HORTICULTURAL ROCKWOOL AS A PROPAGATION MEDIUM

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The following are important desirable characteristics of propagation media:

— The necessary physical consistency to support seeds during germination and cuttings during rooting.
— Freedom from pathogens and other harmful organisms.
— The ability to retain and release sufficient moisture for germination, rooting and, possibly, subsequent growth.
— Good drainage to prevent waterlogging and allow the presence of sufficient air for optimum root growth.
— Ease and low cost of preparation.
— Absence of chemical reactions which are deleterious to plant growth, e.g. very low or high pH values, and high salinity values.
— Presence of nutrients if seedlings or rooted cuttings are to be retained in the medium.
— Consistency from batch to batch.

Many characteristics are inter-related. Air and water retention properties are closely related and greatly influenced by the physical composition of the medium. Ease and cost of preparation; consistency from batch to batch and freedom from pathogens will all have a great influence on the overall cost of the medium. Other characteristics may be desirable and it is unlikely that any medium will be perfect in all respects. Compromises are needed depending on local conditions and situations.

The manufacture of rockwool. Rockwool has been produced as an acoustic and insulation material for about 50 years. The production technology has been modified but the end product has remained basically unchanged.

The raw materials are natural rocks such as basalt and limestone with metallurgical coke as fuel. The rocks and coke are weighed and fed into a type of blast furnace through which air is blown so that the coke burns.

At a temperature of approximately 1600°C the rocks melt producing a form of natural molten glass which is tapped off from the bottom of the furnace. A stream of molten rock is tapped from the furnace and flows onto a series of high speed rotors. These spin off molten droplets which lengthen into

fibres which are cooled by a blast of air. Chemical binder is sprayed into the air stream which also carries the fibres clear of the rotors and deposits them on a conveyor as a thick felt.

The felt is conveyed along a production line where it is pressed, hardened, trimmed and, finally, cut into slabs and packed. This is insulation rockwool — a sterile, firm, buff-coloured, fibrous felt.

Horticultural rockwool. Insulation rockwool — or fibre-glass for that matter — is useless for horticultural purposes. It is impossible to wet and does not have the correct physical properties. Several disappointments have occurred as a result of growers using ordinary insulation rockwool for horticultural purposes. Research into the manufacture and use of rockwool for horticultural purposes began in Denmark. The European material — "Grodan," (registered trade name of Grodania a/s, Hedehusene, Denmark) — has been in commercial use for over ten years. Currently it is largely used as blocks for plant propagation; in granulated form as an additive to potting mixtures and as wrapped cubes and slabs for soil-less production of a wide range of crops. Horticultural rockwool use in Denmark, the Netherlands and Britain has increased rapidly in recent years as peat quality and availability have decreased and soil pasteurisation/fumigation problems and costs have increased. Small quantities of the European material have been imported into Australia but the high volume : weight ratio makes large-scale shipment uneconomic. An Australian manufacturer of rockwool began trials nearly a year ago with a horticultural product and this material has recently been released onto the Australian market under the trade name "Growool," (registered trade name of C.S.R., Sydney, Australia.) Trial results have been very encouraging and comparable with the European product. Horticultural rockwool is different from other materials, however and — as such — requires a different approach. It has a number of potentially valuable uses in the Australian horticultural industry but the true value will only be realised if growers appreciate its place in the whole plant production system. Horticultural rockwool is a new product in the armory of Australian growers who must understand its properties and pay attention to the details necessary for successful use.

Properties of horticultural rockwool:

1. *Density*: Propagation blocks, wrapped cubes and growing slabs have a density of approximately 70kg/m^3. Consequently it is a very lightweight material. A carton containing 2240 propagation blocks weighs only about 10kg. Carefully monitored trials have been carried out with material of different densities. Lower densities are associated with

softer material which soon collapses during use while denser material is harder and more difficult for plant roots to penetrate.

2. *Sterility:* Horticultural rockwool is manufactured at 1600°C and, therefore, is free — in the first instance — from unwanted organisms. New material does not require pasteurisation or chemical fumigation and the propagation blocks, wrapped cubes and growing slabs are ready to use without any mixing.
3. *Reaction:* Fresh material produces a pH reading between 7.0 and 8.0 but it has no buffering capacity. Consequently it very quickly takes on the pH of any liquid (water or nutrient solution) with which it is watered.

   The pH has not caused problems in propagation provided the blocks are properly managed. An initial and thorough soaking in water is essential before sowing seed or inserting cuttings. The use of plain water is then perfectly acceptable during propagation until root development occurs when a dilute and complete nutrient solution must be used at every watering. Crops grown in wrapped cubes and growing slabs must be liquid fed continually.
4. *Cation exchange capacity:* Horticultural rockwool has virtually no cation exchange capacity and consequently there is no absorption or exchange of nutrient ions from solution. Thus it is necessary to liquid feed with a complete nutrient solution when plants are held in horticultural rockwool after propagation or when the material is used for hydroponic crop productin systems.
5. *Physical characteristics:* Freshly produced, dry horticultural rockwool has 3%-4% of the volume occupied by rockwool fibres. The remaining 96%-97% consists of trapped air which accounts for the value of basic rockwool for insulation purposes. The direction of fibre lay in the product influences behaviour. Propagation blocks and wrapped growing cubes have vertically oriented fibres which give physical strength and reduce the tendency to collapse. Growing slabs are sufficiently large (surface area and depth) that collapsing is not a problem.

   Root growth between adjacent propagation blocks was a problem since damage occurred when the blocks were separated. The problem has been reduced, however, by the machining of vertical air gaps around the blocks during fabrication. A hole is also formed in the centre of the top of each block to indicate where seeds, seedlings or cuttings should be inserted.
6. *Water-holding ability:* Dry horticultural rockwool has a very high percentage of air spaces which fill with water

when the material is immersed. A single sheet of propagation blocks measuring 266mm × 152mm × 40mm requires about 1.5 litres for saturation.

It is important that the initial wetting is completely uniform and it has been clearly demonstrated that immersion is the most satisfactory method of treating propagation blocks. Sheets of blocks must be placed in a container, e.g. a seed tray, for immersion since sheets of saturated blocks are very difficult to handle. Virtually all the water in the material is available to plants and this is an important difference between horticultural rockwool and the majority of other growing media.

The high percentage availability has a potential danger, however, since plants will change from turgid to wilted very rapidly when the water has all been taken up. Watering with small quantities at regular intervals is desirable and, once again, it is a question of growers becoming familiar with a different material.

Allowing the rockwool to dry out or liquid feeding with nutrient solutions which have high electrical conductivities can lead to an accumulation of soluble salts. Regular monitoring with an electrical conductivity meter will indicate the salt build-up which is easily leached out by applying ordinary water.

7. *Air:water characteristics*: These are important advantages of horticultural rockwool but careful management is required to maximise the benefits. Immersion of dry material results in all the air spaces being filled with water. Free drainage due to gravity occurs when the rockwool is placed on a non-absorbent surface and the material soon reaches field capacity. At this point the percentages of air and water depend on the thickness of the material. Thin material has a high percentage of spaces remaining full of water while thick material has a similar situation at the base but much more air at the top. Consequently we can expect a water-air gradient through the material since rockwool has poor capillary action. It is important to understand this gradient particularly when cuttings are inserted. Insertion too deep will put the cutting base into constantly wet conditions while shallow insertion can mean that insufficient water is available.

Propagators can also influence the waterholding — and, therefore, the air holding — capacity of the material by the type of surface on which the blocks stand. Absorbent or free draining surfaces, such as sand or perlite, produce drier conditions within the blocks and similar results occur

when the blocks are placed in slatted seed trays which allow free air movement below the material. Placing the blocks on non-absorbent surfaces, such as polyethylene sheeting, prevents water loss and keeps the material wet.

Misting propagation systems are often set to provide short bursts of water at frequent intervals. This can cause over-wetting of propagation blocks and result in plant losses. It is desirable to reduce the misting frequency unless the blocks are on a very free draining surface. Alternatively the blocks may be placed in a closed case or tent propagation system when misting is either non-existent or less frequent.

Consequently the propagator is able to influence the air: water ratio within the blocks according to the subject being propagated.

8. *Consistency of product:* Horticultural rockwool is manufactured by an industrial process with carefully controlled raw material inputs. Quality control testing of the product is standard procedure and specifications have been established which allow product consistency to be maintained. Consequently the grower knows how successive batches of the material are likely to perform.
9. *Degradation:* Rockwool is manufactured from rocks and degrades in exactly the same ways. It is, therefore, a natural material with a long life. It can be incorporated into outdoor soils or growing media for containerised plants when the improved aeration and drainage are often beneficial to growth.
10. *Suitability for a production systems approach:* Propagation blocks allow the propagated plants to be moved on with a minimum of root disturbance. A "pot into pot" system is possible when rockwool propagation blocks are placed into previously formed holes in growing cubes. Alternatively the block can be hand or machine potted on into a conventional potting mix.

Yet another approach is to grow plants from propagation through to harvest in a rockwool system. This technique is being used increasingly in Europe and forms the subject of another paper later in this Conference.

Using horticultural rockwool for propagation. Propagation blocks made from Australian horticultural rockwool are sold in sheets measuring 266mm × 152mm × 40mm. Each sheet comprises 28 blocks each measuring 38mm × 38mm × 40mm high. The blocks have vertically orientated rockwool fibres and are partially separated by vertical cuts which are to reduce the likelihood of roots growing from one block into the

next. A small hole on the top surface of each block indicates the centre.

The propagation blocks are suitable for direct seeding with large seeds such as cucumber, zucchini, melon, sweet corn, legumes, etc. Seedlings of tomato, capsicum, aubergine, lettuce, etc. can be pricked out into the blocks and grown on into young plants. A wide range of softwood and semi-hardwood cuttings have been successfully propagated in rockwool propagation blocks. Blocks may be used with either misting or closed case (polyethylene tent) systems of propagation. The system used will be governed by the plant subject being propagated. The water holding and drainage properties of the blocks are influenced by the type of propagation system and by the surface on which the blocks stand. Reference to these factors has already been made previously (Properties of horticultural rockwool).

The blocks must be thoroughly soaked before seeds, seedlings or cuttings are inserted. Sheets of blocks are easily handled in seed trays and a standard Australian tray holds 56 blocks (2 × 28 block sheets). The easiest way of saturating the blocks is to immerse them, in the trays, in a container of water or nutrient solution.

Soaking blocks with water is quite acceptable when cuttings are to be inserted since nutrients are not required until roots have formed. Blocks which are to be used for seed germination can also be soaked in water but liquid feeding is necessary once germination has occurred. When blocks are to receive pricked out seedlings they must be soaked initially in a complete nutrient solution.

Cuttings are easily inserted into the pre-punched holes. Seeds are inserted in the same way but there is every merit in germinating them before insertion. Larger holes are made either with an individual dibber or with a specially prepared multiple dibber board.

Cuttings root quickly and seedlings establish rapidly in rockwool propagation blocks. The young roots soon reach the outside of the block but the air gaps reduce rooting into adjacent blocks. Seedlings or cuttings propagated in rockwool blocks should be potted quickly and then will require little feeding in the blocks. Delays may occur, however, and plants must then be watered with a complete and balanced nutrient solution which contains all the necessary plant nutrients including micronutrients. During potting-on the individual rockwool blocks are torn away from the sheet. Separation of the blocks is easier when they are thoroughly wet.

Cuttings or seedlings are usually potted up into the usual

potting mix. Roots emerge readily from the rockwool blocks into all standard potting mixtures. Plants propagated in rockwool blocks may be hand potted or put through potting machines. Growers who use hydroponic systems may wish to put up the young plants into wrapped cubes which have previously cut holes for the purpose. Plants are then grown on in these cubes until they are set out in the hydroponic system.

A wide range of plants have been successfully propagated from either seed or cuttings in Australian horticultural rockwool. The material also shows promise as a medium in which to establish tissue cultured plants when they are taken out of the propagating flasks.

Interest has also been shown in using rockwool as a propagation and growing medium for plants which are intended for export to countries where the import of soil and similar growing media is not permitted.

INTRODUCING STUDENTS TO PLANT TISSUE CULTURE

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I believe that tissue culture is something that is here to stay and something that all horticulturists should be aware of. So what are we doing about it in the classroom? Just that — making students aware of the benefits and the problems it presents and giving them an idea of the laboratory work involved.

We only have 4 hours in our curriculum allotted to this topic, and, because most of our students are not doing this type of work and laboratory techniques and hygiene are so important, I divide them into 2 hours each of theory and practical. Of course, there are students who do more practical work but this has to be apart from normal school hours.

The theory I tackle on a "what, when, why, who, and how basis."

The "WHAT," of course, covers not only a basic definition but also the fact that tissue culture is a term of convenience covering both techniques like, *in vitro*, micro-propagation, and mericloning, and also different parts of the plant — protoplast, cell, tissue and organ culture. I think it may be this rather loose descriptive term that causes some of the criticism — on the one hand it is praised as a marvelous method for the exact reproduction of clones (18); on the other, a scientist extolls it as a wonderful source of variation (8). Both are true but the

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former is more likely to occur in using quite a large piece of organised tissue, and the latter only a cell or disorganised callus.

"WHEN" did it start goes back to Haberlandt (7) at the turn of the century, White (19) in the 30's, and Morel (11,12), who really excited the commercial world with his papers on orchids. Of course I also pay tribute to Dr. de Fossard (3) who has done so much to break through the mystique and make tissue culture a commercial reality in Australia.

"WHY." Listing the reasons for doing it (3) — the main point I try to get across is that it is not a kind of magic micro-chip that will make all other methods of propagation history. From the plant propagator's point of view, it is just another method to be tried if there are problems with traditional methods. These problems can be wide ranging — not just difficult to propagate material — shortage of material or space to stock it — seasonal problems — disease problems — and this brings me to my second point, which is the need for virus indexing. There is a laconic comment in an article in HortScience that whereas before mericloning, orchid viruses were a minor problem; they are now common, widespread and costly (9). Obviously rapid multiplication can apply equally to the good and the bad.

"WHO" is doing it ranges from back kitchen operators to sophisticated nurseries — genetic engineering and plant improvement to botanical research.

Lastly, "HOW" do we set about it — plant material, programmes, media, equipment, disinfestation, taking the explant, incubation, and finally growing on. A formidable list but possible by the enormous amount of research that has been done giving well-documented regimes for a vast array of plants. What our students need, I think, is an idea of where to look for the information they require and, hopefully, to understand it when they have found it.

We discuss media — the reasons for various ingredients, and the total lack of reasons for others as well as the relevant merits of moles and milligrams.

Equipment — I show slides of a wide variety of what can be used as opposed to what we use ourselves.

Disinfestation again is usually well documented and, of course, depends greatly on the delicacy of the plant material to be used.

Incubation facilities I also show on slides, varying from those in research laboratories to Dr. de Fossard's plastic sausages. Regimes of daylength and temperature, again depending on the material used.

The three stages, as suggested by Prof. Murashige are: establishment of the culture, proliferation, and preparation for transfer to soil (13). Lastly potting up — the need for increased humidity and controlled temperature in the early stages.

So we come to our 2 hour practical session; 2 hours, that is, for the students — but an enormous amount of time goes into the preparation.

Obviously it is more interesting for everybody if we get results so I choose some of the easier material — usually carnations and chrysanthemums, plus something extra to see what happens. And this is where the fun comes in. All this material has to have a standard disinfestation and the same incubation regime but we mix up several media and try everything on each of them.

Usually one or more just add water — M & S Medium A (14) or B (15) or something like that and one or more specific ones. This year we made up Cooke's 1977 African violet brew (1). We use the little disposable tubes, colour coding the media by different tops. To dispense the media I have a veterinary syringe. This I find much easier on the hand than a Cornwell one — it has a greater capacity, so for 10 ml it is really a very easy movement. For sterilization we have an ancient autoclave, or we use a pressure cooker.

At the same time we sterilize petri dishes with filter papers and McCartney bottles with ordinary water for cooling instruments after flaming.

We also prepare our chlorine mix using 5% calcium hypochlorite, and 0.1% 7 × detergent as recommended by Dr. de Fossard (3). Originally we used powder but have now discovered the granulated, which makes weighing and mixing much pleasanter — it doesn't affect your throat and nose like the powder.

Next came one of our biggest problems — masses of sterile water in convenient containers with a tap so that the plant material could be rinsed after the chlorine treatment; 3 rinses in 30 ml McCartney bottles and say 6 bottles per student and up to 14 students in each of two classes plus spillage — approx. 15 to 16 liters.

We use tea urns — seal the ventilation holes — cover the taps and boil the water for an hour. This has worked with great success for several years but I have now been told that is unsafe unless it is boiled 3 times each time for an hour, cooling in between so I am investigating the possibility of using UV light instead of heat. We do not have laminar flow cabinets so we prepare the lab as best we can, putting away unnecessary equipment, washing over the benches and spraying with 70% ethanol (3) before putting out the sets of instru-

ments and equipment for each student. I have copied Dr. de Fossard's idea of a screen but make them a little larger and of Perspex. Lastly, the plant material is collected and put under the shower for an hour.

And so we come to the laboratory session, where we try to underline that this is a laboratory and not a potting shed operation. Not that hygiene is not important in both but it is critical here.

Our lab has fixed wall benches around 3 sides and four rows of movable ones in the centre. The sterile equipment is laid out round the sides and the students, after "scrubbing-up", come to the centre benches where there is a set of dummy equipment for each.

The first thing is to get their plant material, prepare it, put it in McCartney bottles, label them and fill with the chlorine solution. There, once again, we opt for a standard disinfestation process of 20 minutes in 5% that is suitable for the main material we use — the extra material just has to have the same — last year the leaves and petioles of African violets came through it perfectly well despite other evidence to the contrary (4).

During the 20 minutes I demonstrate excising axillary buds, dissecting leaves and petioles, and sterilising seed. The students then practice.

The less movement by numbers of people at the actual work area the better. How are they going to place their equipment so that, hopefully, they try to cool their red-hot scalpels in water and not alcohol, and so on until the buzzer goes. Then armed with paper tissues saturated in 70% ethanol for their benches and hands, away they go to their side bench work stations.

What are our results? I am amazed and delighted with them. Students average about 8 to 10 tubes each and our contamination rate runs at about 6% which I consider remarkable.

Our biggest problem is probably an understandable lack of dexterity resulting in mangled material and ending up with a piece of dead surface tissue being placed on the medium so that statistics are not really possible on adverse effects of treatment or medium. However positive results can be interesting.

The African violet, for instance, proliferated from both leaf and petiole segments on Cooke's medium, also on M & S medium A.

Chrysanthemums seem to grow on anything but also rooted well on M & S 1962 (16) as well as on Eark & Langhans (6).

In the early stages I had problems getting roots and so took the plant out of the medium, cut off the shoots, dipped them in Formula 20 and potted them up. Away they went saving a whole stage of sterile culture. This is now recommended for *Saintpaulia* (8) and *Episcia* (17) but I think might well be tried for many more species.

Mark Cunningham of Waldron, Ind. recommends a 2 year special academic training and suggests that, for greater opportunities, at least a Masters degree in lab management (2) be obtained.

Miss Lila Dick, teaching micropropagation to students in Scotland, reports on it as a Horticulture Science topic in schools, a compulsory lab class in 1st year of Ordinary National Diploma in Horticulture at college and also as a thesis topic for B.Sc. post graduate and for the Ph.D. degree (5).

Dr. de Fossard's tissue culture course in Australia runs for a week.

Ryde School of Horticulture teaches tissue culture as a third year elective, and at Burnley Horticultural College, the Diploma student learns to use tissue culture techniques to produce fern and orchid mericlones (10). All we are doing is making students aware of a new technique. Should we be doing more or is this a laboratory rather than a horticultural exercise?

Our course is being revised. Should laboratory techniques and chemistry calculations be compulsory subjects? Should tissue culture be an elective or a post certificate course or do we keep it low profile and leave the laboratory training to the School of Biological Science, College of Advanced Education or to the university level?

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PASTEURIZATION OF GROWING MEDIA BY MICROWAVE RADIATION

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Abstract. The pasteurization or disinfestation of growing media is now an accepted part of nursery hygiene. Media can be pasteurized by physical or chemical means, but the preferred method of treatment involves steaming the medium at 60°C for 30 minutes. Such methods are essentially a disinfestation, as some organisms survive the treatment.

Methods of pasteurization suffer from disadvantages such as high cost, time consumption, and a limitation in the volume treated. Thus a new

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Methods of pasteurization suffer from disadvantages such as high cost, time consumption, and a limitation in the volume treated. Thus a new

method of media treatment has been investigated — the exposure of the media to microwave radiation.

