 months approximately 2000 seedlings germinated following sowing (April 1993). Small numbers of seedlings, recognizable by a single linear leaf, were observed each spring thereafter.

First flowering began after 4 years; flowering was initiated in May 1995 with 14 flowers appearing. Flowering was correlated to rhizome weight, and by May 1997 approximately 85% of rhizomes over 3.00 g produced 1 or 2 flowers (Fig. 1).

Leaf number and stem number also were correlated with rhizome weight (Figs. 1 and 2.).

Table 1. Effect of fertilization on *Trillium* stem number, leaf number, and flower number.

Fertilizer class	Weight initial	Average number wt. (g)	Stem number	Leaf number	Flower
0	1	0.62[1]	1.0	2.6	0.0
1	1	0.70	0.9	2.6	0.0
0	2	2.20	1.0	3.0	0.1
1	2	1.78	1.1	3.1	0.1
0	3	4.35	1.3	3.8	0.8
1	3	3.90	1.2	3.5	0.8
0	4	7.36	1.7	5.0	1.4
1	4	8.24	1.7	5.1	1.6

[1] Values represent the mean of 5 replicates of 25 plants each.

The application of fertilizer to tree bands for 1 year did not have a significant effect on stem number, leaf number, or flower number (Table 1).

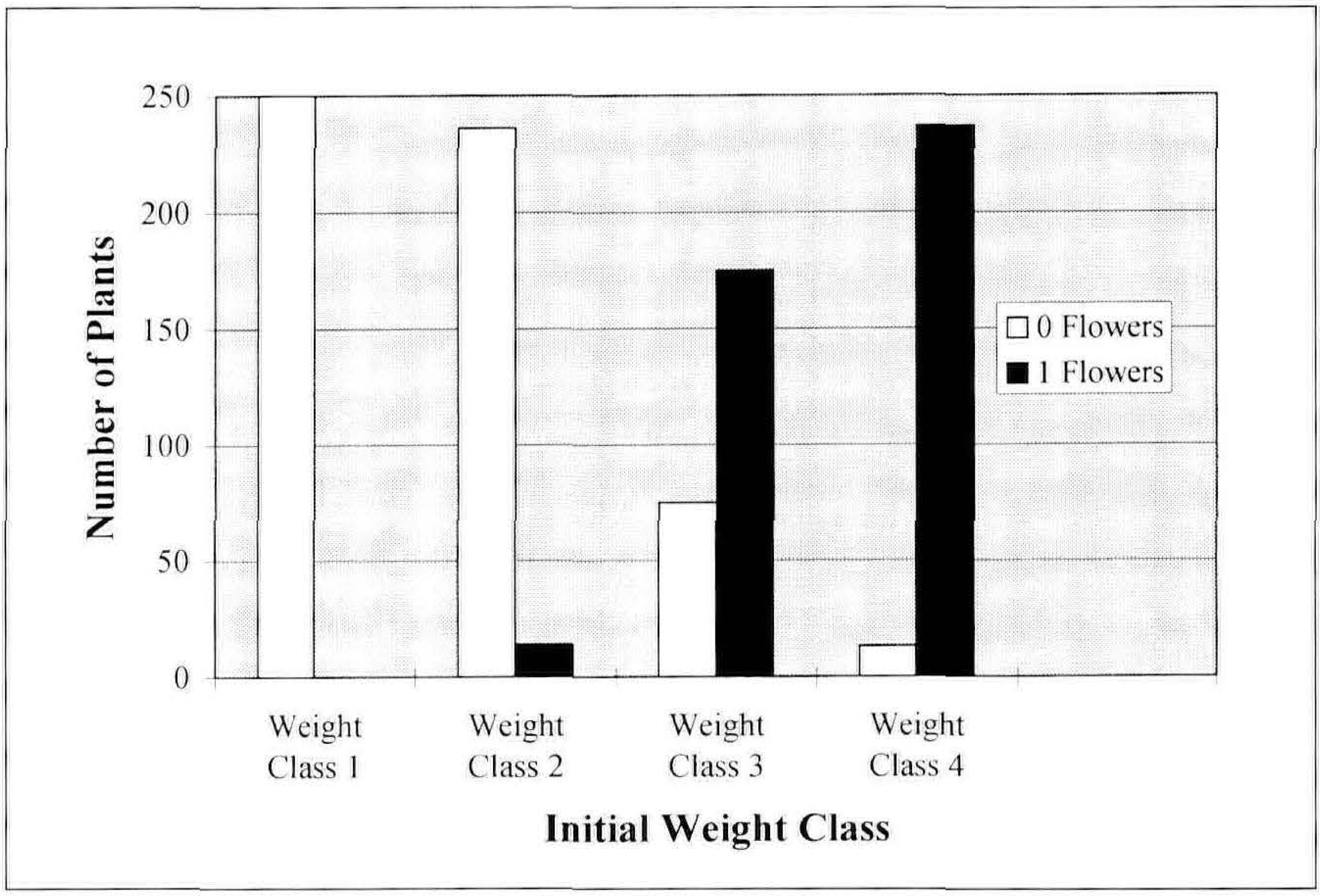

Figure 1. Number of plants producing flowers by rhizome weight class.

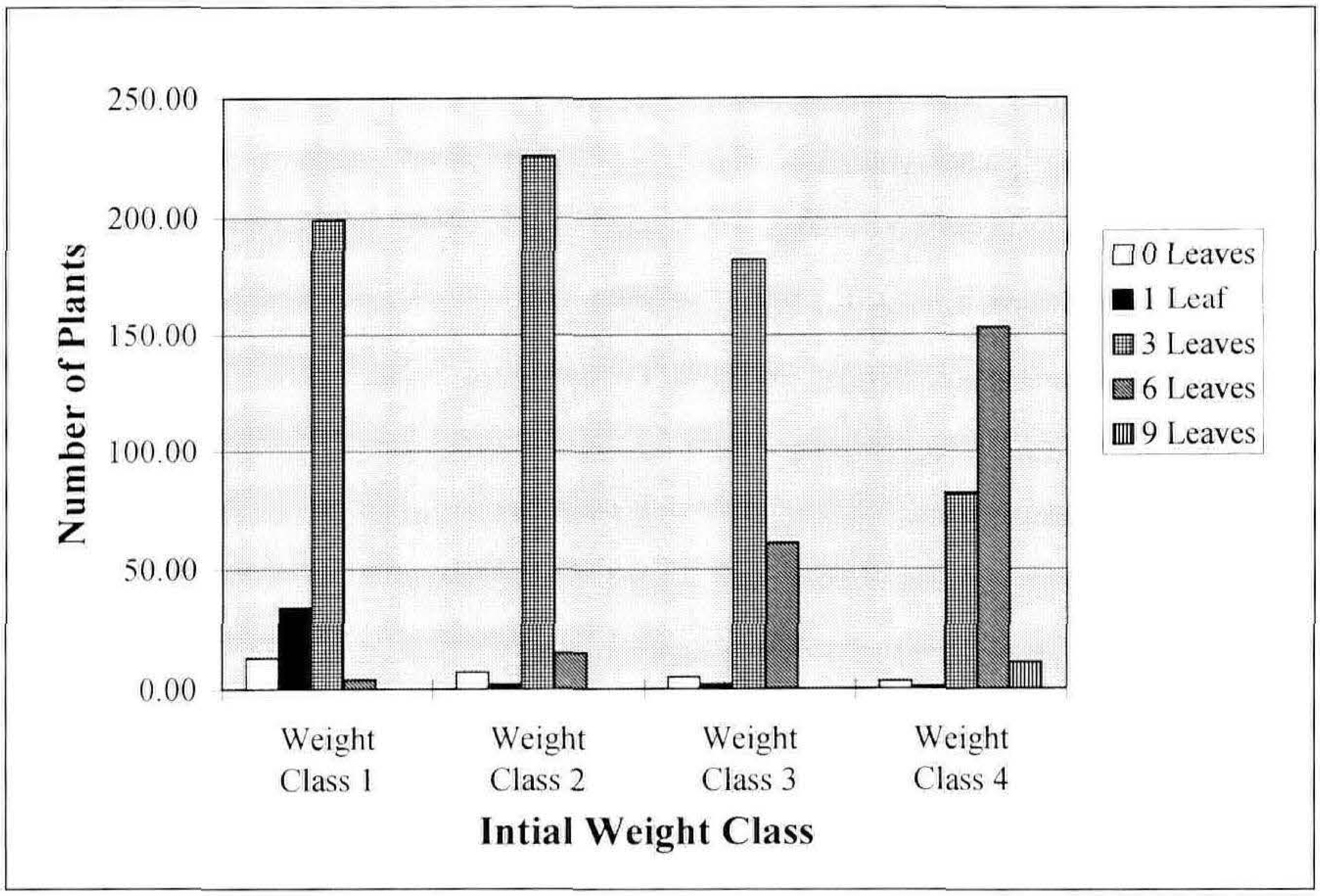

Figure 2. Number of plants producing multiple leaf production by rhizome weight class.

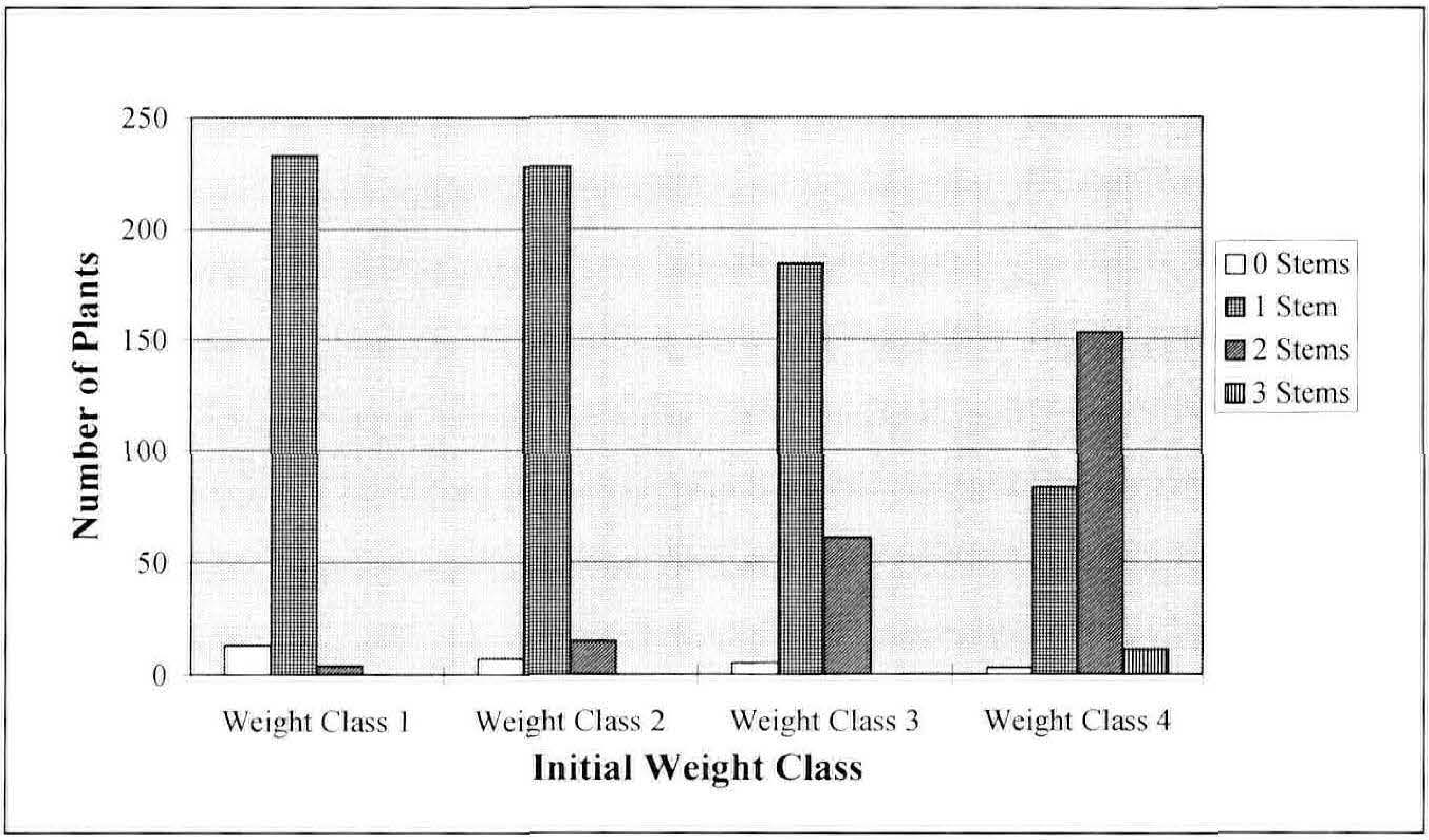

Figure 3. Frequency of multiple leaf stems by rhizome weight class.

SUMMARY

- Seed germination occurred sporadically over 4 years with maximum germination (20%) occurring after 2 years in the seed bed.
- First flowering was initiated after 4 years in seed bed.
- Rhizome weight varied from 0.10 to 14.62 g after 4 years in the seed bed.
- Fertilizer application to potted rhizomes did not increase stem, leaf, or flower number in first year of study.
- Stem, leaf, and flower number were correlated with initial rhizome weight: 66% of rhizomes with initial weight over 5.31 g produced 2 or more stems; 94% of rhizomes with initial weight over 5.31 g produced 1, 2, or 3 flowers; 97% of rhizomes with initial weight over 1.26 g produced 3 or more leaves.

Growing a New Propagator: Illinois Responds to an Industry Need

Kathy Freeland
Midwest Groundcovers, P.O. Box 748, St. Charles, Illinois 60174

One of the best-kept secrets of the American economy is the explosive growth of the horticultural industry. Growth and expansion have created a great need for an educated and skilled workforce in all phases of the industry.

In August of 1996, many months of discussion culminated in an organizational meeting. A partnership between Illinois Green Industry leaders, their organization—the Illinois Nurserymen's Association—horticultural educators, and the Illinois State Board of Education was formed.

Driven by the need to find skilled, qualified workers in an increasingly technical industry, this partnership is spearheading the way by generating interest in the horticultural industry and looking ahead to the future. This unique program draws on manufacturing apprenticeship programs as well as European models to provide students with "hands-on", practical work experience and advanced classroom education.

The 5-year program begins in the junior year of high school. Students apply for the program through the Illinois Nurserymen's Association (INA) with a letter of recommendation from their agriculture/horticulture teacher or school principal. Once accepted, at least five trips to participating nurseries and landscape firms are made during the year. Students observe jobs at every level and phase of the operations visited. Throughout the academic year, students must maintain a "C" average or better in their academic courses.

During the senior year of high school, approved students again follow nursery professionals and landscapers on the job. Spring semester finds candidates employed at the firm of their INA sponsor. Class credits are earned for the work experience. At the end of the year, students must re-apply for the full-time apprenticeship program. After graduation, students who have been accepted will work for their host employer during the summer months.

After enrolling in an approved college program, the student continues the relationship with the INA host and will be reimbursed for tuition expenses. During this first year students are expected to meet the academic requirements of the participating community college as well as work 1000 h at the host site during the year.

The program continues in the same vein during the 2nd and 3rd years. At each step, both the student and the host are given a list of current, industry-based skills which are expected to be learned. This list is reviewed and maintained throughout the program. At the end of 3 years, if the apprentice has successfully completed the academic requirements of the college Agriculture/Horticulture course and the job skill portion of the program, the student will graduate with an Associates Degree, receive a Journeyman's Certificate from the INA, an be well prepared for a rewarding career in the Green Industry.

This is a program where everyone gains. Students are given the opportunity to

receive advanced education and employers win dedicated and skilled employees.
Current Illinois Participants:

- Midwest Groundcovers
- The Growing Place
- Platt Hill Nursery
- Green View Companies
- Somonauk High School
- Willowbrook High School

No Excuses Accepted: Plants You Should Already Grow!!

Phill King
Greenwood Propagation, PO Box 1 90, Hebron, Illinois 60034

Hamamelis vernalis 'Autumn Embers'

This selection of vernal witchhazel was made by Mr. Roy Klehm of the Beaver Creek Nursery in Poplar Grove, Illinois.

Mr. Klehm first noticed the impressive fall coloration in a large block of *H. vernalis*. He at first felt that the plant was perhaps another species or cultivar mistakenly mixed in with its more common sisters. The fall coloration is a rich red with overtones of purple, yellow, and orange. The breathtaking effect is that of a glowing campfire on a crisp fall evening. Best fall coloration is triggered with the hard frosts of colder climates and the plant is at its best there.

The flowers are colored in shades of ripe grain and are quite fragrant.

A national mailorder nursery firm has sought this plant as its "cover girl" and many have been quite surprised that Mr. Klehm did not wish to patent the plant.

Unlike the recent published reports of rootability of witchhazels this plant roots quite well in June-July.

Perhaps the best selection of witchhazel to date within the realm of fall color, 'Autumn Embers' is the equal of fothergillas in the north.

Ilex verticillata 'Stop Light'

This "sister" to 'Red Sprite' appears to exhibit the growth form of its sibling.

The size of the fruits and their retention lead to the name that is quite descriptive. Fruits are often found to be 60% the size of a marble and are born in rich abundance. A traffic light in the landscape is an apt metaphor for this excellent plant. We have seen fruits retained to March if not taken by songbirds. 'Jim Dandy' works well as a male pollinator. Summer foliage is a rich green and the plant is a strong grower in youth.

Softwood cuttings root well in late June (Chicago). Growth from a rooted cutting will be 18 to 24 inches by the end of the second season.

Acer tegmentosum 'White Tigress'

This exceptional small tree was selected by Charles Brotzman of Brotzman's Nursery in Madison, Ohio.

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Its most prominent characteristic is the stunning bark. The striking bark occurs when the lenticels join together to form a white striping over the rich green background. Plants as young as 1 year in age exhibit this trait.

A national mailorder nursery feels that the bark effect of this maple is more striking than that of any birch and much more unique. A number of nursery operators and landscape architects who have seen the plants at our northern Illinois nursery have been shocked to find such a stunning selection which is hardy.

Plants provided with winter shade (under established oaks) have proved completely hardy during a snowless winter to -24 F at Trevor, Wisconsin. This is the finest snakebark maple for those of us living in Zones 4 to 5.

. Propagation by softwood cuttings rooted in June under fog has been quite successful.

Second year growth of 36 inches plus is easily achieved. Mature plants reach about 20 ft in height with a rounded form in Madison, Ohio.

Fothergilla gardenii 'Beaver Creek'

This excellent selection of *Fothergilla* is from Mr. Roy Klehm of Beaver Creek Nursery. Mr. Klehm selected 'Beaver Creek' from a single plant and has rooted all further generations from that selection. The uniformity and superior form of this selection is unsurpassed in the selections of *F. gardenii* presently available. The growth form is that of a full low-growing mound about 35% wider than tall in youth.

Field-grown specimens are "cookie cutter" in form with no variation in shape, making choosing of finished nursery plants a delight. Other selections of *F. gardenii* that we have seen vary from upright to wide spreading in shape within the same crop. This variation is probably due to the fact that many *F. gardenii* being rooted use seeding-grown mother plants as stock sources.

'Beaver Creek' also exhibits a flower bud hardiness not often seen in *Fothergilla* in northern climates. Unlike most *F. gardenii* the flowering occurs evenly over the entire plant; not the one-sided flowering most often seen.

Fall coloration is a rich combination of red, purple, and gold with yellows and oranges intermixed.

The plant is a good grower and will tolerate up to 50% shade quite easily.

Softwoods are rooted late June and overwintered without disturbance of the root system.

It took much cajoling to get Mr. Klehm to name this selection which we can now use as a standard for future selections of *F. gardenii*.

Seed Germination of *Stewartia pseudocamellia*

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Stewartia pseudocamellia is a Japanese summer-flowering tree that is cultivated only rarely in American gardens. This *Stewartia* bears 3-inch white flowers in mid-summer, orange-yellow foliage in the fall, and a year-round display of exfoliating pinkish-red bark. Difficulties in both vegetative and sexual techniques of propagation are largely responsible for its limited use. The purpose of our study was to document the seed biology of *Stewartia*, identify dormancy mechanisms, suggest reasons for the decline in viability, and recommend techniques for germination and production of this valuable species.

Desiccation Intolerance. Previous attempts to allow stewartia seed a period of dry after-ripening resulted in a rapid decline in seed viability. This trend led us to examine stewartias in the context of their taxonomic relationship with the tropical and subtropical members that dominate the *Theaceae* family. Seeds from tropical regions tend to lack the tolerance to desiccation that temperate species have acquired. Three days of air drying or 15 min of oven-drying at 80C were sufficient to destroy the embryo, as revealed through tetrazolium testing. To prevent desiccation damage, seeds were harvested when the capsules were green and indehiscent. Viable seed, as revealed though a cut test, appears plump and deep purple in color. The endosperm is oily or waxy and the embryo is white, spatulate, and approximately 3 mm in length. Nonviable seed is brown and shriveled. The internal contents are similarly brown and crumbled.

Stratification. *Stewartia* differs from tropical members of the tea family, in its requirement for cold stratification to break seed dormancy. In the germination studies, all treatment were exposed to 3 months of warm stratification (25C) followed by varying periods of cold stratification (4C). First noticeable signs of germination were observed after 5 months of cold stratification (2%). Six months of cold stratification yielded 19.5%, while 7 months yielded 51%. Emergence of the germinants generally occurred within 72 h of warming. Cold stratification seemed to have an effect on embryo growth; cold-stratified embryos were 25% longer than embryos receiving no chilling. Chilling also had a promotive effect on degrading the inner integument, which appeared stretched and flaking after 6 months of chilling.

Light Levels and Hormone Effects During the Rooting of Selected Tree Taxa

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INTRODUCTION

Light reduction treatments such as etiolation or opaque banding applied to stock plants prior to cutting collection have been shown to increase rooting success of difficult-to-root species (Bollmark and Eliasson, 1990; Leakey and Storeton-West, 1992; Maynard and Bassuk, 1986). However, stock plant light reduction treatments (shading) can be difficult to apply, especially on mature trees (Hecht-Poinar et al., 1989). Zaczek (1994) in a recent study with typically difficult-to-root mature *Quercus rubra* demonstrated that rooting was significantly improved by subjecting shoot cuttings to shade levels up to 97% of ambient daylight in the rooting environment. Potentially, high levels of shade applied in the rooting environment could prove to be useful in rooting cuttings from other recalcitrant species or cultivars. This study examined the effects of shade levels in the rooting environment, with and without hormone application, on the rooting of cuttings of eight tree taxa.

MATERIALS AND METHODS

Softwood shoot cuttings of *Acer griseum*, *A. rubrum* 'Bowhall', *A. rubrum* 'Franksred' Red Sunset®, *A. saccharum* 'Legacy', *Cornus kousa*, *Quercus alba*, *Q. ellipsoidalis*, and *Q. palustris* were collected from several sources and kept cool and moist until treatment application. The *Q. palustris* and *Q. ellipsoidalis* cuttings were collected from the most recent growth flush in mid to upper crowns of 18-year-old trees on 14 June 1995. Cuttings were trimmed in length to 15 cm (6 inches) and had all but the uppermost 3 leaves removed before they were treated and placed in the rooting chamber that same day. *Cornus kousa* cuttings were collected from four mature trees located on the campus of The Pennsylvania State University on 16 June 1995 and processed as single node cuttings the same day. Single node *A. griseum*, *A. rubrum*, and *Q. alba* cuttings were collected at The Buddies Nursery, Birdsboro, PA on 20 June 1995 and processed for rooting over the next 2 days. Potted stock plants of *A. griseum* were approximately 1.5 m (5 ft) tall. Field-grown trees of *A. rubrum* cultivars were between 4 to 5 m (13 to 16 ft) tall and approximately 5 cm (2 inches) in caliper. Cuttings of *Q. alba* came from 1 to 1.5 m (3 to 5 ft) tall plants estimated at 4 years of age. The *A. saccharum* 'Legacy' cuttings were collected from two trees approximately 4 m (13 ft) tall and 5 cm (2 inches) in caliper located in an experimental planting (The Pennsylvania State University) on 7 July 1995 and processed that day.

All cuttings were trimmed to size, soaked in a solution of Olympic Triathlon (Olympic Horticultural Prod., Mainland, PA) at a rate of 1.3 ml liter^{-1} of water (1 tsp gal^{-1}) for 5 min, rinsed in water, soaked in a solution of Clearys 3336-F (W. A. Cleary Chemical Corp., Somerset, NJ) at a rate of 1.6 ml liter^{-1} water (0.2 oz gal^{-1}) for 5 min, removed, and air dried. For each species, 180 cuttings were processed except for *C. kousa* where 216 cuttings were used. One-half of the number of cuttings of each species were treated with indole-3-butyric acid (IBA). For all but *A. griseum*, the bases of freshly trimmed cuttings were dipped for 5 sec 2 cm (0.8 inches) deep in either 95% ethanol (control) or in an IBA and ethanol solution. The concentration of the hormone solution was 10,000 ppm for all *Quercus* species, *A. saccharum* 'Legacy', and *C. kousa* and 5000 ppm for *A. rubrum* cultivars. Cuttings of *A. griseum* were dipped 2 cm (0.8 inches) deep in either Hormodin #3 powder (0.8% IBA in talc) or in talc alone (control). Cuttings were then inserted in a mix of peat moss, perlite, and sand (1 : 1 : 1, by volume) in Ray Leach Single Cell Cone-tainers^{Tm} (Stuewe and Sons Inc., Corvallis, Oregon). For each species, both hormone-treated and control cuttings were randomly divided in thirds and placed randomly within one of 2 shade levels or control in the rooting chamber. For each species, 30 (36 for *C. kousa*) cuttings were subjected to each of the 6 shade/hormone treatment combinations.