Although the method is restricted in the volume of material that can be treated, it is a very rapid technique and because the material is heated directly it is also energy efficient. The method can be used to either completely sterilise media, or to disinfest them so that at least some of the bacteria and saprophytic fungi survive.

It is envisaged that the technique could be used to treat a continuous supply of a medium moving along a conveyor, thereby eliminating a major bottle-neck in nursery production.

INTRODUCTION

A system of nursery hygiene is normally implemented to promote healthy plant growth by minimising the outbreak of disease. This system emphasises the prevention of disease rather than its cure and has been widely accepted because nurseries simply cannot afford high plant losses. In Australia, hygiene programs are based upon the views of Baker (1), which require the use of clean stock, clean soil, and a sanitary method of growing plants. It is the preparation of clean growing media that is the subject of this paper.

The use of pasteurized media means that plants are grown in material which is either free from pests and diseases that may be detrimental to plant growth, or that the incidence of pests and diseases has been reduced to an acceptable level (4). Of the many methods used to treat media for pasteurization, only two have achieved wide acceptance — chemical treatment of the medium, and the use of heat and/or steam.

The chemical treatments involve the use of gases, volatile liquids, or fungistatic drenches (2). The most widely used of these methods involves the injection of a liquid into the medium, allowing the chemical to vaporise.

The medium is sealed under plastic, which traps the gas, and is allowed to stand for 24 to 48 hours. Depending upon the chemical used, it may not be possible to use the medium for several days or even weeks, as the sterilant remains in the medium. Other problems associated with chemical pasteurization include the non-specificity in what is killed, the danger to the user and inadequate penetration of the medium.

The use of dry heat to pasteurize media invariably reduces moisture levels and, because higher temperatures are required than for steam or steam-air techniques, they are often fuel inefficient. Media are generally slow both to heat and to subsequently cool. Furthermore, since the conduction of dry heat through the medium is relatively poor, these techniques also suffer from the problem of inadequate penetration.

Thus the use of steam or steam-air mixtures remains as

the most widely used and preferred technique for media pasteurization. The steam is passed through the medium, raising its temperature to 60°C, at which temperature it is maintained for 30 minutes. The medium is then allowed to cool to atmospheric temperatures before it is used. Properly controlled, steam pasteurization eliminates harmful organisms, but beneficial micro-organisms survive. The technique is more effective than the other methods described because the use of steam enables a rapid and even conduction of heat through the whole volume of the medium. The use of steam is more effective than dry heat because the specific heat of water is about four times that of air.

All of the methods so far described suffer from some common problems. They are all comparatively expensive procedures, either to operate or to establish. They handle only small volumes of media and they are time-consuming. Thus media pasteurization often becomes the bottleneck of the nursery production line. Furthermore, there is often an uneven treatment of the medium and the nutrient status of the medium may be altered. Thus a cheaper, simpler, and more rapid system of media pasteurization has been sought.

The use of microwave radiation to pasteurize media seems to overcome many of these problems. Preliminary studies on the technique have shown that it effectively kills micro-organisms and that killing is very rapid (3). The radiation heats the water molecules inside organisms, as well as those inside the medium, and so it kills directly. It is a very rapid treatment and, despite limitations in the volumes of media that could be treated, it appears to be an energy efficient process.

MATERIALS AND METHODS

So that the results could be applied to a variety of growing media, two soil-based and two soil-less media were treated (Table 1). Each of the media was sterilised by either steam or microwave methods. Steam sterilisation involved heating at 60°C for 30 minutes, while samples to be irradiated were placed inside a Litton or Sharp domestic microwave oven with a radiation frequency of 2450 MHz. The media were exposed to the radiation for durations of 0.25, 0.50, 1.0, 2.0 and 6.0 minutes. Three replicates were used for all treatments.

After sterilisation, 50.0g samples of the media were placed in 50.0 ml of sterile water. The water was then filtered from the media and diluted to one in 10, 10^2, 10^3, 10^4, or 10^5 times in sterile water; 2.0 ml samples of each of these dilutions were then placed on plates containing malt extract agar, with the pH adjusted to 3.5 with lactic acid. At most dilutions there was so

Table 1. Media treated by steam or by microwaves.

Soil Based Media		Soil-less Media	
A.	30 parts sandy loam 15 parts mountain soil 6 parts coarse sand	B.	1 part sawdust 1 part scoria 1 part sand
D.	1 part sandy loam 1 part fine bark 1 part sawdust	C.	1 part brown coal 1 part coarse sand 1 part scoria

much fungal growth that identification was not possible, but the one in 10^5 dilution provided individual colonies, that could be easily separated and identified. The low pH of the agar deterred the growth of bacteria and the plates were incubated in the dark at 20°C for ten days before the colonies were counted and identified.

Because there were no pathogenic fungi present (or at least recovered by the technique described above) in any of the media, the microwave technique had not been shown to be effective against them. Accordingly, water-agar plates were inoculated with isolates of *Pythium* spp., *Phytophthora cinnamomi*, *Fusarium oxysporum*, *Rhizoctonia* spp. and *Penicillium* spp. These plates were then exposed to radiation for durations ranging from 3 to 24 seconds. The exposure times are so brief because the agar boils very quickly. The subsequent growth of fungi was then observed after incubation for four days in the dark at 20°C. It is interesting to note the responses of water, agar and potting media to exposure to microwave radiation (Table 2). The technique can be used to sterilise both water and agar, which may be of importance for tissue culture work.

Table 2. Duration time — temperature (°C) for different media after exposure to microwave irradiation

Duration (min.)	1	2	4	6	10	20
Soil mix	88	89	97	108	128	183
Agar (20g/l)	74	99	100	—	—	—
Water	66	100	100	100	100	—

In addition to the effects that microwave radiation has on microorganisms, they alter the medium itself.

Consequently the effects of microwave radiation on soil temperature and moisture content were monitored. The pH and conductivity of the media were also measured to determine whether the microwaves altered the nutrient status. These changes were then compared with the changes wrought by steam sterilisation. For these studies the media were fertilised with either Osmocote or Nutricote while they were being mixed. A more thorough mineral analysis was made by Consolidated Fertilizers, Ltd.

Finally the microwave oven itself was investigated to determine its reliability as a source of microwave radiation. The time versus power relationship to cause the boiling of agar was also established. The use of domestic microwave ovens for this study was far from ideal, but they did allow the study to proceed and valuable information to be obtained.

RESULTS

The microwave ovens used provided a consistent and controllable level of radiation (Figure 1). Treatment with the microwave radiation raised media temperatures very rapidly. (Figure 2), and consequently dried the media (Figure 3). Neither steam nor microwave sterilisation of the media caused significant changes in their pH (Table 3), although there were some minor changes in pH with time after treatment. Both pasteurization techniques increased the conductivity of fertilised media (Table 4), but it is worth noting that the microwave radiation had a less drastic effect than the steam. Again the conductivities increased with time after the pasteurization procedure.

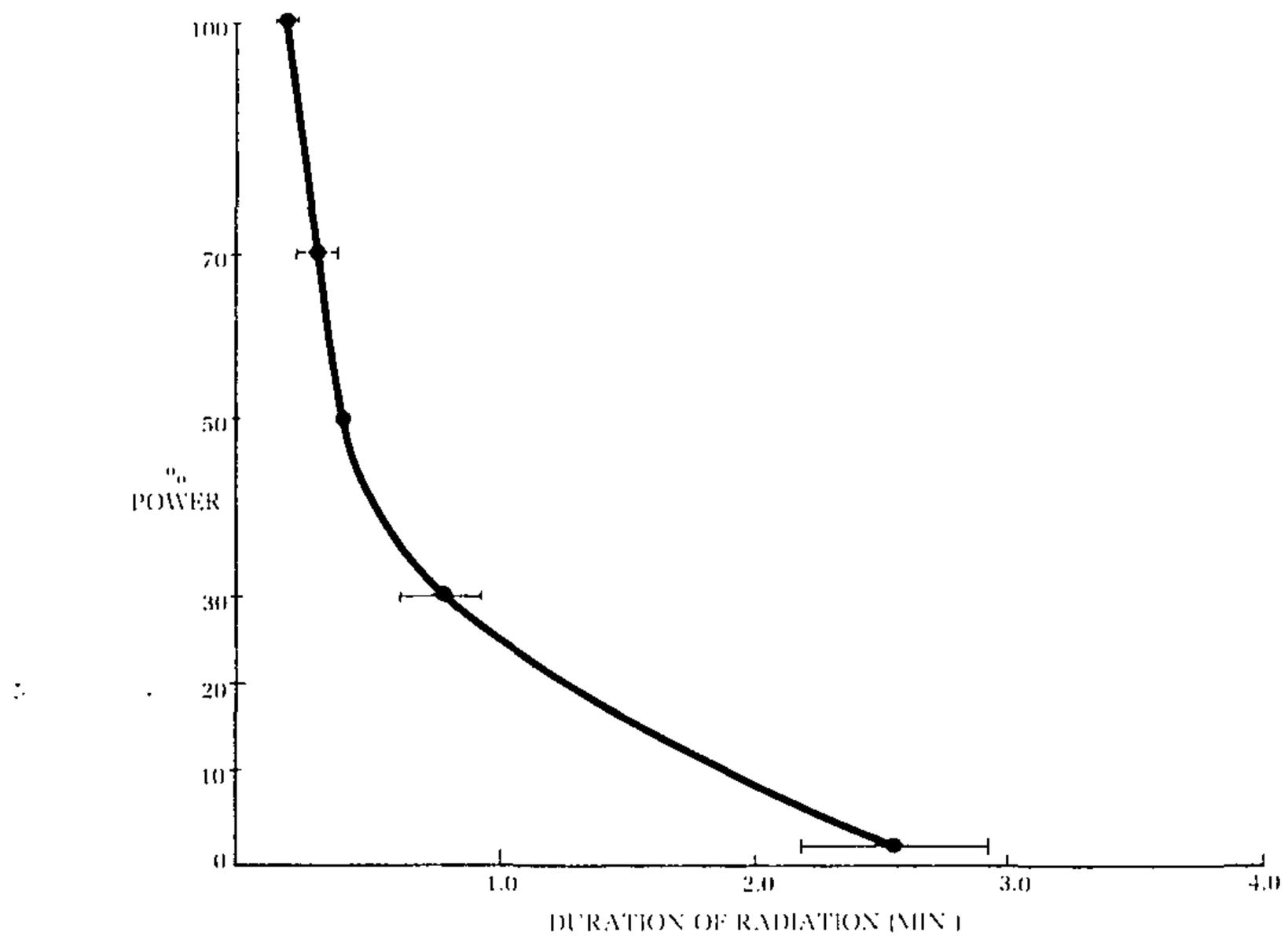

Figure 1. Duration of radiation versus power required to boil agar (P.D.A.)

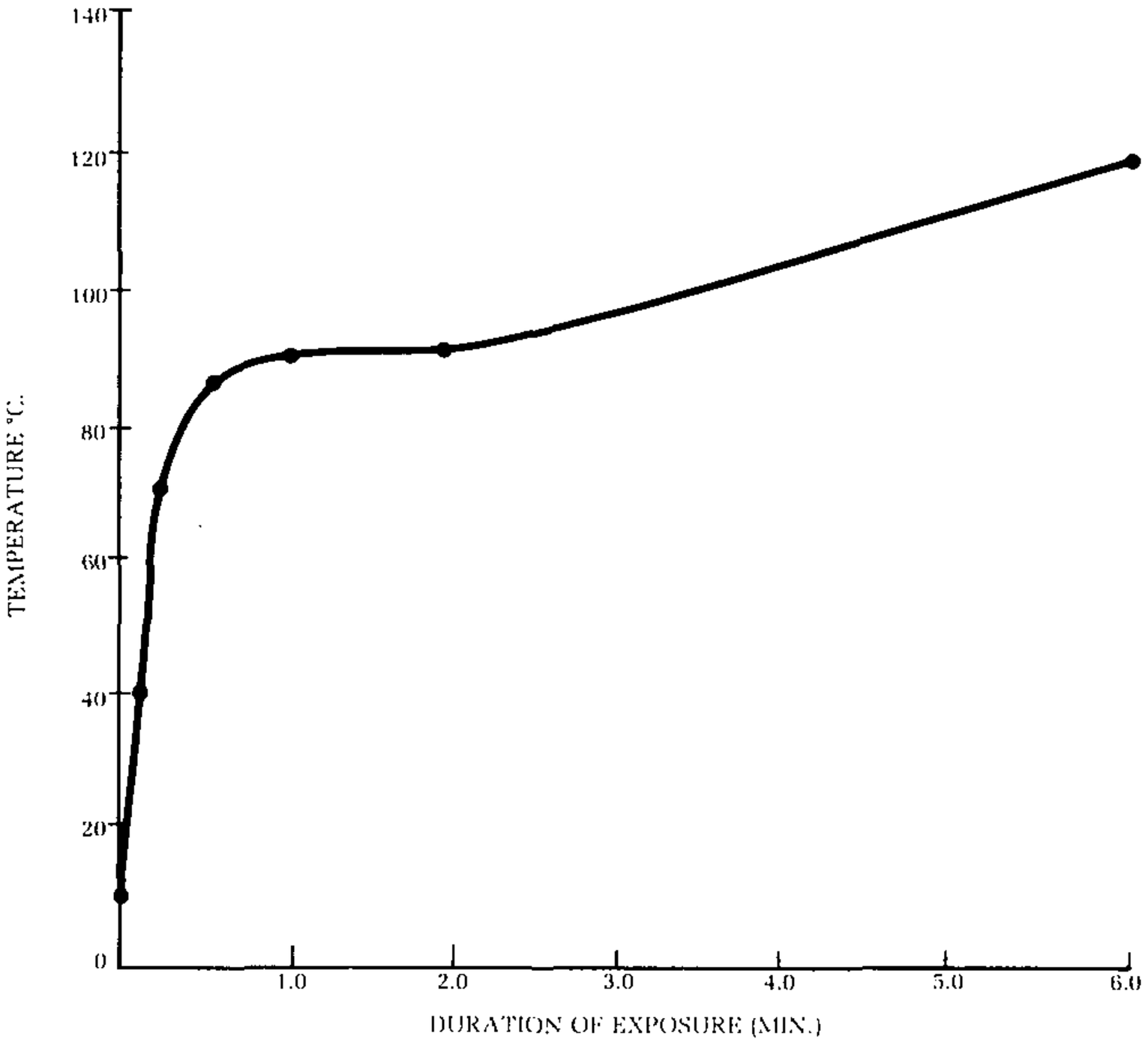

Figure 2. Media temperature versus duration of exposure to microwave radiation

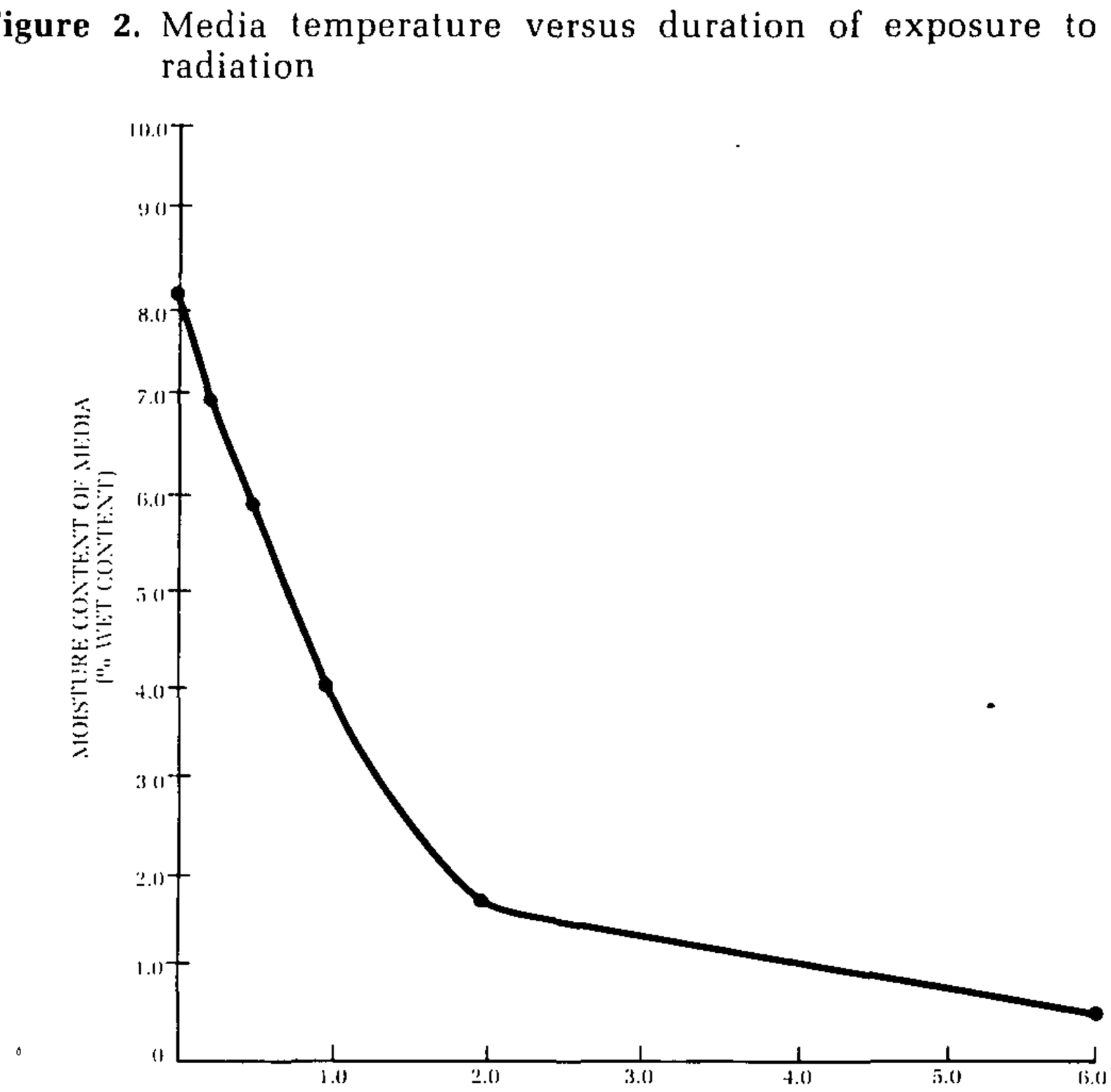

Figure 3. Moisture content of media versus duration of microwave radiation.

Table 3. Effects of steaming and microwave treatment on the pH of media

Media type	Control	Steaming	Microwave (5 Min.)
Soil-based + Osmocote	5.1	5.0	4.9
Soil-based + Nutricote	5.1	4.8	4.9
Soil-less + Osmocote	5.2	5.1	5.4
Soil-less + Nutricote	5.3	5.2	5.4

Table 4. The relative effects of steam and microwave treatment on the conductivity of various media

Media type	Steam treatment	Microwave
Soil-based + Nutricote	0.30	0.33
Soil-based + Osmocote	0.25	0.27
Soil-less + Nutricote	0.36	
Soil-less + Osmocote	0.49	

Note: Conductivities measured in $MS.CM^{-1}$

The mineral analysis of microwaved media showed the same type of result (Table 5), where there are only slight increases in the microwaved media in comparison with untreated media. Many of the differences can be regarded as insignificant.

Table 5. Mineral analysis in parts per million.

Media: — Microwaved — Oven-dried	NO_3	P	K	Ca	Mg	Fe	Cu	Mn	Zn	Na	Cl
Soil-based +	54.5	98	53	628	135	94	8.4	36	19.2	39	10
Osmocote	60+	80	97	523	103	92	9.9	49	20+	25	10
Soil-less +	60+	200+	1023	3244	1570	200+	15.1	101	20+	297	135
Osmocote	60+	200+	640	3321	1590	182	14.6	100+	20+	316	105
Soil-based +	34.5	56	39	537	114	111	10.4	48	20+	24	10
Nutricote	42.5	102	44	566	225	68	6.9	36	17.1	34	10
Soil-less +	60+	200+	442	3056	1372	200+	5.7	66	18.0	266	80
Nutricote	60+	200+	524	3030	1394	200+	3.6	74	13.5	298	60

Both steam and microwave pasteurization reduce the number of fungi and bacteria present in the media (Tables 6 and 7). Microwave treatment has the greater effect of the two and may sterilise the media completely. If short durations of microwave radiation are applied then both fungal and bacterial populations may be reduced without being entirely eliminated. Microwave irradiation of agar plates inoculated with fungi shows that the fungi may be killed and the plates sterilised very rapidly (Table 8). Thus the radiation effectively kills known plant pathogens.

Table 6. The effects of steam-treatment on fungal and bacterial populations

Medium	Steam-Treated	Untreated
A. Soil-based	Fungi: 18 Bacteria: 2 Total: 20	Fungi: 14 Bacteria: 9 Total: 23
B. Soil-less	Fungi: 21 Bacteria: 1 Total: 22	Fungi: 45 Bacteria: 11 Total: 56
C. Soil-less	Fungi: 21 Bacteria: 11 Total: 32	Fungi: 24 Bacteria: 1 Total: 25
D. Soil-based	Fungi: 16 Bacteria: 8 Total: 24	Fungi: 32 Bacteria: 2 Total: 34

Table 7. Effects of microwave exposure on microbial populations.

			Exposure to radiation (minutes)					
Medium	Microorganism	Control	0.25	0.50	1.0	2.0	6.0	10.0
A.	Fungi	23	2	8	1	2	2	—
	Bacteria	3	—	—	1	—	—	—
	Total	26	2	8	2	2	2	—
B.	Fungi	45	3	—	1	—	—	—
	Bacteria	11	4	—	—	1	—	—
	Total	56	7	—	1	1	—	—
C.	Fungi	24	2	—	—	—	—	—
	Bacteria	1	2	2	1	1	1	1
	Total	25	4	2	1	1	1	1
D.	Fungi	32	—	—	—	—	—	
	Bacteria	2	1	1	1	1	1	—
	Total	34	1	1	1	1	1	—

Table 8. Effect of microwave exposure on fungal cultures.

	Power rating (%)										
	0	50				70			100		
Duration (sec.)	0	6	12	18	24	6	12	18	3	6	12
Pythium spp.	✓✓✓	✓✓✓	✓xx	xxx	xxx	✓✓✓	xxx	xxx	✓✓✓	✓✓✓	xxx
Phytophthora cinnamomi	✓✓✓	✓✓✓	xxx	✓xx	xxx	✓✓✓	xxx	xxx	✓✓✓	✓✓✓	xxx
Fusarium oxysporum	✓✓✓	✓✓✓	✓✓✓	✓✓✓	xxx	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓x
Rhizoctonia spp.	✓✓✓	✓✓✓	✓xx	✓xx	xxx	✓✓✓	xxx	xxx	✓✓✓	✓✓✓	xxx
Penicillium spp.	✓✓✓	✓✓✓	✓✓✓	✓✓✓	xxx	✓✓✓	✓✓✓	✓xx	✓✓✓	✓✓✓	✓✓✓

NOTE: ✓ Indicates culture activity growing
x Indicates culture has been killed

In summary, the results show that the pasteurization of potting media and agar plates by microwave radiation is more rapid and effective than the use of steam. It also appears that microwave radiation has fewer effects on the physical proper-

ties of the media treated. Microwave radiation may be used to either pasteurize or sterilise media.

DISCUSSION

Although somewhat limited, this study shows the potential of microwave radiation as a viable alternative to the other forms of commercial media pasteurization. The technique clearly provides an efficient means of raising media temperatures. This is because the radiation acts directly upon the water molecules held within the medium, and does not rely on heating and conducting heat from other components therein.

Indeed, provided there is sufficient water in the medium, microwave radiation pasteurization is essentially a steaming process, with the steam being generated within the medium itself.

Unlike conventional heat systems, which heat the surface of a mass first and then the rest of the mass is heated by conduction, microwaves penetrate the mass according to an inverse square law. Thus the medium is heated simultaneously both at the surface and within. This explains why media temperatures rose so dramatically, and why there is such an even penetration of heat through the whole medium. For the microwave radiation to raise the temperature, the media must have relatively high moisture content. It would seem that moisture contents of between 10 and 15% are suitable for pasteurization; most potting and growing media would contain about these levels of moisture. Because exposure times are so brief it is unlikely that the technique would dry the media to any significant extent.

Both steam and microwave pasteurization techniques alter the physical and chemical properties of the media. Most of these alterations are small, but the changes in conductivity may be important. Steam does appear to cause an initial release of nutrients from the fertilizers, while the release due to microwave radiation is smaller. The release of nutrients by steam is probably due to the combination of high temperature and moisture level. It is also worth noting that soil-less media consistently have higher conductivities than soil-based media. The relatively low release of nutrients by microwave radiation is regarded as another advantage of the technique.

There is no doubt that microwave radiation represents an effective means of killing living organisms. Both fungal and bacterial populations may be reduced or eliminated entirely by this technique. By choosing the appropriate exposure times it is possible to eradicate pathogens, while leaving at least some

of the beneficial micro-organisms alive. Since microwave radiation acts directly on water molecules, and because most organisms contain high levels of water, many microbes will be killed directly by the radiation rather than by the heat conducted from the media. This is a far more efficient means of achieving pasteurization than any of the other techniques. For this reason too, many of the troublesome weed seeds that can survive steam sterilisation would be killed by the microwave technique.

The microwave technique, however, is not without its problems. No large volume trials have been performed to determine the efficiency and economy of the technique in a commercial situation. The radiation is dangerous and adequate operator-safety must be assured. Such problems do not seem to be insurmountable; it has been suggested that the power of commercial units could be as high as 60 kw with a frequency of 896 or 915 MHz, which would be cheaper to manufacture and allow deeper penetration (see acknowledgements). Large microwave generators are already in use in other industries and the safety problems have been solved, so this no longer represents a limitation to the use of microwave radiation in nursery sterilisation techniques.

Microwave radiation can be used for many other laboratory sterilisation procedures. It has been used for the preparation and sterilisation of agar plates in this study, and may replace the costly and time-consuming exercise of autoclaving in many laboratory and tissue culture procedures. Although this work concerns only the sterilisation of growing media, other work is proceeding that investigates the use of microwave radiation as a more general sterilising technique.

The system of pasteurization described in this paper is not suitable for commercial use. The system envisaged for this purpose (Figure 4), involves the use of a continuous supply of mixed media passing along a conveyor, through a "tunnel microwave generator" to a work bench. This would allow the pasteurization of large volumes of media and, because it is a continuous process, the usual production bottleneck would be eliminated. The variable speed at which the conveyor may operate provides a means of altering the exposure of the media to the radiation.

In conclusion, it can be seen from the results reported here that microwave radiation provides a rapid and efficient means of pasteurizing growing media. Although full commercial studies have not been done, it would seem that this process may be more economic than other processes because exposure times are so brief. The direct killing of organisms rather than relying on the conduction of heat contributes to

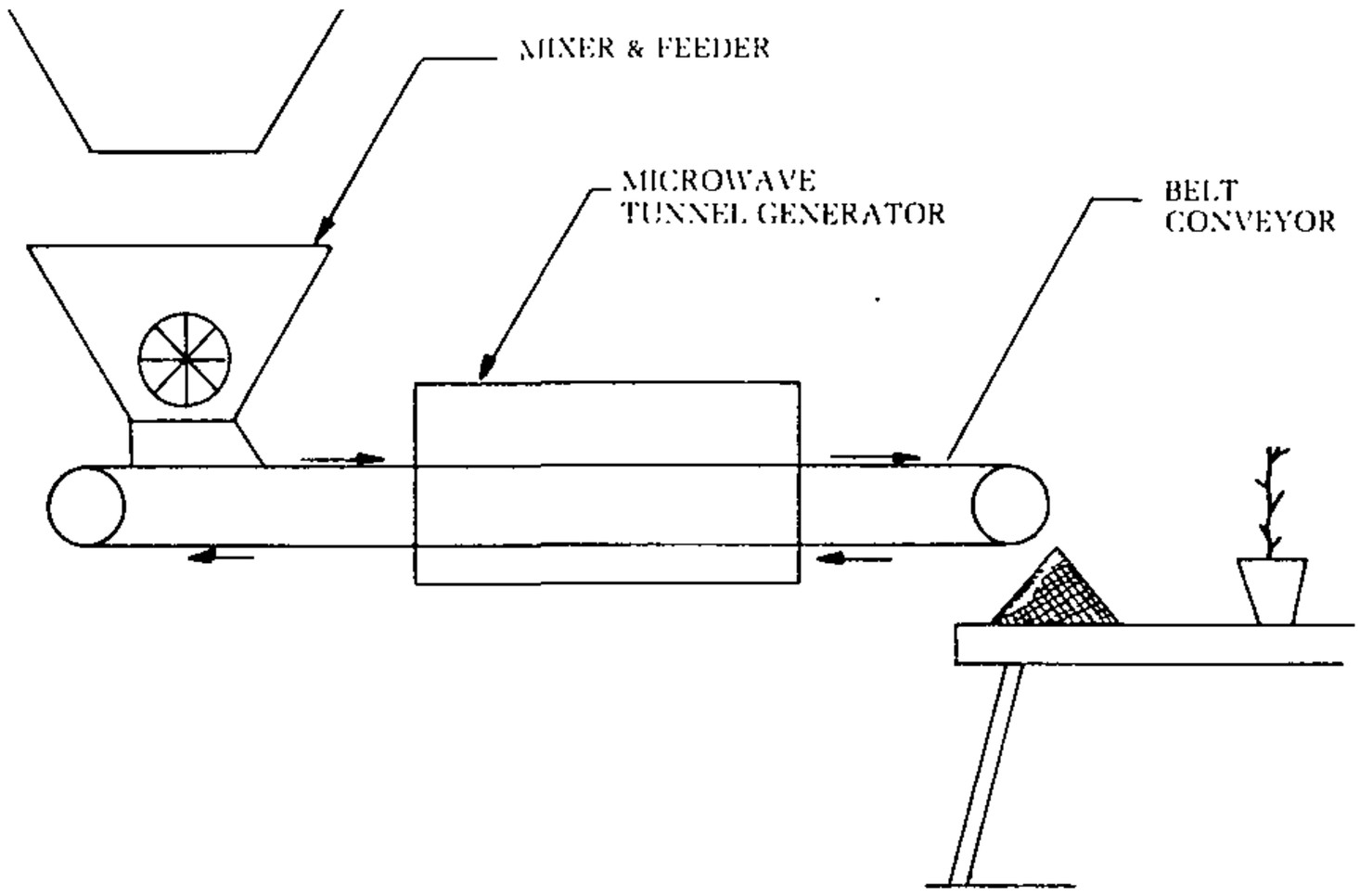

Figure 4. Schematic diagram of a microwave sterilisation technique.

both the speed and the efficiency of the process. The application of the microwave technique to other pasteurization or sterilisation processes should not be ignored.

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GROWING CLEMATIS JACKMANII HYBRIDS

RUTH E. AULD and ARTHUR CARRALL
Castle Hill Nursery Pty. Limited
Kellyville, New South Wales

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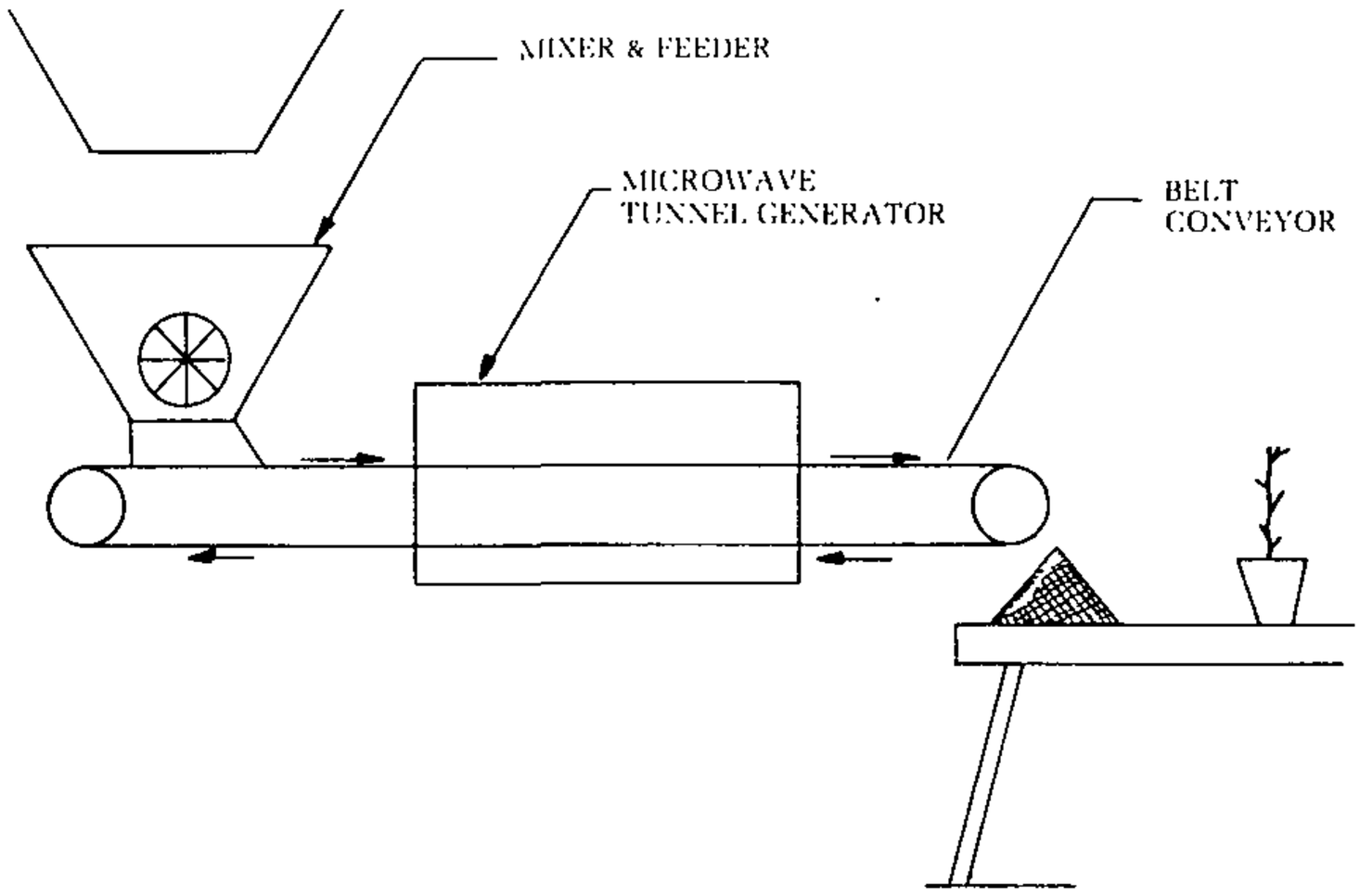

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carefully selected and the roots kept cool by placing flat stones or rocks on the soil surface over the root area some degree of success can be obtained.

It is worthwhile to note that although clematis can be difficult to grow and provides few problems, lucrative markets for this beautiful flowered climber are available in the Mountain and Tablelands areas of New South Wales as well as for interstate shipments.

To be successful in growing clematis hybrids a programme of sanitation must be employed to eliminate disease rather than trying to arrest it after the cutting material or plants have been affected. Such a programme must start before the cuttings are taken from the mother plants. Common sense and regular attention to sanitation are essential requisites for success.

MATERIALS

Cutting material was obtained from the Southern Tablelands and brought to Sydney in an insulated van — a journey of approximately 7 hours. When material is kept in plastic bags it remains turgid for at least 3 days, even the flowers remaining fresh.

The mother plants were sprayed once a week from the time the foliage appeared until one week prior to collecting cutting material. They were sprayed with captan (2 oz.) and Benlate (¼ oz.) + 1 tsp. wetting agent, in 100 litres of water.

We also believe that the leaves are more prone to drop if the cuttings are sprayed after they are severed from the mother plants and processed into cuttings.

METHODS

Time for making cuttings was in the spring, from September until mid-November. The green wood was considered suitable as soon as it began to firm and reach the stage when it would snap without bending. The material was cut in the early morning while the dew was still on it — before sunrise.

Cuttings are made with two nodes, having prominent buds which ensure good growth and development. The cuttings, 7 to 12 cm in length, are severed 7 mm below the bottom node; the lower leaves are removed and the top leaves halved.

Cuttings are treated with a 5 sec quick-dip of 0.4% IBA, and community planted in 175 mm squat pots, 25 cuttings to a pot.

Fifty mm pea gravel is washed and sterilized and placed in the bottom of the pots for extra drainage to a depth of 14

mm. The remainder of the pot is filled with a mix of 2 parts German peat to 3 parts screened coarse washed river sand.

The cuttings are dipped in the IBA solution to a depth of 7 mm and inserted in pots and placed in a glasshouse with bottom heat set at 21°C. Intermittent mist is employed with a Jeffrey's Weatherwatch, which misted approximately every 8 to 10 minutes during the hot part of the day, for about 10 seconds. At that time of the year the temperature fluctuated between 20° to 25°C. Callus formed in 3 to 4 weeks and roots were initiated from 6 weeks on.

No dead leaves or material was removed from the pot surface and some browning off occurred. This did not prove a deterrent as once the buds burst they continued to make growth. At 7 weeks the cuttings were taken from the glasshouse and placed in a shadehouse for a further 10 days and given a syringe of water during the hottest part of the day.

Although the strike rate was only 70%, it was noted that the top section of some cuttings died although the lower nodes under the surface remained healthy; having been repotted into propagation mix at various times, they produced shoots which proved to us the value of double-noded cuttings.

Cuttings were then potted into 75 mm tubes with John Innes soil mix and placed in a shadehouse of 65% shadecloth. The young plants made rapid growth, and in January were repotted in 150 mm pots and staked.

Some plants bloomed and were sold in the autumn, but the bulk of the crop was wintered over in the shadehouse until spring. They were then top dressed with sand, and hoof and horn meal which promoted rapid growth, enabling the plant to reach the top of the 50 cm stake in a few weeks; most terminated with a beautiful flower 7 to 17 cm across, according to the cultivar.

One experiment used was to make the cuttings at the site where the mother plants were grown, process, bundle and wrap them in wet newspapers then place them in plastic bags for transportation. This proved quite successful.

It was noted that a dressing of 3 year old chicken manure applied to mother plants during late autumn was beneficial and produced strong vigorous growth and superior flowers.

The inclusion of coarse ash to our sawdust mix improved drainage and aeration.

Ingredients for composting sawdust were: 60 cu. yd sawdust, 15 cu. yd pinebark, and 15 cu. yd coarse ash

Fertilizers added were:

Single superphosphate	23 Kg.	Iron sulfate	12 Kg.
Sulphate of potash	46 Kg.	Urea (46 %N)	140 Kg.
Gypsum	60 Kg.	Agra magnesium, 95%	30 Kg.
Esminel	12 Kg.		

CONCLUSION

Rooted cuttings of *Clematic jackmanii* hybrids may be grown in the Sydney, Australia metropolitan area up to marketing sizes providing care is taken with all steps of the procedure mentioned and particular attention is given to the timing of taking cuttings and subsequent handling of the rooted cuttings.

POPLAR BREEDING

RUDOLF R. WILLING

"Bonhaven"

Yass, New South Wales

Poplars have been grown in many widely different regions of the world since very early times, especially in the East and Far East. In Europe, when the North American poplars were introduced and hybridized with the European poplars, the expansion of poplar cultivation really began.

In Australia the early settlers introduced several species, growing them mainly as ornamental trees. Only very few clones were known: two clones of *Populus alba*; the Lombardy poplar, or *P. nigra* 'Italica.' (the best known poplar of them all); the Yunnan poplar, *P. yunnanensis*; and the American cottonwood, *P. deltoides*. There are no native poplars in Australia nor in the Southern Hemisphere. All poplars growing in southern Africa, South America, and New Zealand are introduced or mainpulated clones. In the 1940s some of the so-called "Schreiner hybrids" were introduced. They are known as Androscoggin poplar, Geneva poplar, Oxford poplar, and Rochester poplar. They are hybrids between species of the section AIGEIROS and TACAMAHACA, and are grown in Australia mainly as ornamentals. A little later the introduction of the well-known Italian hybrid-clones I-154, I-214, I-488 and a few others occurred to add some poplar clones which could be of interest to the wood-producing industry. In the late 1950s the match companies decided to grow their own raw-material: poplar wood for making match splints locally. It was near Grafton, N.S.W. where the first plantation for growing match wood was established. This interest in poplars stimulated the research work already underway in the Botany Department of the A.N.U. Under the direction of Prof. L.D. Pryor, work on the introduction of semi-evergreenness into cottonwoods was already in progress and, besides species and provenance intro-

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Yass, New South Wales

Poplars have been grown in many widely different regions of the world since very early times, especially in the East and Far East. In Europe, when the North American poplars were introduced and hybridized with the European poplars, the expansion of poplar cultivation really began.