The rooting chamber was located in a greenhouse and consisted of 1-m-tall (3.3-ft) frames constructed of poly vinyl chloride (PVC) pipe on three 1.7 m × 3.0 m (5.5 ft × 10 ft) roller benches covered entirely by a single sheet of 6-mil polyethylene. This formed a single rooting chamber which minimized potential humidity and temperature differences among treatments. Intermittent cool fog was provided by 4 ultrasonic humidifiers (Sunbeam model 667, Northern Electric Co., Chicago, IL) set outside opposing ends (2 per end) of the tent. Ambient daylength was maintained, but whitewash (Kool-Ray white shading compound, Continental Products Co., Euclid, OH) was applied to the exterior of the greenhouse to reduce light levels and limit solar heating inside the polytent. It is essential to provide relatively heavy shading to minimize solar heating during summer use of polytent systems in climates with high irradiance. Our previous experience (Zaczek, 1994) has shown that moderate temperatures can be maintained in a polytent rooting environment with ca. 80% to 85% shade. Therefore, we consider a shade level in this range a "control" treatment. To provide the shade treatments, the rooting chamber was subdivided into 3 shade level compartments. Two compartments had black polypropylene shade fabrics (80% and 47%) (Yonah Manufacturing Co., Cornelia, Georgia) suspended 10 cm (4 inches) above the roof and along the vertical walls of 2 sections of the rooting chamber. The third compartment (control) received no shade fabric except was bordered by a 47% fabric wall from the adjacent shading treatment. Shade fabric on the inside of the chamber between shade levels was suspended from the top of the chamber down below the top of the cuttings but leaving the lower 25 cm open. This coupled with the porous nature of the shade fabric allowed for humidity and air exchange between the three compartments.

Percentage shading for the 3 treatments was determined by measuring photosynthetic photon flux density (PPFD, µmoles m^{-2} s^{-1}) on different days and times during daylight hours at 15 locations in each treatment and outside the greenhouse using the quantum sensor of a portable infrared gas analyzer (model LCA-2, Analytical Development Co., Ltd., Hertz, England). The percentage reduction of ambient sun (percentage shade) for each compartment was determined relative to the outside ambient PPFD reading [(1-(PPFD tray/PPFD outside))×100]. Shade levels were 97%, 91%, and 83% (control). For reference, the average ambient sun (outdoor) PPFD was 1584 μmoles m^{-2} s^{-1}.

Relative humidities were maintained at 100% except for short time periods when the chamber was opened to check for roots, apply fungicides, or change chart paper. Air temperatures varied less than 1C (1.8F) on average among shade treatments.

Fungicide solutions, either Cleary's 3336-F at a rate of 0.7 ml $liter^{-1}$ water ($^1/_2$ tsp gal^{-1}) or Chipco Aliette (Rhone-Poulenc Company, Research Triangle Park, North Carolina) at a rate of 1.2 g $liter^{-1}$ (0.2 oz gal^{-1}) were sprayed on the leaves ca. every 2 weeks during the rooting period. Approximately weekly, the chamber was opened and the Leach tubes were checked for emerging roots.

Statistical analyses were performed for each species or cultivar. Logit analysis (Fienberg, 1980) was performed (at the p=0.10 level) to determine if the categorical variable rooting was related to shade or hormone treatments or both simultaneously. When significant relationships between rooting and treatments were established, pairwise comparisons among treatment means were made at the p=0.05 level using CONTRAST, a computer program (Hines and Sauer, 1989) based on a chi-square procedure (Sauer and Williams, 1989). For continuous data, analysis of variance (at the p=0.05 level) (Steel and Torrie, 1980) was used to test for differences in the number of roots per rooted cutting and days to root among shade and hormone main effects and their interaction. When significant treatment effects on the number of roots per cutting and number of days to root were detected, Duncan's multiple range test was used to compare treatment means. Log transformation was used for the number of roots per cutting because the data were not normally distributed, the treatment standard deviations were proportional to the treatment means, and some of the values were less than 10 (Fowler and Cohen, 1990). In cases where some species or cultivars rooted poorly overall (<10%) resulting in low numbers, incomplete cells, or missing data for specific treatment combinations, the application of the forementioned statistical analyses was not warranted nor performed.

RESULTS AND DISCUSSION

Rooting was influenced by shade and hormone treatments either alone or together but the responses varied among species and cultivars. Rooting averaged 28% overall. Rooting by species across all treatments ranged from 1% to 64%. The IBA-treated cuttings averaged 37% rooting compared to 21% for control. Mean rooting was 25%, 33%, and 26% for shade levels of 97%, 91%, and 83% (control), respectively. Percentage rooting for the various species, shade, and hormone treatment combinations ranged from 0% to 87% (Table 1). Cuttings of *Q. palustris*, *Q. ellipsoidalis*, and *A. saccharum* averaged less than 10% rooting over all treatments and further statistical analyses were limited for these species.

For the other species, logit analyses indicated that rooting was statistically related to hormone treatment alone for *C. kousa* and *A. rubrum* 'Franksred' Red Sunset™ (p=0.95 and p=0.60, respectively). The IBA-treated cuttings of these two species rooted at rates nearly twice that of untreated cuttings. Rooting response for *A. rubrum* 'Bowhall' and *A. griseum* was dependent on both shade and hormone treatments together (p=0.91 and p=0.32, respectively). The highest percentage rooting for both *A. rubrum* 'Bowhall' and *A. griseum* required IBA treatment.

However, with IBA treatment, the greatest percentage rooting for *A. griseum* was under the control shade treatment (83%) whereas *A. rubrum* 'Bowhall' rooted most often at increased shade levels (either 91% or 97%).

Shade level as a single factor was significantly related to rooting of *Q. alba* ($p=0.80$) with the most cuttings (30%) rooting under the 91% shade level. At this same shade level, rooting was highest or equal to the highest for 7 of 8 of the species or cultivars. Only among cuttings of *A. griseum* did the control treatment result in the highest percentage rooting.

The number of roots per cutting was significantly greater ($p<0.05$) for hormone-treated cuttings compared to control cuttings in 3 of 5 comparisons (not so for *A. griseum* and *A. rubrum* 'Bowhall') by species (Table 1). However, for *A. rubrum* 'Bowhall', shade level significantly ($p<0.01$) influenced the number of roots with the most occurring at the 97% shade level. Numbers of roots for *Q. alba* cuttings also was somewhat greater at 97% shade compared to other shade treatments but the effect was not quite statistically significant ($p=0.07$). Shading had no significant influence on the number of roots per cutting for the other species or cultivar comparisons. There was no significant interaction ($p>0.05$) between shade and hormone treatments for the number of roots in any species tested.

The number of days to root was significantly influenced by hormone treatment ($p<0.05$) for *A. griseum* and *A. rubrum* 'Bowhall' and nearly so ($p=0.08$) for *C. kousa*. In these cases, hormone-treated cuttings rooted faster than controls (Table 1). Shade treatments significantly ($p<0.01$) influenced the number of days to root for *A. rubrum* 'Franksred' Red Sunset™ cuttings averaging more days to root in the most shade (97%) than either of the other shade levels. There was no significant interaction ($p>0.05$) between hormone and shade treatments for the number of days to root in any taxa tested.

It is commonly assumed by propagators that leafy cuttings should be subjected to a rooting environment with a light level that is conducive to photosynthesis (Davis, 1988; Hartmann and Kester, 1983). However, little scientific evidence supports this assumption (Davis, 1988) and cuttings do not require high light levels until rooting occurs (Dirr and Heuser, Jr., 1987; Loach and Gay, 1979). Photosynthesis during rooting is not an absolute requirement of cuttings for root formation (Davis, 1988), a conclusion that is supported by the rooting of many non-photosynthetic, leafless hardwood cuttings and rooting of *Pisum* cuttings in darkness (Davis and Potter, 1981). Zaczek (1994) showed that rooting for mature *Q. rubra* benefitted from rooting environment shading levels up to 97% which is near the light compensation point for seedlings of that species. In this study, percentage rooting, for most species, was greatest at shade levels at or more than 91% suggesting that relatively high levels of light in the rooting beds are either unnecessary or detrimental for the species tested at least until rooting occurs.

Optimum levels of shading for stockplants varies from species to species and even among genotypes of a species (Moe and Andersen, 1988). Our results suggest that the optimum level of shade during rooting also appears to vary by species and genotype and additionally may depend on the presence or absence of hormone application.

Shading during rooting does not appear to be universally beneficial to all species or cultivars especially to those that already have reasonably successful propagation protocols. For example, *A. rubrum* 'Franksred' Red Sunset™, which is considered

Table 1. Percentage rooting, the average number of roots per rooted cutting, and the average number of days to root by species, shade, and hormone treatment. Within a species, shade- level means (in a column) with different letters or IBA level means (in a row) with an asterisk are significantly different at the p=0.05 level. Percentage rooting means tested based on pairwise comparisons using CONTRAST. Numbers of roots and days to rooting means tested using Duncan's Multiple Range Test.

Species	Shade (%)	Rooting (%)			Number of roots per cutting			Number of days to root		
		IBA	no IBA	mean	IBA	no IBA	mean	IBA	no IBA	mean
Acer griseum	83	36.7	10.0	23.3a	5.0	1.3	4.2	109	126	112
	91	26.7	20.0	23.3a	4.1	1.7	3.1	107	125	115
	97	3.3	3.3	3.3b	2.0	1.0	1.5	94	114	104
	mean	22.2*	11.1*		4.5	1.5		107*	124*	
Acer rubrum 'Bowhall'	83	26.7	6.7	16.7a	4.6	2.5	4.2a	85	97	87
	91	66.7	20.0	43.3b	7.1	2.5	6.0a	69	86	73
	97	66.7	23.3	45.0b	13.5	12.7	13.3b	63	91	70
	mean	53.3*	16.7*		9.4	7.3		69*	90*	
Acer rubrum 'Franksred' Red Sunset™	83	80.0	56.7	68.3	16.7	5.7	12.1	69	64	67a
	91	86.7	46.7	66.7	18.0	3.4	12.9	69	71	70a
	97	76.7	40.0	58.3	16.3	3.0	11.7	92	89	91b
	mean	81.1*	47.8*		17.1*	4.2*		76	73	
Acer saccharum 'Legacy'	83	13.3	3.3	8.3	1.5	1.0	1.4	112	112	112
	91	10.0	20.0	15.0	1.7	1.8	1.8	110	104	106
	97	0.0	0.0	0.0	-	-	-	0	-	-
	mean	7.8	7.8		1.6	1.7		111	105	

Cornus kousa	83	77.8	44.4	61.1	10.4	6.8	9.4	112	122	115
	91	83.3	47.2	65.3	11.0	5.7	9.1	113	119	115
	97	83.3	50.0	66.7	11.4	6.0	9.4	107	110	108
	mean	81.5*	47.2*		11.0*	6.2*		110	117	
Quercus alba	83	16.7	23.3	20.0ab	2.8	2.1	3.4	120	117	118
	91	30.0	30.0	30.0a	2.1	1.3	1.7	111	116	114
	97	16.7	10.0	13.3b	4.6	1.3	3.4	111	111	111
	mean	21.1	21.1		2.9*	1.6*		113	116	
Quercus ellipsoidalis	83	0.0	0.0	0.0	-	-	-	0	-	-
	91	3.3	0.0	1.7	1.0	-	1.0	73	-	73
	97	3.3	0.0	1.7	1.0	-	1.0	119	-	119
	mean	2.2	0.0		1.0	-		96	-	
Quercus palustris	83	10.0	3.3	6.7	1.7	1.0	2.0	43	48	44
	91	23.3	3.3	13.3	1.7	2.0	1.8	59	73	61
	97	0.0	3.3	1.7	-	2.0	2.0	0	40	40
	mean	11.1	3.3		1.7	1.7		54	54	

easy-to-root (Flemer, 1982), showed little benefit to rooting from shade. However, *A. rubrum* 'Bowhall', considered difficult to root (Flemer, 1982), benefitted greatly from shade levels at or greater than 91%. The *Quercus* species are notoriously poor rooters (Dirr and Heuser, Jr., 1987; Flemer, 1962; Teclaw and Isebrands, 1987) but *Q. alba* and *Q. palustris* performed best at the 91% shade level. These results suggest that the benefit of increased shading during rooting appears to be most pronounced in species or cultivars that have been traditionally difficult to root.

Maintaining high light levels during rooting apparently is not warranted for most of the species tested. Therefore, growers can expect cost savings associated with reduced demands for cooling, humidification through misting or fogging, and supplemental lighting.

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The Recycling of Propagation Materials

Michael Kolaczewski

Flora and Fauna, Horticultural & Biological Consultants, 324 Silver Street, Elgin, Illinois 60123

INTRODUCTION

The reuse of certain products or byproducts in manufacturing is not new. The nature of various horticultural production methods culminates with materials passing through the manufacturing scheme once. This type of operational setup can, and will continue to add costs to production, and can impact upon the desired net income of an operation. This qualitative look at what our firm does to stream line production costs may be applicable to your company.

No one wants to spend more on getting a product into a customer's hands than necessary. Added costs impact upon prequoted prices, affect bids, and upset bankers. How then do you keep costs down yet produce a marketable plant product? For myself, I have settled upon a propagation method which allows me to reuse various components over and over again.

The 1-gal plastic pot inventory, Lerio Mfg., is at about 5500 units. There are about 2500 to 3000 pots in production at any one time. An almost equal number of various bandpots, Anderson Mfg., are also in the mix as well. Bandpot prices, for a 6-inch bandpot, are at about 13¢ per unit, priced per thousand. If you would use more, say 25 to 50 thousand, the price would drop several pennies. You of course must factor in a shipping cost, but this is a one time charge, which is reasonable when sending a truck load, versus a few boxes via UPS. In fact, the majority of our 4- and 6-inch bandpots and 1-gal containers have been in continuous use for over 5 years.

Plants are shifted from plug trays into bandpots, and in some cases, later finished in 1-gal containers. In most cases, plants go from plugs into bandpots, and are later sold, or installed as a "bandpot" 1 gal. The consideration here is that over 85% of what is grown is used in house. We are "barerooting" the majority of the plants grown. These for the most part are installed into landscapes, when the resale plants go out, some are knocked out of their pots. Those that are not, go to people who know to return the pots for which they get a credit. The pots come back, are cleaned and reused.

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The potting mix, when recovered from the bareroot process, can be used again either as remix, or after an extended time, as soil incorporation on residential landscape projects. The bark and bark mix are usable (reusable), for anywhere from 18 to 24 months before degradation, or total composting, depending upon your definition.

Current local bulk soiless-mix prices, pine-bark based, are at about \$34 to \$49 yard^{-3}. A bagged mixed product, pine-bark based, is running around \$5.50 per 3.0 ft^3 bag, with about 4.5 yards, 42 bags, worth of product per pallet. That costs out to \$245.70 per pallet, \$52.61 per yd^3, and \$1.95 per ft^3. Pine-bark-based mixes have several pluses in their favor. They hold back nitrogen, have natural tendencies to suppress soil pathogens, and are adaptable to a wide range of crops. Obviously, product cost can be expensive, and recycling some of this product can hold the budget in line. We have been using Spinout™ a root growth regulator for about 1-1/2 years. It is either incorporated by applying it to the inside of containers, or used as an underlayment under bottomless pots and trays via its being applied to a sheet of fabric to line flats. These sheets are being reused for several production cycles. They are being retreated as needed with Spinout™, and used again as a pad under or in flats.

The thing to consider is that with any manufacturing system the outlay for equipment or materials can incur significant upfront costs. Of course, you can build these prices into your product cost, some you will recover now, and others will have to be recouped over long term. With a returning element in the manufacturing cycle, subsequent production has a fixed hardware cost. This stabilizes price, and as long as other factors are equal, a better profit margin could be expected. Accurate forecasting of crop numbers with regards to amounts of potting mix, space, growing time, and other factors need to be addressed in order to have a handle on how much of a profit return is to be expected.

Buying materials that are more durable, in other words that will last longer, allow for multiple production cycle, or multi-year use. Blow-molded trays and inserts are lighter, cheaper, and cost less than heavier plastics. However, they may not be suited to last more than one season. The down side here is that they enter the waste stream sooner than a reusable product.

The obvious question to ask is, is it worth the time and cost to reuse products? Is your operation set up to reclaim materials from around your nursery? What do you do if you have a multiple site operation? Recycle at each site, have a central processing location, don't bother at all? There are many factors to consider, your operation may not be recycle friendly anyway. In some cases, large production flat or liner-tray operations may not lend themselves to recycling propagation materials. Liners or seedlings are stuck directly into flats, and are finished and sold in their propagation container, thus lowering the handling and transplanting costs. The cost is of course passed on, along with the container, which may not return to your facility. It may end up at the project site or in the garbage.

With my operation, growing space is limited. Bandpots are used to get plants to a certain size, and then they either go out into installations, or they must be shifted into larger pots. These larger containers then take up more room, which limits the number of plants that can be accommodated. So I have tried to schedule propagation to coincide with installations and sales. As plants go out, the open space can be filled with another crop of cuttings, seedlings, or divisions for another production cycle. Currently, there are three production runs during the year's growing season. I also have an overwintering facility that is ventilated and heated. This structure is covered with a permanent material to get maximum use for many years to come. This allows for winter propagation, protection of stock plants, as well as the saleable inventory. The overwintering structure lets me get the jump on the spring growing season by several weeks, or up to a couple of months. Indeed, after visiting several colleagues' operations, I have begun to grow plants under cover 365 days a year.

Profit is important to any business, especially the net profit margin. Yet as you may know, operating costs, budget overruns, and general waste can drain away money, and leave you floundering. Some simple procedures have helped me to keep a handle on costs, improve production techniques, and of course be profitable. I hope that this presentation can be of use to you, and your company as well.

Economic Propagation Benches

Tom Demaline
Willoway Nurseries, 4534 Center Road, P.O. box 299, Avon, Ohio 44011-2399

Rolling benches built from steel products have many cultural and economic advantages for propagation. The first advantage is that steel benching can be easily disinfected for control of disease. Secondly benching built from steel products have a longer life verses wood products. The third advantage is rolling benching allows a propagator to increase the usable area in a greenhouse — thus reducing overhead cost.

Typical benching in a 29-ft greenhouse consists of five benches of 54 inches each, with four aisles of 20 inches each. With rolling benches you can increase your usable growing area by 20%.

The first step to building rolling benches consisted of saddles made from 1-inch galvanized pipe which are welded together and cemented into the ground. The saddles are spaced 12 ft apart along the length of the bench.

In the second step two length's of 1-1/4-inch pipe are used to roll the bench top from one side of the saddle to the other. The bench top is constructed from 1/4-inch ridged galvanized cattle fence. Each sheet is 54 inches wide and 16 ft long.

In the next step 3/4-inch galvanized pipe is tack welded to the galvanized cattle fence every 2 ft to allow the bench top to move from side to side on top of the rollers. Then threaded rod is bent into an "U" to act as a safety catch so the bench will not tip if it gets out of balance. The "U" is attached to the bench top. As the bench top moves to one side, the safety "U" moves under the 1-inch pipe on the saddle. Safeties are spread every 50 ft.

For the mist line 3/4-inch PVC pipe is used. The 3/4-inch PVC is attached to the bottom of the 3/4-inch galvanized bench top and supports with a #1 EMT clamp. The mist line moves with the bench top. One-half-inch PVC risers are used for each mist nozzle. The risers are spaced 64 inches apart on the bench and are staggered from bench to bench. The mist nozzle is a D.G.T./Volmatic nozzle available from Agro Dynamics.

Biotherm root-zone heating is used on the top of the bench. This hot water heat source creates an even uniform bottom heat to the soil which increases rooting percentages and reduces rooting time. The tubing is spaced 2 inches apart. Automotive heater hose (3/4 inches) is used to connect the supply line in the ground to the bench tops. This flexible hose allows the bench top to roll. Each house has a soil-probe-operated thermostat to control the soil temperature. With root-zone heating in cold climates, you will need a supplemental heat source to heat the air in the greenhouse. We use a 1-1/4-inch steam line under each bench to provide the additional heat. This heat source is operated by a Wadsworth Step 50 greenhouse controller.

In the final step 48-inch galvanized expanded metal is placed on top of the biotherm tubing to keep the tubing in place. The expanded metal also allows the bench to be more versatile for other crops. This type of benching will provide a low maintenance propagation area at an economical cost. Rolling benches also maximize the space in your greenhouse to increase your return per square foot.

Table 1. Cost for benching 450 ft^2 bench.

Bench costs		
Pipe saddles	\$11.83 each × 12	\$106.47
Safety	1.00 each × 6	6.00
Cattle fence 14.99 each × 6.25 sheets	166.50	93.69
3/4 inch pipe for tops	225 ft	166.50
*Optional expanded metal	24.00 each × 12.5 sheets	300.00
1-1/4 inch pipe for rollers	27.84 each × 10	278.40
Concrete		79.38
TOTAL		\$1,030.44
Cost per ft^2		\$2.28
Cost per ft^2 excluding expanded metal		\$1.62
Heating		
Biotherm tubing	27 × 100 × .32¢ per ft	\$864.00
Biotherm header		15.40
Thermostat		46.50
TOTAL		\$925.90
Cost per ft^2		\$2.05
Mist		
PVC pipe with fittings and hangers		\$38.25
Mist nozzles	\$2.11 each × 19	40.09
TOTAL		\$78.34
Cost per ft^2		17.4¢

Field Establishment and Growth of *Asarum naniflorum* 'Eco Decor'

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INTRODUCTION

There are approximately 12 taxa of the genus *Asarum* (syn. *Hexastylis*) native to the deciduous forests of the Southeastern United States. Several ornamental characteristics combine to make these low-growing herbaceous plants suitable for use in the landscape. These include attractive foliage; triangular to heart-shaped evergreen leaves, with or without silvery-grey variegation; rhizomatous growth habit resulting in single specimen (clumping) or groundcover (running) plants; and curious jug- or bell-shaped purplish-brown spring flowers. They are hardy in USDA Zones 5 to 9.

Although these evergreen wild gingers are occasionally seen in gardens, their landscape potential has not been fully realized. This is due in large part to propagation difficulties using traditional methods. Seed set under cultivation is low and potential seed production per plant under optimal conditions is low. Division is possible but slow; on a commercial basis it would require the maintenance of large numbers of stock plants. Establishment of single-clone stock blocks would be time consuming and expensive. Micropropagation offers the potential for large-scale rapid propagation and distribution of clones selected for ornamental qualities, vigor, and cultural adaptability.

METHODS AND MATERIALS

In vitro. Sterile cultures of *A. naniflorum* 'Eco Decor' obtained from SMK Plants (Billings, MT) were cultured onto M.S. (Murashige and Skoog, 1962) basal medium containing (in mg liter^{-1}) 0.4 thiamine-HCl, 0.5 pyridoxine-HCl, 0.5 nicotinic acid, 100 myo-inositol plus 2% sucrose, and 0.7% Phytagar. Plants were subcultured monthly to proliferation maintenance medium consisting of basal medium supplemented with 1 mg liter^{-1} BA. For rooting, basal medium was supplemented with 1 mg liter^{-1} NAA.

Greenhouse and field. In vitro-rooted shoots, single or multiple crowns, were either rooted in the greenhouse in Metro-Mix 510 in market packs under a humidity dome on the mist bench for 4 to 6 weeks, then taken to the field, or rooted directly in the field in a raised bed or in tree bands placed in flats in a raised bed.

In Experiment 1, 122 in vitro-rooted microcuttings were planted 3 inches on center in 5 ft × 10 ft-raised beds under 63% shade in a lath house. The growing mix consisted of sand, peat moss, and loam (1 : 1 : 1, by volume). A 1-inch layer of pine straw mulch was placed around the plants to conserve moisture and reduce weed growth. After an initial thorough watering, water needs were checked daily for 2 weeks then weekly. There were no problems with pathogens and insects, slugs were controlled with slug bait.

In Experiment 2, 33 in vitro-rooted microcuttings were potted and placed in the greenhouse for 6 weeks and then taken to the field, while 39 microcuttings were planted directly into the growing mix in the raised bed (Expt. 1).

In Experiment 3, 48 in vitro-rooted microcuttings were either planted directly into 2.38 inch × 3.75 inch-tree bands using Metro-Mix 510 and placed in a raised bed in the field, or were planted directly into the growing mix in the raised bed in the field (Expt. 1).

RESULTS

Experiment 1. An initial experiment was set up to determine if original plant size, measured as weight and leaf number, was correlated with plant size after one growing season. Plants were planted and placed in a greenhouse for approximately 1 month and then were planted in the field. After 14 months, 95% of the 122 plants had survived and grown. On average, plants increased their weight by 23 g, or were 6260% heavier, and had almost 18 more leaves which represents a 250% increase in leaf number. Original plant size, measured as either weight or leaf number, had no predictive value for final plant size.

Experiment 2. The next experiment was set up to determine if we could by-pass the greenhouse acclimation period and plant the in vitro-rooted plants directly in the field. A 6-week greenhouse acclimation period had no influence on plant survival or growth after 14 months of growth in the field.

Experiment 3. A third experiment was set up to compare growth and survival of plants placed directly in the field either in a raised bed or in tree bands. After 14 months, the plants placed directly in the raised bed were discarded due to *Thielaviopsis* black root rot and; therefore, there was no way to directly compare growth between plants in tree bands versus those placed directly in a raised bed in the field. While 100% of the plants survived planting in the tree bands, growth was greatly reduced if compared to growth in Experiments 1 and 2. This may be the result of insufficient container size limiting nutrient and water availability.