In Australia the early settlers introduced several species, growing them mainly as ornamental trees. Only very few clones were known: two clones of *Populus alba*; the Lombardy poplar, or *P. nigra* 'Italica.' (the best known poplar of them all); the Yunnan poplar, *P. yunnanensis*; and the American cottonwood, *P. deltoides*. There are no native poplars in Australia nor in the Southern Hemisphere. All poplars growing in southern Africa, South America, and New Zealand are introduced or mainpulated clones. In the 1940s some of the so-called "Schreiner hybrids" were introduced. They are known as Androscoggin poplar, Geneva poplar, Oxford poplar, and Rochester poplar. They are hybrids between species of the section AIGEIROS and TACAMAHACA, and are grown in Australia mainly as ornamentals. A little later the introduction of the well-known Italian hybrid-clones I-154, I-214, I-488 and a few others occurred to add some poplar clones which could be of interest to the wood-producing industry. In the late 1950s the match companies decided to grow their own raw-material: poplar wood for making match splints locally. It was near Grafton, N.S.W. where the first plantation for growing match wood was established. This interest in poplars stimulated the research work already underway in the Botany Department of the A.N.U. Under the direction of Prof. L.D. Pryor, work on the introduction of semi-evergreenness into cottonwoods was already in progress and, besides species and provenance intro-

ductions and evaluation, work was aimed at the production of hybrids between species of different sections within the genus.

Most poplars are very sensitive to photoperiod. Poplar species or clones derived from parents originated at high latitudes perform poorly in low latitudes. Bud-dormancy occurs early and leads to limited height and diameter growth. Those long-day clone's performance in Grafton, latitude 29°S, is unsatisfactory and makes the selection of successful clones imperative. On the other hand, poplar species or clones from low latitudes, or the semi-evergreen clones, fail to go dormant in high latitudes and are severely damaged or killed by low winter temperatures in these latitudes. The great variation in clonal behavior makes it important to select the most suitable clones for a particular latitudinal environment. The best performers in Grafton are not the clones to be grown in Victoria or Tasmania and vice versa. Of all the poplars tested in Grafton, it was the cottonwood, *P. deltoides missouriensis* (syn. var. angulata), which gave best results. We responded by two methods: raising provenances from low latitudes (Texas, Mississippi), and selecting the best performers. On the basis of form, growth rate, and disease resistance, clonal selections were made and this material is the basis of the Grafton plantation. This simple method of raising provenances from imported seed from the southern U.S., and selecting and cloning the most suitable individuals is very effective and will yield many good poplar clones in the future.

The second method used to produce poplars most suited to a particular environment is hybridization. Intrasectional hybrids are easily produced and no difficulties experienced. Our main objective in this particular programme was to try to combine semi-evergreenness with the qualities of the cottonwoods. We already had some data collected from previous experiments, crossing *P. deltoides* (Syn. *P. monilifera*) with the semi-evergreen clone *Populus nigra* 'Persistente'. This semi-evergreen poplar is, in experiments, completely day neutral. In growth cabinets, under a 6 hour day-length, growth was still continuous. At sites where poplar planting is carried out in Australia winter temperatures are endured. Budbreak and growth begin as soon as temperature and moisture conditions are favourable. In milder climates leaves are retained until the next season's leaves begin to emerge. This semi-evergreen clone is a *male* and during the growing season difficult to distinguish from *P. nigra* 'Italica'. *P. nigra* 'Persistente' has been grown in Chile for a long time and is considered to be a mutation of *P. nigra* 'Italica'.

We knew that the segregation pattern in the F_1 produced 50% deciduous and 50% semi-evergreen types. We speculated

that semi-evergreenness is based on one single dominant gene. The semi-evergreen parent is heterozygous, semi-evergreen being dominant to the deciduous habit, and the cottonwood homozygous recessive. A large number of hybrids with various cottonwood clones has been made; the segregation pattern was as expected and selections of evergreen segregates with good growth and form were selected and cloned. A number of clones proved very successful in Grafton and also under irrigation at Cobrawonga, Victoria. Many of these semi-evergreen clones are very well suited to shelterbelt- and windbreak stands. Unfortunately, at this time (1965), hybridizing and therefore the introduction of semi-evergreenness into other species could be done only within the section AIGEIROS, the black poplars. Despite the compatibility that exists between the AIGEIROS and TACAMAHACA sections, crosses could not be made, as at that time no female clone of the TACAMAHACA section was available in Australia. We have *P. yunnanensis* and *P. simonii* as male clones and, as already stated, *P. nigra* 'Persistente' is male also. This situation has changed. Some new clones of *P. yunnanensis* have been imported and seedlings of several provenances of *P. simonii* are in cultivation. Apart from direct crosses with the *P. n.* 'Persistente', hybridizing with semi-evergreen cottonwood hybrids, which have reached the flowering stage by now, would achieve a similar result.

In the meantime the situation concerning the possibility of producing hybrids intersectionally has changed completely. It is now possible to interbreed any two poplar clones or species from different sections and combine desired features in new hybrids.

Populus is divided taxonomically into five sections, representing some 30 species with numerous subspecies. The number of provenances and clones is endless.

The five sections are:
A. TURANGA; B. LEUCE, with 2 Subsetions: TREPIDAE and ALBIDAE; C. AIGEIROS; D. TACAMAHACA; E. LEUCOIDES.

The section TURANGA is represented by *P. euphratica* and its various subspecies. It is found in Turkestan, Iran, and Syria, where it is of economic importance; but it also occurs in Turkey, Pakistan, Palestine, Egypt, Libya, Algeria, etc. A tree of medium height, often bushy, *P. euphratica* is light and heat demanding and can tolerate brackish water. It is, among poplars, the most resistant to salinity. Its propagation is mostly done by seedlings. Softwood cuttings under high humidity strike readily but hardwood-cuttings are difficult to root. This

species cannot be hybridized with any others without special manipulation. Hybrids of this species seem to be very desirable. Our hybrids made between *P. euphratica* and cottonwood and between *P. euphratica* and *P. yunnanensis* are better trees, strike from hardwood cuttings, and seem to be salt-tolerant.

The section LEUCE with its two subsections, the aspens and the true white populars, covers vast areas, extending from the polar circle to North Africa. The many species of this section are important in many countries of Europe, the Middle East, and North America. Stem cuttings of the aspens do not root, though cuttings of hybrids between aspens and the white poplars do strike quite readily. Hybrids within this section can be found quite frequently and are easily manipulated. They do not hybridize with species of other sections without special manipulation.

The section AIGEIROS are the black poplars. Here we can distinguish between two groups: the Eurasian group, represented by *P. nigra*, and the North American group by *P. deltoides*, the cottonwoods. Hybrids between these two black poplars have been extremely successful and, in Western Europe, have practically ousted the native *P. nigra*. Members of the AIGEIROS section hybridize readily with each other; they also hybridize without special manipulation with species of the TACAMAHACA section and LEUCOIDES section.

The section TACAMAHACA, the balsam poplars, is represented in North America by its two native species: *P. trichocarpa* and *P. balsamifera* (Syn.: *P. tacamahaca*). In Asia *P. suaveolens*, *P. simonii* and *P. yunnanensis* are the native species of the balsam poplars. Within the section hybrids can be readily manipulated, also with species of the AIGEIROS- and LEUCOIDES sections.

The section LEUCOIDES is represented in the Far East and one species in North America. Representatives of this section seem to be compatible with species of the sections AIGEIROS and TACAMAHACA. We have been able to produce hybrids between *P. lasiocarpa* and *P. ciliata*, representing section LEUCOIDES, and with species of the TACAMAHACA and AGEIROS sections.

We can confirm that, within the five sections, the species, subspecies, and clones can be easily hybridized and are therefore compatible. Between the possible 10 cross combinations of the five sections *only* 3 combinations are compatible. They are: AIGEIROS X TACAMAHACA, AGEIROS X LEUCOIDES, TACAMAHACA X LEUCOIDES.

The remaining 7 possible combinations are incompatible. They are: AIGERIOS X LEUCE, AIGEIROS X TURANGA,

LEUCE X LEUCOIDES, LEUCE X TACAMAHACA, TURANGA X TACAMAHACA, TURANGA X LEUCOIDES, TURANGA X LEUCE.

Intensive research over many years to find a method to overcome the incompatibility barriers has finally been successful. Now we have several methods at our disposal and can produce hybrids of any desired combination between species of any section. It is difficult to imagine all the possibilities existing now to broaden the base for poplar breeding. It will give excellent opportunities for the selection of clones improved in growth, form, disease resistance and will widen the scope immensely.

To handle a large number of crosses in the glasshouse, branches bearing the female flowerbuds were grafted on to rooted cuttings and placed in different glasshouses, according to species and intended cross. The grafts were "bottle-grafts"; the understock was rooted about 4 months prior to grafting, the grafting was done 3 to 4 weeks prior to natural flowering in the field. White poplar females give good results by placing flower bud-bearing branches in containers filled with water. The development of white poplar seed is fast, so that grafting is not necessary. Seeds are germinated immediately on ripening in flats filled with a perlite-vermiculite mixture and covered by a sheet of glass. Germination occurs within hours. Nutrient application twice weekly brings the seedlings within 3 weeks to a size ready for transplanting into a mixture of 2 parts sterilized soil, 1 part peatmoss, and 1 part sand.

The poplar species vary greatly in their flowering time and, to be able to make any intended cross, especially with males of species flowering late in the season (*P. euphratica* flowers in mid-summer), pollen from previous years has to be used.

Pollen extraction and storage: branches bearing male flowerbuds are brought into the glasshouse or laboratory, separated according to species, about 4 weeks prior to anthesis in the field and placed in water-filled containers. Anthesis occurs about 2 weeks later and pollen is released over several days. Pollen is collected daily, desiccated over silica gel for 12 to 24 hours; it has to be dry and held at -18°C. Under those conditions pollen remains viable for several years and is the source of most pollen used for the various experiments.

A pollen grain, when it comes into contact with the stigma surface, will germinate by responding to specific conditions; it is interacting with the environment of the stigma. Very complex interactions of stigma- and pollen substances are taking place to allow the pollen to germinate, the tube to penetrate

the stigma surface, to grow through the stylar tissue and the micropile to release finally the nuclei and combine with the egg-nuclei to form the zygote. All these events are based on harmonious interaction of the various processes in pistil and pollen. Biochemical interactions, especially an interplay of enzymes and growth substances, coordinate events that lead to fertilization. It is understood that, if genome differences are such that these intricate and complex interactions do not occur, embryo formation cannot be achieved.

Our experiments in this field with the genus *Populus* enabled us to gain some insight into some events, which occur right at the beginning of the pistil-pollen interaction, germination and penetration. They lead us to believe that the mechanism for successful or unsuccessful interspecific interaction is based on the biochemical makeup of the tryphine of the pollen and the stigma surface. The exine products of the pollen (here called tryphine) are synthetized in the tapetum; they are transfered during the final stages of pollen maturation to the pollen grain and therefore are sporophytic in origin. Our experiments show that tryphine on its own, separated from the pollen grain, produced the same pistil-pollen reactions as complete, viable pollen grains. Hexane soluble materials from the exine (tryphine) of an incompatible pollen parent, coated on to a compatible pollen, renders this pollen incompatible, and vice versa; an incompatible pollen coated with compatible tryphine will produce reactions of a compatible pollen and produce viable embryos. The tryphine, as far as poplars are concerned, seems to be the carrier of materials responsible for the compatibility or incompatibility reactions.

To overcome the incompatibility we approached the problem in basically two ways and were able to achieve fertilization and to produce thousands of new hybrids.

A. We made up the shortage or replaced the information of the pollen carried by the tryphine by using "factor pollen" or exchanged the tryphine.

B. We disorganized or removed the inhibitor-promotor complex of the style by treating the stylar surface with certain reagents (organic solvents). Transplants of pistils and injections of pollen directly into the ovaries must be considered as modification only of this same principle.

To comply with the requirements of method A, we mixed live incompatible pollen with dead non-viable compatible pollen, termed "factor pollen" by us. We were able to obtain fertilization, the dead pollen supplying the necessary reaction materials for compatibilty and the incompatible pollen, the genetic material necessary. In such pollenmixtures it was

found that, until the percentage of the nonviable (killed) pollen reached about 50% of the mixture, there was little action by the incombatible pollen. Increasing levels of treated pollen of up to 90% produced highly successful responses. More than 90% of the number of seeds produced in a normal compatible cross was obtained. "Factor-pollen" was produced in two ways:

1). Repeated freezing and thawing, about 10 times, resulted in the loss of viability with little impairment of its reaction materials.

2). Gamma irradiation was done by exposing dry pollen to a radiation dosage of 100,000 rads from a cobalt source, and very good results with such pollen mixes were obtained.

For usage, "the factor-pollen" (of the compatible type) is mixed with fresh or frozen viable incompatible pollen, ratio 9:1, and dusted on receptive stigmas, using a small water colour brush. The whole inflorescence is treated at the same time. To exchange the tryphine, the two pollen types, a compatible one, and the incompatible pollen of the species to be used for hybridization, are immersed separately in an organic solvent, such as hexane, ethyl acetate, or toluene, to extract the tryphine and, after several minutes, filtered. No pollen grains must remain in the extracts. After evaporation of the solvents a fatty substance, mainly tryphine, remains. After mixing the pollen- "fat" of the compatible pollen with the incompatible pollen, this pollen becomes compatible and pollination can proceed. It is important not to use the alcohols, ethanol or methanol. They kill the pollen outright whereas the other solvents mentioned have no detrimental effect on the viability of the pollen grains and can be used for pollen storage also.

To test theory B, the stylar incompatibility reaction has to be inhibited, so that no callose and other pollen tube growth-interfering substances may be formed and delay, and finally stop the pollen tube growth of the incompatible pollen. This can be very easily and effectively done by removing the stylar surface exudates, using a solvent such as hexane. Just before pollination the stigma surfaces in the receptive stage are carefully brushed with a camelhair brush, which is slightly moistened with the solvent. Only small traces of the solvent must come into contact with the stigmatic surface; otherwise the tissue is "burned" and fertilization inhibited. Pollination can be carried out as soon as the solvent treatment has been completed, or it can be delayed for several hours.

The fact that the incompatibility reaction can be prevented, by either stigma or pollen treatment, suggests that at least two factors (one at each location) are involved and that the

incompatibility process is inactivated by the removal of either. We call them here P (pollen) and S (stigma) factors.

Developed and used by us, these methods have produced large numbers of hybrid populations which otherwise could not have come into existence. The base for poplar breeding is broadened very greatly.

Improving poplars for disease resistance becomes very important in Australia. In 1972 the poplar rust species, *Melampsora medusae*, appeared and, in the following year — 1973, *Melampsora larici-populina* became widespread. Several biotypes of these two rust races have developed and more will come into existence. Their virulence may change and, as a result, the level of resistance of the poplar clones may change also. Work done by Dr. W. Heather has helped us immensely to understand development and behavior of the *Melampsora* fungus as well as its enemy, the hyperparasites *Cladosporium* and *Eudarluca*. Breeding of rust resistant poplar clones is the basis of poplar silviculture in Australia.

The introduction of semi-evergreenness into all other clones of the remaining sections can now be easily achieved. Species and clones, difficult to strike from cuttings, but otherwise of interest and value, can be used as parents to produce progenies which root from stem cuttings. Soon we shall know if hybrids of those wide crosses can produce fertile seed. If they do, back-crosses can be made and all the hopes of the poplar breeder can come true.

THE NATURE OF CALLUS AND ITS IMPORTANCE TO THE PLANT PROPAGATOR

FREDERICK C. HELLRIEGEL

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Abstract. The ability of wounded plant tissue to regenerate is important for successful plant propagation. It enables a union to occur in budding and grafting, healing to occur at the base of cuttings, and allows rapid multiplication of selected plants in tissue culture techniques.

Regenerating cells from wounded tissues emanate primarily from the cambium region of the plant and they grow over the wound both radially and laterally. The overwalling of these cells is called callus and the nature of callus and its part in the rooting and unification process is explained in this paper.

With some species excess callus forms, inhibiting root primordia from emerging and preventing the formation of a viable root system on cuttings. This problem is examined with reference to the pH and nature of the propagating medium, the time of year of selection of cuttings, auxin application, wounding, trimming of callus, environment, and the type and condition of stock material. Certain recommendations are given for problems encountered with the propagation of some Australian native plants.

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1.0 Grafting. Success in grafting depends on various factors including species characteristics and compatibility, correct timing, protection of all cut surfaces, proper aftercare, and close cambial contact between the stock and the scion (13).

1.1 The Graft Union. The graft union may be considered to be the healing of a wound with an extra piece of tissue, the scion, incorporated into the wound. This healing process involves callus proliferation and is dependent on physiological and environmental conditions which are suitable for high cell activity. These normally occur during early spring.

The cambial regions of both the stock and scion are meristematic (the tissues are capable of dividing and forming new cells). Mass proliferation of parenchyma cells interlock and form callus tissue in this region. Once the wound has completely healed some of these cells will differentiate into cambial cells producing xylem and phloem and enable a vascular connection to be made between the stock and the scion.

The expert grafter will aim to align the two cambial regions as closely as possible because it is in this area that callus proliferation is the highest. Poor matching may result in a failed union or a delay in the healing process. In the technique of cleft grafting *Camellia reticulata* hybrids, which are poor callus producers, some nurserymen tend to slightly offset the scion to ensure intimate cambial contact for at least one point.

1.2 Role of Temperature, Oxygen and Moisture. More than 50 years ago Shippy (18) showed that with bench grafting of apples the rate of callus formation increases directly with temperature (range 4° - 32°C). In bench grafting and hardwood cutting operations, callusing can proceed steadily by storing the grafts at low temperatures (7 - 10°C) or rapidly by storing at higher temperatures (25 - 28°C) for a shorter time. The grafts or hardwood cuttings may then be kept at reduced temperatures to prevent further callus and root development dependent on the logistics of the grafting operation.

Shippy (18) also showed that because of the high respiration rate of actively dividing cells, oxygen and moisture are important factors in the production of callus tissue. Waxing or taping the union protects the developing callus tissue from desiccation. For some plants this may be a restrictive factor in callus development, e.g. some *Vitis* spp., and a water saturated environment without waxing is more desirable. In practice, callusing in peat provides this environment.

1.3 Graft Chimeras. Chimeras can occasionally occur from adventitious buds which arise from the callus around the graft

union. The Bizzarria orange is one such chimera which has been propagated by vegetative methods.

2.0 Budding. Budding may be considered to be a form of grafting, the main difference being in the technique. Only one bud is used whereas grafting uses a scion with several buds. The importance of good callus production is as essential with budding as it is with grafting.

2.1 The Bud Union. Mosse and Labern (16) have shown that in the technique of T budding the apple, the cambial layer of the stock actually remains on the inside of the bark flaps. The rootstock is responsible for producing most of the callus and it emanates from the exposed cells of the xylem cylinder. Providing environmental conditions are suitable, the callus begins rapid growth 2 days after insertion and continues for several weeks. The second stage involves formation of a continuous cambium between the bud and rootstock and complete lignification of the callus is completed in about 12 weeks.

Callus development differs marginally with other budding techniques such as chip, patch or flute, but in each case callus development is an essential part of the healing and unification process.

CUTTINGS

3.1 Callus Development. The development of callus at the base or along wounded surfaces of cuttings is, as it is in budding and grafting, a response by the plant to wounding. The regenerating cells from the wounded tissues emanate primarily from the cambial region (see Figures 1 and 2) and they grow over the wound both radially and laterally (1). This overwalling can, with some species and given certain conditions, occur to excess and a large thick mass of lignified callus may form at the base of the cutting. Some Australian members of the Proteaceae family commonly exhibit this problem, including species in the genera *Grevillea*, *Buckinghamia*, *Hakea*, and *Stenocarpus*.

Conditions favorable for the normal development of callus are also generally favorable for root initiation. This is why callus development was once considered an important factor in the root initiation of cuttings. It needs to be clearly stated that callus is part of the healing process and therefore should be considered separately to the rooting process. Only very rarely do roots actually originate in the callus tissue. The main advantage of callus development is in sealing the end of the cutting and preventing decay.