CONCLUSIONS

In vitro-rooted microcuttings of *A. naniflorum* 'Eco Decor' can be planted directly into the field and survive. Further research needs to be conducted using tree bands to obtain growth comparable to direct field planting. In vitro-rooted microcuttings of *A. naniflorum* were not difficult to establish and grow under field conditions.

Acknowledgment. This research was partially funded by a grant from the Perennial Plant Association.

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Pot-in-Pot Production of Nursery Stock

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INTRODUCTION

The pot-in-pot production system has been increasing in acreage steadily during the 1990s. The system is centered around the production of shade and flowering trees and large shrubs in containers which are placed in the ground. A permanent container (socket pot) is placed in the ground where it may last for a decade or longer. A production container, with plant, is inserted into the socket pot. The time a plant is in a production container can be from 6 to 9 months but not more than 2 years. Unit sizes have varied from 3 gal up to 30 gal. On an acre basis, more units in the 7-, 10-, and 15-gal sizes may be in production today. The socket pot and production pot need to be two distinctly manufactured units. Compatible units during the past few years have been manufactured only in the mid-range sizes. Container media consists of the common bark-based media existing in the industry.

THE SYSTEM

Holes are augered using a size related to the size of the container. Spacing is dependent upon the size of the canopy at harvest time. Common spacing in both directions has been 4, 5, or 6 ft. Where soil percolation of water is not rapid, drainage (tile) is provided near the bottom of the hole and throughout the length of the row. The socket pot is inserted into the augured hole. It should rest on firm soil so that it will not settle any deeper. It is leveled. The socket pot determines the orientation of the plant in production and new plant growth needs to continue the axis formed by the trunk. New growth will grow vertical whether the trunk is straight or tilted. Copper-treated paper or fabrics are placed at the bottom to cover the drain holes to keep roots from escaping. Escaped roots destroy the socket pot and thus disrupt the value of the system. A spacer is set in the bottom of the socket pot. The spacer should be a fraction on an inch taller than the length of the air gap between the bottoms of the two containers. This prevents the weight of the production container and plant from becoming wedged into the socket container. The industry may or may not place fabric over the entire production area. Fabric (landscape fabric) may be more common in the Southeast U.S. An "X" is cut in the fabric above each socket container it is covering. The fabric keeps down weeds and allows movement around the area at all times. Most acreage in the Northeast and Central part of the U.S. have left the area open. The production pot is treated on its inner surface with copper in order to reduce circling roots and root escapes. Once the plant is placed in the production container, it can be transported to the production site and inserted into the socket container. Microirrigation is a must and the nozzle should be one that sprays water across the entire media surface. Water schedules on timers should be adjusted to multiple waterings per day. Weed control and fertilization practices are similar to those existing in container production.

BENEFITS

- More plants per acre.
- Can harvest on any day of the year.
- A container-grown plant that should not be root bound.
- Plants have the advantage that they are anchored in the ground and do not blow over in the wind.
- Overwintering uses the natural ground heat without the need to heal-in or move to a structure.
- Moisture and nutrients can be monitored better than in a field situation.

Adventitious Bud and Shoot Formation in Pawpaw [*Asimina triloba* (L.) Dunal] Using Juvenile Seedling Tissue

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INTRODUCTION

Current clonal propagation methods for the North American pawpaw [*Asimina triloba* L. Dunal] are limited to budding and grafting techniques (Layne, 1996). No work has been published detailing a micropropagation system for the pawpaw, but Callaway (1992) indicated limited success in regenerating shoots using leaf tissue. Successful micropropagation systems have been developed for related *Annona* species (George and Nissen, 1987). The objective of this research was to observe the effect of ontological age on adventitious bud and shoot development of pawpaw nodal explants in culture. Explants from a juvenile source (seedlings) and mature sources (forced stems and shoots produced on root pieces) were used to study the effect of ontogenetic age during the establishment phase.

MATERIALS AND METHODS

Seedling Explants. Stratified seeds were planted in vermiculite and germinated in a 25C growth chamber. Approximately 12 weeks after planting, seedlings had 6 to 10 nodes.

Mature Wood Explants. Dormant stems were collected from 26 genetically different mature, flowering trees and surface sterilized. Stems were forced in beakers in a 25C growth chamber. After 6 weeks, shoots had expanded to ≥ 10 cm.

Explants from Shoots Produced on Root Pieces. Root pieces (≥ 5 mm diameter, 10 to 12 cm length) were obtained from mature trees in a native stand. Shoots were forced on root pieces kept in a 22C greenhouse and after 20 weeks shoots had expanded to ≥ 10 cm.

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- A container-grown plant that should not be root bound.
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Explants from Shoots Produced on Root Pieces. Root pieces (≥ 5 mm diameter, 10 to 12 cm length) were obtained from mature trees in a native stand. Shoots were forced on root pieces kept in a 22C greenhouse and after 20 weeks shoots had expanded to ≥ 10 cm.

Explant Preparation. Single node explants were excised from each source, washed and surface disinfested (10% Clorox for 10 min). After rinsing, single explants (1 to 3 cm in length) were inserted vertically and cultured on 20 ml of M.S. medium supplemented with 10 μM BA and 0.1 μM TDZ in 25 × 150-mm test tubes. Medium pH had been adjusted to 5.8 ± 0.1 prior to autoclaving and solidified with 0.6% Bacto-agar (Difco Laboratories, Detriot, MI). Culture tubes were maintained under 16-h photoperiod of 20 μmol sec^{-1} m^{-2} of light provided by cool white fluorescent bulbs. Culture room temperature was constant 25C.

Explant transfer and data evaluation occurred at 2-week intervals and at each interval, the percentage of explants with elongating axillary shoots was recorded. Axillary shoots were determined as the number of shoots (> 2 mm in length) arising from a leaf axil. Formation of adventitious buds (< 0.5 cm) and shoots (≥ 0.5 cm) was also recorded at each transfer interval. Adventitious buds and shoots were determined as buds and shoots arising at any location on the explant other than in a leaf axil.

RESULTS AND DISCUSSION

The effect of ontogenetic age on explant performance was seen with the inability of explants from 26 mature sources to respond in culture (Table 1). From 551 mature explants, 72% were successfully disinfested, but only 4% survived the culture environment. No explants from mature sources produced axillary shoots or adventitious buds. The small percentage of explants from mature sources that survived in the culture environment showed some tissue proliferation after approximately 7 months in culture.

Table 1. Percentage of North American pawpaw (*Asimina triloba*) explants showing axillary bud elongation of seedling, shoots produced from root cuttings, and mature source nodal explants after 4, 6, and 8 weeks on an MS medium supplemented with 10 μM BA and 0.1 μM TDZ.

	Weeks in culture		
Explant Source	4	6	8
Seedling (n=25)	60%	72%	100%
Shoots from root cuttings (n=42)	0%	0%	42%
Mature (n=551)	0%	0%	0%

Seedling explants, ontologically juvenile tissue, responded rapidly in vitro. After 4 weeks in culture, seedling explants had expanded axillary buds and after 6 weeks, the expanded shoots were suitable for subculture. At 8 weeks, axillary buds elongated on all seedling nodal explants and multiple adventitious buds and shoots had formed.

Shoots produced on root cuttings did not respond as rapidly or at the high percentages of the seedling explants, but the explants did respond in culture. Within 8 weeks, axillary shoot elongation occurred in nearly half of the explants from shoots produced on root cuttings. The explant response indicates that shoots produced on root cuttings may be an alternative explant source for tissue culture studies.

Discoloration of the medium was observed for all explant sources. Explant exudation caused a reddish-brown discoloration of the medium at the basal end of the explants. Explant exudation has been documented in other members of the Annonaceae and was attributed to phenolics and polyphenoloxidase in the medium (Jordan et al., 1993). Tissue damage can cause explant exudation of phenolic compounds that turn brown as oxidation occurs (Hartmann et al., 1997).

This study indicates that tissue culture of pawpaw is possible, but the ontological age of the explants must be considered. Explants from mature sources require an extended period of time to induce explant responses. This study provides preliminary information about the effect of age on establishment of pawpaw in culture, but additional research is necessary to develop a micropropagation system for the pawpaw.

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Seed Storage Media Effects on Persimmon Germination

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INTRODUCTION

Common persimmon, *Diospyros virginiana*, is a medium to large narrow tree that produces edible fruit. Tripp and Raulston (1995) state "*Diospyros virginiana* has alot to offer American landscapes". Persimmon is an attractive native tree that may be a valuable landscape tree because it is tolerant of diverse environmental conditions (Bir, 1992; Dirr, 1990; Whitcomb 1983).

Persimmon seeds were collected from native trees in Caldwell County, Kentucky on 7 Dec. 1995. The seeds were prepared for storage by two methods: (1) Moist seed — cleaned (cap, skin and the easily removed pulp removed), and (2) Dry seed — cleaned, dried for 3 days, and the remaining pulp removed. The following treatments were replicated three times: (1) moist seeds; (2) dry seeds; (3) moist seeds in dry perlite; (4) moist seeds in moist perlite; (5) dry seeds in dry perlite; (6) dry seeds in moist perlite; (7) moist seeds in dry peat moss; (8) moist seeds in moist peat moss; (9) dry seeds in dry peat moss; (10) dry seeds in moist peat moss. Plastic 1-gal storage bags containing 25 seeds per replicate with three replicates per treatment were placed in the refrigerated storage (40F) immediately after treatment.

The seeds were removed from refrigerated storage and planted into a commercially prepared media (Pro-Mix BX) in 10 inch^3, 8.25-inch-long tubes (SC-10 Super Cells, Stuewe and Sons, 2290 S.E. Kiger Island Drive, Corvallis, OR 97333-9461) on 27 April 1996. Germination data was collected weekly through 10 June 1996 when maximum germination for the best treatments was repeated.

Table 1. Percent germination for stored persimmon seed.

Storage media/seed preparation	Percent germination
Moist perlite/moist seed	93.3a[1]
Moist perlite/dry seed	89.3a
Moist peat/dry seed	86.7a
Moist peat/moist seed	84.0a
Dry perlite/moist seed	82.7a
Dry peat/dry seed	20.0b
No media/dry seed	16.0b
Dry perlite/dry seed	14.7b
Dry peat/moist seed	12.0bc
No media/moist seed	4.0c

[1]Means with the same letter are not statistically different at the 0.05 probability level using Fishers protected LSD.

RESULTS AND DISCUSSION

Percent germination data (Table 1) suggest that storage in moist medium is beneficial regardless of the seed preparation. As moisture and cool temperatures are required for stratification of many plants this would be expected. Dry perlite as a storage media for moist seeds was not significantly different from using moist perlite or peat moss as a storage media for moist seeds. It is speculated that dry peat moss removed moisture from the remaining pulp on the moist seeds to the point that their germination percent was the equivalent of the dry peat moss/dry seed. Therefore, stratification could not be completed in the seed stored in dried peat moss until moisture was provided at planting.

SIGNIFICANCE TO THE INDUSTRY

Persimmon seed that is to be collected in the fall, refrigerated over the winter, and directly seeded in the spring should be stored in moist perlite or moist peat moss and placed in a sealed container in order to optimize germination. If a dry media is to be used as a storage medium, perlite is the preferred medium when moist seeds used. For convenience of handling, the seed can be cleaned or cleaned and dried before storage in moist perlite or peat.

Acknowledgements: The authors would like to express their appreciation to R. June Johnston for technical assistance.

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Specific Differences in Shoot Tip Culture of Roses

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Twenty rose taxa (species, cultivars, and rootstocks) that were growing on farms at Gifu University and Gifu Rose Garden Ltd. were propagated in vitro by shoot tip culture. The shoot tips from all 20 rose taxa survived and elongated on all media. Fourteen of them were 100% viable on media of suitable concentration. *Rosa rugosa* 'Alba' and 'Rubra', *R. multiflora*, and *R.* ×*odorata* produced 4.1- to 8.2-mm-long shoots, but those of *R. canina* and its cultivars and *R. pimpinellifolia* were shorter (1.0 to 2.2 mm). *Rosa rugosa* and *R. banksiae* were intermediate.

INTRODUCTION

In order to breed rose cultivars that are resistant to crown gall disease, we developed an in vitro test method to evaluate resistance, which we reported at the third IPPS-Japan Annual Conference in 1996 (Zhou et al., 1996). Culturing rose plantlets in vitro is essential for this method. In the study presented here we propagated 20 rose taxa (species, cultivars, and rootstocks) by shoot tip culture. This paper reports the growth characteristics of these shoot-tip cultures.

MATERIALS AND METHODS

Shoot segments (3 cm) with an axillary bud were excised from shoots of 20 rose taxa (species, cultivars, and rootstocks) (Table 1) growing on farms at Gifu University and Gifu Rose Garden Ltd. The shoot tips were sterilized for 10 min in 1% sodium hypochlorite solution containing 0.01% Tween 20. The shoot tips (1 mm) were excised from the shoot segments and transferred to media. The basal medium was Murashige and Skoog (MS) medium containing 3% sucrose and 0.2% Gelrite. The plant growth regulators added to the basal medium were gibberellin A_3 (GA_3) 0.1 µM and 6-benzylaminopurine (BAP) in the range of 0.01 to 10 µM. All media were adjusted to a pH 5.7. Cultures were kept at 25C with a 16-h light period. Data was taken after 6 weeks in culture.

RESULTS AND DISCUSSION

The shoot tips for all rose taxa survived and elongated on all media. However, viability, shoot length, and most suitable medium for each plant was different (Table 1).

Rosa rugosa 'Alba' gave the best results, with a viability of 100% on all media. *Rosa canina* and six of its cultivars, 'Brogs Stachellose', 'Heinsohns Rekord', 'Pfander', 'Entree', 'Kuiper', and 'Uniform', as well as *R. multiflora* 'K2', *R. coriifolia* 'Froebelii', *R. banksiae*, *R.* ×*odorata*, *R. rugosa*, and *R. rugosa* 'Rubra' were 100% viable on media of suitable concentration, but the viability of *R. canina* 'Pollmers' and *R. canina* 'Veendam' was under 75%.

Table 1. Growth of rose species and cultivars after 6 weeks in shoot-tip culture.

Species/cultivars	Most suitable medium*	Viability(%)	Most suitable medium	Shoot length (mm)
Rosa canina	A	100	A	1.5
R. canina 'Brögs Stachellose'	B	100	B	2.1
R. canina 'Entree'	F	100	F	2.3
R. canina 'Heinsohns Rekord'	C	100	C	1.3
R. canina 'Kuiper'	C	100	C	1.9
R. canina 'Pfänder'	C	100	C	1.0
R. canina 'Pollmers'	D	75	F	1.0
R. canina 'Schmid's Ideal'	E	95	F	2.2
R. canina 'Uniform'	F	100	E	2.3
R. canina Veendam'	B	65	B	1.9
R. rugosa	C	100	C	2.5
R. rugosa 'Alba'	D	100	D	8.2
R. rugosa 'Rubra'	E	100	E	7.7
R. multiflora	C	95	C	4.9
R. multiflora 'Matsushima No. 3'	F	95	E	2.5
R. multiflora 'K2'	D	100	E	1.9
R. coriifolia 'Froebelii'	A	100	A	1.5
R. banksiae	D	100	D	2.6
R. ×odorata	C	100	C	4.1
R. pimpinellifolia	B	90	B	2.2

*Most suitable medium: MS medium with plant growth regulators added to the medium as follows:

A: GA_3 1.0×10^{-7} M, BAP 1.0×10^{-5}.
B: GA_3 1.0×10^{-7} M, BAP 3.2×10^{-6}.
C: GA_3 1.0×10^{-7} M, BAP 1.0×10^{-6}.
D: GA_3 1.0×10^{-7} M, BAP 1.0×10^{-7}.
E: GA_3 1.0×10^{-7} M, BAP 3.2×10^{-8}.
F: GA_3 1.0×10^{-7} M, BAP 1.0×10^{-8}.

Rosa rugosa 'Alba' and 'Rubra', *R. multiflora*, and *R.* ×*odorata* produced 4.1- to 8.2-mm-long shoots, but those of *R. canina* 'Pfander' and *R. canina* 'Pollmers' were shorter (1.0 mm). Other species and cultivars were intermediate (1.3 mm to 2.6 mm).

Of the six species, *R. multiflora* and *R.* ×*odorata*, with an average shoot length of 4.9 mm and 4.1 mm, respectively, were comparatively long, while *R. canina*, with 1.5-mm shoot length, was the shortest. *Rosa rugosa* (2.5 mm), *R. pimpinellifolia* (2.2 mm), and *R. banksiae* (2.6 mm) were intermediate.

With *R. canina* and its nine cultivars, shoot elongation was slow as a group. *Rosa canina,* and *R. canina* 'Brogs Stachellose', 'Schmid's Ideal', 'Entree', 'Uniform', 'Veendam', and 'Kuiper' had shoot lengths of 1.5 to 2.3 mm, while those of the other cultivars were 1.0 to 1.3 mm. For *R. rugosa* and its two cultivars, the shoot length of 'Alba' and 'Rubra' was longer than that of the species. Among *R. multiflora* and its two cultivars, the shoots for *R. multiflora* and 'Matsushima No.3' were long, but short on 'K2'.

Murashige and Skoog medium with BAP and GA_3 was suitable for the shoot tip culture of these rose species and cultivars. The most suitable concentrations for these roses are shown in Table 1. The most suitable medium for maximum viability and maximum shoot length was in most cases the same for a given species and its cultivars, but differed when compared with other species and their cultivars.

Shoot tip multiplication of roses has been reported in *R. hybrida* (Davies, 1980; Skirvin and Chu, 1979) and old world roses (Khosh-khui and Sink, 1982), however, only a small number of species and rootstock cultivars were evaluated in these studies. In our study, 20 taxa consisting of species cultivars and rootstock were used, and all species and cultivars had high viability and growth. Our results indicate that it is feasible to propagate these roses with selected media. For different rose species, shoot tip growth in vitro is different because of physiological and genetic differences (Cai et al., 1984), and Arnold et al. (1992) reported that BA and NAA both had significant effects on the proportion of viable plantlets and on multiplication rates while low or high concentrations of these growth regulators in the medium generally caused a reduction of plant material. In our study, of seven rose species, *R. multiflora, R.* ×*odorata, R. rugosa,* and *R. banksiae,* which are of east Asian origin, shoot tip growth was strong. However, for *R. canina* of European origin, shoot tip growth was weak. Our interpretation is that the geographical and climatic conditions of the place of origin produce special characteristics in these rose species.

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A Preliminary Report on the Symbiotic Germination of Nine Japanese Terrestrial Orchids

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In order to develop an effective propagation method, symbiotic culture was attempted in nine species of Japanese terrestrial orchids. After 3 min of surface sterilization in sodium hypochlorite solution together with ultrasonic treatment, mature seeds were sown on slants of medium (the medium having been inoculated with orchid mycorrhizal fungi), cultured, and compared with nonsymbiotic controls. Approximately 10% to 70% of the seeds with embryos showed activity by the TTC test following the sowing. All but the *Cypripedium macranthum* var. *speciosum* were found to germinate with inoculum from a number of *Rhizoctonia* fungal strains. Three species of *Goodyera* (*G. biflora* var. *macrantha, G. foliosa* var. *laevis, G. hachijoensis* var. *matsumurana*), when inoculated with fungi from the binucleate *Rhizoctonia* fungus group among the 20 fungus strains tested, germinated with virtually the same TTC activity level as embryos. The fact that six of the species' germination rates were well below the TTC test results was thought due to the unsuitability of the test culture conditions. However, since numerous effective fungal strains proved effective with five species other than *C. macranthum* var. *speciosum,* which developed a symbiotic relationship with only one of the fungal isolates tested, it was predicted that for symbiotic germination among three species (*Aorchis cyclochila, Dactylorhiza aristata, Gymnadenia camtschatica*) the binucleate *Rhizoctonia* fungal group would be suitable, while *R. repens* would be appropriate for two other species, *Amitostigma kinoshitai* and *Ponerorchis graminifolia* var. *graminifolia.*

INTRODUCTION

Many native Japanese plants are facing extinction. The main reason orchid species in Japan are on the decrease is the indiscriminate horticultural overharvesting peculiar to this country (Japan Society of Plant Taxonomists, 1993). This is because many species collected do not have an effective propagation method to date; thus there is over-reliance on the collection of plants from natural habitats such as mountain areas. Given the threat of extinction, these orchid species must be protected and at the same time the development of effective propagation methods is essential in order to meet the demand.

As a means of both preserving and propagating temperate terrestrial orchid species which are difficult to grow, symbiotic germination using mycorrhizal fungi from the orchid root is utilized, along with the conventional nonsymbiotic germination approach (Clements et al., 1986; Rasmussen, 1995). In the symbiotic culture technique, were it possible to establish an orchid-fungus association favorable to the orchid, it would presumably provide a very practical culture method (Hadley, 1970; Rasmussen, 1995), but there are few studies on orchid-fungus associations among

Japanese orchid species (Tsutsui and Tomita, 1988; Masuhara and Katsuya, 1989; Tomita, 1995).

Thus, in the present study, we attempted a symbiotic culture with orchid mycorrhizal fungi for nine species of orchids native to Japan, and conducted a preliminary investigation for each species in terms of the suitability of the symbiotic culture method and the problems encountered.

MATERIALS AND METHODS

From July to October of 1996, seeds from the following species were collected immediately before capsule dehiscence: *Amitostigma kinoshitai* (Ohwi et Hashimoto) Hashimoto, *Aorchis cyclochila* (Franch. et Savat.) Hashimoto, *Cypripedium macranthum* Sw. var. *speciosum* (Rolfe) Koidz., *Dactylorhiza aristata* (Fisch.) Soo, *Goodyera biflora* (Lindl.) Hook. f. var. *macrantha, G. foliosa* (Lindl.) Benth. ex Clarke var. *laevis* Finet, *G. hachijoensis* Yatabe var. *matsumurana* (Schltr.) Ohwi ex Hatsushima et Amano, *Gymnadenia camtschatica* (Cham.) Miyabe et Kudo, and *Ponerorchis graminifolia* Rechib. f. var. *graminifolia.* Seeds of *Aorchis cyclochila, G. biflora* var. *macrantha*, and *G. hachijoensis* var. *matsumurana* were collected from strains cultivated in a greenhouse at Hirosaki University, while seeds of the six other taxa were cross-fertilized in their natural habitat of Aomori Prefecture, with the permission of the landowner, and the seeds collected.

The seeds were then placed in 5-ml bottles for 3 min with a sodium hypochlorite solution (1% available chlorine) to which a few drops of surface-active agent had been added. Along with surface sterilization, ultrasonic treatment of each container was performed to enhance germination (Miyoshi and Mii, 1988). Then, following several washings in sterile distilled water, the seeds were sown on the medium. The TTC test (Van Waes and Debergh,1986) was used to check activity of some of the seeds.

Oat-powdered agar (Tomita, 1995) was used for the symbiotic germination medium and T medium (Tsutsui and Tomita, 1990) for the nonsymbiotic culture medium. Seeds were sown on a slope of 20 ml of medium in a 25 mm × 150 mm test tube, with a sowing density of 200 to 300 seeds with embryos per test tube. At least five replicate tubes were prepared for each treatment.

In the symbiotic culture, a fungal block 5 mm in diameter was inoculated into the upper and lower end of the medium slope immediately after sowing. Fungi were isolated from the orchid mycorrhizae. A total of 20 strains were used (Table 1), 15 of which were identified as belonging to *Rhizoctonia*; five strains of binucleate *Rhizoctonia*, five of *R. repens*, and five strains of multinucleate *Rhizoctonia*. The other five strains were from other than *Rhizoctonia*.

The seeds were cultured for 16 weeks and the germination rate and postgermination growth were then evaluated. Seeds in which the embryos showed sufficient swelling to break the testa were considered to have germinated (Arditti, 1967). Growth was assessed on a scale of 1 to 5 as follows: (1) germination; (2) marked swelling of protocorm (equivalent to long diameter of testa); (3) shoot beginning to differentiate a protocorm; (4) bud elongation or leafing out; and (5) root differentiation. The mean values were obtained.

Culturing was done at 23±1C in the dark, but following germination moved to continuous illumination (500 lux) in the test tubes showing growth, to the 3rd and 4th stages.

Table 1. Orchid mycorrhizal fungi used in the experiment.