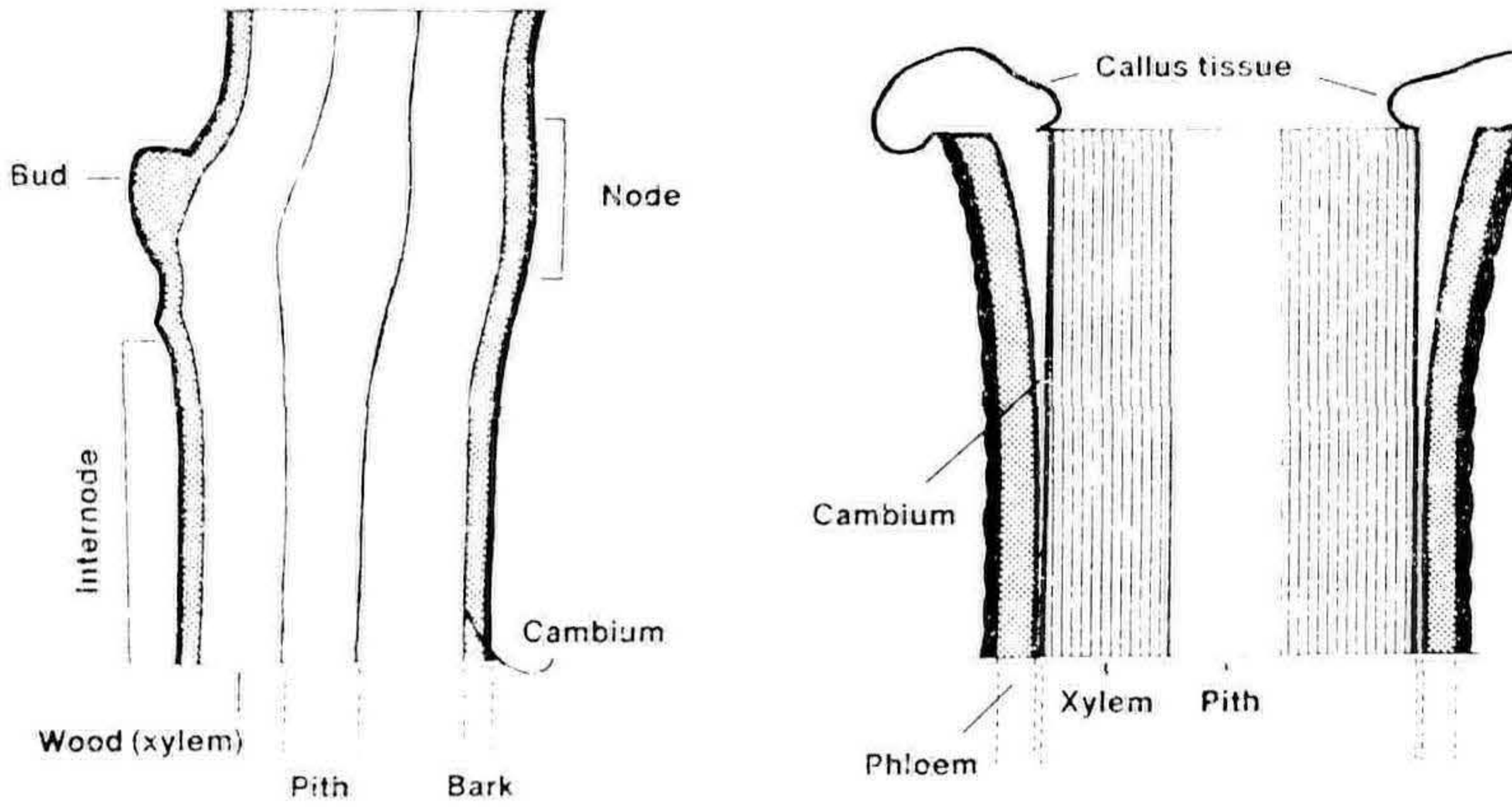

Figure 1. Anatomy of a vine cane and site of origin of callus tissues.

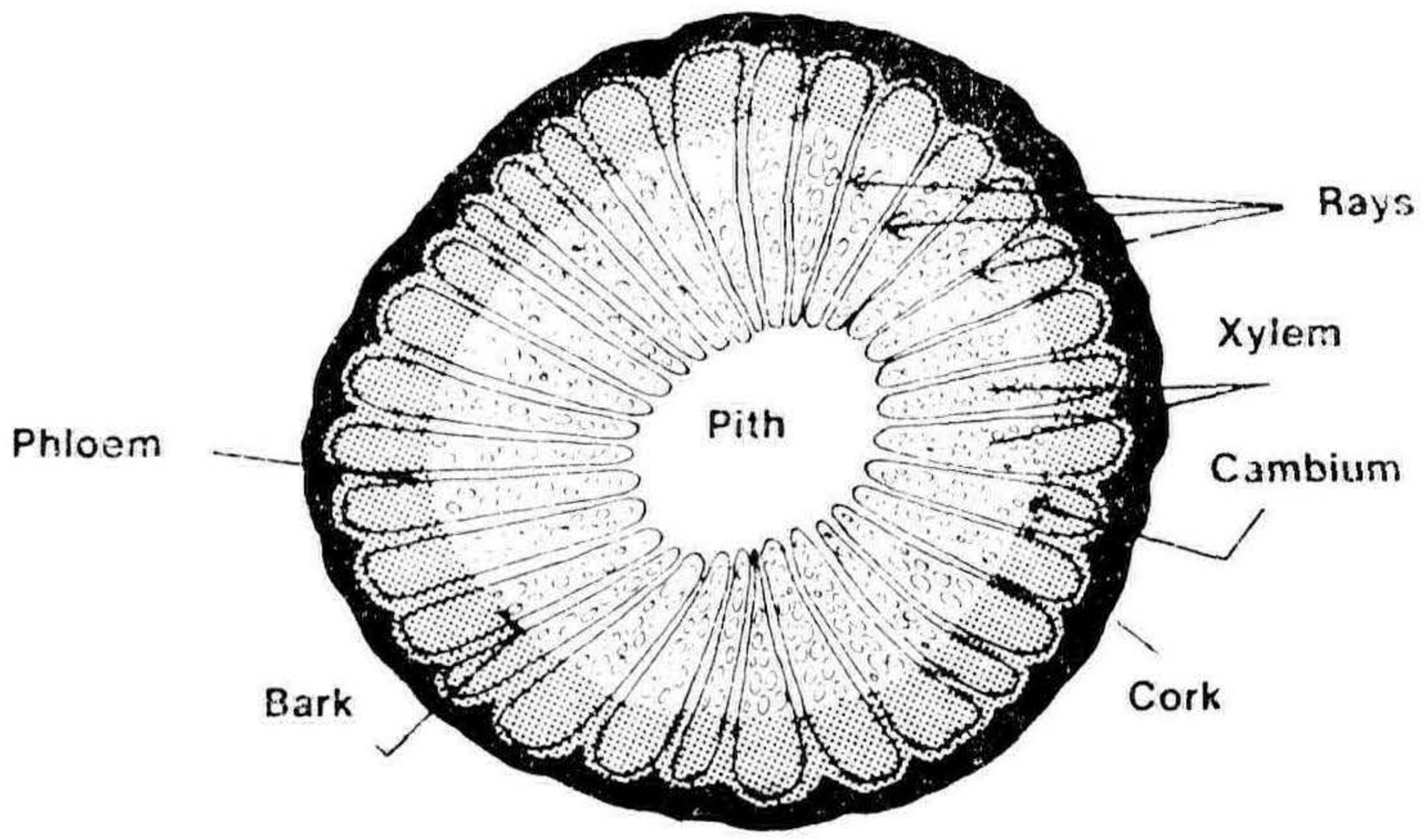

Figure 2. Cross-section of a vine cane illustrating the position of the main tissue components.

3.2 Root Initiation. The regeneration of plants from cuttings involves a careful manipulation of factors such as:

(i) the environment surrounding the cutting.

(ii) the anatomical, morphological, and physiological characteristics of the plant material

(iii) any treatment, either physical or chemical.

Garner and Hatcher (11) point out that a "carefully regulated interplay" of factors is necessary to stimulate rooting, particularly for plants which are considered to be shy-rooting. This interplay needs to be borne in mind when considering callus development and root initiation.

4.0 Factors Affecting Callus Development and Root Initiation:

4.1 Type and Selection of Cutting Material. Three main categories can be recognized in classifying the type of plant material to be selected from cuttings of woody perennial plants. They are softwood, semi-ripe, and hardwood. It is impossible to generalize about any type of material being the most suitable for optimum rooting for a range of plants. However, it is possible to generalize about the relationship between the type of plant material and the degree of callus development. Generally callus proliferation will be greatest on hardwood cuttings and the least development will occur on softwood material.

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Experimental Trial — Effect on Rooting and Callusing of Tip and Basal Cuttings of Grevillea 'Ivanhoe'

Aim: To examine the degree of callus development and root initiation on tip and basal cuttings of *Grevillea* 'Ivanhoe'.

Materials and Methods: Tip and basal cuttings were selected from 1 yr old healthy stock plants in February, 1982. The cuttings were surface sterilized in a 0.5% sodium hypochlorite solution. The rooting medium was 2 pts coarse river sand, 1 pt peat and 1 pt perlite. Treatments were a control, a hormone talc preparation, [Seradix 2 (IBA4 g/kg)] and a liquid dip equivalent (IBA at 3000 ppm for 5 secs). Each treatment consisted of 30 cuttings (two replicates of 15 each). Cuttings were set into 15 cm pots — 15 cuttings per pot and placed under intermittent mist, with bottom heat at 23°C ± 1°C. All cuttings were drenched with a fungicide, (Captan) at a rate of 15 g/10 litres water. All cuttings were harvested after 4 weeks.

Tip Cuttings. Sixty percent of the tip cuttings had formed a strong, well branched root system. Liquid dip preparations performed marginally better than talc preparations. Cuttings which failed to root looked healthy and although the bases had callused, little over-callusing was evident at this stage.

Results: (See Tables 1 and 2)

Table 1. Effect of auxins on rooting and callusing of basal cuttings of *Grevillea* 'Ivanhoe'.

Treatment	Percent Excess Callus	Percent Rooted	Average Root Length	Average no. Roots/Cutting
Control	50	—	—	—
Talc, IBA 3g/kg	60	10	1 cm	8
Liquid, IBA 3000 ppm	50	10	1	8

Table 2. Effect of auxins on rooting and callusing of tip cuttings of *Grevillea* 'Ivanhoe'.

Treatment	Percent Excess Callus	Percent Rooted	Average Root Length	Average no. Roots/Cutting
Control	5	20	1 cm	6
Talc, IBA 3g/kg	10	55	5 cm	8
Liquid, IBA 3000 ppm	10	60	5 cm	8

Some of the control cuttings (no hormone treatment) had begun to form roots. Little callus development had occurred.

Basal Cuttings. Minimal root development occurred on the basal cuttings. Varying degrees of callus development were evident and some of the cuttings had clearly begun to over-callus.

Discussion: It is fairly well established in commercial horticulture that for plants which are difficult to root, young growth and juvenile growth will often give improved rooting over older growth. The increased rooting ability of shoot tips is likely because of higher concentrations of naturally occurring rooting auxins and co-factors, coupled with the fact that there is less differentiation in the primary (shoot) growth and more cells are potentially meristematic.

Poor rooting with a stronger tendency to over-callus on basal cuttings of *Grevillea* 'Ivanhoe' is likely because of the change in the carbon/nitrogen ratio of the plant material and the lignification of cell walls which occurs during secondary growth.

Other Species. Persoonia pinifolia is considered to be difficult to propagate by conventional methods (10). Elliot (8) has achieved 90% success with this species by selecting young, soft growth in late spring which has slightly firmed.

* * * * * *

4.2 Source of Cuttings. For difficult-to-root species the genotype of the parent plant can be an important factor in ability to root adventitiously (14). This is to be expected when considering the sort of variation which occurs amongst sexually propagated species. It may also explain why very young cuttings of *Grevillea* 'Robyn Gordon' selected from physiologically stable, tissue culture raised plants are so easy to strike.

4.3 Physiological Condition of Plant Material. Factors which influence the physiological condition of the propagation material are climate, production schedules for mother stock, nutrition, and protected environment structures. In Queensland the vigour of *Grevillea* 'Robyn Gordon' is far greater than

in Victoria, and suitable cuttings may be larger and taken over a longer period of time.

Generally with species which tend to over-callus during the late autumn/late winter period should be avoided. This is because of the physiological condition of the stock plant. The plant has a higher C/N ratio and increased lignification of cell walls. Flower initiation also occurs for most Proteaceae during this period and vegetative growth is minimal. It has been shown by Dore (7) that cuttings are best taken either before or after, rather than during, the flowering period.

Hard pruning of stock plants during late autumn/early winter, coupled with a light, slow-released fertilizer application will encourage young healthy growth suitable for propagation in late spring/early summer.

4.4 Auxins. The important role of rooting hormones is well established in modern horticulture. IBA, NAA, and to a lesser extent, IAA and 2,4-D, are utilized to hasten root initiation and encourage more uniform rooting.

Empirical trials are necessary to determine the optimum hormone treatment for a particular species. Ellyard (9,10) has recommended concentrated, quick liquid dips as consistently yielding optimum results for a range of Australian native plants.

It has been my experience that liquid formations may be applied more accurately to plant material with marginally better results than talc formulations. Excess callusing for many of the "holly-leaved" grevilleas is more likely to occur with talc preparations, especially if excess talc is allowed to remain on the base of the cutting.

4.5 Rooting Media. Rooting media should have the general qualities of good drainage, aeration, and moisture retention. As a result of trials carried out at Burnley Horticultural Center (B.H.C.), a medium consisting of 2 parts coarse, washed river sand, 1 part sieved German peat moss, and 1 part perlite is recommended for a wide range of plants. Excess sand or poorly drained sand will encourage a hard, lignified callus and excess peat contribute to poor drainage and aeration, increasing the likelihood of basal rot.

4.6 Temperature. Temperature has a definite effect on the rooting of cuttings and callus development. Ooishi *et al* (17) showed that callus formation and rooting of camellia cuttings were greatly stimulated with rising temperature; 16%, 36%, and 87.5% root formation was shown at 17°, 23°, and 30°C, respectively.

Preliminary trials at B.H.C. with a species which is very difficult to root and consistently over-calluses, *Grevillea john-*

sonii, have suggested that increased temperatures encourages callus development but does not alone stimulate rooting.

4.7 pH. The pH of the propagating medium will influence the ability of some plants to regenerate roots from cuttings and may affect the nature of the callus. Studies on *Thuja occidentalis* showed that rooting increased between pH 5.1 and 9.3 but with no evident change in the callus. However studies on *Populus balsamifera* (5) showed that increasing the pH from 6.8 to 11.0 resulted in increasingly calcified and dense callus which inhibited the emergence of root primordia.

Most standard propagating media have a pH of approximately 5. Trials to determine pH responses for a range of plant material under propagation may yield interesting results.

4.8 Wounding. Wounding the base of difficult-to-strike cuttings can hasten root and callus development and improve the quantity and quality of roots (21), especially along the margins of the wound. This is probably due to a concentration of naturally occurring hormones and increased carbohydrate levels along the wounded area. Day (6) suggests that wounded cuttings are able to absorb more water from the propagating medium and, therefore, probably increased absorption of rooting hormones.

4.9 Trimming of Callus. Cuttings which have over-calused may be removed from the propagating bed, the callus trimmed, and the cuttings re-dipped in hormone. After resetting in the propagating medium, rooting will often follow. Balfour (2) proposed that the reason this occurs is that the paring of the callus reduces its growth and the food supply it draws on is left available for the vascular cambium. This then grows more actively and, as a result, produces root initials. It is more likely that the factors which have combined to cause this excess callus also contribute to discourage root development. When the outer layers of lignified cells are removed, developing primordia are sometimes evident. With the physical barrier removed and an increased application of hormone, rooting often results.

4.10 Nodal Cuttings. Most propagators tend to prepare cuttings by cutting either through, or just below a node. This procedure is based on tradition rather than scientific fact as the vascular cambium which is responsible for most root initiation forms a continual longitudinal cylinder in the steam. Chadwick (4) reported that large callus growth on *Weigela florida* 'Eva Rathke' could be avoided and better roots initiated, by preparing tip cuttings and making the basal cut 1 to 2 cm below the node. This technique may have application for many Australian plants which tend to over-callus. It can also make more economical use of propagating material.

5.0 Tissue Culture. Tissue culture is the development of new plants in an artificial medium under sterile conditions. For rapid multiplication of most woody perennial plants the multiple shoot technique is utilized. Callus tissue will still develop on species such as *Grevillea* 'Robyn Gordon' (12) using this technique.

It is possible to develop this callus tissue in a test tube and grow it indefinitely on nutrient agar. From this undifferentiated callus mass, adventitious roots and shoots can be encouraged by applying the correct amount of auxins and cytokinins for the species. However these plants may show considerable variation as "somaclonal variation" often occurs in these plants due to complex changes at the cellular level (15). Therefore the main horticultural value in these variants is in plant breeding and scientific research. This is an exciting new field with great potential for the horticultural industry.

Most of the research in this area has occurred on food crops, e.g. sugar cane, potato, *Brassica* spp., but Skirvin and Janick (19,20) have observed variation in callus-derived somaclones of five *Pelargonium* cultivars. It is interesting to note that one of these variants has been released as a new cultivar in U.S.A. called 'Velvet Rose'.

Acknowledgements. Figures 1 and 2 reprinted with kind permission from Ag. Bulletin, *Propagating and Grafting of Grapevines.* John A Considine. Victoria Dept. of Agriculture.

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PROPAGATION OF PIN OAK *(QUERCUS PALUSTRIS)* TO PREVENT WINTER LEAF RETENTION

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INTRODUCTION

The pin oak (*Quercus palustris*) is a tree of considerable amenity value in the cooler areas of southeast Australia. It is vigorous and hardy on most soils, it is quite drought tolerant and gives heavy summer shade and brilliant autumn colours. To date it has shown only a low susceptibility to the oak leaf miner.

However pin oak has one obviously unattractive habit. In mature trees the upper crown loses its leaves in late autumn but most of the dead leaves on the lower crown persist and are shed gradually during winter and spring, giving the tree a rather tattered appearance for much of this period. This gradual loss of leaves necessitates a number of winter clean-ups by residents or park authorities, rather than one concerted effort in autumn.

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The habit of winter leaf persistence was investigated by Scaffalitzky de Muckadell (1) in the European beech (*Fagus sylvatica*). He showed that growth from scions taken from the upper part of the tree of this species, when grafted onto seedling rootstocks shed all their leaves in autumn, while growth from scions taken from the lower part of the tree retained their foliage throughout the winter. These differences were attributed to the different physiological ages of the scion material. Scions from the lower crown had apparently retained the juvenile characteristic of winter leaf-retention.

AIM OF STUDY

A trial was established in 1965 by the Research Unit of Canberra's City Parks Administration to determine whether winter leaf persistence in pin oak is a function of physiological age and, if so, whether this phenomenon could be used to improve the habit of the species as an amenity specimen.

METHODS AND MATERIALS

In 1965, 1966, and 1967 a total of six large pin oak trees were selected in Canberra on the basis of health, shape, and autumn colour. Scions from the upper and lower levels of the crowns of each tree were collected from October to January (spring to mid-summer) each year and grafted onto open-rooted seedling stock. Tip cleft grafts, side cleft grafts, and budding were used. The plants were lined out in nursery beds for observation and in 1970 all surviving stock was planted out with a seedling control on an unwatered site in Canberra for long term study.

By autumn 1968, differences in leaf fall pattern were noticeable between grafts taken from the different parts of the crown. Thorough assessments were made in 1972, 1973 and 1976, recording height, autumn colour, and percentage defoliation throughout the winter period.

RESULTS

The success of budding and grafting was only 29% for 1965, the only year for which records of losses were kept.

The results of height growth and defoliation habit of each clone, as well as the control, for 1973 and 1976 are summarized in Table 1.

Table 1. The effect of origin of scion material on height growth and defoliation habit of grafted pin oak trees.

Clone No.	Origin of scion within crown of parent tree	Mean Height (meters)		Mean percent of leaf loss per tree by 1st June (early winter)		Percent of trees totally defoliated by 1st June (early winter)	
		1973	1976	1973	1976	1973	1976
101	Upper	4.1	5.0	100	100	100	100
101	Lower	4.0	5.2	20	56	11	11
102	Upper	3.4	4.6	100	100	100	100
102	Lower	3.5	5.2	85	96	71	49
103	Upper	3.3	5.0	100	100	100	100
103	Lower	3.6	5.2	22	40	11	0
104	Upper	3.7	5.0	100	100	100	100
104	Lower	3.6	4.8	62	54	25	0
105	Upper	3.3	4.4	100	100	100	100
105	Lower	3.0	5.3	66	63	33	0
106	Upper	3.3	5.3	100	100	100	100
106	Lower	3.0	4.7	50	30	0	0
Seedlings		2.2	4.0	93	30	85	0

DISCUSSION

The poor survival of grafts in 1965 may be attributed to the late season of grafting. Recent communication with nursery propagators indicate that propagation of pin oaks by budding usually gives close to 100% success.