Isolate No.	Fungal group (anastomosis group)	Group	Origin of isolate	
			Host orchid	Habitat
No.614	Binucleate *Rhizoctonia*	(I)	*Dactylorhiza aristata* (Fisch.)Soo	Sapporo, Hokkaido
No.706	"	(C)	*Gymnadenia camtschatica* (Cham.) Miyabe et Kudo	Bikuni, Hokkaido
No.715	"	(unknown)	*Cypripedium macranthum* Sw. var. *speciosum* (Rolfe) Koidz.	Sapporo, Hokkaido
No.861	"	(unknown)	*Cymbidium goeringii* (Reichb. f.) Reichb. f.	Noto, Ishikawa
No.9410	"	(unknown)	*Goodyera schlechtendaliana* Reichb. f.	Ajigasawa, Aomori
No.612	*Rhizoctonia repens*	(II)	*Cremastra appendiculata* (D. Don) Makino	Sapporo, Hokkaido
No.618	"	(I)	*Gymnadenia camtschatica*	Shakotan, Hokkaido
No.737	"	(I)	*Spiranthes sinensis* (Pers.) Ames var. *amoena* (M. v. Bieb.) Hara	Niigata, Niigata
No.864	"	(unknown)	*Spiranthes sinensis* (Pers.) Ames var. *amoena* (M. v. Bieb.) Hara	Bibai, Hokkaido
No.9407	"	(unknown)	*Cymbidium goeringii*	Hirosaki, Aomori
No.101	Multinucleate *Rhizoctonia*	(unknown)	*Gymnadenia camtschatica*	Zenibako, Hokkaido
No.621	"	(I)	*Dactylorhiza aristata*	Sapporo, Hokkaido
No.634	"	(I)	*Gymnadenia camtschatica*	Oohira, Hokkaido
No.714	"	(unknown)	*Oreorchis patens* (Lindl.) Lindl.	Chitose, Hokkaido
No.9412	"	(unknown)	*Gymnadenia camtschatica*	Hiraka, Aomori
No.606	Non *Rhizoctonia* Isolates	(I)	*Calanthe discolor* Lindl.	Shinoyama, Hyogo
No.620	"	(I)	*Gymnadenia camtschatica*	Sapporo, Hokkaido
No.622	"	(I)	*Calanthe discolor*	Sapporo, Hokkaido
No.640	"	(I)	*Calanthe discolor*	Kitakata, Gifu
No.726	"	(unknown)	*Calanthe tricarinata* Lindl.	Chitose, Hokkaido

RESULTS

Table 2 presents the TTC test results for mature seed immediately after sterilization along with the symbiotic and nonsymbiotic germination results. The results shown for symbiotic culture include at least one orchid species seed from the strains listed in Table 1 which had been established with a fungal strain. From the color reaction results in the TTC bath water solution, the percentage of active seeds from among the tested seeds with embryos ranged widely from 10% to 70%.

Germination was recognized in symbiotic culture with *Rhizoctonia* isolates in all nine orchid species tested. In the non-*Rhizoctonia* fungi-inoculated types, no germination whatsoever was observed although embryo swelling was found. In the multinucleate *Rhizoctonia* fungi-inoculated cultures, aside from *G. biflora* var. *macrantha*, eight species showed no germination. Moreover, in the eight species excluding *C. macranthum* var. *speciosum,* germination was achieved from inoculation with a number of *Rhizoctonia* fungal isolates.

Amitostigma kinoshitai. There was no germination in the nonsymbiotic controls. Germination was evident in both the binucleate *Rhizoctonia* and *R. repens* fungi-inoculated groups. Germination rate and postgermination growth were better in the *R. repens* group than in the binucleate *Rhizoctonia* fungi-inoculated group. The percentage of embryo staining in all seeds with embryos was 35.5% by TTC test, and No. 9407 isolate showed the highest germination rate of 8.6%.

Aorchis cyclochila. Symbiotic germination was only found with binucleate *Rhizoctonia* inoculation. No difference in the germination rate was noted between the symbiotic and nonsymbiotic culture techniques, but seedling growth was better with symbiotic germination. From the TTC testing, the embryo staining in all seeds with embryos reached 70.5%, against the maximum germination rate of 20% among nonsymbiotic culture seeds.

***Cypripedium macranthum* var. *speciosum*.** Symbiotic germination in this orchid species was only achieved with isolate No. 706. The nonsymbiotic culture achieved a higher germination rate and subsequent seedling growth. Even in the nonsymbiotic approach, however, germination was only 10% of the TTC test embryo staining ratio.

Dactylorhiza aristata. Symbiotic germination resulted only with the binucleate *Rhizoctonia* fungal isolates. There was more actual growth than by nonsymbiotic germination, especially with isolate No. 614.

Goodyera biflora* var. *macrantha. The embryo staining rate was 59.8% by TTC test. There was over 50% germination with either of the binucleate *Rhizoctonia* fungal isolates, and seedling growth after germination was better than by nonsymbiotic germination. Of the nine orchid species tested, germination was achieved only by the multinucleate *Rhizoctonia* isolate No. 9412.

Goodyera foliosa* var. *laevis. In this species the culture reaction tended to be the same as for *G. biflora* var. *macrantha,* except that no germination resulted from inoculation with the multinucleate *Rhizoctonia* fungal group. The germination rate and actual growth with *R. repens* were virtually the same as in the nonsymbiotic culture, but the results were better with the binucleate *Rhizoctonia* fungi.

Table 2. Effects of fungal endophytes on seed germination and seedling development of nine Japanese terrestrial orchids.

Mycorrhizal fungi isolate	Orchids: Germination percentage (A) and developmental index (B)							
	Amitostigma kinoshitai		*Aorchis cyclochila*		*Cypripedium macranthum*		*Dactylorhiza aristata*	
No.	A	B	A	B	A	B	A	B
614	5.4b[Z]	2.4b	15.9a	2.5a	0b	-	26.3a	3.6a
706	2.3b	2.1b	16.5a	2.3a	0.4b	1.0b	13.0b	2.8a
9410	3.6b	2.2b	17.0a	2.3a	0b	-	22.6a	3.2a
618	8.5a	2.8b	0b	-	0b	-	0c	-
864	8.2a	3.0ab	0b	-	0b	-	0c	-
9407	8.6a	3.6a	0b	-	0b	-	0c	-
9412	0c	-	0b	-	0b	-	0c	-
Asymbiotic control	0c	-	20.0a	1.7a	1.1a	2.0a	27.4a	1.5b
Colored embryo with TTC test (%)[Y]	35.5		70.5		10.6		59.5	

Symbiotic culture results are shown for at least one of orchid species seeds observed to have germinated from among the fungi incubated in Table 1. Symbiotic culture was performed on oat powdered medium (Tomita, 1995). Tsutsui and Tomita medium (1990) was used for asymbiotic control.

[Z] Mean separation within column by Duncan's multiple range test at 5% level.

[Y] The seeds after sterilization were soaked in 1% 2,3,5-triphenyl tetrazolium chloride(T.T.C.) for 24 h at 30C in the dark (Van Waes and Debergh, 1986). At least 400 seeds tested.

***Goodyera hachijoensis* var. *matsumurana*.** The germination rate and growth of this species when symbiotically cultured with the binucleate *Rhizoctonia* isolates was better than in the nonsymbiotic culture. Germination did not result in the *R. repens* or multinucleate *Rhizoctonia* fungal inoculates.

***Gymnadenia camtschatica*.** Symbiotic germination resulted only when the symbiont was a binucleate *Rhizoctonia* isolate. Post-germination growth was better by symbiotic culture, but there was a higher germination rate with nonsymbiotic culture.

***Ponerorchis graminifolia* var. *graminifolia*.** The germination rate and actual seedling growth were almost the same in the control or seeds cultivated symbiotically with binucleate *Rhizoctonia* fungi isolates. Both the germination rate and seedling growth were better with *R. repens* than in either the control or binucleate *Rhizoctonia* fungal inoculation approach.

Orchids									
Germination percentage (A) and developmental index (B)									
Goodyera biflora var. *macrantha*		*G. foliosa* var. *laevis*		*G. hachijoensis* var. *matsumurana*		*Gymnadenia* camtschatica		*Ponerorchis graminifola*	
A	B	A	B	A	B	A	B	A	B
57.1a	4.6a	52.4a	3.8a	34.0ab	3.5a	10.2ab	1.3a	17.6ab	1.5b
54.5a	4.6a	45.6a	3.7a	45.8a	4.0a	7.6b	1.8a	12.5b	1.3b
50.6a	4.6a	46.8a	3.9a	30.3ab	3.9a	0c	-	10.8b	1.6b
34.4b	2.0b	40.3a	1.6b	0c	-	0c	-	18.2ab	1.9b
46.2ab	1.9b	36.1ab	1.3b	0c	-	0c	-	23.1a	2.8a
45.0ab	2.0b	45.8ab	1.5b	0c	-	0c	-	20.5a	2.5a
13.6c	1.4b	0c	-	0c	-	0c	-	0c	-
46.1a	1.9b	51.3a	2.1b	30.1b	2.1	13.5a	1.0b	16.8ab	1.3b
59.8		61.5		52.2		27.0		43.5	

DISCUSSION

From the results of the TTC test, which have a close relation to germination activity (Van Waes and Debergh, 1986), the tested seeds showed 10% to 70% staining immediately after being sown, and were thus considered to have high germination activity. However, given the germination test results (Table 2), only the three *Goodyera* species showed virtually the same germination rate as the active seed percentage indicated by the TTC test. The other species, either in symbiotic or nonsymbiotic conditions, showed less than half or a much lower germination rate than that indicated by the TTC test, so the test conditions were considered inappropriate for germination. *Dactylorhiza majalis* and several other terrestrial orchids exhibited the effects of culture temperature on the symbiotic seedling growth (Rasmussen, 1995). *Ponerorchis graminifolia* was reported to undergo a germination promotion effect after sowing by the addition of low-temperature treatment (Ichihashi, 1989). Besides the screening tests for orchid seeds and mycorrhizal fungi, it was clear that due consideration should be given to the seed culture, environmental, and other conditions as well.

Many reports credit the binucleate *Rhizoctonia* group (a species related to *Ceratobacidium cornigerum*) with a strong growth-enhancing effect on the symbiotic seedlings of *Goodyera* species (Alexander,1982; Rasmussen, 1995; Tomita, 1995), a finding corroborated in the present investigation. Even within the *Goodyera* genus, the range of symbiotic fungal groups in the three tested species was different, and in *G. biflora* var. *macrantha*, a symbiotic relationship developed with the same multinucleate *Rhizoctonia* fungal strain as with *G. oblongifolia* (Harvais, 1974).

The difference in the range of fungal strains resulting in symbiosis even within the same genus is of great interest in investigating the orchid-fungus association for developing a propagation method using symbiotic germination.

In symbiotic culture, another issue is the nourishment dependence on the fungus of the orchid for propagation (Tsutsui and Tomita, 1988). As with *Bletilla striata* (Masuhara and Katsuya, 1989) or *Pectelis radiata* (syn. *Habenaria radiata* Spreng)(Tsutsui and Tomita, 1988), species that readily germinate even asymbiotically and form a symbiosis with many fungal strains and groups, the dependence on the fungus is thought to be low. In such orchid species, there is not much to be gained from using symbiotic culture for seedling propagation.

Among the nine orchid species tested in the present study, the three belonging to the *Goodyera* genus were easily germinated by nonsymbiotic culture, and *G. biflora* var. *macrantha* in particular showed somewhat less fungal dependence than the other orchid species. However, since in all three of the species belonging to the *Goodyera* genus, seedling growth was promoted by inoculation with the *Rhizoctonia* fungal group isolate when compared to the nonsymbiotic culture method, we consider the symbiotic method to be an effective means to propagate seedlings.

Based on the foregoing, with the exception of the three *Goodyera* species, the test culture conditions may well have not been ideal for the germination of the other six orchid species. However, one may assume a suitable fungal group exists from the fact that numerous fungal isolates proved effective. The present findings suggested that the binucleate *Rhizoctonia* fungal group is suitable for the three species, *A. cyclochila*, *D. aristata*, and *G. camtschatica*, while the *R. repens* fungal group is suitable for *A. kinoshitai* and *P. graminifolia* var. *graminifolia*. In forthcoming screening of the mycorrhizal fungi applicable for symbiotic culture of various orchid species, we believe that effective fungi can be efficiently selected by testing the fungal groups which appear suitable for symbiotic culture. From careful study of the culture conditions for germination, seedling production from symbiotic germination is also possible.

In only one line of *C. macranthum* var. *speciosum* was there any symbiotic germination, and it would be risky to assume a suitable fungal group based on only the present experimental results. The use of the symbiotic germination method as a means to propagate this orchid species would necessitate both study of the seed culture conditions and the screening of more fungal strains. In parallel with this, the asymbiotic method should be investigated because there is a need to find a more effective culture method.

On the basis of the above findings, it was clear that the use of the symbiotic germination method was actually of use as a means to propagate the three species belonging to the *Goodyera* genus among the nine orchid species tested. Detailed studies are needed of all culture conditions, aside from the fungus inoculated, in order to prove the use of the symbiotic germination method as a means to propagate the other six orchid species.

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Inducing Callus and Regeneration of *Haworthia*

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***Haworthia* is a genus of succulent plants which belongs to the family *Liliaceae*. There are about 500 species, mainly located in South Africa. In the present study, leaf and flower stem segments were cultured in order to induce callus in four different species of *Haworthia*. It is considered difficult to propagate *Haworthia* via leaf cuttings, root cuttings, division, or seed. In this study, the propagation of *Haworthia* by tissue culture was investigated.**

MATERIALS AND METHODS

Four different species of *Haworthia, H. truncata, H. arachnoidea* (syn. *setata*), *H. emelyae* (syn. *picta*), and *H. turgida,* were used. Leaf segments and flower stems were washed for 24 h with water and sterilized using ultrasound for 15 min, 70% alcohol for 2 min, and 50% sodium hypochlorite solution with a few drops of Tween 20 for 15 min, followed by three rinses in sterile distilled water. Each leaf was cut into two parts and the flower stems were cut about 1 to 2 cm in length.

Naphthalene acetic acid or 2,4-D plus kinetin or BA were added to Murashige and Skoog (MS) basal medium to induce callus. In total, 21 different media containing either NAA or 2,4-D combined with kinetin or BA were used in order to investigate the effects of plant growth regulators on callus proliferation. The leaf and flower stem segments were cultured at 23±2C and 300 lux (16-h photoperiod) or in the dark. During callus culture, shoot and root numbers were recorded. MS medium without any growth regulator and Hyponex medium were also used to examine their effect on induction of root formation.

RESULTS AND DISCUSSION

Inducing Callus. Calli were induced from leaf segment of all four species of *Haworthia.* Although there are reports of callus being induced from flower stems in *Haworthia*, this is the first report of callus being induced from leaf segments.

Proliferation of Callus. The most effective callus-proliferation medium was the MS medium supplemented with 0.2 mg $liter^{-1}$ NAA plus 0.2 mg $liter^{-1}$ BA under dark rather than light conditions. After a month of culture, *H. arachnoidea* showed the highest proliferation rate, 316.0%; followed by *H. turgida*, 202.7%; *H. emelyae*, 200.0%; and *H. truncata*, 50.6% F.W.

Shoot Formation. The most effective shoot induction medium was the MS medium with 0.2 mg $liter^{-1}$ NAA plus 0.2 mg $liter^{-1}$ kinetin under light conditions. The number of shoots formed during 4 months of culture were: *H. arachnoidea*, 53.8±14.8; *H. emelyae*, 39.9±24.2; *H. truncata*, 22.1±13.9; and *H. turgida*, 10.3±5.3.

Root Formation from Shoots. The most roots, 7.8 was the average, were formed from shoots of *truncata* during the 1 month callus culture on the MS medium containing 0.2 mg liter^{-1} kinetin. The Hyponex medium without growth regulators was not as effective in inducing roots on shoots, with 2.3 roots on average formed. The numbers of roots were: *H. truncata*, 4.1±2.0; *H. emelyae*, 3.3±2.1; *H. turgida*, 1.3±0.9; and *H. arachnoidea*, 0.8±1.0. The regeneration rate of plantlets from callus was similar to the rate of root formation from shoots. The difficulty of regenerating plantlets from callus still remains.

Induction of Axillary Buds by Nodal Segment Culture and Rooting of Axillary Shoots of *Epipremnum aureum*

T. Yamamoto, Y. Ito, F. Uchida, and I. Mitsuishi
Department of Horticulture, University of Minami-Kyushu, Hibarigaoka, Takanabe-cho, Miyazaki Prefecture. 884

Nodal segments (5 mm in length) were excised from the shoots of potted *Epipremnum aureum* Bunt. which had been obtained from a market. After sterilization with 1% sodium hypochlorite solution, nodal segments were placed on Murashige and Skoog (MS) media with differing concentrations of benzyladenine (BA 0, 5, 10, and 15 mg liter^{-1}). The highest value of axillary bud induction (%) was observed in the MS medium supplemented with 10 mg liter^{-1} BA. When young nodes were used as explants, a number of adventitious shoots were formed on the explants. In this case, two types of shoots were observed, one with spotted leaves similar to the donor plant and another with unspotted green leaves.

It was found in both the media supplemented with 10 mg liter^{-1} BA or 10 mg liter^{-1} kinetin that the axillary bud break (%) of the plants derived from micropropagation was higher than that of the plants grown from soft cuttings.

When the axillary shoots reached about 2 cm in length, the shoots were excised from the explants and transferred to a vermiculite medium in vivo. As shown in Table 1, the rooting (%) of the shoots induced on the medium with 10 mg liter^{-1} kinetin was higher than those on the media with 10 mg liter^{-1} BA and control. Benzyladenine in the shoot-induction medium suppressed the rooting in the vermiculite medium. The shoot induction medium with 10 mg liter^{-1} kinetin had a promotive effect on the number of roots and on the maximum root length. Using this method the period necessary for obtaining good transplants was shortened, and the regenerated plants are now growing normally in a greenhouse.

Table 1. Rooting of axillary shoots in a vermiculite medium.

Hormones in axillary bud induction medium	Rooting (%)			Number of roots**	Length of maximum root (cm)
	5	10	20*		
Free	20	30	75	1.7±0.2	3.0±1.0
Kinetin (10 mg liter^{-1})	50	83	83	2.6±0.3	7.7±2.6
BA (10 mg liter^{-1})	5	10	70	1.8±0.3	3.6±0.7

* Days after transplantation
** Values 25 days after transplantation

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* Days after transplantation
** Values 25 days after transplantation

Hygro-Greening Trial Using a Floating Garden for Water Filtration

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INTRODUCTION

In order to clean the surface of bodies of water in urban areas, a new system of hygro-greening was trialled to improve pond and stream amenities in and around urban areas, and also to purify the water by absorbing excess nutrients. In this concept a floating garden was used to clean the water, and also improve the social environment.

MATERIALS AND METHODS

Plant Height Control. On a floating garden, controlling the weight of the plants in order to keep the garden afloat is a serious problem. In order to control the height to which the plants would grow on the floating pad, trials were carried out on tulip bulbs. They were dipped in various PGR solutions (Uniconazole at 25 ppm, 50 ppm, and 100 ppm) overnight. Prior to this treatment, the bulbs had been cold stored for a month at 5C to break dormancy.

After PGR treatment, the bulbs were planted in a floating pad. The dates of flower stalk emergence and flower opening were recorded. The length of flower stalk, the length and width of outer perianth, and the longest leaf were measured.

Water Clean Up. The floating garden pad was placed on the water and irrigated twice each day for 15 min by means of a mini water pump. To re-create the polluted water, the same concentration of Anon's solution was used as found in naturally occurring bodies of water. The initial pH value was 7.2 and the EC value was 5.2 ms/cm, and the concentration of NO_2-N exceeded 0.3 mg liter^{-1}.

Floating garden pads were planted with begonias, azaleas, and gardenias. Their concentration of NO_2-N was measured after 2 and 4 weeks using a convenient measuring kit for NO_2-N (Sibata Co. Ltd.).

RESULTS AND DISCUSSION

Plant Height Control. The stalk length of the tulips was greatly decreased by the PGR treatment. In addition, this treatment also resulted in a delay in flowering time and a decrease in the size of petals and leaves.

Water Quality. The concentration of NO_2-N in the solution decreased in 4 weeks. Plant growth was normal and was not affected by the polluted water.

Therefore, this system of hygro-greening can be recommended as a method of cleaning water by the use of a living (green) filter.

The Practical Use of Biotechnology in Agriculture High School Education

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INTRODUCTION

Biotechnology education was introduced to the curriculum of Hiratsuka Agricultural High School in 1990 when the three departments of the school were reorganized. The aim of the adoption of biotechnology education was to give the students a deeper understanding of living things and also to give them some confidence in agriculture. The main aims were to give the students some basic technology, such as sterilization using a newly-built clean room, or showing them themes for research.

SOME PRACTICAL EXAMPLES WHERE BIOTECHNOLOGY WAS USED

Experiments in Multiplication of Disease-Resistant Eggplants. A common problem with eggplants grown continuously in the same field, is the occurrence of a disease called *Verticillium* wilt. So the development of disease-resistant eggplants was tried first. Healthy plants were chosen in a field where the disease was present and from those healthy plants, some healthy leaves were taken and cultured (Fig. 1). The newly obtained small plants were planted and compared with the grafted healthy plants from the continuously used field. In these two kinds of plants no differences were found and no sign of disease appeared in the new plants. The result of this research was presented at the Japan Students' Science Exhibition and gained an award from the governor of the prefecture.

Figure 1. Shoot formation from leaf of eggplant.

Micropropagation of *Lilium auratum* Lindl. by Tissue Culture. *Lilium auratum* Lindl., which is known as the flower of Kanagawa Prefecture, has decreased in the wild recently because of the deterioration of its natural environment and rapid urbanization. Tissue culture was adopted as the first step in increasing the numbers. Healthy flower buds were taken from plants growing in the field. Each part of the organ (filament, style, anther, and stigma) was separated and cultured, and the highest percentage of bulbs were obtained from the filament. The concentration of sugar in the culture medium was found to be largely responsible for the size of the bulb.

We made a liquid-culture device by utilizing empty juice bottles and also made a simplified water pump. By using these devices the multiplication was done more efficiently (Fig. 2). A patent was obtained for this device. The bulbs obtained through

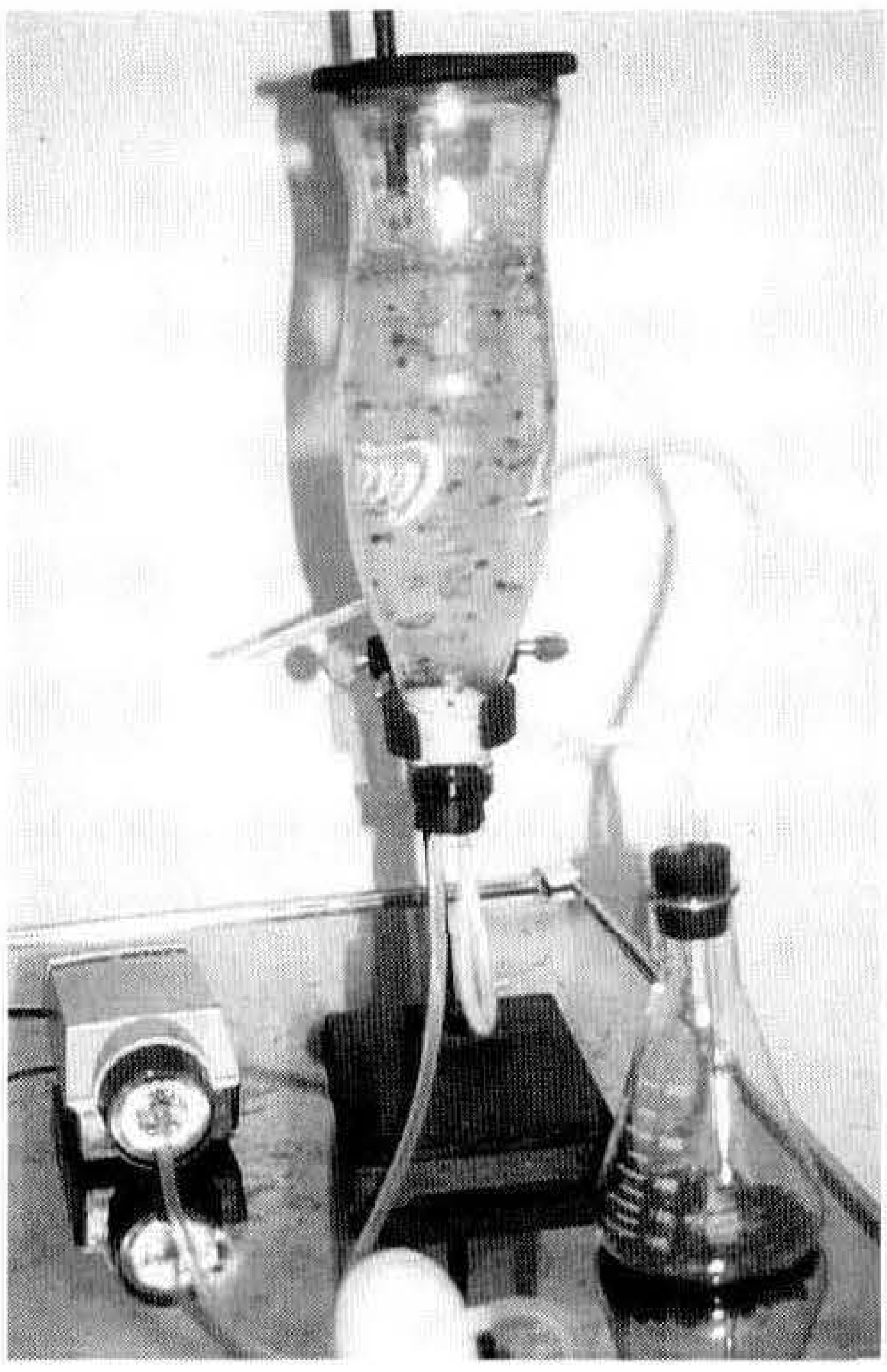

Figure 2. A simplified water pump and chamber.

culture were cooled and acclimatized and in 2 years produced flowers.

Rose Growing Using Virus-Free Plants. One of the students, who was planning to follow his father's profession of rose growing, experimented with growing virus-free roses using the shoot-tip culture method on the cultivar Tineke® rose. He cultured the plants in rockwool and obtained cut flowers with a better quality and a longer life expectancy. He received first prize in the " All Japan Agricultural Club Conference of High School Students."