The defoliation habit of grafts from the upper crown was most encouraging. Without exception these grafts have shed all their foliage by late autumn, in a similar fashion to most deciduous trees. This has been the case for as long as observations have been recorded (since 1970). Grafts from the lower crown have consistently shown the juvenile characteristic of varying degrees of leaf retention over the winter. The contrast in the two habits is shown in Figure 1.

Other characteristics of the grafts are not significantly different from seedlings. The form of grafts from both upper and lower crown levels appears to be less pyramidal than seedlings but the difference is not marked. There is a tendency for grafts to form low multiple leaders and heavy lower branches, a habit that can be corrected with simple tree surgery at an early age. To date there has been no evidence of intraspecific graft incompatibility.

Since 1980 the Government Nursery at Yarralumla, A.C.T. has been producing a proportion of their pin oak stock by budding tissue collected from the upper crown levels of select-

Figure 1. Ten year old grafted pin oak trees showing defoliation habit of upper crown scion wood (left row) and lower crown scion wood (right row), in mid-winter.

ed trees. The success rate from budding has been very high and it has been reported that budded stock has a first year growth rate far higher than that of seedlings.

CONCLUSIONS

The habit of winter leaf retention in pin oaks can be effectively eliminated by propagating adult tissue from the upper crown of mature trees onto seedling rootstocks. The technique appears to be technically and economically feasible as a routine nursery procedure. It is possible to produce both persistent and early deciduous leaf types to allow landscapers the choice of both forms, as well as allowing selection for other attributes, such as autumn colour.

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PROPAGATING AND PRODUCING STONE FRUIT TREES IN ONE YEAR

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Climate. To achieve this goal, a suitable climate is essential. Our operation is carried out in the central western slopes of New South Wales where we have a 7½ month growing period for stone fruit, from mid-September to the end of April (early spring to late fall). This procedure is known as "June budding" in the Northern Hemisphere.

Seed. Golden Queen peach seed is our main stock. We used to purchase these dried, direct from the cannery, and had only 50% germination. We found out that they were dried on a concrete slab in direct sunlight in temperatures of up to 40°C, up to 4 inches (100mm) deep and raked over when manpower was available. We now cart the seed home in bulk direct from the hoppers and dry on a slatted floor in a shed, resulting in 80% + germination. This seed is purchased at late summer and, after drying, is bagged. In late fall the bags of seed are immersed in water for 24 hours to swell the kernel. (Failure to do this will result in a very poor germination, the majority of seeds germinating the following year). The bags are then removed from the water, allowed to drain for 48 hours and then stratified in refrigeration at 2°C for 3 to 3½ months. Planting takes place in late winter (mid- to end of August).

Land Preparation. This is commenced in mid-autumn (April); an old lucerne (alfalfa) area is firstly sprayed with Roundup and then plowed and, with continual working, we endeavour to have the land in a small seed bed condition by late winter.

Sowing. Drills approximately 1 inch (25 mm) deep are run a metre apart and the seed is hand-dropped 50 to 75 mm apart, then covered with a hill to a depth of 75 mm. Germination starts in early spring (mid-September).

Weed Control. This starts when approximately 80 to 90% of the seed has germinated and consists of three aplications, a month apart, of 1 kg of active ingredient Surflan per hectare. Trees are over-sprayed with no adverse effects and the Surflan is watered-in within 24 hours of application. This gives very good control of annual grasses, particularly Barnyard Grass, our main problem. Not starting our weed control programme until after the peach seed has germinated, (we intend doing trials this year on the effect Surflan has on peach seed germination) means that we are committed to do one hand hoeing of the area. After budding, when trees are approximately 18 inches (500 mm) high, and a lot of green has disappeared from

the bark, either Triquat or Gramoxone is used as a knock-down. Inter-row cultivation is done with tynes and rotary hoes mounted on a high-rise tractor.

Fertilisation. This is essential if we are going to produce a suitable tree in 12 months. At sowing, a ready mixed fertilizer containing 10% nitrogen, 33% phosphate, and 10% potassium is applied at the rate of 2½ kg (5 lbs) per 30 metres (100 ft) of row. This is followed 3 weeks after germination with a similar application. Following this, Nitram is applied at the same rate at 3 week intervals. With this rate of Nitram the odd tree will burn, demonstrating that maximum rates are being applied.

Irrigation. This is done by overhead sprinklers. All watering is done at night and knocker speed has been doubled as the sodium chloride salt content in the water at times goes to 120 ppm, possibly not high by a lot of standards but the danger level for plums, particularly when the bud is in the soft rosette stage, is 70 ppm; we have found that by keeping the leaves wet instead of letting them dry before the next round of the sprinkler we can minimize burn.

Budding. This is our busiest time of the year and the time when most stress is placed upon all those concerned as we have from about 20th November to the end of December (late spring to early summer), a period of six weeks, to complete same. Suitable mature budwood is not available prior to mid-November, and we are running out of growing time if we bud after the end of December. The stock trees at the time budding starts should be a minimum diameter of 5 mm, or at least average knitting needle thickness, and well watered to ensure sap flow. T-budding is the method used and if we can't push the bud straight in without physically opening the bark we move out of this block of trees, water it well, and come back in a few days time. Too much importance cannot be placed on having an adequate sap flow in the stock. The same applies to budwood. It has to come from well-watered trees, virus-tested whenever possible, and of a size to suit the stock. The reason we insist on having the budwood source well-watered is that we snap all our buds off the stick (leaving the back wood behind); too many buds are lost from dry sticks. If the sap is flowing in both the stock and the budwood, the budwood cut and trimmed before wilting, stored correctly and free from virus, one should never expect less than 90% take in stone fruit trees. Very few people realise the financial impact that virus can have on the industry. At times we have dropped to a 50% take with virus-affected budwood obtained from Research Stations, as well as private orchards; the growth was so poor on those that took that the trees were unsaleable at one year old. I feel that we should lobby whenever the opportunity

arises to have more funds made available to Agricultural Departments to extend their virus testing facilities.

Buds are tied in with rubber bands 120 mm long and 3.5 mm wide leaving the bud itself uncovered. These are a lot faster than tapes to tie and deteriorate in about three weeks saving the labour of cutting them off. Wherever possible we endeavour to bud high enough to leave some leaf growth below the bud.

Immediately after budding, 50% of the tree is cut off and 15 days later the stock is cut to just above the bud, a good proportion of which should then be pushing; any sucker growth is left until the bud is approximately 150 mm (6 inches) long. It is then completely trimmed off, and this is when the tree really starts to grow.

Pest Control. Temik, a granulate, is incorporated into the soil immediately after suckering. This translocates into the tree and gives very good control of thrips and other insects that would check or otherwise damage the young growth. Gusathion is used late in the season for tip moth control.

Digging. This commences early in June (early winter) using a U-shaped blade behind a high-rise tractor. We endeavour to dig the whole crop prior to delivery starting.

Being in an area isolated from all orchards, and able to rotate, disease control is relatively easy, but because of the fact that a lot of the trees go into old orchard situations all trees are dipped in a No-Gall solution immediately after digging.

In conclusion, if you are prepared to accept the extra worries of producing a one-year tree, (because everything has to be done when the tree is ready , not when you are ready), you can produce a tree that is very acceptable to the trade. It is dug with a minimum of root damage, and no loss of bottom buds shooting and dying because of shading; it is a tree that can be adapted to any of the training methods used in orchards today.

PLANT BIOTECHNOLOGY, SOMACLONAL VARIATION, AND VARIETAL IMPROVEMENT

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INTRODUCTION

Plant improvement and varietal selection originated with the dawn of human society. Under the pressure of deliberate

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INTRODUCTION

Plant improvement and varietal selection originated with the dawn of human society. Under the pressure of deliberate

selection many of our domesticated species are distinctly different from their wild relatives. For example, the cabbage, the cauliflower, and brussel sprouts are all derived from the same species, *Brassica oleracea*, as a consequence of deliberate selection for the specialised development of the leaf, flower, and axillary buds, respectively.

Any varietal improvement program has a set of defined objectives. From an agricultural viewpoint, improvement focuses on those variables which maximise yield and economic return, such as disease resistance, earliness and maturity characteristics, drought tolerance, and features which enhance mechanisation and reduced energy dependent inputs. At the other end of the spectrum, the floriculture and nursery industry may see the maintenance of uniformity on the one hand, and spectacle and uniqueness of new cultivars on the other, as the desiderata.

Whether the concern is large scale, efficient production of food and fibre crops, or the use of plants to enhance our aesthetic environment, plant breeding has and will figure prominently. In essence, plant improvement is a numbers game. Unique or rare gene combinations have to be identified and recovered from a large population of plants. Such specific gene combiantions may result from recombination in a hybrid gene pool. Unique mutants may occur spontaneously or be induced by mutagenesis. The skill or art of the plant breeder lies in his ability to rapidly identify those variants he considers useful. His job is made easier if techniques can be devloped to enhance the frequency of potentially useful variants.

Plant biotechnology, which includes plant cell culture and the exciting area of genetic engineering, has the potential of greatly amplifying both the amount of genetic variability available to plant breeders and the power of selecting useful genotypes.

PLANT CELL CULTURE

For an increasing number of species, cell lines can be induced to proliferate under defined culture conditions. Plant tissue culture media consists of defined amounts of inorganic salts, trace elements, vitamins, a carbon source for energy, and phytohormones. Virtually any part of a plant can be induced to form a cell line, including the root and stem section, hypocotyl, cotyledons, leaves, and even immature haploid pollen grains.

Cultured plant cells have the enormous advantage of totipotency, i.e., rapidly growing undifferentiated cell lines can be induced to form shoot and root primordia which develop into

fully fertile plants. The principal determinant of this differentiation process is the relative levels of auxins and cytokinins in the culture medium. Generally, a high ratio of cytokinin to auxin induces shoot formation while the converse tends to favour root initiation. For any given species, the culture conditions which favour rapid undifferentiated cell proliferation as against plant regeneration is arrived at empirically.

Plant propagators and the nursery industry were quick to see the advantages of tissue culture in terms of rapid propagation of desirable genotypes. There is now a large number of plant species which are amenable to rapid propagation by tissue culture technology (10). In recent times geneticists and plant breeders have successfully applied these techniques to many important agriculture crops. The objective was to augment the armoury of conventional plant improvement. Exciting consequences have followed this development.

SOMACLONAL VARIATION

It often happens that valuable scientific applications emerge from unexpected quarters. Because a tissue culture cycle was seen essentially as cloning a particular genotype it became the accepted dictum that all plants arising from tissue culture should be exact copies of the parental plant. Phenotypic variants which occurred among regenerated plants were dismissed as "artifacts of tissue culture". The variants were viewed as transitory consequences from exposure to phytohormones and were labelled as epigenetic events which somehow made them unworthy of further scientific interest. Now it seems this was a premature and erroneous judgement. Tissue culture apears to be an unexpectedly rich and novel source of genetic variability. This variation is called somaclonal ("protoclonal") variation and has been reviewed in detail by Larkin and Scowcroft (3).

(A) **Agricultural species**

(i) *Sugarcane.* The first real developments to utilize tissue culture generated variation as a plant breeding tool began in the experiment station of the Hawaiian Sugar Planters' Association. This initial work, followed by research in Fiji and Taiwan, has resulted in sugarcane genotypes with increased resistance to several diseases including downey mildew, Fiji virus disease, and eyespot disease.

Our own research to explore the potential of somaclonal variation to improve Australian sugarcane cultivars began in 1979. We were concerned with disease resistance, in which eyespot disease *(Helminthosporium sacchari)* figured promi-

nently. All lines were derived from the cultivar, Q101, which is agronomically valuable, except that is susceptible to eyespot disease. Following prolonged culture (up to 15 months) a large number of plants were regenerated and subsequently grown under glasshouse conditions.

To facilitate screening a large number of somaclones, a leaf bioassay was developed to quantify the sensitivity of the leaves of a given plant to a standardised concentration of the fungal toxin responsible for leaf damage. The sensitivity is measured as the initial rate of leakage of electrolytes from leaf discs briefly exposed to the toxin. This metric proved to be highly repeatable and consistent for a given cultivar (4).

The distribution of toxin sensitivity among these somaclones is depicted in Figure 1. Many of the somaclones proved to be resistant or essentially immune to the effects of the toxin and the mode of the distribution is significantly shifted to the resistant side of Q101. All 52 somaclones of Q47, a highly resistant cultivar, retain their resistance. Most importantly these resistant somaclones of Q101 retain their resistance through subsequent cane generations. Second and subsequent tissue culture cycle somaclones derived from resistant somaclones also tend to retain toxin insensitivity.

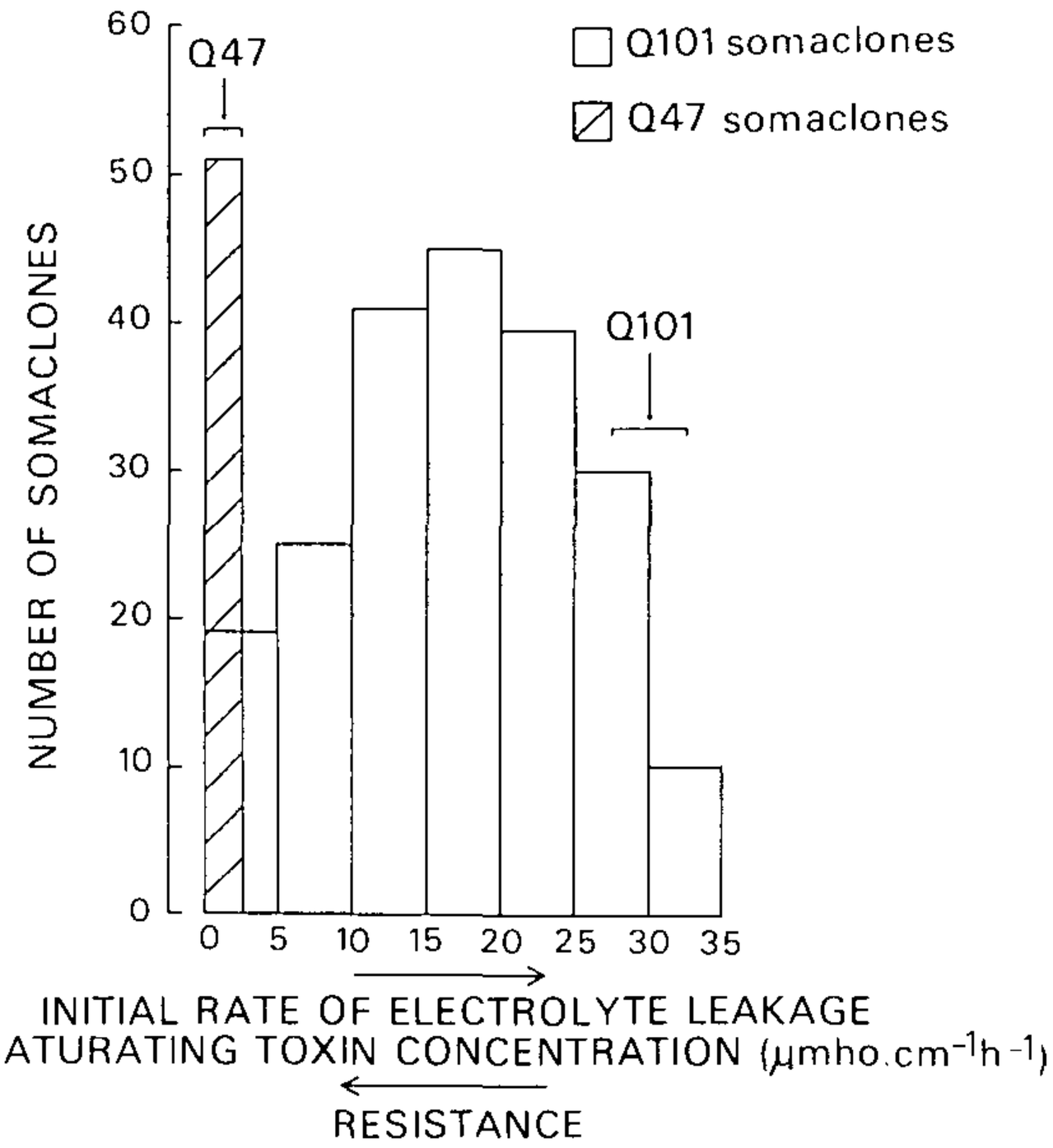

Figure 1. The distribution of reaction to eyespot toxin of Q101 somaclones, and Q47 somaclones. The parental reactions are as indicated by arrows.

Recent research in Taiwan has found variation among sugar cane somaclones from 8 cultivars in characters such as yield, sugar content, stalk number and weight, fibre percentage, and several leaf characters. Under stringent field experiments some of these somaclones showed significantly increased sugar yield relative to their parental cultivar. This research has also recovered resistant somaclones from parents susceptible to either downey mildew or culmicolous smut disease.

(ii) *Tobacco.* Because tobacco has been amenable to cell culture and plant regeneration for some time it might be expected that somaclonal variation has been observed in this species. And indeed this is so.

Burk and Matzinger (1) derived by anther culture a series of dihaploid lines from a tobacco cultivar which had previously been inbred for 15 generations. It would be expected that the 41 dihaploid lines were identical both with each other and the parent from which they were derived. However, significant variability was observed for all the economically important characters examined, namely: yield, grade index, days to flowering, leaf characters, alkaloid content, and reducing sugars. Surprisingly, the variability observed was as great as that normally associated with a segregating F_2 population from a cross between two different cultivars.

Recent work has also shown that even when specific loci controlling chlorophyll synthesis are considered, the "mutation rate" among regenerating plants is a staggering 3 to 4%.

(iii) *Potato.* Perhaps the most significant demonstration of the potential value of somaclonal variation was provided by Shepard *et al.* (8) in potato. In North America the 70 year old cultivar, Russet Burbank, represents 39% of the potato crop. This cultivar, along with most "old" potato cultivars, though not particularly remarkable in any specific character, has been retained because it is a good "all-rounder". Nevertheless, each year about 22% of the world potato crop is lost through disease. The sterility or very low fertility of many cultivars discourages their use in breeding programs.

Shepard *et al.* (8) argued that it might be simpler to selectively improve a popular cultivar than to create a new one. Screening over 1000 somaclones produced from leaf protoplasts of 'Russet Burbank', they found significant and stable variation in compactness of growth habit, maturity date, tuber uniformity, tuber skin colour, photoperiod requirements, and fruit production. Some characteristics, such as greater tuber uniformity and early onset of tuberisation, were agronomic improvements over the parent, Russet Burbank.

It is most significant that some somaclones were recovered which were resistant to disease pathogens. Five of 500 somaclones were more resistant to *Alternaria solani* toxin than the parent and of these, four showed field resistance to early blight. About 2.5% (20 of 800) somaclones screened were resistant to late blight *(Phytophthora infestans)* some of which were resistant to multiple races of this pathogen.

These variant somaclones have retained their phenotype through a number of vegetative generations. Sixty-five selected somaclones have now been analysed in detail for variability under field conditions (7). Among 35 characters analysed statistically significant variation was found for 22 characters. All clones differed from Russet Burbank for at least 1 character and one somaclone differed for 17 characters. The modal class of 15 clones differed from Russet Burbank in 4 characters.

(iv) *Rice.* Among rice somaclones, variants have been reported in characters such as number of tillers per plant, number of fertile tillers per plant, average panicle length, frequency of fertile seed, plant stature, and flag leaf length.

Oono (5) has made a detailed analysis of some 800 somaclones derived from a homozygous line of a selfed doubled haploid. Chloroplast content, flowering date, plant height, fertility, and morphology were examined in each of these somaclonal derivatives and in each of two subsequent selfed generations. For these characters only 28% of the plants were normal with respect to the parental phenotype. There was wide variation in seed fertility, plant height, and heading date. Chlorophyll deficiencies were seen in the second generation of 8.4% of the lines, which is a comparable frequency to that expected form X-ray and γ-irradiation. Sectorial analysis of plants derived from a single seed callus showed that at least most of the variations were induced during culture and were unlikely to pre-exist amongst the 75 homozygous seeds used to initiate the experiment. In the second selfed generation after somaclone regeneration some of the mutant characters were segregating and some were fixed. It was estimated that mutations affecting these five traits were induced in culture at a rate of 0.03-0.07/cell/division.