An Investigation of Bud Development of *Phalaenopsis* Using a Scanning Electron Microscope. The germination of virus-free seedlings of *Phalaenopsis* was observed through the scanning electron microscope belonging to our school. The seeds are very small, with a diameter about 0.5 mm (Fig.3), however, within 10 days the growth of the embryo was recognizable and within 30 days the protocorm could be seen (Fig. 4). This process was shown at the World Orchid Exhibition.

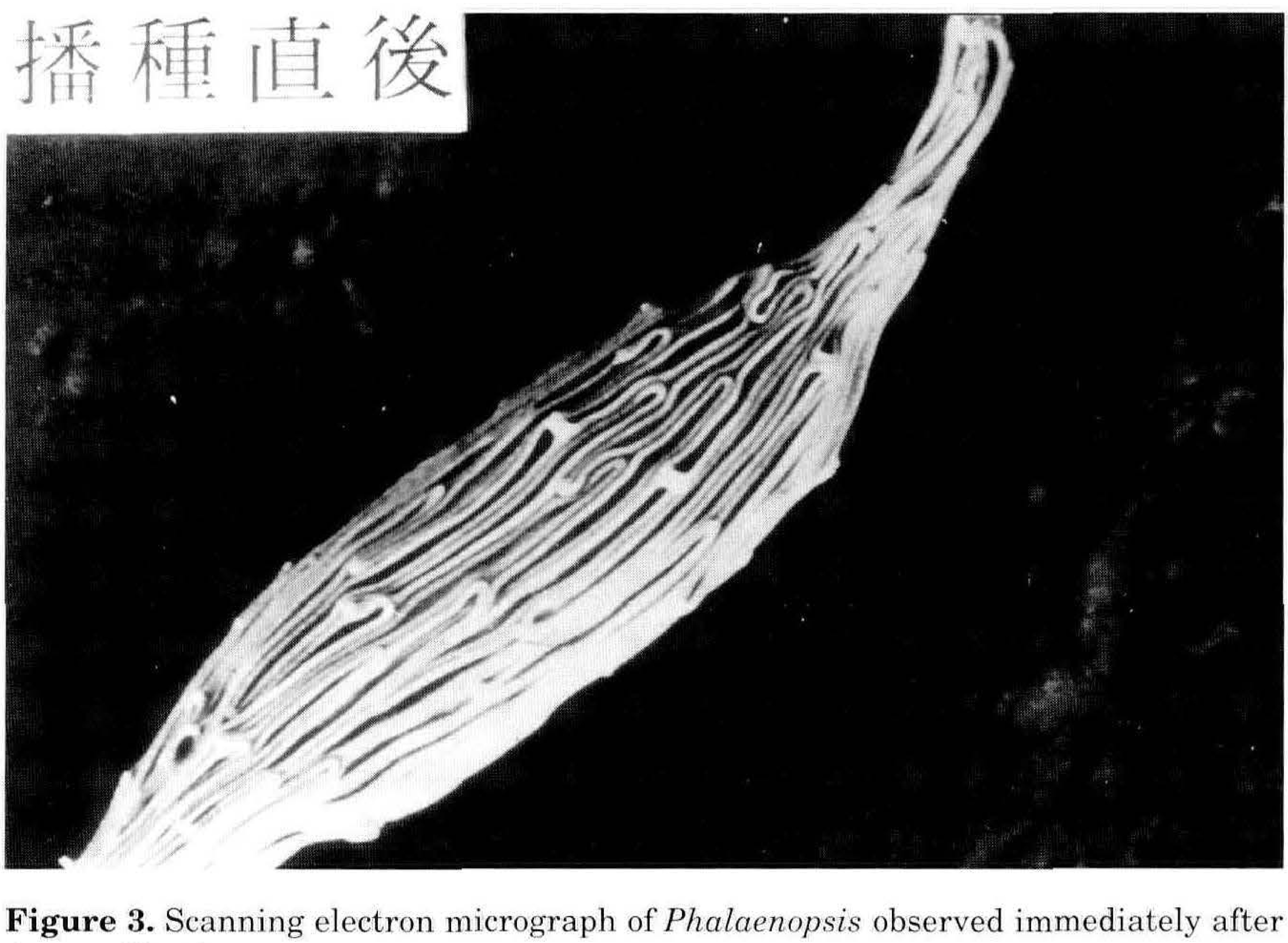

Figure 3. Scanning electron micrograph of *Phalaenopsis* observed immediately after the sterilization.

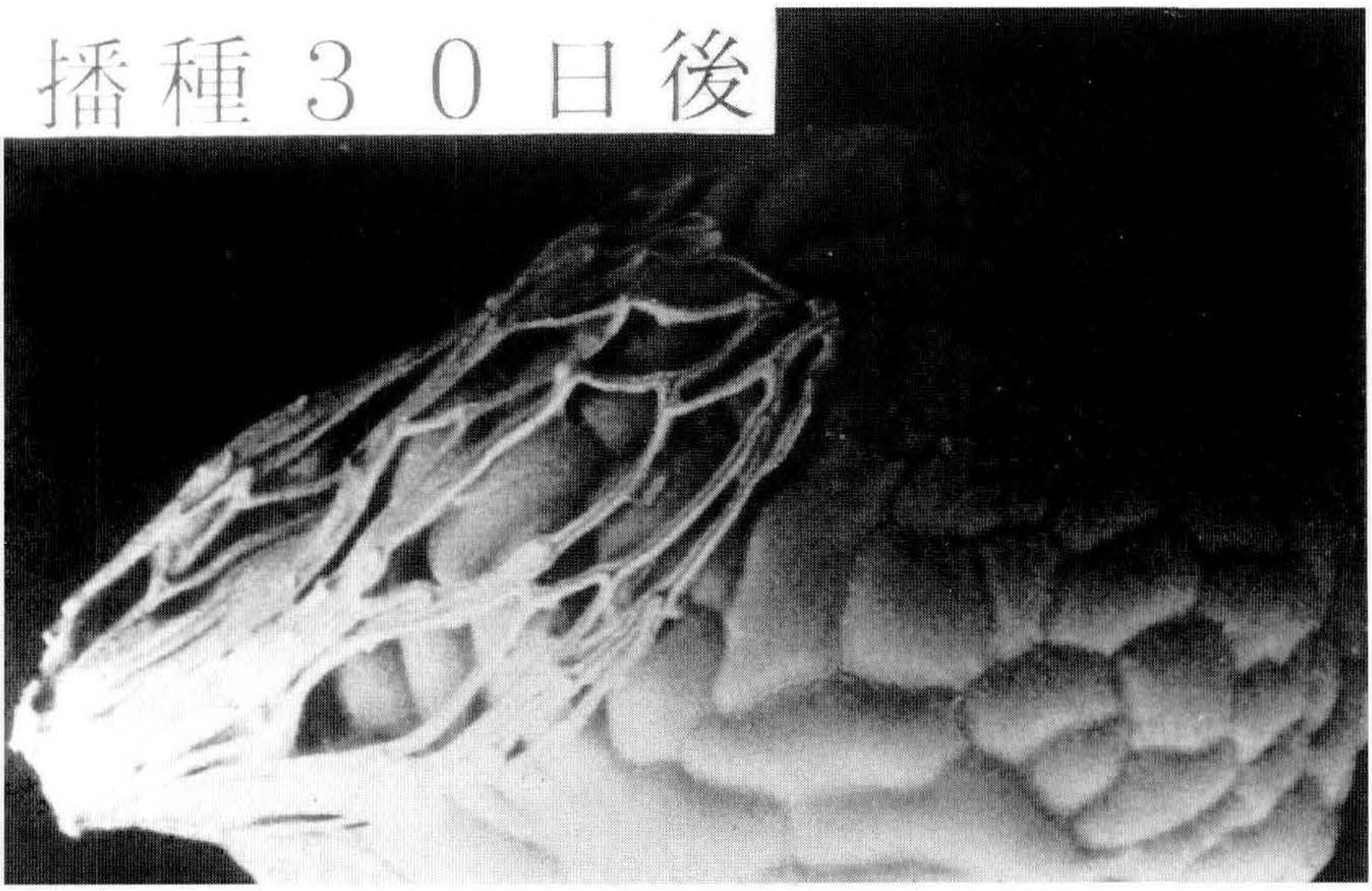

Figure 4. Scanning electron micrograph of *Phalaenopsis* observed 30 days after sterilization.

THE EFFECT OF BIOTECHNOLOGY EDUCATION

The students were very interested in the study of biotechnology and we were able to give them more confidence by presenting them with opportunities to make public their ideas and the results of their research. Biotechnology education is not only necessary but can help to answer the problems associated with modern agriculture, it can also be a very effective method of developing students' thought processes. We are now considering biotechnology education as a means to motivate them, in doing so, in our opinion, we could contribute a great deal to the education of the students of agriculture.

The Multiplication of *Dracaena* by Tissue Culture

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INTRODUCTION

The genus *Dracaena* includes many species used as ornamental foliage plants, however, because their growth rates are often slow, the production of saleable plants is a long process. Recently the quality of plants of *Dracaena* available for sale has deteriorated. Tissue culture is a potential method of solving these problems.

In this report we investigate the effects of phytohormones on the production of callus, shoots, and roots from stem explants of *D. deremensis* and *D. concinna.*

MATERIALS AND METHODS

Dracaena deremensis 'Souvenir de Schriever' (syn. 'Warneckii') and *D. concinna* 'Tricolor Rainbow' were used. After washing for a few minutes in running water, the stems were dipped into 70% ethanol for 1 min, sterilized with NaOCl solution (1% active chlorine) for 6 min, and washed with sterilized distilled water. The stems were cut into approximately 1-cm lengths and placed on media containing MS basal medium supplemented with 3% sucrose and various combinations of auxins (1 mg liter^{-1}), IAA, NAA, 2,4-D, and IBA, cytokinins (1 mg liter^{-1}), BA, and kinetin (KI) (Table 1). Explants were cultured at 25C under 3000 lux fluorescent illumination for a 12-h photoperiod. After 58 days of culture the response of the stem explants was recorded.

RESULTS AND DISCUSSION

After 58 days of culture, the stem explants of *D. deremensis* and *D. concinna* showed different reactions to the phytohormones as shown in Table 2 and Table 3. On the MS medium containing NAA, stem explants of *D. deremensis* 'Souvenir de Schriever' produced callus and shoots, while on the medium containing IAA and IBA, they produced roots (Table 2).

On the other hand, on the MS medium containing IBA, NAA, and 2,4-D, stem explants of *D. concinna* 'Tricolor Rainbow' produced callus, shoots, and roots. The media containing NAA and 2,4-D were especially effective for shoot growth (Table 3).

Consequently this method of culturing stem explants on MS medium containing NAA or 2,4 D is considered effective for the micropropagation of *D. deremensis* 'Souvenir de Schriever' and *D.concinna* 'Tricolor Rainbow'. Development of this culture system may contribute to an improvement in the quality of nursery plants of *Dracaena* available on the market.

Table 1. Combination of phytohormone in MS solid medium used for the differentiation in *Dracaena deremensis* 'Souvenir de Schriever' and *D. concinna* 'Tricolor Rainbow'.

Medium no.	Phytohormone	
	Cytokinin	Auxin
1	BA	IAA
2	BA	NAA
3	BA	2,4-D
4	BA	IBA
5	KI	-
6	KI	IAA
7	KI	NAA
8	KI	2,4-D
9	KI	IBA
10	KI	-
11	-	IAA
12	-	NAA
13	-	2,4-D
14	-	IBA
15	-	-

Table 2. Effect of phytohormone on differentiation in *Dracaena deremensis* 'Souvenir de Schriever'.

Medium no.	Explants cultured (no.)	Explant survival (no.)	Explants producing (no.)		
			Callus	Shoots	Roots
1	2	1	0	1	0
2	2	2	0	1	0
3	3	3	0	0	0
4	4	4	1	4	0
5	3	3	0	1	0
6	3	2	0	2	0
7	4	3	0	3	0
8	2	2	2	0	0
9	2	2	0	2	0
10	3	3	0	3	0
11	3	3	0	2	1
12	3	3	1	2	0
13	2	1	1	0	0
14	4	4	0	4	2
15	3	3	0	3	0

Table 3. Effect of phytohormone on differentiation in *Dracaena concinna* 'Tricolor Rainbow'.

			Explants producing (no.)		
Medium no.	Explants cultured (no.)	Explant survival (no.)	Callus	Shoots	Roots
1	3	2	0	2	0
2	3	2	2	0	0
3	3	3	2	1	0
4	3	3	2	3	1
5	3	3	2	1	0
6	3	3	0	1	0
7	3	3	2	1	0
8	3	2	2	0	0
9	3	3	1	2	0
10	3	3	0	0	0
11	3	1	0	0	0
12	3	3	2	2	2
13	3	3	2	2	2
14	3	3	3	2	3
15	3	1	0	0	0

Horticulture in New Zealand

Peter F. Waugh
Carann Horticultural Supplies, Matangi, Hamilton, New Zealand

In the short time available to me I would like to present to you an overview of the nursery industry in New Zealand by way of a few slides.

- Most visitors to New Zealand are amazed at the number of sheep on pastures and country roads. This is typical New Zealand — travellers being held up by a flock of sheep off to the shed to be shorn. Wool is a major New Zealand export.
- New Zealand I.P.P.S. president John Liddle's nursery, Liddle Wonder, near Wellington, grows trees and shrubs for the garden centre market on capillary watering beds. Many nurseries are changing from planter bags to hard plastic pots to improve their presentation.
- Most New Zealand nurseries are small by international standards and are often family concerns but they are innovative. The New Zealand Rose Company, Whenuapai, a container rose nursery also grows in the field and the manager is the son of one of New Zealand's best cut flower and patio rose breeders, Frank Schuurman. Nurseries are palletizing orders and using trolleys to improve distribution efficiencies and profit.
- Duncan & Davies, one of the older tree and shrub nurseries, still producing field stock at Taranaki. The climate at Taranaki is windy and without shelter the plants would be severely wind damaged (no snow) and not make satisfactory growth in a season.
- Thirkettle Nurseries (Nelson) container tree and shrub growers use capillary watering for the 750 plus taxa in production. Thirkettle's has plenty of land and pot their plants by the beds with a tractor driven potting machine.
- Titoki Nurseries, Brightwater, Nelson is a small native plant nursery producing New Zealand plants for revegetation of pasture and hill country. Seed is saved from local gene types — which is called eco-sourcing.
- Bedding plant nurseries like Willow Grange (Pukekohe) supply commercial vegetable growers with transplants and garden centres with cell packs of new flower cultivars for home gardeners. The nursery uses European irrigation gantries and other labour-saving machinery to increase production to meet demand while keeping an eye on costs. A newly updated, inline, direct seeder is pushing production capabilities way ahead of market needs and has reduced the number of growers servicing the bedding market.
- Smaller growers are establishing to supply niche markets with special lines especially for larger grade perennials. Texture Plants (Christchurch), a one full- and one part-time staff retail nursery operation, specialises in architectural and interesting foliage plants.

- New Zealand native plants are being grown in increasing numbers for home garden beautification and farm and wetlands revegetation. Mike Growford (Nikau Nurseries, Nelson) produces and retails a wide range of native species in polythene planter bags, the most popular production container in New Zealand. The bags are available in 3/4 pint to 95 pint sizes — PB5, PB6, and PB8 are the most popular sizes for woody material.
- Gethsemane Gardens high on the hills above Christchurch, the second largest New Zealand city, has large display gardens based on religious themes. They produce and retail an extremely large range of small-grade plants in hard plastic pots from this sloping site. The production and propagation systems are simple.
- Auckland-based GOL producers, Prop-ex, were one of the first companies to install cover crop, open sided, polythene-covered structures to protect their stock from high winter rainfall.
- At Appletons' Nursery (Nelson) open-ground *Pinus radiata* seedling production is carried out with direct sowing of seed in beds in spring and lifting of the seedlings the following winter for forest planting. This crop is grown from selected hybrid seed raised by Government orchard nurseries from selected, vigorous, heavy-timber-producing clones. At Appletons' Nursery native tea tree is cut from natural stands and used to shade and shelter emerging tree seedlings. Sawdust is used as a mulch on the beds to keep the soil moist. A trial comparing frost cloth and tea tree for shade and protection is being done. Tea tree lasts two to three seasons.
- *Phormium* 'Firebird' is a new flax clone produced for export cut foliage, container/patio growing in Europe, and for garden beautification in Mediterranean zone areas. The foliage is used by native people, Maori, for making baskets, garments and weaving.
- The way we grow plants is changing. At Plants for Places, an Auckland wholesale nursery, wire forms are being used to grow ivy (*Hedera*) for patio plants, indoor decoration, and as Christmas trees.
- Growers are quickly learning to use new techniques and products. An example is a *Trichoderma*, a beneficial myccorhizal fungus, being tested as a soil disease suppressant and for improved fertilizer uptake. The trial is one of seven polytechnic horticultural department replicates throughout New Zealand designed to transfer technology to the new nursery stock producers.
- Palmers Megastore, Auckland, is the newest outlet of the largest garden retail group in New Zealand. This store features the use of large graphics and banners to get across colour gardening images to consumers and promote impulse purchases of potted flowering lines for instant effect for garden and patio decoration. Colour gardening is a developing trend now 20 years old and showing no sign of abating.

Cyclamen Seedling Production by Tissue Culture

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INTRODUCTION

Cyclamen are mainly propagated from seed. However, uniformity of the important characteristics, such as color and type of flower, is poor because of the complexity of inheritance. Although numerous attempts have been made using in vitro culture techniques over a long period, these trials have not been successful, especially in large-scale culture. Recently, we solved the problems associated with tissue culture and achieved large-scale culture. We now aim to commercialize cyclamen seedlings produced by our tissue-culture methods.

CHARACTERISTICS OF THE MICROPROPAGATION SYSTEM

1) Only the leaf is used, thus no damage is sustained by the stock plant and cultivation may be started at any time.
2) We have developed two propagation methods, somatic embryo (SE) culture and adventitious bud (AB) culture:

	SE culture	AB culture
Process:	callus formation/multiplication	AB formation
	↓	↓
	SE formation	AB multiplication
	↓	↓
	plant regeneration	AB growth
	↓	↓
	explant	rooting
Advantage:	(I) morphologically similar to seed origin (II) low cost	(I) available with most cultivars and lines

FUTURE PLANS

1) Micropropagation of existing cultivars, new culitvars, favorite selections, local selections, stock plants, seed propagation, and F_1 seed plants.
2) Marketing of the cyclamen seedling, 'Victoria'.
3) Division of the production system into culture, growing on, and sales divisions.

The Control of Root Systems by the Use of Slit Containers

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Last autumn, we started to sell CS plug-trays with 40 and 88 holes. These were developed to incorporate the theory of controlling a root system by the use of slit containers. This theory is as follows:

A large proportion of the water supplied to the medium in a plastic container is drained through the hole at the bottom of the container, but because of surface tension, some of the water remains at the bottom of the container and on the inside lower surface of the container. Some condensation is formed on the inside surface of the container due to the differences in temperature between day and night. This only allows roots to take up water, as a result root distortion can occur, leading to root circling around the inside surface of the base of the container without forming many new roots. In order to prevent root circling and to encourage the formation of new roots, it is necessary to get rid of the remaining water at the bottom of the container.

Slit containers prevent root circling and the CS plug tray avoids root circling or looping owing to the slits. Excess water can be drained out of the container and be dispersed evenly in the soil. The roots stop growing as they reach the inside surface of the container, the root tip ceases growth when it comes in contact with the container wall, and many new roots are formed from the proximal part of the tap root.

As a result, the medium is used effectively and sound root growth is fostered. Therefore, one can grow bigger seedlings in slit containers and the plants can stay in them longer.

In addition to the above, other features include the projection and slant of the four corners leading the water and roots downward, the four upper corners prevent the plant from leaning and the wedge-shape of the container makes replanting easier.

Also because of the steep downward slant, the seedling is easier to remove.

The container is made of thick polystyrene, therefore, sufficiently strong to use several times.

When shipping seedlings, it is possible to bend the plug tray into a semi-circle (40 and 88 hole trays) thus saving space. The opening of the plug tray is wide enough to insert your hand.

By placing the plug tray in a basket, it can be moved easily (40 and 88 hole trays). Also, keeping the plug tray on the ground allows good drainage and ventilation, leading to healthy growth.

The important point is that a seedling with a sound root structure will grow on quickly after transplanting in the field. Good conditions during the early stages of the seedlings' growth have a beneficial effect on their later growth. Because of demands for international standard sizes from the flower and vegetable industry, five sizes of plug trays with 72, 128, 200, 288, and 406 holes are now available.

Besides these plug trays, there are also slit containers that are octagonal in shape (24-mm-diameter size). As plant roots have a tendency to grow toward the corners of containers, this shape utilizes this tendency to prevent root circling. A slit container is an effective method of controlling the growth of the root. By direct planting of the seedling into this container, there is no need to transplant again before shipping. The cultivation time is shortened thus keeping costs low. The container is designed to be handled by the upper part for convenience.

New Plant Varieties Bred by the Sakata Seed Corporation

Shoji Shiotsuki
Sakata Seed Corp., Yokohama, Kanagawa 224

Osteospermum. Our new cultivars open their flowers when the sun is not shining and even at night. They are only 20 to 25 cm tall. They can be shortened with growth retardant and are therefore useful in pots or as bedding plants.

***Impatiens* — New Guinea Cultivars.** Our new cultivars also flower in summer and they grow into big plants faster than overseas cultivars. They are suitable for bedding plants or for use in pots and containers. Six colors are available: purple, scarlet, white, red, salmon, and bright pink.

***Dianthus* — Potted Carnations.** Our cultivars grow even at low temperatures. They can be used in many ways including small to large pots.

Pelargonium. We now offer a new series which have shiny and smart-colored flowers, with only a slight blotch at the center of the flower, or sometimes none at all. They are multiflorous, resistant to *Botrytis*, and easy to grow.

Clematis. Our seven new cultivars are good for use in pots because they do not need any supports. They are multiflorous, flower lower down the stem than existing cultivars,and are available in six colors: purple-blue, shell-pink, blue, white, rouge, and pink.

Mid-sized *Campanula* Cultivars. These new cultivars are F_1 dwarfs. They germinate uniformly, grow well, and require little chilling. After bolting, treatment with a growth retardant produces a compact plant. Usually they flower in May without heating but should they be required in March or April, artificial heat and extra lighting is needed. Three colors are available: pink, white, and blue.

Nemesia. Our new cultivars have bigger flowers and stronger stems. They can be grown at low temperatures, close to freezing point, and are sold only in the cell tray. Three colors, yellow, rosy-red, and white have been produced.

five sizes of plug trays with 72, 128, 200, 288, and 406 holes are now available.

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Pelargonium. We now offer a new series which have shiny and smart-colored flowers, with only a slight blotch at the center of the flower, or sometimes none at all. They are multiflorous, resistant to *Botrytis*, and easy to grow.

Clematis. Our seven new cultivars are good for use in pots because they do not need any supports. They are multiflorous, flower lower down the stem than existing cultivars,and are available in six colors: purple-blue, shell-pink, blue, white, rouge, and pink.

Mid-sized *Campanula* Cultivars. These new cultivars are F_1 dwarfs. They germinate uniformly, grow well, and require little chilling. After bolting, treatment with a growth retardant produces a compact plant. Usually they flower in May without heating but should they be required in March or April, artificial heat and extra lighting is needed. Three colors are available: pink, white, and blue.

Nemesia. Our new cultivars have bigger flowers and stronger stems. They can be grown at low temperatures, close to freezing point, and are sold only in the cell tray. Three colors, yellow, rosy-red, and white have been produced.

Recommended Varieties from the Dai-Ichi Seed Co. Ltd.

Sohei Ikeda
Dai-Ichi Seed Co. Ltd. 1-1-4 Shibuya, Shibuyaku, Tokyo 150

ROSES

Red Spirit® rose. Bright red flowers throughout the year which have a stable colour. The petals do not get dark even under low temperature conditions. This selection has few thorns and is easy to handle.

Vorgue® rose. The flowers have light pink petals with a darker pink edge. The large flowers are held upright on strong stems.

Femma® rose. A very productive cultivar with good quality petals; it is particularly suitable for all kinds of flower arrangements.

Madonna® rose. Novel cardinal-red flowers on a spray type rose; it has nicely shaped strong petals and a good vase-life.

Nana® rose. This polyantha-type rose with ball-shaped flowers was bred for improved cut-flower qualities and is suitable for training by pruning.

CARNATIONS

Féerique® carnation. This unique variety has round orange petals with rose pink stripes and edges and semi-double flat-shaped flowers. The flowers are produced mid to late season in average quantities.

La Vie en Rose® carnation. A productive early variety with many bright rose-pink, round-petalled flowers and long stems, it is easy to grow as it has few side buds.

Mystic Green® carnation. A mid-season cultivar with nicely shaped, light-green, round-petalled flowers with a long vase-life, its green colour is most pronounced at high temperatures.

Renoir® carnation. Flowers with bright orange, round petals marked with rose-pink stripes are produced early in the season. It is also very heat tolerant. The large flowers are good for cutting.

Millet® (applied for as Daimil). The elegant round beige petals of the flowers of this unusual and distinctively colored cultivar, will ensure that it commands a high market price. It is late flowering and the productivity is not high.

SPRAY CHRYSANTHEMUMS

Cayman® chrysanthemum. A yellow medium-sized pom-pom cultivar, which has many flowers and good foliage. The response time is 7.5 weeks. It is a tall cultivar, with good uniformity of flowering, making it easy to grow.

Faero® chrysanthemum. Another medium-sized pom-pom cultivar, this one is white with a green center. It produces a lot of flowers and has good foliage. Response time is 8 weeks and it is medium to tall growing.

Margarita® chrysanthemum. A pure white with green center, medium-sized single-flowered cultivar, it produces many flowers and good foliage. Response time is 8 weeks and it is tall growing.

Xenos® chrysanthemum. The light pink, green-centered, single flowers of this medium-small-sized cultivar, are produced on rather short stems. However, it does have a lot of flowers and a quick response time of 7 weeks.

Flores® chrysanthemum. This is a pure-white-flowered cultivar with a green center, the single flowers are round and of medium size. It has good flower shape and good foliage. Response time is 8 weeks on this medium-tall cultivar. In winter time it needs a rather high temperature.

Our Promising New Varieties for Cut and Potted Flower Production

T. Oridate
The Yokohama Nursery Co., Ltd., 15, Karasawa, Minamiku, Yokohama, Kanagawa Prefecture

We, at the Yokohama Nursery Company, introduce a lot of new selections for cut-flower and potted-flower production.

POTTED-FLOWER VARIETIES

Mini *Dianthus* Little Princess series. The 'Little Princess' series maintains a 10 to 15 cm height during the growing season, and has high heat resistance for the summer. Flowering is almost year-round, and we offer three different colors, rose-pink, white, and pastel-pink.

***Dianthus* Love Love Queen series.** This series is quite new, so we will be introducing it for the 1998 season. It is best grown in medium to large pots, and reaches a height of 30 to 40 cm. Two colors, rose and apricot, are available.

***Alstroemeria*.** We have two cultivars 'Magic Love' and 'Endless Love' for pot culture. The colors are dark pink and soft pink.

Bulbs. We have introduced many new bulbs suitable for flower or potted flower production including, lily, tulip, freesia, and muscari.

CUT-FLOWER VARIETIES

***Alstroemeria*.** Recently, small-flowered cultivars of this plant have become popular. These cultivars produce more flower stems than the large-flowered cultivars. We have several colors of these available.

***Lilium*.** We import many bulbs of both Oriental and Asiatic hybrid cultivars from the Netherlands. We can advise on which cultivar to choose and how to grow them.

***Anthurium*.** The demand for *Anthurium* has grown considerably, however, as production in Japan is still small, many flowers are imported. We can offer young plants of *Anthurium* and provide information on how to grow them.

A Japanese Pioneer in the Tissue Culture of Ornamental Plants

Kimiaki Murasaki
Miyoshi & Co., Ltd.,187, Kami-sasao, Kobuchizawa, Kitakoma-gun, Yamanashi Prefecture

Ever since Miyoshi & Co., Ltd. was established in 1949, we have been producing, distributing, and developing flower seeds, plants, and bulbs. The main emphasis has been on vegetative propagation and tissue culture techniques; production and sales began in 1968. Since then we have been among the leaders in this field, producing disease-free, high-quality plant materials.

We have made big progress in the production of *Gypsophila, Dianthus* (carnation), *Gerbera, Limonium*, and other crops by the use of tissue culture. In 1975, we started the mass production of *G. paniculata* with techniques which resulted in a large demand in the market.

Currently, our top selling product is carnation cuttings produced from tissue cultured nuclear stocks and we produce over 15 million cuttings a year. Our original *Limonium* cultivars are very well known in the market, and we have put a lot of effort into their selection and hybridization, especially the *L.* Beltlaard and Emille groups which have become very popular in world markets. We propagate the plants for export, in vitro at the Grand Biotechnology Co. (G.B.C.) in Taiwan, which was jointly established with our international partners.

Miyoshi is also the first Japanese large-scale distributor of plug seedlings, which have become well accepted in the market. We started producing plug seedlings in 1986 at the jointly established T.M. Ball Laboratory Co., Ltd.

Gardening is currently booming and we opened the Miyoshi Perennial Garden this summer in order to market our large collection of perennial species directly to the general public. Five hundred perennials are planted in this garden of 3000 m^2 and visitors can enjoy a continuous display of these flowers from spring to autumn.

In order to expand sales in the fast growing market of pot and bedding plants, we have established another international, joint venture company, M&B Flora Co., Ltd. This company produces all kinds of plant materials for the bedding and house plant markets.

The Effect of Concentrated Sulfuric Acid Treatment on the Seed Germination of *Lathyrus latifolius*

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Atsugi Central Farm, Tokyo University of Agriculture, 1737 Funako, Atsugi, Kanagawa 243

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Department of Agriculture, Tokyo University of Agriculture, 1-1-1, Sakuragaoka, Setagaya-ku, Tokyo 156

This study was carried out to investigate the effect of concentrated sulfuric acid treatment on the seed germination of two cultivars of *Lathyrus latifolius* ('Rosa Perle' syn. ['Pink Pearl'] and 'Red Pearl'). Concentrated sulfuric acid treatment of more than 5 min resulted in increased seed germination percentages. It is therefore possible to improve the germination of *L. latifolius* seed easily by the use of a concentrated sulfuric acid treatment.

INTRODUCTION

Recently, *Lathyrus latifolius* has shown promise as a cut flower and landscape plant. *Lathyrus latifolius* has a hard seed coat and it is known that seed germination takes a long time using normal sowing techniques, and the resultant germination percentages are frequently low. It is necessary to chip the seed coat prior to sowing (Colin,1996).

In this study, we investigated the effect of a concentrated sulfuric acid treatment on seed germination.

MATERIALS AND METHODS

In this experiment, seeds of *L. latifolius* 'Rosa Perle' and 'Red Pearl' were used. The seeds were soaked in concentrated sulfuric acid for 0, 5, 10, 15, and 20 min. After treatment, the seeds were washed with running water and were transferred in a plastic cup with tap water added to total darkness for 24 h.

After 24 h, the seeds were sown in 9-cm petri dishes on two layers of filter paper moistened with distilled water and placed at 20C in the dark. Germination progress was checked every 24 h.

RESULTS AND DISCUSSION

Table 1 shows the germination percentages of both cultivars. The germination percentage of 'Rosa Perle' was 90%, 4 days after concentrated sulfuric acid treatment for 15 min. Regardless of treatment time, the germination reached 100% 8 days after treatment, compared to 43% germination in 8 days without treatment. Germination of 100% was obtained for 'Red Pearl' using the concentrated sulfuric acid treatments of 10 and 15 min in 5 days after treatment. All seeds germinated within 7 days after the 5-min treatment and within 8 days after the 20-min treatment. Without treatment the germination reached 50% after 8 days.

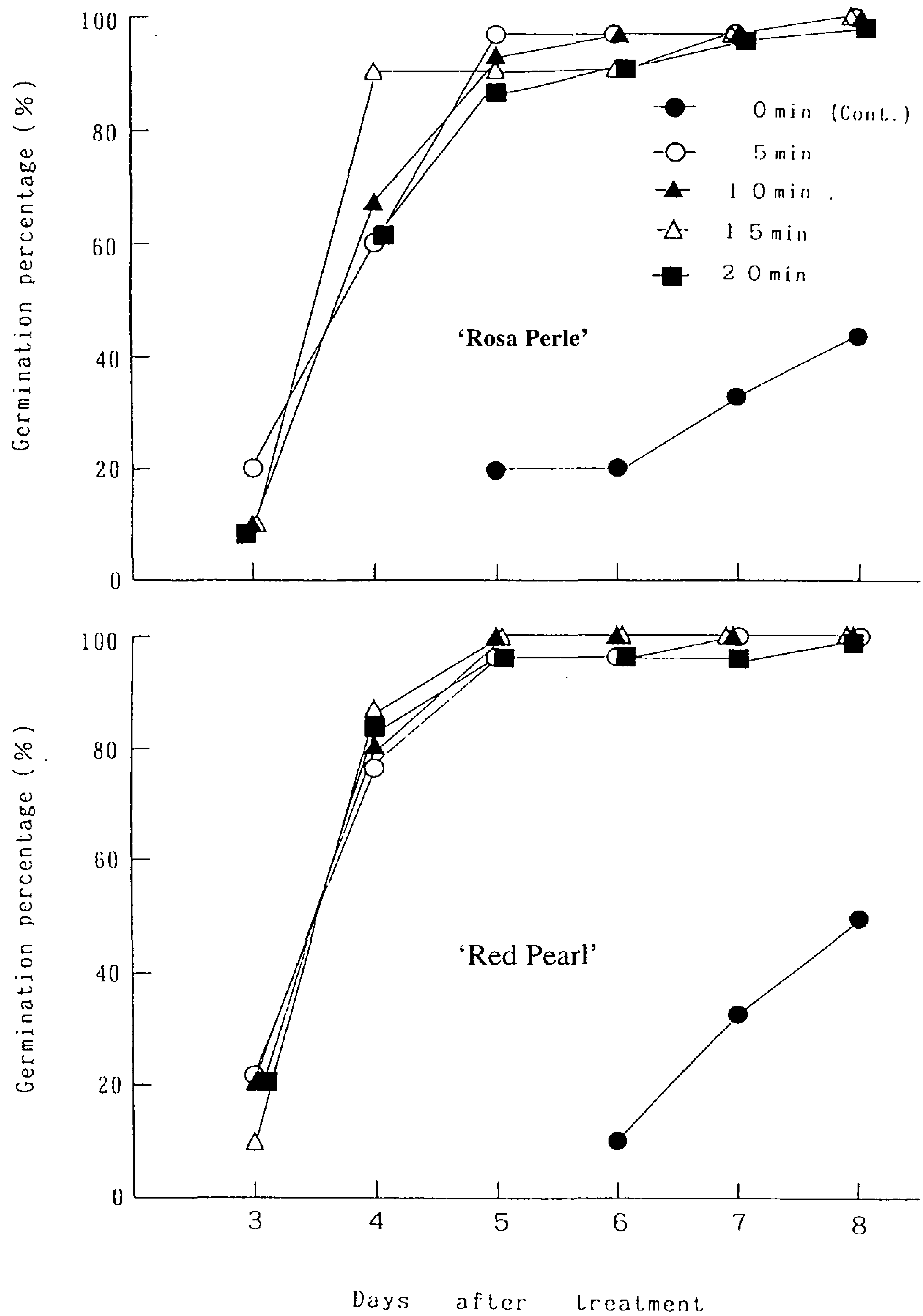

Figure 1. Effect of concentrated sulfuric acid treatment on seed germination of *Lathyrus latifoluis*.

Table 1. Effect of sulfuric acid treatment on seed germination of *Lathyrus latifolius*.

Cultivar	Treatment (min)	Days after treatment 3	4	5	6	7	8
'Rosa Perle'							
	0	0	0	20	20	33	43
	5	20	60	97	97	97	100
	10	10	67	93	97	97	100
	15	10	90	90	90	97	100
	20	10	63	87	90	97	100
'Red Pearl'							
	0	0	0	0	10	33	50
	5	23	77	97	97	100	100
	10	20	80	100	100	100	100
	15	10	87	100	100	100	100
	20	20	83	97	97	97	100

These results indicate that seed germination percentages of *L. latifolius* can be increased by concentrated sulfuric acid treatment of more than 5 min. Water absorption increases after the concentrated sulfuric acid treatment.

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Cutting Propagation of *Ligustrum lucidum* 'Tricolor'

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Large-scale propagation of *Ligustrum lucidum* 'Tricolor', which is a garden cultivar of glossy privet with variegated leaves, has been impossible because of difficulties encountered in cutting propagation. This cultivar, however, has great promise for landscaping purposes. In this study, the effects of the physiological status and shading on the stock plants, as well as different types of cuttings on the rooting of the 'Tricolor' were investigated.

MATERIALS AND METHODS

Experiment 1. The Effect of Age and Quality of Stock Plants on the Rooting Rate of the Cuttings. Four different kinds of stock plants of *Ligustrum lucidum* 'Tricolor' were used in the experiment: a 3-year-old seedling selected from self-pollinated seeds (3S), a 2-year-old and a 5-year-old cutting-grown plant (2C and 5C), and a 5-year-old grafted plant (5G). The 8-cm, two-leaf cuttings were taken on 24 July 1990, then treated with 20 ppm of indole-3-butyric acid (IBA) for 16 h. The next day, 40 to 100 cuttings were randomly selected and set in a propagation medium consisting of Kanuma soil, peat moss, and vermiculite (1 : 1 : 1, by volume) (KPV soil) in a sealed tunnel.

Experiment 2. The Effect of Shading Stock Plants on the Rooting Rate of the Cuttings. Cuttings were taken from the 5G stock plants, which had been shaded for 6 weeks from 12 June 1990, at the level of 0%, 50%, 75%, and 87.5 %, respectively, using black cheesecloth. Fifty to sixty cuttings were selected from each of the treatments, and grown on in the same way as in Experiment 1, except for the IBA treatment at 40 ppm. To test the effect of duration of shading, 6-year-old grafted stock plants were given 50% shade for 0, 1, 2, 3 weeks, respectively, until 17 Aug. 1991, when 60 cuttings were taken from each stock plant and treated just as in Experiment 1.

Experiment 3. The Effect of Timing of Taking Cuttings and Setting, Presence of Leaves, and Concentration of IBA on the Rooting Rate of the Cuttings. Cuttings were taken from 12-year-old grafted stock plants on two different dates, 27 Feb. and 10 March 1997. All the cuttings except those taken on 10 March were kept at 5C until the day before setting. Four hundred 10-cm cuttings were taken on each date and then divided into two groups according to the setting date, 11 and 19 March 1997. Each of the two groups was further divided into four groups with four different kinds of treatment; without leaves, with two leaves left on the top, and 10 or 20 ppm IBA (25 cuttings per treatment). After setting in KPV soil, all the treated cuttings were kept in a 50% shaded tunnel prepared in an unheated greenhouse with 50% shading.

RESULTS AND DISCUSSION

Experiment 1. Cuttings from the 3S and 2C stock plants showed a higher rooting rate than the others, suggesting that younger stock plants would give a high propagation efficiency using softwood cuttings.

Experiment 2. Rooting efficiency was the highest under 50% shade and was reduced according to the level of shading, whilst no shading greatly inhibited rooting.

The 1-week shading of the stock plants gave the highest rooting efficiency and the shading duration seemed to be negatively correlated to the rooting rate. Shading of the older stock plants was considered to be effective, suggesting that 50% shading of stock plants for 1 week before taking cuttings might give the best results when taken in early August.

Experiment 3. Cuttings without leaves showed a markedly higher rooting rate than those with two leaves, regardless of the cutting and setting times. Generally, cutting propagation of evergreen plants is not done at the same time of year as deciduous plants. These results, however, clearly indicated that *L. lucidum* 'Tricolor' could be propagated using defoliated cuttings even when taken from older stock plants during dormancy. From these results, a 2-year cutting propagation cycle is suggested to propagate *L. lucidum* 'Tricolor' as follows. Firstly, cuttings from older stock plants grown under shade are used to produce new stock plants when they are 2-years old. Then secondary cuttings are taken from these new stock plants for growing on to plants for sale as well as for the source of stock plants in the next propagation cycle. Material obtained from stock plants at the time of winter pruning is also shown to be a useful source for cuttings.

The Effects of the Basal Medium, and the Addition of Sugar and Banana on the Growth of *Oncidium* Plantlets Cultured In Vitro

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INTRODUCTION

We have reported previously that the growth of in vitro plantlets of *Cymbidium* and *Cattleya* was promoted markedly when organic matter was added to the basal medium (Kusumoto and Furukawa, 1977; Kusumoto, 1979a; Kusumoto 1979b). This report describes the effects of the basal medium and the concentration of added sugar or banana on the growth of *Oncidium* plantlets cultured *in vitro.*

MATERIALS AND METHODS

The protocorm-like bodies (PLB) were used as experimental material and were obtained by in vitro culture of axillary buds from the peduncle of *Oncidium* 'Aloha Iwanaga'.

Plantlets with 5-mm-high buds and no root were selected, and 40 pieces (5 g) were planted on each medium. Murashige and Skoog's (MS) nutrient medium was used as the standard basal medium, and 0.1 ml liter^{-1} of NAA and BA, plant growth-regulating substances, 3 g liter^{-1} of Gellan gum, and 20 g liter^{-1} of sucrose were added.

Each plantlet was cultured under 16-h day length at 2500 lux and 24±2C conditions. A check of plantlet growth was made 60 days after planting.

Experiment 1. Several media, MS, White (W), Knudson's C (KC), and Hyponex (H), were used as basal media in this experiment as well as MS media at 3/4 and 1/2 concentrations were investigated.

Experiment 2. Banana flesh (100 g liter^{-1}) was added to each basal medium to check the effect of banana on the growth of the plantlets.

Experiment 3. The amounts of sugar and banana flesh added, was varied to check the effect on the growth of plantlets.

RESULTS AND DISCUSSION

The results are shown in Tables 1, 2, and 3. The subsequent growth of the plants raised in vitro has proved to be excellent and it is suspected that the good stiff leaf and compact root growth noted are a result of the in vitro culture. The results from Experiment 1 show that the MS medium was the most suitable basal medium. With the decrease in concentration of the MS medium, the growth index and number of roots on the plantlets decreased, and the length of the roots increased. Medium H was slightly inferior to ½-MS medium, but it could be utilized. When the W and KC media were used, the colour of the plantlets changed from green to yellow, growth and height were adversely affected. It is thought that the concentrations of salts in the W or KC media were too low in comparison with the MS medium. These results

Table 1. Effects of basal medium and concentration of MS medium on the growth of *Oncidium* plantlet cultured in vitro.

Medium*	Avg. fresh weight (g)	Growth index**	Avg. height of leaves (cm)	Avg. number of leaves	Avg. number of roots	Avg. length of roots (cm)
MS	0.85	6.76	7.70	6.24	5.25	1.48
3/4 MS	0.68	5.42	7.34	6.10	5.13	2.08
1/2 MS	0.65	5.18	6.92	6.05	4.75	3.21
W	0.45	3.58	3.76	5.23	4.56	4.07
KC	0.45	3.60	4.25	5.08	4.25	2.55
H	0.56	4.48	7.68	5.70	5.25	3.42

* MS=Murashige and Skoog, W=White's, KC=Knudson's, H=Hyponex.
** Growth index=total fresh weight per planting fresh weight.

Table 2. Effects of basal medium and concentration of MS medium on the growth of *Oncidium* plantlet cultured in vitro.

Medium*	Avg. fresh weight (g)	Growth index**	Avg. height of leaves (cm)	Avg. number of leaves	Avg. number of roots	Avg. length of roots (cm)
MS	0.85	6.76	7.70	6.24	5.25	1.48
MSB-100	1.12	8.96	10.85	6.40	6.25	4.01
3/4 MSB-100	1.08	8.66	10.75	6.20	6.00	4.85
1/2 MSB-100	0.97	7.76	8.87	6.17	5.38	5.73
WB-100	0.84	6.79	6.72	5.88	5.63	6.39
KCB-100	0.74	5.96	7.03	5.90	5.18	4.39
HB-100	1.12	9.02	9.15	6.25	6.40	4.59

* MS=Murashige and Skoog, W=White's, KC=Knudson's, H=Hyponex, B=banana.
** Growth index=total fresh weight per planting fresh weight.

show that *Oncidium* produced in vitro require a reasonably high concentration of salts in the medium. The results of Experiments 1 and 2 showed that the addition of 100 g liter^{-1} of banana flesh to each medium promoted growth considerably. It must be emphasized that the results from the addition of 100 g liter^{-1} of banana flesh to the HB (Hyponex with banana) medium was as good as that obtained from the MS medium with banana. Furthermore, the addition of banana flesh to all media promoted root elongation. It is well known that increasing the sugar content of media has a beneficial effect. The addition of 1.5 times (30 g liter^{-1}) of sugar to the MS medium in Experiment 3 provided the best results in the growth of the explants,

Table 3. Effects of basal medium and concentration of MS medium on the growth of *Oncidium* plantlet cultured in vitro.

Medium*	Avg. fresh weight (g)	Growth index**	Avg. height of leaves (cm)	Avg. number of leaves	Avg. number of roots	Avg. length of roots (cm)
MSS-20	0.85	6.76	7.70	6.24	5.25	1.48
MSS-30	1.14	9.19	9.60	6.25	6.08	3.25
MSS-40	1.29	10.34	9.60	6.55	6.80	4.36
MSB-100	1.12	8.96	10.85	6.40	6.25	4.01
MSB-150	1.36	10.86	9.94	5.78	6.38	4.31
MSB-200	1.40	11.19	10.23	6.16	6.60	5.24

* MS=Murashige and Skoog, B=banana, s=sucrose.
** Growth index=total fresh weight per planting fresh weight.

comparable to the MSB-100 and HB-100 media. Increasing the banana flesh quantity added to the medium did not change the height or number of leaves of the explants, but increased the number of roots, and promoted root elongation.

The high growth index of the explants in the media with added banana flesh was caused by good root development. The conclusion is that *Oncidium* plantlets in vitro give the best results on an MS medium, with 30 g liter^{-1} of sucrose and 100 to150 g liter^{-1} of banana flesh added.

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The Effects of the Physical and Chemical Properties of Growing Media on the Growth of Herbaceous Flowering Plants in Cell-Tray Culture

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INTRODUCTION

The cell-tray culture of flowering plants is increasing in Japan and many kinds of media designed for this type of culture are now on sale. Overseas, many growing media have been investigated (Baker,1957; Bunt, 1988) and their physical and chemical properties and effect on plant growth have been clarified (Fontano and Nelson, 1990; Sonneveld, 1990; Biernbaum,1992; Lang,1994). On the other hand, an investigation of Japanese media has not been carried out and their effects on the growth of flowering plant seedlings are unknown. We produced nine media (Table 1), by mixing six commercial media, and investigated the effective volume (%) of pore space for air capacity and NO_3 content of the media.

MATERIALS AND METHODS

The nine media had three water-content levels in the range pF0 to pF1.0 water tension which correlates to pore space, each at three NO_3-content levels. The minimum levels of phosphorus and potassium in the media were adjusted to 60 and 100 mg per 100 g dry weight, respectively, by the addition of superphosphate and potassium.

Table 1. Design of physical and chemical properties of the media.

Medium no.	Water content	NO_3 content (mg per 100 g)
1	7.2	75
2	7.2	115
3	7.2	154
4	11.4	75
5	11.4	115
6	11.4	154
7	14.5	75
8	14.5	115
9	14.5	154

On 7 July 1997 we sowed 30 seeds of vinca (*Catharanthus roseus* G. Don) 'Flash', *Petunia* 'F1 Telster', geranium (*Pelargonium*) 'F1 Pink', marigold (*Tagetes erecta* L.) African tall marigold, cosmos (*Cosmos bipinnatus* Cav.) 'Parade', and *Impatiens* Super Elfin hybrid in cell trays (128 cells).

RESULTS AND DISCUSSION

Of the three water content levels, the fresh weight of the whole plant and shoot length for vinca, geranium, and marigold were highest in the 11.4% medium. Petunia, cosmos, and impatiens were highest in the medium with 14.5% water content. Growth in the 7.2% water content medium was inferior to others in shoot fresh weight and shoot length.

Table 2. Effect of water content of media between pF0 to 1.0 on the growth of plants (mean of five plants).

Organ	Water content (%)	Vinca	Petunia	Geranium	Marigold	Cosmos	Impatiens
Plant F.W.	7.2	0.64 g	0.69 g	1.11 g	1.70 g	0.66 g	0.65 g
(g)	11.4	0.87 g	0.74 g	1.27 g	2.58 g	0.61 g	0.66 g
	14.5	0.59 g	1.29 g	1.15 g	1.61 g	0.79 g	0.87 g
Shoot	7.2	5.7	5.7	5.1	13.9	15.5	2.9
length	11.4	6.1	5.9	5.9	18.7	12.4	2.7
(cm)	14.5	6.1	7.2	5.8	16.1	15.3	3.2
Number of	7.2	7.6	7.5	6.5	8.0	8.0	8.7
leaves	11.4	7.7	8.5	6.7	6.9	7.5	11.6
	14.5	7.9	9.1	6.8	8.9	14.7	14.7

Among the NO_3 media levels tested, the heaviest fresh weight with marigold was obtained in the 75 mg 100 g^{-1} medium, geranium was in the 115 mg 100 g^{-1} and cosmos was in the 154 mg 100 g^{-1}. No significant differences were observed between the various NO_3 levels on the growth of vinca, petunia, and impatiens.

There was an interactive effect between the water levels and NO_3 levels to leaf fresh weight, i.e. vinca, geranium, tagetes, and cosmos were significantly heavier in the 11.4% water content medium with 115 mg 100 g^{-1} NO_3 content as opposed to the 7.2% with 75 mg 100 g^{-1} medium.

These results indicate that a medium containing about 11.4% water in the range of pF0 to pF1.0 with an NO_3 content of 115 mg 100 g^{-1} is suitable for plant growth in cell trays. In general, a soil water content in the range pF0 to 1.0 relates closely to the drainage and air capacity of the soil, and the NO_3 content in the medium is very important to the nutrient condition of the plant and also relates to pH, EC, and leaching of base in the medium.

Therefore, it is important when making media for use in cell trays, to aim for air capacity and NO_3 content in the range indicated.