(v) *Other species.* Table 1 provides a list of other agriculturally important species in which variation has been observed among plants regenerated from cell culture. Increasingly, this cell culture approach is being explored as an adjunct to the improvement of agriculture species.

(B) **Horticultural and Floricultural Species.**

(i) *Pineapple.* Among some 450 somaclones of pineapple (11), variation was observed in spine and leaf colour, wax

Table 1. Additional species displaying somaclonal variation

Species	Variant characters
Oats	plant heights, heading date, leaf striping, twin culms, awn morphology
	heteromorphic bivalents, ring chromosomes
Maize	abphyl syndrome, pollen fertility
Barley	plant height, tillering, fertility
Sorghum	fertility, leaf morphology, growth habit
Onion	bulb size and shape, clove number, aerial bulbil germination
Rape	flowering time, glucosinolate content, growth habit

secretion, foliage density, leaf width and leaf spine formation. The origin of the cell culture explant had a dramatic effect on the occurrence of variation. If the explant for the initiation was syncarp or slip, nearly 100% of the somaclones were variant, whereas if the crown was used only 70% of the somaclones were variant.

(ii) *Pelargonium*. A remarkable degree of variability has been observed among plants regenerated from 5 different cultivars of *Pelargonium* (8). In contrast, plants propagated from stem cuttings were all indistinguishable from the parent plants. Somaclonal variation was observed in leaf shape, size and form, flower morphology, plant height, degree of fasciation, anthocyanin pigmentation and essential oil composition. From one cultivar, Attar of Roses, 28 out of 55 somaclones examined were variant.

Cytological examination of the somaclonal variants did reveal some ploidy changes but only in a small proportion of them. In some of the cell culture lines there was a tendency for increased variability with increased duration of the culture cycle. From this program a new cultivar, Velvet Rose, has been released.

(iii) *Begonia*. In several floricultural species, such as *Begonia*, adventitious bud technique is used for rapid clonal propagation. This technique is based on the phenomenon that adventitious shoots induced on petioles of detached leaves originated from single cells. This technique has been extended to the induction of adventitious shoots on leaf explants.

In a mutation breeding program with *Begonia* × *hiemalis*, leaf explants of 2 different cultivars were either not irradiated or irradiated with X-rays (6). Adventitious shoots were then induced on leaf disc explants from both X-ray treated and unirradiated leaves. From these shoots a second cycle of adventitious shoot formation was initiated and adventitious shoots so derived were subcultured to produce plantlets and finally flowering plants. These somaclonally derived plants

were examined for variation in the colour, size and form of flowers and leaves.

Among a total of 894 plants examined from the 2 cultivars, 266 were considered mutant. While X-rays caused a higher frequency of mutant plants, a high frequency was also found among plants derived from unirradiated leaf disc explants. The frequency from non-irradiated leaves of one cultivar was a staggering 43% whilst in the other, 7% mutant plants were found. The majority of these variants were solid mutants.

(iv) *Other species*. Somaclonal variation has also been observed in *Chrysanthemum* for such characteristics as flower colour and the temperature required for flower induction (2) and also in daylily and carnation.

Among vegetable crops variation has also been observed in somaclonally-derived plants of onion, lettuce, and tomato.

ORIGIN OF SOMACLONAL VARIATION

An understanding of the causes of somaclonal variation is important, first to be able to enhance the level of variation where increased variability is the objective. Second, where the goal is to clonally propagate a cultivar to produce uniform progeny the ability to suppress the phenomenon could be very desirable.

Doubtless, many different genetic processes operate to generate somaclonal variants. A discussion of some of the possible processes is to be found in Larkin and Scowcroft (3). Gross karyotypic changes and chromosomal rearrangements have been documented in both cell cultures and regenerated plants. However, these gross changes seem to reflect the capacity of cell culture to generate varation rather than as an underlying cause of phenotypic variability. While abnormal karyotypes have been observed in somaclones of potato and pelargonium, for example, these represent only a small proportion of the total phenotypic variants observed.

Cryptic chromosomal rearrangements leading to translocations, deletions and inversions, for example, could have a genetic consequence affecting an individual phenotype. For example, a small rearrangement may delete or otherwise switch off a dominant allele thereby allowing the recessive allele to affect the phenotype.

There is evidence in higher organisms, including plants, of a phenomenon where particular stretches of DNA (transposable elements) can move from one locus to another at relatively high frequency. The transposition of such elements from one chromosomal location to another generates mutations. A tissue culture environment may be conducive to sequence

transposition. This appears to be the case in animal cell cultures. Such a high frequency transposition would generate extensive phenotypic variability.

It has been shown for higher organisms, including plants, that the quantity of a specific gene product can be increased or decreased simply by amplification or diminution of the gene copy number. The artificial nature of a tissue culture environment may impose sufficient selection pressure to cause both amplification of some genes and diminution of others. This would obviously affect the phenotype of plants regenerated from the cell lines so affected.

CONCLUSIONS

Somaclonal variation among plants regenerated from cell culture is extensive both in the range of species and diversity of characters affected. It has already been recognised as being a significant source of genetic variability for varietal improvement. Several research programs have already been initiated to exploit its potential usefulness.

On the negative side, somaclonal variation has also been recognised as a hindrance to product uniformity by those who utilise cell culture for the rapid propagation of floricultural and ornamental species. In this context the frequency of somaclonal variation appears to be enhanced in older cell lines. Thus, an expedient approach to reduce the incidence of somaclonal variation is to continually reinitiate explants from the parental genotype and to regenerate plants only from relatively recently explanted material.

Somaclonal variation may find its greatest usefulness in concert with selection for desirable mutations at the cellular level. It is no longer surprising that in the recovery of cell culture mutants the frequencies have been relatively high and mutagenic treatments often enhance the frequency only marginally if at all. Many agronomic traits are known or suspected of having a cellular basis. These include disease resistance, particularly where a host-specific toxin is involved, tolerance of adverse soils (salinity, metal toxicity), herbicide and temperature stress. For each of these attributes genotypes have already been recovered following cell culture selection. Cellular selection and somaclonal variation collectively provide promising new technology from plant improvement.

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LABOUR REDUCTION TECHNIQUES FOR PROPAGATING AZALEAS AND MAGNOLIAS BY CUTTINGS

JON. T. SLYKERMAN

Slykerman's Nurseries
5 Leah Avenue, Upwey, Victoria

Preparation and Pasteurization of Medium. One part German peat and three parts coarse river sand are mixed in a 6 cu.yd. concrete mixer. This is driven by a 3 h.p. electric motor. The drum revolves at 3/4 rpm.

Heat pasteurisation of the medium is performed in the revolving drum by a diesel oil burner. (Fig 1.) This is best described as a "conduction heater" or an "indirect flame heater."

A vented mild steel pipe, approximately 6 ft. long, is attached to the burner and carries the heat inside the drum. When mixing, the drum revolves in a counter-clockwise direction, pulling the soil to the right hand side of the drum. The heat is directed into the air space on the left hand side of the drum. The hot air then warms the steel drum. The medium is warmed by contact with the hot air and heated metal surface inside the steel drum. Hence the reason for the above names.

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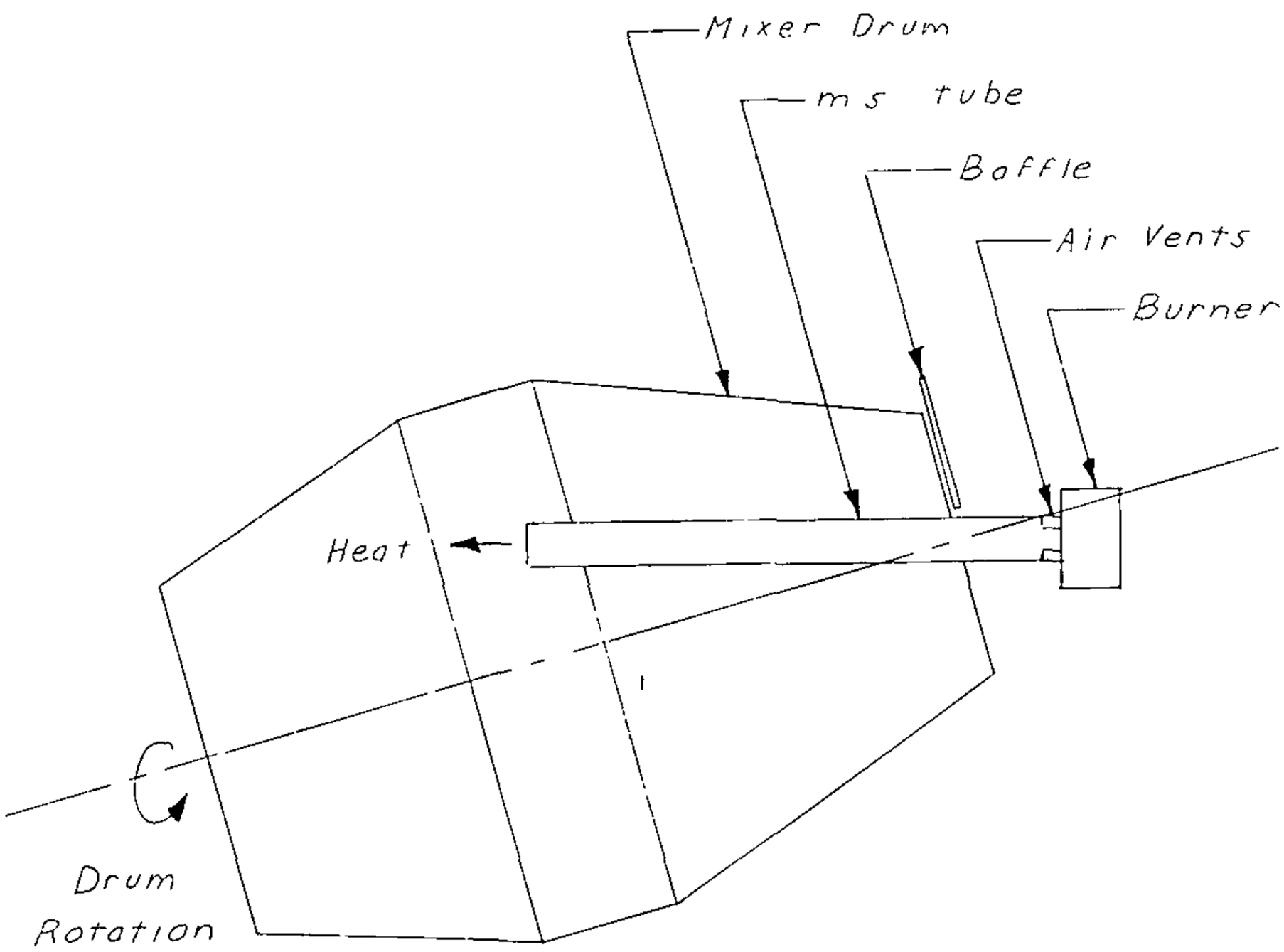

Figure 1. Burner and drum layout for mixing and pasteurizing medium.

The peat is first loaded into the mixer using a front end loader. Water is sprayed into the revolving mixer to thoroughly wet the peat. To save time the burner is then started, followed by loading of the sand. A sheet metal "baffle" is then placed over the top half of the mouth of the drum. This reduces the amount of heat escaping, and speeds up the heating time. Normally this is 1 to 2 hours, depending on volume, water content, and outside air temperature. The temperature of the medium is checked with an 18-inch stem thermometer inserted through a hole in the side of the drum. We currently heat the medium to 60°C and keep it there for ½ hr.

The cooling cycle is initiated by removing the "baffle", sprinkling water on the outside of the drum, and disconnecting the ignition of the oil burner, allowing it to blow outside air into the mixer. This normally takes 1 to 2 hours, depending upon volume and outside temperature.

When the medium has cooled to at least 30°C, we add 4 lb/cu.yd. of 8 to 9 month Osmocote, 1 lb/cu.yd. Micromax, and 1 lb/cu.yd. dolomite lime. After further mixing for approximately 1 hour, the medium is emptied onto a bench in front of the mixer, where it is placed in tubes or trays.

The filled trays or tubes are placed on a "handy angle" roller conveyor, where they are thoroughly watered. This is followed by punching holes in the medium, with a multi-hole

punch. (Fig. 2). This is a device with dowling pins or nails to form holes, which saves individual dibbling. The main feature of this is a stripper plate to hold down the tubes as the pins are withdrawn.

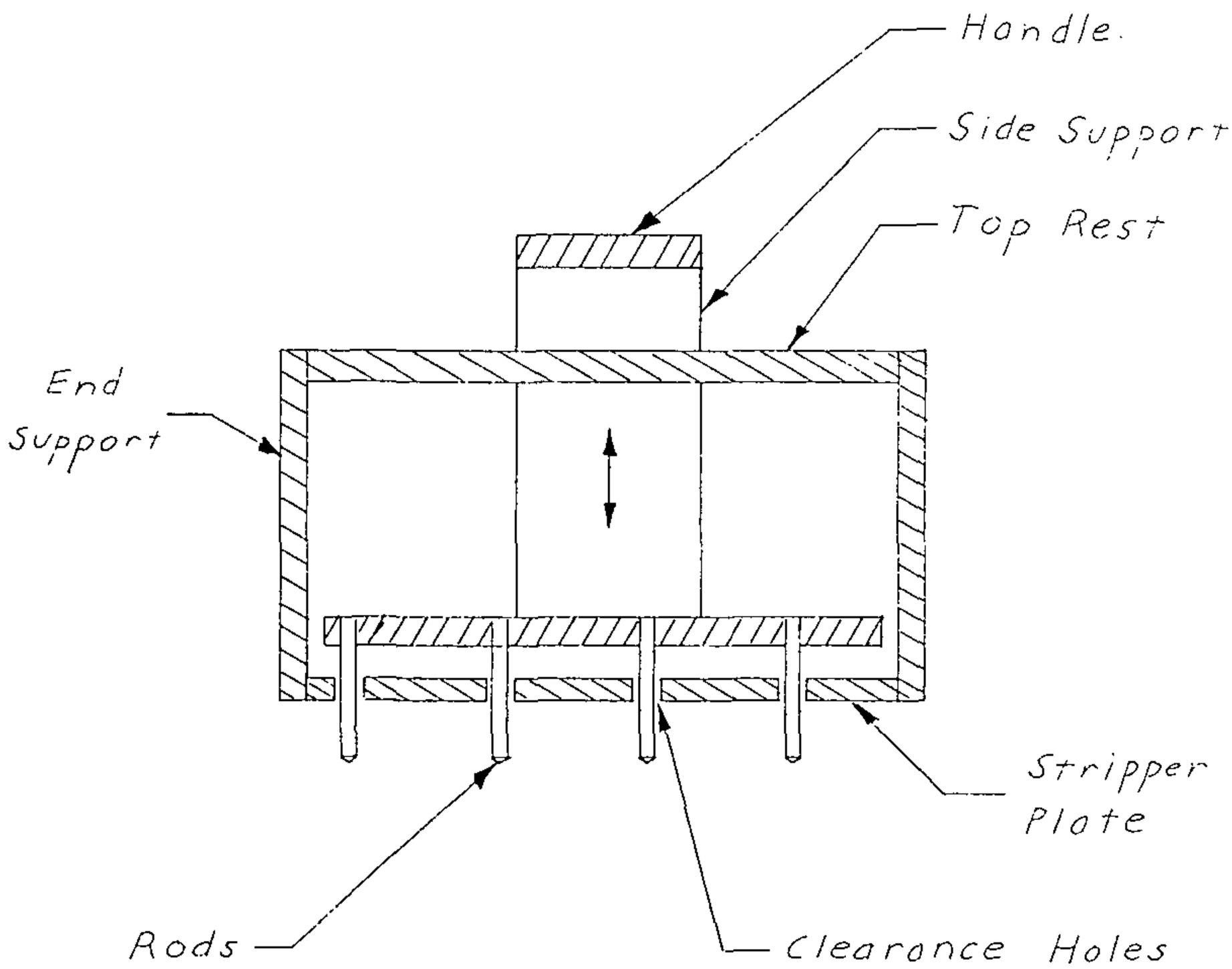

Figure 2. Cross section of multi-hole punch (not drawn to scale)

Magnolia Cuttings. Species and cultivars propagated are: *Magnolia heptapeta (M. denudata)*; *M.* × *soulangeana*, 'San Jose', 'Purpleform', 'Picture', 'Lennei', 'Lennei Alba', 'Rubra'; *M. quinquepetala*, *M. q.* 'Nigra'; *M. kobus*, var., *stellata*; *M. salicifolia (M.* × *proctoriana)*, *M.* 'King Rose'; and *M. kobus* var. *loebneri* 'Leonard Messel'.

The first crop of cuttings is taken in mid-summer (the week before Christmas in Australia). They are taken early in the morning, mainly from stock plants. Soft, juvenile shoots are cut off using secateurs; they are protected from direct sun till they arrive at the propagating shed. Normally 1 to 2 leaves are left on a cutting 6 to 9 in. long. Large shoots are cut into 2 or 3 cuttings with a node at the top and bottom. Leaves are not trimmed, with the exception of 'Lennei', which has extremely large leaves. The cuttings are then dipped in a solution of Rovral, Alliette, and Malathion. they are then side wounded, (approximately ¾ in.) and the bases are trimmed using a grafting knife.

A hormone powder of equal parts IBA powder and Captan is used. For the *M. kobus* var. *stellata* types, 2% IBA is used, with 1% IBA for the others. We have experimented with liquid hormones on *M. heptapeta* with little success.

Because magnolias have large fleshy root systems the cuttings are inserted in 6cm (2½ in.) tubes. They are then placed under mist with bottom heat of 20 to 25°C. After approximatley 6 to 8 weeks they are moved to an unheated polyhouse. The mist house is then filled with a second crop of magnolia cuttings, during late summer (mid- to late February).

Azalea Cuttings. Approximately 70 species and cultivars of azaleas are propagated, mainly Indicas and Kurumes.

For the first time this year, the cuttings from the previous year, which had been stuck in plastic seedling trays, had their tops pruned off with an electric hedge trimmer. These were used for cuttings. Our procedure for this is to strip the cutting and pinch the top out, then dip it in the same fungicide solution as used for the magnolias. The person sticking them gathers a bunch of approximately 15 cuttings with the tops level. The bottoms are then cut off with secateurs, leaving cuttings approximately 2 in. long. These are then dipped as a bunch in 1% IBA powder with 10% Captan added. The trays of cuttings are then placed in a glasshouse which is heavily whitewashed and equipped with bottom heat and fine sprinklers. Depending upon weather conditions, the sprinklers are manually turned on for 10 to 20 seconds every 1 to 2 hours. This is gradually reduced to a daily watering after 2 months. At the age of 4 to 5 months, they are sprayed with 2.5% Atrinal to encourage branching.

The previous year's cuttings, which have been pruned, are moved to a shadehouse. They are potted directly into 5-in. pots from the seedling trays, eliminating the tube stage. Although this is a severe setback, they recover to grow into bushy, good commerical quality plants.

Summary. Labour reductions are achieved by the following:

a) Simultaneous mixing and pasteurising of the medium in large quantities.

b) Use of a multi-hole punch to eliminate dibbling.

c) Use of roller conveyors to reduce handling.

d) Use of an electric hedge trimmer to obtain cuttings.

e) Elimination of tubing.

PROPAGATION OF ORCHIDS USING SYMBIOTIC FUNGI

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Abstract. The propagation of Australian terrestrial orchids from seeds or plants collected in the wild, using the fungi with which they are normally associated, is described. This technique relies heavily on the successful growth of the appropriate fungi to supply the orchids with essential nutrients for growth.

INTRODUCTION

All orchids found growing in the wild are thought to be associated with certain species of fungi (1,8). The association between orchids and fungi may persist throughout the life of the orchid, or it may be seasonally absent in some species. These fungi are thought to contribute greatly to the uptake of nutrients from the substrate in or on which the orchid is growing. Research into this aspect of the association has revealed that these fungi can convert, amongst other things, cellulose from soil into soluble carbohydrates that subsequently can be transferred to the orchids (2,13,19). These soluble carbohydrates, many of them rare natural sugars, are essential for the well being of the plants, a fact verified experimentally with plants grown *in vitro* by Ernst (11). These fungi are also thought to be responsible for the successful germination of orchids in the wild (1). This concept, since its inception by Bernard (4), has been supported by experimentation a number of times. Seeds of various orchids when sown *in vitro* on a prepared medium inoculated with certain fungi would germinate, while seeds of the same species left uninoculated but sown on an equivalent medium would, over the same time periods, barely germinate (5,6,7,8,9,2) Not everyone has agreed with this concept. Knudson (15,16) proposed an alternative concept; that orchid seeds could germinate in the absence of fungi by being able to assimilate organic and inorganic nutrients available in the substrate. In effect he proposed and experimentally showed that orchids could be grown asymbiotically *in vitro*.