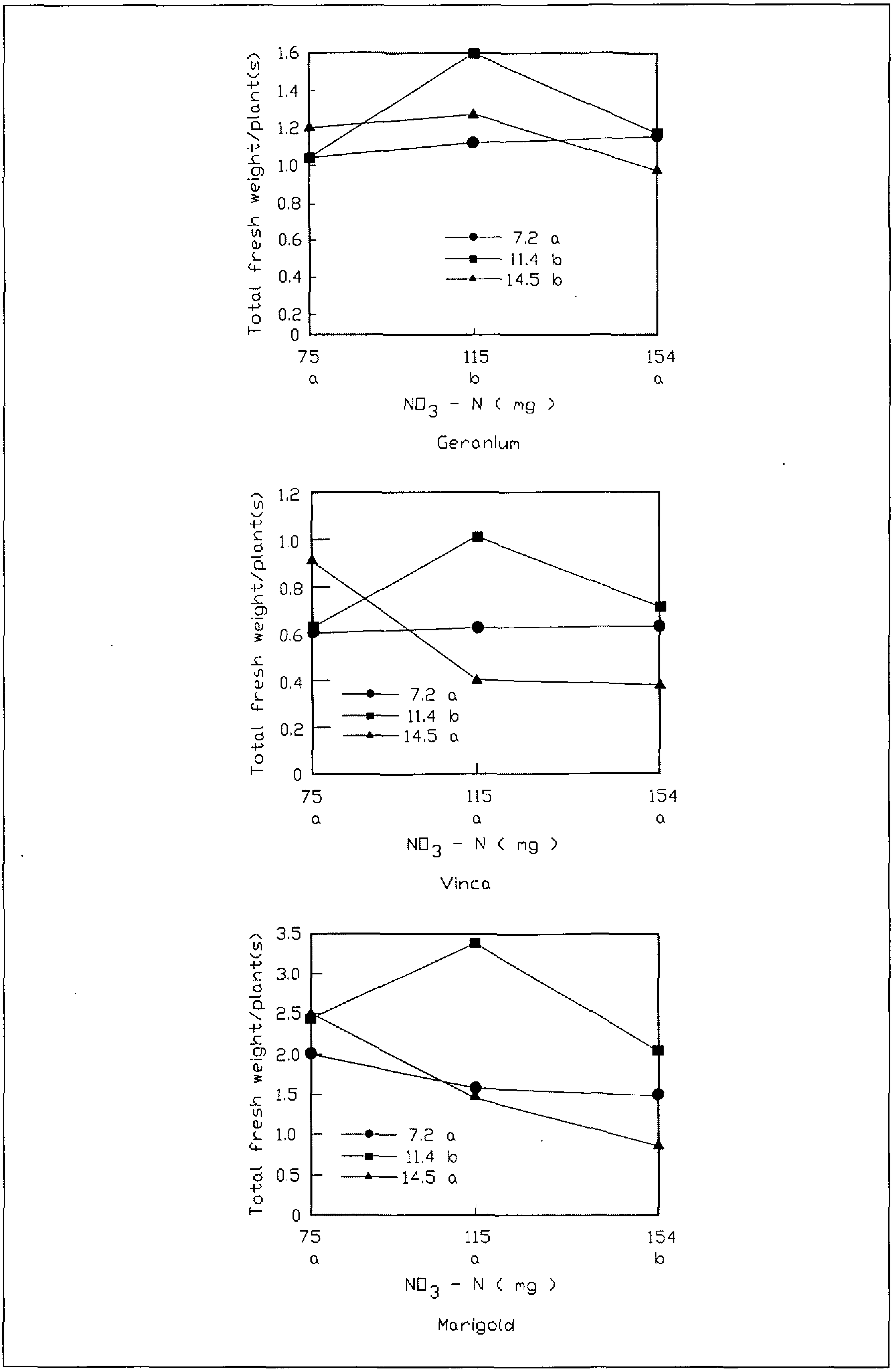

Figure 1. Effect of water content and NO_3 content in media on fresh weight of leaves (mean of fine plants). Different letters indicate significant differences by Duncan's multiple range test at 5% level.

Table 3. Effect of NO_3 content in media on the growth of plants (mean of five plants).

Organ	NO_3 content (%)	Vinca	Petunia	Geranium	Marigold	Cosmos	Impatiens
Plant F.W.	75	0.72	1.07	1.09	2.22	0.58	0.73
(g)	115	0.77	1.06	1.33	2.15	0.59	0.77
	154	0.62	0.69	1.11	1.49	0.89	0.77
Shoot	75	4.3	6.3	5.2	15.9	11.1	3.1
length	115	6.2	6.6	6.2	17.4	14.9	2.9
(cm)	154	5.8	5.9	5.4	15.4	17.2	2.8
Number of	75	8.3	8.2	6.6	9.2	5.8	11.6
leaves	115	7.8	8.5	6.8	8.9	8.3	12.5
	154	7.2	8.5	6.7	8.3	9.2	10.9

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Raising Seedlings of the Sasa lily (*Lilium japonicum*) in Vitro

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Native Japanese *Lilium* species, which have been often used in the breeding of Oriental hybrid lilies, are difficult to cultivate. The degree of difficulty of raising seedlings (from the most difficult to easiest) of the species is as follows:

- *Lilium noblissimum* (the Japanese name is tamoto-yuri) — the most difficult species;
- *Lilium japonicum* (sasa-yuri) and *L. auratum* (yama-yuri);
- *Lilium alexandrae* (uke-yuri) and *L. rubellum* (otome-yuri);
- *Lilium speciosum* (kanoko-yuri) — relatively easy.

All of the species mentioned above show good germination, but they grow very slowly. During the first year, they produce only small bulbs (ca. 2- to 5-mm diameter). They are also susceptible to pests and diseases. At the flowering stage (5 to 6 years after sowing) almost all plants lose their vigor because of infection by viruses and infestation by bulb mites. Therefore, we tried to raise seedlings of several Japanese lilies in vitro in order to conserve them for garden use and to prepare stocks for breeding with commercial cultivars of oriental and regale hybrids. In this report, we concentrate on the results obtained with the sasa lily (*L. japonicum* Houtt), but these methods can be applied to other species.

MATERIALS

Sasa lily bulbs collected from Gifu Prefecture were cultivated in the Hakone Botanical Garden of Wetlands, and after open pollination, mature pods were harvested to use for the following experiments.

Experiment 1. Seedling Growth in Vitro. Seeds were sown on a medium containing half-strength MS medium supplemented with 0.3 mg liter^{-1} IAA, 30 g liter^{-1} sucrose, and 8 g liter^{-1} agar (pH 5.7) on 27 Oct.1995. After 4.5 months, the first subculture was carried out on the same medium. Then, on 2 July 1996, the seedlings were subcultured on an MS medium plus 0.3 mg liter^{-1} IAA, 60 g liter^{-1} sucrose, and 7 g liter^{-1} agar (pH 5.7). After another 2 months, they were subcultured on a medium with the sugar changed to 90 g liter^{-1} yellow soft sugar. On 21 Dec. 1996, 21 March 1997 and 25 Aug. 1997 (22 months after sowing), the seedlings were successively subcultured on the same medium.

Results. Sixteen and one-half months after sowing (4 March 1997), the average total fresh weight (FW) of the seedlings was 11.8 g. The average FW of the largest 31 bulblets was 8.06 g, and of the middle 3 and smallest 146, it was 3.66 g and 0.46 g, respectively. At 20.5 months after sowing (10 July 1997), the average total FW of the seedlings was 27.61 g. The 20 largest and 19 middle-size bulblets reached 11.47 g and 5.72 g, respectively.

Experiment 2. The Effect on Germination of Cutting Away the Seed Coat. After harvest in Oct. 1996, the seeds were divided into four groups; 1) intact seeds (control); 2) intact seeds sown in vitro, but after 1 month of culture, one side of the seed coat was cut away; 3) just before sowing, one side of the seed coat was cut away; and 4) just before sowing, both sides of the seed coat were cut away. Seeds of each group were sterilized with 2% sodium hypochlorite solution for 20 min. After rinsing with distilled sterilized water, all of the seeds were sown on the medium as in Experiment 1.

Results. Seeds in the control group (no treatment) did not germinate within 4.5 months of sowing. However, seeds with one side of the seed coat cut away after 1 month from sowing, germinated well, i.e. 78%. The cutting treatments were very effective, seeds with the seed coat cut away on one or both sides showed more than 70% germination within 2 months.

CONCLUSIONS

Just before in vitro sowing, removal of a part of the seed coat proved very effective for rapid germination. After six subcultures with an interval of 3 months between, the seedlings grew to maturity (about 2 years after sowing). We think that autumn is the best season for transplanting the seedlings from in vitro to ex vitro in a greenhouse because the spring - summer period in Kanagawa Prefecture is too hot to grow *L. noblissimum, L. japonicum, L. auratum, L. alexandrae,* and *L. rubellum.*

Production of Interspecific Hybrids of *Dianthus* species by Ovule Culture

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Various *Dianthus* species are widely distributed in Japan, and some of them have quite high ornamental value because of their lovely flowers. However, almost all of these species have characteristics which make them unsuitable for commercial production, for instance, a single flowering season and a dislike of hot summers. Also, it is difficult to obtain viable seeds from crosses of the species because of the degeneration of the hybrid embryos. Therefore, little effective breeding has occurred in the past.

In the present study, interspecific crosses were carried out between *D. chinensis* and various other *Dianthus* species and the resultant interspecific hybrids were successfully obtained by using the embryo rescue technique.

MATERIALS AND METHODS

Several plants of *D. chinensis, D. caesius, D. plumarius, D. superbus*, and *D. caryophyllus* were used. After cross pollinations between *D. chinensis* and the other species, the ovaries were collected and sterilized with 70% ethyl alcohol for 30 sec, and 2.0% sodium hypochlorite for 5 min. Then, they were rinsed with sterilized water.

The ovules were excised from the ovaries and put onto a culture medium containing agar-solidified, modified MS medium.

The plantlets which developed in the ovule culture were transplanted to pots and acclimatized. They were further grown on in a greenhouse and were examined for their characteristics.

RESULTS AND DISCUSSION

Seed production by normal methods, crossing *D. chinensis* with other *Dianthus* species was tried and several viable seeds were obtained from the crosses *D. chinensis* × *D. superbus* and *D. chinensis* × *D. plumarius*. However, viable mature seeds were not obtained from any other crosses.

Well developed plantlets were obtained from all crosses between *D. chinensis* and other *Dianthus* species using ovule culture. Therefore, this system must be considered an effective method for producing interspecific hybrids of *Dianthus*.

The plantlets were grown on in a greenhouse and their characteristics, especially flowering time and heat resistance were monitored. The cross between *D. chinensis* and *D. caesius* produced one plant which flowered almost year-round with good heat resistance and a compact, pretty flower. This hybrid is now the subject of an application for plant breeder's rights under the name 'Little Princess'.

Propagation and Cultivation of Cycads

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Guidelines for collection and storage of cycad pollen, the pollination techniques, seed harvesting viability assessment, seed germination, and the growing on of cycad (*Encephalartos*) seedlings are discussed in this paper. The male cone axis elongates and cone scales become separated. Female cones elongates slightly and some skill is required to decide when they are receptive for pollination. Artificial pollination can be done with dry pollen, or a slurry. Pollination is repeated at 3- to 4-day intervals. Cones should not be harvested prematurely for seed gathering. Seed are placed in water to test for viability. Cycad seed germinates 3 to 8 months after sowing. A cable-heated sand bed with intermittent spray mist is the ideal system for germination. Seedlings are transplanted after germination and a well drained potting mix is required. Plants are transplanted to bigger containers as they grow bigger.

INTRODUCTION

In large natural stands of cycads, sufficient evidence is available to believe that specific insect vectors are responsible for the transport of pollen from the male cones to female cones. In reduced natural populations, the reduced number of cones also reduces the chances of synchronous coning and successful pollination. The same applies to garden plantings where, if pollination does occur, the identity of the male may be unknown and hence hybrids of doubtful parentage can be produced. In order to produce reputable seed from garden plantings of cycads, it is, therefore, necessary to adopt artificial pollination procedures. This paper suggests guidelines for collection and storage of cycad pollen, the pollination techniques, seed harvesting and viability assessment, and seed germination.

PROPAGATION

Collection and Storage of Pollen. Male plants of the genus *Encephalartos* produce from one to eight (sometimes more) cylindrical cones per cycle. Just prior to the time of pollen release, the cone axis elongates and the individual cone scales become separated. In the "wooly" species, like *E. friderici-guiliemi, E. ghellinckii,* and *E. lanatus*, the cone often also bends sideways and downwards towards the time of pollen shedding. In many cases the temperature of the male cones rises quite steeply, this being especially noticeable towards the evening. The rise in temperature may also coincide with a strong odor as in the case of *E. villosus*. Pollen is released from the hundreds of small pollen sacs on the undersurface of each cone scale. Left undisturbed, the cone would normally continue to shed pollen over a period of a week or so.

Pollination Techniques. In natural populations, the female cones of most species are ready for pollination when the male cones shed their pollen, usually in autumn. In garden plantings, this is not necessarily true and some skill is required to decide when to carry out the pollination of the female cones. A slight extension in the cone axis of the full-sized female cones often results in crack-like openings between the upper rows of cone scales. This is certainly a good indication of the female's receptivity, and under natural conditions, would provide access for the pollinating beetles.

Various techniques for the artificial pollination of cycads have been proposed. Essentially the pollen must be transferred to the interior of the upper part of the female cone, so that it can travel down amongst the spirally-arranged cone scales and come into contact with each of the ovules, two of which are borne on each scale with the micropyle (opening for pollen entrances) pointing towards the axis. Some authorities use the pollen in a dry condition and place it amongst the topmost cone scales, using a bicycle pump or air syringe to force the pollen into the cone. Others prefer to make a slurry of about 1 teaspoonful pollen to a cupful of water and to squirt this into the topmost section of the female cone. It is sometimes necessary to remove one of the uppermost scales from the female cone to gain a 'port of entry' to the cone. This should be done with a clean sharp knife so that the scale removed can be re-inserted as a 'plug' at the end of the process. Because of the difficulty in predicting exactly when the female is ready, it is advisable to repeat the pollination procedure, say at 3- to 4-day intervals a few times.

Seed harvesting and viability assessment. The period for seed maturation on the cone varies from species to species. In most cases it takes 6 to 10 months from the time of pollination to seed harvesting, but in some plants, like *E. arenarius* and *E. transvenosus*, it requires well over 1 year for this part of the life cycle to run its course. Cones should not be picked prematurely for seed gathering. When the seeds are ready, the first few cone scales loosen from the cone axis and fall away to expose those below. The sequence works its way down over a period of a week or so. Each cone scale is shed with its two seeds which are clearly recognized by the red, orange, or yellow colour of the fleshy external part of the seed coat (sarcotesta). As the scales and seeds fall from the cone, the seeds can be gathered for viability assessment and cleaning. In some species the cone does not disintegrate as described above but the whole structure dries out progressively. In these cases, a loosening and softness of the cone scale is a good indication of the time to harvest seeds.

A preliminary screening test to determine whether the seeds are fertile, is to place them, still with the outer seed coat intact, in water. Those that float are buoyant because of air cavities resulting from insect attack or the lack of an embryo. A more reliable test is to select a few sample seeds randomly from the harvest and slice them longitudinally and cleanly into two halves. A very small embryo and its coiled suspensor will be present only in fertile seeds while infertile seeds will have a small cavity where the embryo would normally be found.

The seeds are best cleaned by soaking them in water for 1 to 2 days so that the outer fleshy layer becomes soft and can be separated easily from the hard inner kernel. The cleaned seeds should again be subjected to a float test and a sample number dissected to establish their viability. Seed prepared in this manner should be dried and then stored in a cool well ventilated area until being planted. A sprinkling of an insecticide powder will inhibit insect activity.

Seed germination. It is unusual for cycad seeds to germinate immediately after harvesting. A 3- to 8-months maturation period is typically required during which time the embryo continues to develop before being ready to germinate. Moisture and warmth are the key ingredients for germination. A cable-heated sand bed with intermittent spray mist irrigation is the ideal system, but good results can be achieved with seeds in vermiculite, perlite, sphagnum moss, a well drained potting mixture in seed trays, plant pots, or even between two sheets of moist undercarpet felt. Seeds should be laid horizontally and buried to about one-half their depth in the medium.

Evidence of germination is provided when a root-like, elongating cotyledon base, breaks through the star-shaped crown at the end of the seed and turns downwards into the medium. Soon afterwards the root emerges from the cotyledon base. Many growers remove seeds from their germination beds at this stage and plant them in small nursery bags (containers), or alternatively they plant several seedlings in one communal pot. The medium of choice is a well drained potting soil. Moisture, warmth, and hygiene are more important than soil nutrients at this stage since the plantlet draws most of its nutrition from the seed by means of the terminal ends of the cotyledons which remain in the kernel. After a few weeks, the first leaf breaks through from between the two cotyledons where they join the succulent taproot. A reasonably high light intensity is needed to prevent undue legginess of the leaves. All being well, the seedling will continue to grow to produce more and bigger leaves each season. From time to time it is necessary to move the plants into bigger containers as the root system develops. As this development occurs, the plants should be hardened off to adapt to greater light intensities and to be able to withstand wider variation in ambient temperatures, humidities and soil moisture conditions.

Propagation of Mauritian Plants For a Landscaping Project

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A large number of plants were propagated for planting in a unique landscape at a hotel complex on the Indian Ocean Island of Mauritius. Most of the plants are indigenous to the island and therefore unavailable commercially or in botanic gardens. Seed and cutting sources had to be identified, propagation techniques developed, infrastructure established, and the site cleared and prepared for planting. The project can be regarded as the largest source of indigenous Mauritian plants in the world.

INTRODUCTION

Patric Watson is a South African landscaping designer who is known as a trendsetter who creates unique landscapes for example: Lost City, Wild Coast Sun, and Thabanchu Sun. He uses the whole of nature as a source and the list of plants he requires often includes plants that are indigenous to the specific area which have never been propagated in a nursery, as well as, endangered species. These plants are often not available in collections at botanic gardens and have to be sourced in nature and subsequently propagated. The role of the plant propagator is, therefore, absolutely crucial in a project of this nature. We have been involved in a number of his projects and the one described in this paper is the Coco Beach Resort on the east coast of the Indian Ocean island of Mauritius.

Approximately 95% of the indigenous vegetation on Mauritius has been removed for agriculture and other development. The vegetation can roughly be divided into two types: coastal and upland.

THE PROJECT

The project had to be completed in only 2 years. The existing landscape consisted mainly of traditional landscaping plants and Sun Hotels was convinced to destroy it and to venture into something completely new.

Patric made a long list of plants which are indigenous to Mauritius and the surrounding islands using books. No indication of how many plants was given because he usually uses what has been propagated to create the new landscape. The first problem to overcome was to locate a source of plants to be used for propagation. With the help of the local authorities and enthusiasts, we located most plants in their natural habitat. It required, however, that Gerhard de Jager, (one of the authors) had to circle the island on a weekly basis to collect the material at the right time. Seed, seedlings, and cuttings were used, but the most successful was seed. The collection of seed, however, was a demanding task as the plants had to be visited regularly to harvest them when they were ripe and before they were harvested by birds or the local population. Patric Watson insists that no plant is impossible to propagate. If this was the case, he believes, they would not exist anymore! Propagation of a large number of plants unknown to the nursery industry under these circumstances required very special intuition and skill and total dedication from the propagator. The propagator must be able to use various propagation techniques successfully, has to think like a plant, be hands-on, and apply constant vigilance 7 days a week.

The nursery industry on this small island was not at all suitable for supplying plants in adequate numbers. The necessary infrastructure had to be constructed in a short period of time. The first shade house was destroyed by a cyclone (160 km h^{-1}). The second one was subsequently equipped with a steel frame. For cuttings 80% shade net was used, and for hardening off, 50% shade. Wind breaks had to be planted to protect the nursery against the strong wind and salt spray from the sea. Virtually all the material and consumables for the nursery had to be imported from South Africa. A local manufacturer was contracted to make plastic plant bags of different sizes. Bags were designed by ourselves. Seedbeds were equipped with perspex covers for protection against the weather. Nursery staff was recruited from the local population. We found that the people from the east coast tend to grow their own vegetables and, therefore, had the basic interest and feel for plants.

One of our biggest problems in the nursery was scheduling. Plants were often grown on for longer than normal in a specific bag size, depending on the requirements from the site.

The hotel is sited on granite outcrops. To clear the site, most of the existing (exotic) vegetation was chopped off, burned, and then treated repeatedly with herbicides. Earth moving machines were brought in to make holes in the granite. Each hole had to be filled with growing medium before plants could be planted.

THE RESULT

Apart from the fact that a unique landscape was established in a hotel resort, the plants that were used serve as the largest collection of a wide variety of Mauritian plants. They can be used as source for propagation material for similar projects on the island or elsewhere. Many of the plants are rare and normally not available elsewhere. Two thousand bottle palms were used to establish a palm forest. Plants are still being planted to complete the project. About 600 large coco palms and 1400 plants of *Dictyosperma* (which are indigenous to Mauritius) were harvested by subcontractors. Other indigenous plants include *Hibiscus* and *Crinum*.

Popularization of Indigenous Plants

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The majority of South Africans are "locked into" a European style of gardening and make use of plants that do not occur naturally in the region. The use of indigenous plants has several advantages, of which drought resistance is the most important. Because many indigenous plants are less attractive than the popular exotic plant, a special marketing approach is necessary to change the attitude of gardeners. An approach, which appears to be successful, is to promote the idea of gardening for wild life, not indigenous plants. Once a gardener has learned which plants attract birds, butterflies, and small animals it becomes natural to plant indigenous plants.

INTRODUCTION

The majority of South Africans are locked in to a Eurocentric style of gardening and make use of plant taxa that do not naturally occur in the region. This style of gardening was introduced into the country decades ago as a result of the early colonization of South Africa by the English and Dutch. Written articles, video, and film material as well as horticultural training curricula, have ensured that this gardening mentality remains entrenched and that use of indigenous material has in the past been limited to a few "nature freaks".

With the awakening of environmental awareness among the general public during the past decade, gardening with indigenous plants has become fashionable and an increase in sales has been realized by some wholesale growers and retailers alike. Gardeners are becoming more aware of an 'African' approach to garden design.

Many native or indigenous species of plants in containers lack the visual impact of exotic best sellers like *Abelia* ×*grandiflora* 'Francis Mason', *Euomymus* taxa, *Hebe* cultivars, and the host of new introductions which are brought to our shores each year. A very different method of marketing indigenous plants is needed to compete in a market which favors exotic cultivars. The following advantages in the use of indigenous plants need to be highlighted:

- South Africa is a country with a climate of continuous drought, and the odd wet season. Indigenous plants are often more drought resistant than their exotic counterparts which may originate from countries with high rainfall. Indigenous plants are more adapted to South African climatic conditions, this is especially true if the plants actually occur naturally in the area of planting.
- Indigenous plants will in many cases, attract more birds and "urban wildlife" than exotic plants. Local insects are more adapted to the natural plants, e.g., butterflies mainly use indigenous plants as host plants. The South African public is very aware of conservation and this fact can be used to influence their gardening style in favor of "urban conservation".

Propagation Media

Pruning

Pyrus

Quercus

Question Box

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Shipping

Shoot Growth

Shrubs, Deciduous

Woody Plants

Woody Plants

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A

Some of the indigenous species do not take well to transplanting once the seedling begins to mature. The polystyrene trays should be treated with Styrodip to prevent the roots growing into the walls of the trays. The more robust healthy seedlings can then be selected to plant into bags or pots and the others discarded. Other benefits of planting into trays are that it takes a skill which not all people have to handle and transplant the small seedlings. With minimum training anyone can plant a plug. Also the seedlings can stay in the trays for up to 3 years, which with the erratic supply of seed, can be an added bonus of planting up more than you need in a bumper year to ensure a constant supply of a species.

CONCLUSION

A big part of the pleasure I derive from the nursery is the propagation of rare and endangered species. This, I feel, is a worthwhile cause because at the rate of development and habitat destruction in this country cultivation may be a plant's only chance of survival and I feel privileged and blessed that I can be a part of that. The cultivation of a wide variety of indigenous plants, for which no information is available, requires a lot of experimentation to overcome problems with regard to sourcing and cleaning of seed, timing of germination, breaking of dormancy, transplanting, and other challenges.

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Production of Quality Export Chrysanthemum Cuttings

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Propagation of chrysanthemum by means of cuttings is an operation that is carried out by specialized cutting producers. Because of the competitiveness in the chrysanthemum industry, quality is of utmost importance for the cutting producer. Quality of cuttings is determined by: cultivar choice, evenness, presence or absence of pathogens and insects, size, vigor, vegetativeness, age of mother plants, and package and conditions during transport. A chrysanthemum cutting producer should continuously check all steps and conditions during propagation. Samples of cuttings should be inspected by independent workers and a bonus and penalty system which is based on the result of the inspection resulted in an increase in productivity and quality at Van Zanten, South Africa.

INTRODUCTION

Chrysanthemums (*Dendranthema* ×*grandiflorum*) are the second largest selling cut flower, with large amount of production in Japan, Holland, South America, and other countries.

Chrysanthemums are grown from cuttings and the flowers are harvested approximately 11 weeks after planting. Because the end product is rather heavy and with a limit on the selling price it is not economically viable to export it over long distances by air.

It is very costly to produce cut flowers because of:

- Climate control (temperatures between 17C minimum and 35C maximum).
- Day length control (long days for the vegetative stage and short days for the generative stage).
- Extensive spraying programs including fungicides, insecticides, and growth regulators.
- Capital layout.
- Cost of labor.

Due to these factors, chrysanthemum production in Holland has changed considerably during the last couple of years. The average growing area per grower has increased from 1 to 4 ha. Only modern greenhouses with a high level of mechanization and automation are used. It is, therefore, obvious that all growers expect only propagation material of the highest quality. In the cutting market a successful trader will have to ensure that its cuttings are of high quality.

Quality in this case, is all the visual, genetic, and physiological factors to which cuttings must comply and which are required to grow the crop successfully. In chrysanthemum, the required quality norms override the cost aspect. If the product falls short of the required quality norms, you will not be able to sell your cuttings regardless of the price. It is, therefore, of paramount importance that a cutting supplier maintains very strict and high quality standards.

FACTORS AFFECTING QUALITY

Cultivar Choice. Literally hundreds of chrysanthemum cultivars are available from a number of international breeders. However, the choice for the cut flower grower is determined primarily by what the market wants. Growers of cut chrysanthemums often rely on propagators to advise them with regard to suitable cultivars. The propagator must thus make sure to provide the correct advice relating to:

- The ease by which the grower can grow a specific cultivar in his/her nursery.
- The infrastructure required because some cultivars require strict environmental control.
- Season of the year.
- True to color and not mixed with other colors.
- Evenness in growth and flowering.

Virus-free. Viruses, such as Tomato Spotted Wilt Virus, are transmitted by insects, while other viruses, such as the stunt viroid, are dormant within the mother stock and can become active as the plant grows. Therefore, it is necessary to inspect the mother stock twice a week and remove any suspicious plants. This is a specialized task and requires a person with knowledge of the problem. A virus can be spread by hand during harvesting of cuttings or by sucking insects. If the infestation exceeds 5% of the mother stock, the planting should be replaced.

Generation. Because of the fact that irradiation is used in the breeding process, cuttings for mother stock should not be used which are older than the fourth generation of the original in-vivo mother stock.

Vegetative Stage. Because chrysanthemum is a short-day plant, the mother stock must always be in the vegetative stage. Precocious flower formation is a disaster and will have the effect that growers will be handing in claims determined on the ruling market price, less a portion of the production costs. Mother stock is kept in the vegetative stage by means of interrupted lighting from 19h00 to 05h30. It is important that the lighting installation is checked daily and controlled. Most growers use a method whereby the number of exposures are recorded by a counter and as a safety measure, are checked at night. It is also important that the grower insures that he/she maintains a radiation level of approximately 85 lux during lighting stages on the mother stock.

Age of the Mother Stock. Some culitvars have a short "long-day leaf number"; this means that although you have lighting on, the mother stock eventually turn generative. To counter this effect, the mother stock should preferably not be kept in production for longer than 14 weeks.

Climate. Extreme temperatures will have negative effects on the production of cuttings. The norms are between 18C minimum and 35C maximum. If the temperatures in the greenhouse drop below 18C, most cultivars will not form buds or will form uneven buds. High temperatures will have the effect that certain culitvars set buds precociously due to increased stress. To ensure good quality, you need to have a good and effective heating and cooling system present to manage climate control.

Free from Insect and Fungal Infestations. The mother stock must always be free of insects and fungi infestations. No cuttings will be allowed to be imported into another country with any of these infestations present. A strict spraying program is therefore of paramount importance, whether it is preventative or corrective. Spraying is done twice weekly and chemicals should be rotated regularly to avoid the build up of resistance. It is important to spray early in the morning to avoid spray damage on the leaves. Although insect-damage can be diagnosed on the mother stock, sticky traps should be placed in the greenhouse to monitor the presence of mature insects.

Size. Size and leaf surface of cuttings must be even. To obtain this, cuttings must be harvested 5 times in a 14-day cycle. The cuttings are mostly picked at 5.5 cm length (bottom of stem to bottom of growth tip). Cuttings that are harvested too old, will be too thick and cuttings harvested too young, too thin. Thick cuttings grow faster than thin cuttings and this will result in an uneven crop for the cut flower producer.

Vigor. Cuttings must root well within 12 to 14 days to form a rooted plant which will flower within 10 to 11 weeks after planting. To ensure strong growth of the mother stock, the fertigation and irrigation program will be determined by the soil analysis and macro- and microelements and the moisture content present. If the feeding and the irrigation are not optimal at all times, cuttings will either be too hard or to soft, which can cause problems during rooting. Growers in The Netherlands, where light intensity is relatively low, root cuttings with 6 to 7 developed leaves on the cutting. Optimum growth of the motherstock will ensure good quality cuttings.

Package and Transport. After cuttings have been harvested in the greenhouse, they must be placed in the coldroom within 1 h to avoid deterioration due to extreme heat conditions. The quicker the cuttings are cooled to 2C, the longer the quality will be maintained. The cuttings must be packed in bags not only to avoid damage, but also to ensure quick and easy handling of the cuttings during the planting process. Condensation must be removed from the bags in the coldroom to avoid rotting in the boxes while in transit. Aircraft temperature can not be kept at 2C and runs up to ±27C. It is thus important that the packing must be well insulated to avoid temperature increase. High temperature during transport affects the shelf life and rooting ability of the cutting negatively.

CONCLUSION

To ensure quality, the chrysanthemum cutting producer has to check and recheck all the steps in the production process continuously. The grower must also receive feedback from the buyer on a weekly basis. To ensure that cuttings conform to the requirements with regard to size and evenness, samples should be drawn from the cold room continuously by independent controllers and checked. It is our experience that a bonus and penalty system, which is based on the result of the quality control process, resulted in a marked increase in productivity and quality. An additional benefit is that it has also resulted in harvesters being able to increase their monthly salary.

Trends in the Nursery Industry in South Africa

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INTRODUCTION

Changes are taking place in the nursery industry in South Africa and elsewhere in the world. Twenty years ago, a nursery was a place where plants were grown and sold. Today nurseries are split between growers and retailers. A relatively new trend is the specialization of growers to produce plugs.

In this paper, I will present an overview of my view of how things are going to change in the retail nursery industry and how the propagator will be affected.

TRENDS IN SOUTH AFRICA AND ELSEWHERE

Internationally the retail nursery industry has to compete with other centers of entertainment such as sport and health clubs. There is thus a tendency to respond by prolonged shopping hours, children's playgrounds, coffee shops, butterfly houses, craft centers, etc. to attract people to nurseries. Eventually the selling of plants will become secondary to the mainline business of getting people into the nursery.

GARDEN NURSERIES

In the U.K. garden centers are often considered as places where plants are sold by people who do not know much about plants. The nursery is the place that is known to have the plants that you want and where advice on the cultivation of the plants can be obtained. In the U.K. a new trend is that of garden nurseries and I believe that it is a trend that will spill over to South Africa. The garden is planted to show people how plants can be used, where they are planted, how they grow, and how they look at different times of the year. Connected to this is the nursery where the plants in the garden are offered for sale.

HYPERSTORES

More and more plants are sold by hyperstores and do-it-yourself (DIY) centers. The selling power of hyperstores should not be underestimated because they are driven by customer needs. Hyperstores make sure that they give the customer what he/she wants, and their display and point of sale are often outstanding.

SPECIALIZATION

My prediction is that the private nurseries and the mama-papa nurseries will in 5-10 years time not be able to exist as they do at present. They will become part of a chain, be branded (for example Garden Pavillion in South Africa), they will join groups or become public companies. Three types of growers will emerge in the future: the specialist plant grower, large growers such as Malanseuns who grows everything, and smaller growers who will specialize in nich markets with special cultivars, etc.

MAILORDER

More plants are sold through mailorder companies in the U.S.A. than through nurseries. This is exiting news for the propagator: you grow them, they will sell it.

To reach that point, however, the grower must be connected to the Internet, not only to let retailers know what you have available, but also to keep up with market trends.

MARKETING

One-to-one marketing is going to become increasingly important. It happens more and more that clients come to a nursery with specific demands and needs. They no longer come to the nursery to see what is available, they see the plants somewhere else, and they always want the plants immediately. If you are informed properly (computer connected) you can sell more plants on a one-to-one basis than what you can in a nursery with a whole range of plants where they sell one-by-one.

Plants are going to be sold very differently in the future than what we are used to. There in an increasing demand for delivery and people are always busy. It is those growers who advertise on TV, offer delivery, and who are connected via Internet who will have an advantage. People will prefer to do shopping from the comfort of their homes to getting out in the heat or cold.

BRANDING

Branding is going to become increasingly important as people associate the colour, logo, and style with a certain type of product. A successful brand need never be changed. It is not only the name, but also the look of the truck, the presentation, the label, etc.

INFORMATION

Growers tend to assume that people know how to grow plants. They don't. To survive, retailers will have to provide customers with information on how and where a plant should be grown and how it can be used. This means that the propagator must supply the retailer with the relevant information since he/she knows the product well. The information should be short and sweet. People are always in a hurry. Thus the shorter your message, the better your chance of getting the message over to them. An example is perhaps the gardening program that I ran on TV on Saturday mornings. They were only 4 min. long, yet very popular.

Plants are the business and life of the propagator. Yet to the majority of people, plants are just another commodity. To compete successfully with the other commodities, plants must perform, be colorful, robust, and floriferous. Customers must be made aware of why a specific plant is unique and how it can be used in the home or garden.

PLANTS FOR THE FUTURE?

- Annuals will always be popular because of the colour. However, they may not be sold in the same quantities. Therefore, the quality will have to be outstanding.
- Perennials such as alstroemeria, daylilies other than the well known yellow ones, Japanese anemones, etc.
- Flowering shrubs.
- Indigenous plants for the different climatic areas in the country.
- Improved cultivars of well known plants. New colors, shapes, and sizes.
- Small plants. People live in smaller homes with smaller gardens than two decades ago and this trend will continue.

CONCLUSION

South African propagators and other nurserymen must take note of the trends in the marketing of plants in the rest of the world and be prepared to adapt to the changing needs of customers. Much can be accomplished by liaison with the Australian nursery industry, we can learn such things as nursery hygiene and marketing. International Plant Propagators' Society and South African Nurserymen's Association each have a different role to play, and gardening writers play a special role.

The Use of Taguchi Methods to Analyze Variables

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Taguchi methods offer plant propagators an opportunity to develop optimal methods or conditions in a cost-effective way. An example used in our tissue culture laboratory is discussed and Internet addresses to find more information are given.

INTRODUCTION

Propagators often face the situation where a new method has to be developed, or an existing one optimized. Usually more than one factor affects the processes of growth, for example: temperature, age of the plant, season, light intensity, day length, growth regulators, etc. To complicate matters, one or more of these critical factors may have a more profound effect on the process than others. Even worse is that two or more of these factors may interact with each other. More often than not, limited amounts of material are available for experimentation and the propagator has little time for experimentation.

The conventional method of investigating all possible combinations and conditions in an experiment is known as a factorial design. It is based on the theory that for a full factorial design, all possible combinations are tested, obviously at great cost and time, with a statistical analysis of results. In contrast to the factorial design, Taguchi's robust design method provides the propagator with a systematic and efficient approach to determine the near optimum conditions. In this paper the method is briefly discussed and an example where I used it successfully is given.

TAGUCHI AND ROBUST DESIGN METHODS

Taguchi methods are a system of cost-driven quality engineering that emphasizes the effective application of engineering strategies, rather than advanced statistical methods. Taguchi methods are known as Robust Design methods in the U.S.A. The approach allows for experiments to be performed and prototypes tested on multiple factors at once so that the process becomes insensitive to experimental conditions and other uncontrollable factors. Dr. Genichi Taguchi developed his philosophy on quality engineering over a period of 30 years after he was recruited to repair Japan's telephone system. Not satisfied with trial and error methods, he developed his own method to design experiments. One of Taguchi's key ideas is the upstream optimi-

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AN APPLICATION OF TAGUCHI METHODS

I was faced with the challenge to find a method to regenerate bulbs from *Nerine* callus in vitro. Seven factors were investigated, each at a high and low level:

Macro-nutrient formulation: Schenk and Hildebrandt (L) vs. Murashige and Skoog (H)
Sucrose: 12.5 g liter^{-1} (L) vs 50 g liter^{-1} (H)
Maltose: 5 g liter^{-1} (L) vs 20 g liter^{-1} (H)
Casein AH: 0 (L) vs 1 g liter^{-1} (H)
Citrate: 0 (L) vs 20 mM (H)
Plant growth regulators (PGRs): None (L) vs usual mix (H)
Charcoal: 0 (L) vs 2 g liter^{-1} (H)

The experiment was laid out using the L8 OA as guide (Table 1).

If a factorial design was used, no less than 128 different media would have to be prepared compared to the 8 used in this experiment. After 3 months, the growth was ranked from 0 to 3, with 0 being the poorest and 3 the best. In this case, the higher the score, the better. To analyze the results, a table was constructed where scores of the main effects were summarized (Table 2).

Table 1. Experimental layout according to Taguchi's method.

	Medium number							
	1	2	3	4	5	6	7	8
Macronutrient formulation	L	L	L	L	H	H	H	H
Sucrose	L	L	H	H	L	L	H	H
Maltose	L	L	H	H	H	H	L	L
Casein AH	L	H	L	H	L	H	L	H
Citrate	L	H	L	H	H	L	H	L
PGRs	L	H	H	L	L	H	H	L
Charcoal	L	H	H	L	H	L	L	H

The scores in the table were calculated as follows:

The score (0.75) for salts at a low level (Table 2), is the average for the media in Table 1 where salts were used at low concentration namely: 1, 2, 3, and 4.

The score (1.5) for salt at a high level (Table 2), is the average for the media where salts were used at the high concentration namely: 5, 6, 7, and 8.

The score for charcoal at a high level, is the average for media 2, 3, 5, and 8.

The conclusion that can be made from the results in Table 2 is that the optimal medium for bulb formation is one which contain a high level of salts, sucrose, maltose, and charcoal together with a low level of casein, citrate, and PGRs. It can also be seen that charcoal was probably the most important variable in this experiment. It is possible to find interactions between the different factors but one must study them with care.

Table 2. Summary of results of seven factors tested for bulb formation on *Nerine*.

Variable	Low level (L)	High level (H)
Salts	0.75	1.5
Sucrose	1	1.25
Maltose	1	1.25
Casein AH	1.25	1
Citrate	1.25	1
PGRs	1.5	0.75
Charcoal	0	2.25

FURTHER INFORMATION

- Two sites on the Internet that may be of use and provide other references are:
  http://www.amsup.com/TAGUCHI
  http://garcia1.larc.nasa.gov/dfca/dfc/tm.html
- Bibliography.
  http://www.quality.org/Bookstore/Taguchi.html
- A free demonstration software application for designing and running Taguchi experiments is available from: http://www.wnet/~rkroy/wp-q4.html

Propagation and Cultivation of South African Restios

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The Restionaceae is a family of evergreen rush-like plants. Three hundred species are endemic to the Cape floral region. Plants from this family have long attracted the attention of horticulturists around the world on account of their sculptural form and their attractive long-lasting seed heads. Restios have potential as bedding plants, as accent plants in landscaping, and their foliage is also of value to the cut flower industry. However, for many years only a few species were in cultivation and available commercially due to the extremely poor germination obtained in most species. The recent discovery that plant-derived smoke is the germination cue for many species has led to a wider range of species becoming available for cultivation. The main requirements for the successful cultivation of restios are a position in full sun, a well drained soil, and plenty of air movement.

INTRODUCTION

The Restionaceae, a family of evergreen rush-like plants, is one of the three major families defining fynbos, the characteristic vegetation type of the Cape floral region. During the last 10 years plants of the Restionaceae have attracted considerable interest from gardeners around the world and Kirstenbosch Botanic Garden has been working to introduce a range of restios to the gardening public. Restios do not produce the striking flowers found in the protea and erica families but have been sought after for their sculptural form and attractive long-lasting seed heads. Restios are generally tufted, reedy-looking plants which vary in height from about 20 cm to well over 3 m and can be used singly as accent plants or in groups as foliage plants. Some of the species are also used as foliage for the cut flower industry and the thatching reed, *Thamnochortus insignis*, supports a flourishing thatching industry. Some restios have large grass-like panicles of golden-brown inflorescences and most restios have dark brown seed heads. Apart from their form, the most attractive feature of the restios are the beautiful papery bracts which vary in colour from pale gold to orange-red, brown, and ebony. Members of the Restionaceae family are largely confined to the Southern Hemisphere. There are approximately 320 species in Africa, about 100 in Australia, three in New Zealand, one in Malaysia and southeast Asia, and one in Chile. In Africa about 300 species are endemic to the Cape floral region and a few species occur further north in South Africa, with one species reaching Zaire and one occurring in Madagascar.

PROPAGATION

Vegetative Propagation. Restios can be propagated by seed or vegetatively by division. The stoloniferous species can be successfully divided just before the crop of new shoots emerges from the ground, generally in early or mid winter. The plants should be divided into fairly large pieces, the roots disturbed as little as possible, and planted out immediately in open ground or in containers. After transplanting the plants should be kept well watered until the new shoots are growing and the plant has "taken". Generally the plants take up to a year to start growing again and do not seem to grow as vigorously as plants raised from seed.

Propagation from Seed. Restios are wind pollinated and many flower during spring or late summer, producing seed after a period of 6 to 11 months. The seed varies from very fine seed, such as *Chondropetalum tectorum* with about 10,000 seeds per gram, to the large nut-like seeds of *Ceratocaryum argenteum* which are 10 mm in diameter. Seed collection is fraught with difficulties as there is very little information available for individual species on the season of flowering, on the period required for seed maturation, and on the timing of seed drop. Seeds of many species look ripe from the outside but on dissection are found to be green and immature.

How to Germinate Restio Seed. Seeds may be sown in trays using a sowing medium consisting of loam, milled bark, and industrial sand (1 : 2 : 2, by volume) and should be covered with a thin layer of milled bark. Seeds of most species are dormant and will give poor germination unless dormancy is broken by treatment with smoke derived from burning plant material. Seeds may be smoke treated in a smoke tent for 30 min after sowing in trays. Alternatively, seeds may be pre-treated by soaking them in Kirstenbosch Smoke-Plus seed primer for 24 h prior to sowing. The seed primer contains smoke derivatives which break seed dormancy and maximize germination. Under natural condition seeds germinate in the autumn and early winter after a fire when soil temperatures fluctuate considerably. Temperatures of approximately 20 to 25C (day) and 8 to 10C (night) are ideal. Seed trays housed in an open shade house in the autumn should obtain sufficient diurnal temperature fluctuation for germination to occur. Seeds take 4 to 6 weeks to germinate. Seedlings should be transferred to small individual containers and grown in the nursery until they reach a size suitable for planting out in the open ground. The germination response of Restionaceae species to plant-derived smoke is shown in Table 1.

CULTIVATION

How to Grow and Maintain Restios. The normal growing season for restios is in the autumn, spring, and early summer. The best time to plant restios in both the summer and winter rainfall areas is at the beginning of the rainy season. The plants are planted in holes of 600 mm square and 400 to 600 mm deep. The soil which is removed from the planting hole should be well mixed with about two spades of compost and then replaced in the planting hole. It is recommended that no fertilizer should be added as this might burn the roots. The plants should be planted at the same level as they were in the bags. Like most other fynbos plants, restios will benefit from a mulch of milled pine bark or rough compost. They must be well watered after planting and after about 6 weeks they should show signs of new growth. Restios, in common with other fynbos species like proteas, do not like to have their roots disturbed and do not like to be planted in small holes in lawns. They are, however, much more robust growers than most fynbos plants and do not seem to be plagued by soil-born fungi or other diseases. The main requirements for successfully growing restios are full sun, a well drained soil, and plenty of air movement. Restios

Table 1. Germination response of Restionaceae species to plant-derived smoke.

Askidiosperma andreanum	**
A. esterhuyseniae	*
A. paniculata	*
Calopsis paniculata	*
Cannomois parviflora	NR
C. virgata	**
Chondropetalum ebracteatum	**
C. hookerianum	***
C. mucronatum	***
C. tectorum	***
Dovea macrocarpa	***
Elegia capensis	*
E. cuspidata	**
E. fenestrata	**
E. filacea	**
Hypodiscus neesii	NR
H. striatus	NR
Ischyrolepis ocreata	**
I. sieberi	***
I. subverticellata	***
Restio bifarius	**
R. brachiatus	*
R. festuciformis	**
R. similis	**
R. tetragonus	***
R. triticeus	**
Rhodocoma arida	*
R. capensis	***
R. fruticosa	*
R. gigantea	***
Staberoha aemula	***
S. cernua	***
S. vaginata	**
Thamnochortus bachmannii	***
T. cinereus	***
T. pellucidus	***
T. punctatus	***
T. spicigerus	***
T. sporadicus	**
Willdenowia incurvata	NR

Key to responses:
*** = indicates very marked increase in germination (<1000%);
** = indicates marked increase in germination (<100%);
* = indicates moderate increase in germination (50-100%);
NR = no response to smoke; all nut-fruited species; seeds remain dormant; other germination cues probably involved.

will respond well to regular feeding with low concentrations of nutrients such as nitrogen. They may be fed with standard organic fertilizers such as Seagrow or Kelpak, or by sprinkling the surrounding soil with a small amount of ammonium sulphate during the growing season. Restios will respond to regular watering by showing more robust growth, but they are essentially plants which are adapted to a long dry season. Maintenance consists of the removal of dead stems. The dead stems of the more grass-like species like *R. festuciformis, R. brachiatus,* and *R. similis* can be left on the plant, as they will be hidden by the new growth. It is important not to damage the new growth, as once damaged, the stems will die.

A GUIDE TO RESTIOS IN CULTIVATION

Identification. Restios are dioecious and the male and female plants of one species can look very different. This does make identification difficult, because both male and female specimens have to be collected to make the identification possible and in a field with more than one restio species it is not always obvious which male and female plants belong together. The inflorescences consist of small flowers carried in panicles, the male inflorescences being more widely spaced and loose, the female flowers compact and protected within the often striking golden or brown bracts.

Better-Known Species Commonly Cultivated in the Past.

***Chondropetalum tectorum* (Dakriet).** This species has a tufted growth form and grows to a height of 1.5 m with a spread of 1.5 to 3.0 m. It has slender compact flowering spikes with brown bracts. It is widely planted in gardens, being one of the few restios that has been available from nurseries for some years. There are large stands in Kirstenbosch Botanic Gardens.

***Thamnochortus insignis* (Dekriet) (Thatching Reed).** This species is an upright tufted plant growing up to 2.5 m in height and spreading to 3 to 4 m wide. It has heavily lignified culms which are ideal for thatching. The spikelets are yellow or golden brown in colour. It is a very attractive ornamental plant which can be grown in lawns with rocks around it, in rockeries, and in open beds. It also makes a good pot plant.

***Elegia capensis* (besemriet).** Besemriet is a very attractive species which grows to a height of 2 m. It grows in clumps or tussocks which have a spread of 1.5 m. This species has slender branches arranged in whorls at the nodes which gives an appearance rather similar to *Equisetum*. It produces golden brown flowers in spring. Besemriet is fast growing and plants can reach a height of 1 m in the 1st year from seed. It is one of the few species that has long been available from nurseries, possibly because its seed germinates readily. It has a long history of cultivation in Britain.

New Restios with Horticultural Potential. Plants of the following species have recently become available in quantity for the first time and are available for commercial cultivation.

***Ischyrolepis subverticillata*.** In its natural habitat this species grows in full sun in seasonally wet river beds. It may be found as close as 50 m from the sea to positions in light shade along small streams high up in the mountains. It is thus a plant for full sun or semishade, sandy, well drained soils, and preferably moist situations.

Mature plants eventually form large clumps 2 m high and more than 3 m in diameter and can be used as accent plants or in groups. *Ischyrolepis* produces small greenish-yellow flowers in autumn which develop into beautiful shiny speckled grey nutlets in the following early summer. The main decorative value lies in the sprays of dark green filiform foliage which is used in the cut flower industry.

Restio brachiatus. In its natural habitat this species only occurs near stream beds. Plants can, however, be grown successfully away from water, and under these conditions they grow to a height and diameter of 1.5 m. Plants are compact and have finely divided stems. They are grey-green in colour and are good contrast plants in fynbos gardens. *Restio brachiatus* flowers in winter, with small cream-colored flowers in arching sprays. Large numbers of very small seeds are produced.

Restio festuciformis. In its natural habitat this species is often found growing along stream banks and in damp places and may form large golden-brown sheets in marshy areas. Plants are very fast growing, often reaching maturity and flowering in the first year after planting. Their pattern of growth provides a changing picture throughout the year. The plants have bright green stems that produce inflorescences with golden-brown bracts in spring, maturing into dark brown seed heads in early summer. The new cycle of bright green stem growth follows shortly afterwards. Mature plants grow up to 400 mm high and 600 mm in diameter and are most suitable for planting in groups of three or more. Plants in cultivation at Kirstenbosch Botanic Garden have only had a relatively short lifespan and have needed to be replaced after 3 to 4 years

Restio multiflorus. This species reaches a height of 1.75 m with a diameter of 1 m. The young plants are decorative with large numbers of bright green, sterile juvenile stems. After 1 or 2 years the fertile stems rise like a fountain out of the center of the plant, providing a striking picture. The female plants produce a mass of small white flowers while the male plants produce golden brown inflorescences.

Restio similis. This species grows to a height of 750 mm with a diameter of 1.5 m. Plants are best grown in groups. The young plants are very striking with beautiful dark green stems which ripple in the wind. The plants produce small cream-colored flowers in autumn. Dark brown seed heads form later and these shed large numbers of small grey seeds.

Thamnochortus cinereus. This species occurs naturally in well drained habitats in the wet mountainous areas. It is one of the most strikingly colorful restios with its many grey-green sterile side shoots. In autumn and winter both the male and female flowering stems rise up above the foliage with large grass-like inflorescences. The male plants produce large silvery tassel-like flowers which stay decorative for at least 3 months. The plants grow to a height of 1 m with a diameter of 1 m and can be used very successfully both as accent plants and in small groups.

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