Whilst this asymbiotic method of propagation has proved enormously successful, enabling the mass propagation *in vitro* of many orchid species, it still does not alter the fact that in the wild state orchids are all associated with certain fungi. Nor does it alter the early concept of Bernard. Moreover, it has been shown that seeds of not all species germinate readily under asymbiotic conditions. Attempts have been made to germinate seeds of certain species, such as *Cypripedium calceolus* L., using a specially prepared medium with limited

success (12,14). Species of Australian terrestrial orchids have also proved especially difficult asymbiotically 9,18,20). A further problem has been the difficulty of transferring asymbiotically-grown seedlings which, in some cases, may have taken up to 25 months to reach a size large enough to transfer to soil mixes. Severe losses during transfer has been the norm (Stoutamire, pers. comms.; Clements, unpublished data).

One other aspect of the association between orchids and certain fungi needs to be expanded upon before going further. This aspect is the dormant period of certain orchids. At this time plants are reduced to an underground tuberoid. During the period of dormancy, usually through the summer months, fungi are absent from most tuberoids but present in the soil as dormant spores or encysted hyphae. Exclusion of these fungi is by way of phytoalexins. These "warding off" chemicals are predominantly to be found present in the epidermal layers of tuberoids. The conclusion to be drawn from the above is that the fungi must reinfect the orchid each growing season if the association is to continue.

PROPAGATION OF ORCHIDS COLLECTED FROM THE WILD

At the Australian National Botanic Gardens there is a very large collection of species of native terrestrial orchids. There are presently some 1300 pots containing more than 400 species. Most of these plants have been collected from the wild over the past 8 years mainly by the author from many parts of Australia.

The purpose of the collection is to have as many species in cultivation as possible and for those species to be represented by a number of collections originating from various parts of the wild species range, thus providing a large genetic base for each species.

The maintenance of this collection is viewed as a long term project. The use of artificial fertilizers is thus avoided. Consequently minimization of genetic change in the plants within the collection is being aimed for. Therefore, the use of artificial fertilizers to stimulate short term growth of plants does not take priority over the long term survival of the collection.

In order to achieve these stated aims the symbiotic method of propagation has been used. This method closely fits that which occurs in the wild. The soil mix used was designed with these aims in mind. It comprises 3 parts washed river sand, forming the main body of the mix while providing good drainage; 2 parts wood shavings (soft and hardwoods), aerating the mix and providing the fungus with raw materials on

which to live; 1 part leaf mould (*Quercus* spp), providing the plant and fungus with a small amount of nutrients which are relatively freely available. This alone provides a suitable mix, in which to grow many species of terrestrial orchids. However, it has been established through trials that the addition of ½ part loam (basalt) aids the general plant growth of many species. The loam is thought to provide the plant with minor elements that may be otherwise locked up in the decaying wood shavings. Fertilizer is not added nor is the mix steam sterilized prior to use. Plastic pots are used in preference to terra-cotta as it has been established that the water retention of the latter during the summer is poor, resulting in the death of plants of many species.

This environment is apparently adequate for the fungus and plants to live in as is shown by the number of species now in cultivation.

It has also been found that it is best to remove the soil from around the tubers, otherwise decay invariably results. Most plants collected while flowering contain the fungus in their roots, which is sufficient to inoculate the potting mix.

Plants once established, using the symbiotic method of propagation, flourish for a considerable length of time. Presumably they could do so indefinitely provided they are repotted once the potting mix is spent of nutrients.

It is usually more convenient to repot the terrestrial orchids during their dormant period in summer. As the fungus is known to be invariably absent from the tuber during this period, it is necessary to transfer some of the old potting mix to the new lot so that the fungus is not lost. Some species are short lived (5 to 10 years) in the wild and this is also the case with these same species in cultivation. It is therefore desirable to replace those plants with seedlings grown *in vitro* from seed collected from the adults before the latter die and replacement from a wild source is the only alternative.

THE SYMBIOTIC PROPAGATION OF ORCHIDS FROM SEED

The propagation of terrestrial orchids from seed using the symbiotic method of germination, similar to that described by Bernard (5,6,9), has been used with great success at the National Botanic Gardens (9,10). Over one hundred species have been raised from seed. A number of these species are classified as rare and endangered (17). The symbiotic method of germinating orchid seeds also duplicates, *in vitro*, that which occurs in the wild. Seeds are sown on a low nutrient medium (powdered rolled oats, 3.5 g; Difco yeast extract, 0.1 g; Davis agar, 10 g; and distilled water, 1000 ml) after surface steriliza-

tion with a 0.5% solution sodium hypochlorite. The medium is then inoculated with an appropriate fungal isolate; the test tube sealed with a sterile cotton wool bung before being placed in an environmental growth cabinet where the 16-hour day temperature is maintained at 20°C ± 3°C, and the night temperature is maintained at 15°C ± 3°C. Under this controlled environment the fungus first grows and covers the entire surface of the agar between 10 to 20 days from sowing. During growth the fungus infects the orchid seeds. Germination of these seeds soon follows providing the correct fungus has been used in the experiment. If not, the seeds either fail to germinate or swell only slightly and never manage to produce viable seedlings.

It takes 6 to 9 months, from sowing, for a seedling to grow, develop, and produce a tuberoid. This rate of development is comparable to that observed in the wild (Clements, unpublished data). It is then a relatively easy matter to transfer seedlings that have reached this state of development to the environment of a potted plant. Results to date show approximatley a 75% success rate in establishing plants grown symbiotically *in vitro* when transferred to a soil mix. In some cases 100% of seedlings have successfully been transferred to the soil mix. These latter successes have occurred when extreme care has been taken to ensure that the plants suffer a minimum water stress at transfer.

The first seedlings germinated symbiotically *in vitro* flowered in cultivation last year. Plants of *Diuris punctata* Smith var. *longissima* Benth., flowered just two seasons after being planted out from the test tube.

DISCUSSION

The symbiotic method of propagating orchids from seed offers the grower a number of advantages that are otherwise unavailable when seedlings are raised in the absence of the fungus. Firstly, seedlings grown *in vitro* already contain the appropriate fungus when they are transferred to the soil mix. It is, therefore, not left to chance as to whether spores of the appropriate fungus fall into and inoculate the soil mix and eventually the orchid. Secondly, it is known that these fungi normally found associated with the orchids actually protect the orchid tissue from being infected by a number of other pathogenic organisms. Although this particular state of control may exist only for the period while the orchid is healthy and actively growing it, nevertheless, assists greatly during the period of establishing the seedlings grown *in vitro*. Thirdly, symbiotically grown seedlings invariably take on the same morphological structure of the plants from seeds germinated in

nature. There is a very short period of adjustment between deflasking and renewal of growth. Consequently larger tubers are established during the growing season before the plants are forced to go into dormancy at the onset of summer.

The symbiotic method of germinating orchid seeds also offers the grower a method of obtaining seedlings of many species that until recently have proved impossible or extremely difficult to grow *in vitro*. At a time when more and more species of plants are being lost to science, the symbiotic method of propagation offers some hope in the conservation of many orchids.

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TISSUE CULTURE OF *EUCALYPTUS*

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Abstract. Clones of several eucalypt species have been propagated *in vitro*, enabling the utilization of genotypes which have been selected as superior individuals. By this means it is possible to produce clonal populations showing superior growth rate, form, and adaptation to specific sites. Large numbers of hybrids exhibiting a marked degree of hybrid vigour can also be grown.

Close cooperation between researchers and the horticultural and forestry industries will be needed to fully exploit the commercial potential of this technology. The clonal propagation of high value horticultural specimens, such as *E. caesia* and *E. macrocarpa*, offers obvious and immediate commercial benefit. Extension of this practice to plantation forestry will require lower production costs but the large demand for plants will stimulate the development of improved and cheaper techniques.

INTRODUCTION

Eucalypts, like most forest trees, have long generation times (from years to decades), are very difficult to cross-pollinate to produce large quantities of seed of hybrids, and selection of genotypes for important characteristics like growth rate and form usually takes several years. All of the above features make tree breeding a slow and costly process.

The vegetative propagation of superior clones can assist in overcoming some of these problems as selected clones can be rapidly propagated for commercial plantations. Since vegetative propagation enables the cost of breeding and selection to be spread over a large number of clonal individuals then advanced breeding techniques (e.g. hybrids between inbred lines, interspecific hybrids, and back-crossing) could become as practical for tree breeding as they are with the breeding of annual crops.

There are several methods of vegetatively propagating eucalypts (35) but for forestry plantations stem cuttings and tis-

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There are several methods of vegetatively propagating eucalypts (35) but for forestry plantations stem cuttings and tis-

sue culture are the only practical methods. This paper mainly discusses micropropagation of eucalypts.

TECHNIQUES FOR MICROPROPAGATION OF THE EUCALYPTS

The techniques for micropropagation of the eucalypts are similar to those developed for other plants. Shoot explants (with the leaf laminae removed) from seedlings or from basal coppice shoots of older trees are surface sterilized in dilute sodium hypochlorite and placed onto a sterile medium consisting of ¼ strength Hoagland's solution (58) and 2% sucrose (Figure 1). After 1 month axillary shoots usually develop and these are subcultured to a shoot multiplication medium (Table 1) where the shoots grow rapidly producing many axillary shoots (Figure 2). Root formation occurs when the shoots are subcultured to a rooting medium containing an auxin, but no cytokinin (Figure 3 and Table 1).

Table 1. Composition of Media[1]

	Shoot Multiplication Medium	Rooting Medium
Murashige and Skoog salts	½ strength	¼ strength
Sucrose	2.0%	2.0%
Agar	0.8%	0.8%
Benzylaminopurine	1 μmol l^{-1}	Nil
Naphthaleneacetic acid	1 μmol l^{-1}	Nil
Indolebutyric acid	Nil	10 μmol l^{-1}

[1] The above media have worked well for a number of species but the optimal hormone concentration varies among clones.

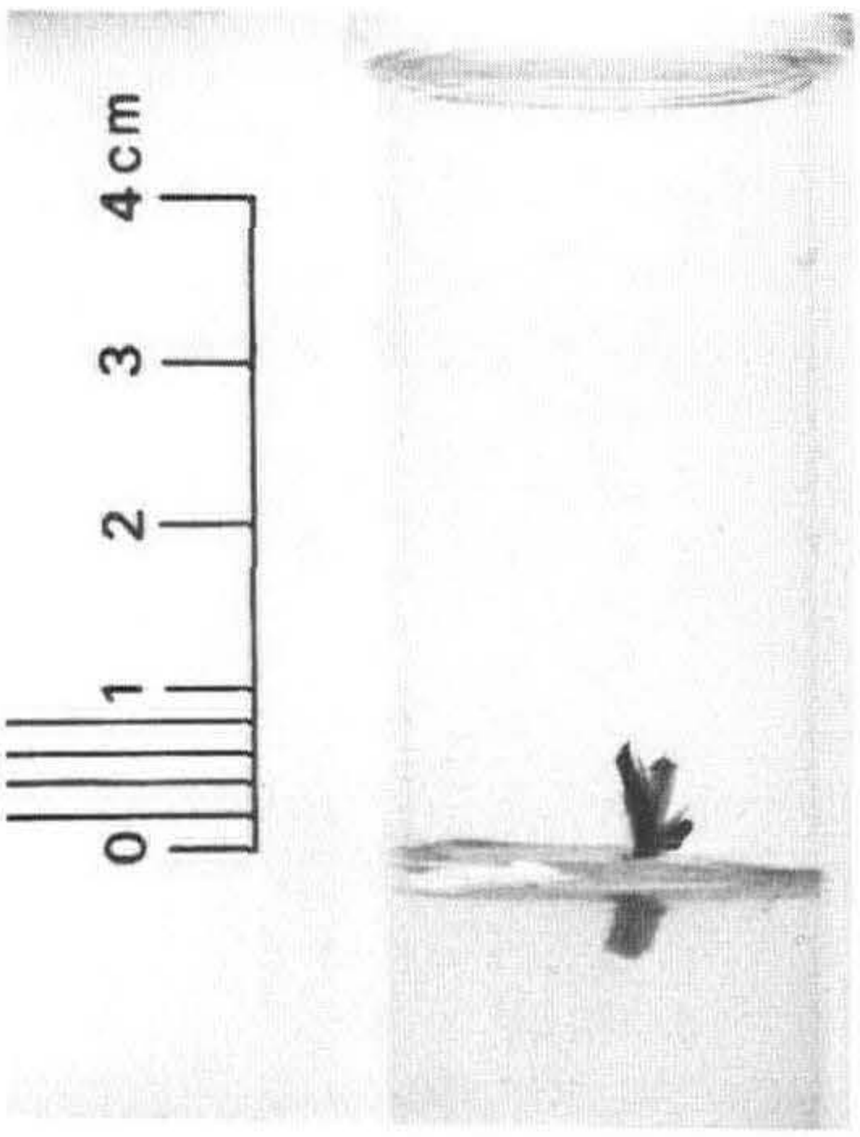

Figure 1. Initial shoot explants.

Figure 2. Shoot growth after 3 weeks on shoot multiplication medium.

Cultures are grown in a cabinet at a constant temperature of 25°C, a photoperiod of 8 h, and a light intensity by fluorescent tubes of 100 μE m^{-2} s^{-1}. Root development on some clones is enhanced by holding them in the dark for 7 days prior to placing them in the growth cabinet.

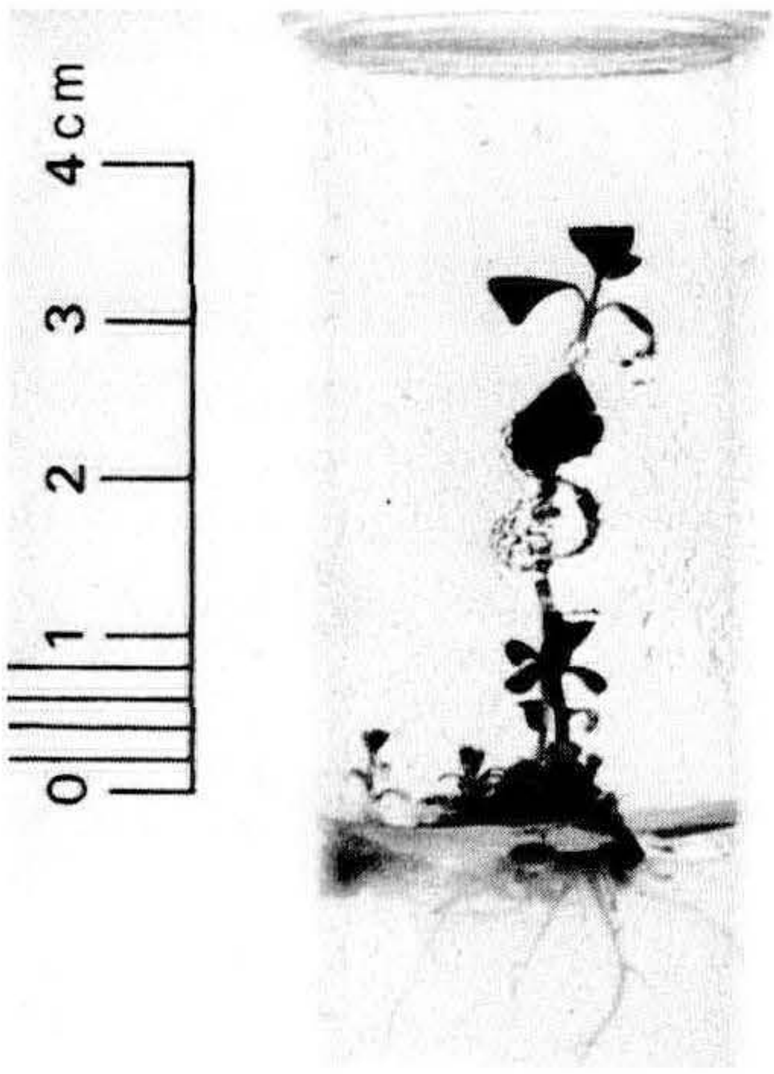

Figure 3. Root formation on shoots

The plants are hardened by removing them from their containers and placing them in a greenhouse under high humidity conditions (intermittent mist or a plastic cover) for two to three weeks (Figure 4).

The media described in Table 1 are very simple, consisting only of mineral salts, sucrose, and two hormones. No organic growth factors or amino acids are essential for propagation; in fact, some of them may be inhibitory (21,37).

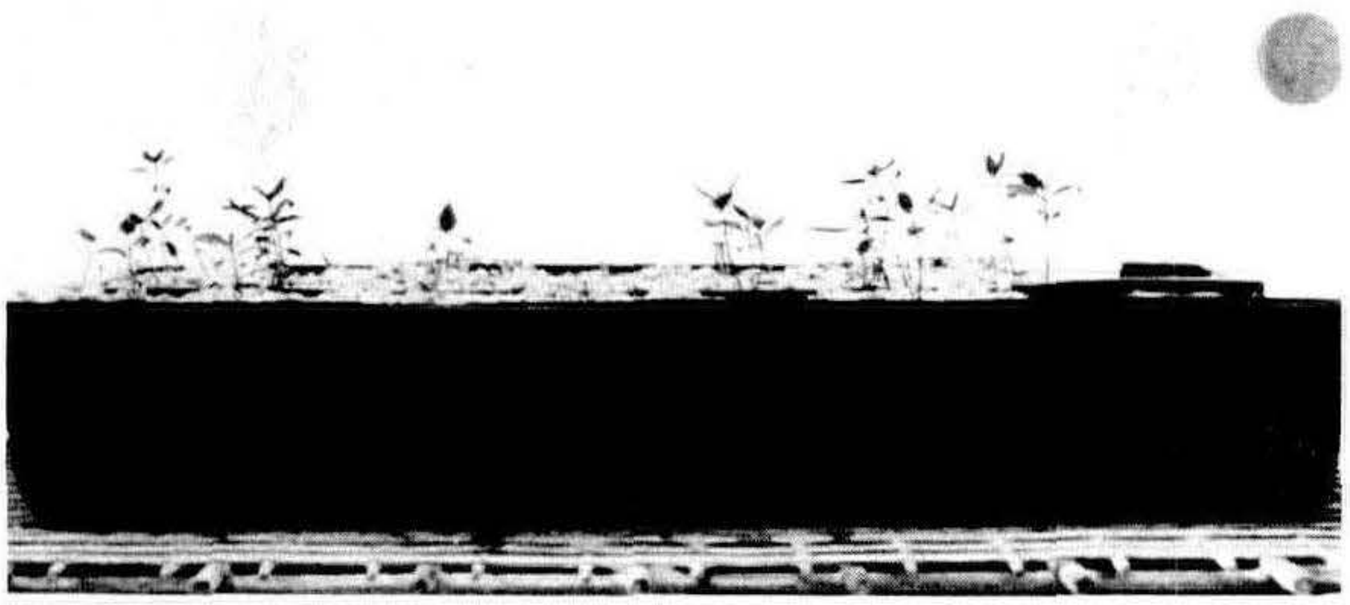

Figure 4. Hardening plants under high humidity conditions.

The three main advantages micropropagation has over propagation by stem cuttings are: a small requirement for space in order to maintain the parent plants, a higher multipli-

cation rate, and the absence of pests and diseases. One square metre of growing space can accommodate 1,000 parent plants in vials, but the same number of parent plants, maintained as hedges, would require about 1 ha in the field, or a large greenhouse if the hedges were grown in pots. The multiplication rate by micropropagation is at least double that of cuttings. After the clones in tissue culture are freed from diseases and insect pests (38) they can be held in this state indefinitely. On the other hand, it is very difficult to maintain hedges and stem cuttings free of diseases and insect pests. The absence of pests and diseases with axenic cultures simplifies long distance transport and quarantine procedures.

Several eucalypt species have now been propagated *in vitro* (Table 2). For all of the species we have propagated (36) the shoot multiplication rate is adequate (at least three-fold every 3 weeks), even for shoots from the crowns of adult eucalypts. However, some species (e.g. *E. regnans* and *E. globulus* subsp. *bicostata*) have a low and variable rooting percentage (less than 30%). Further research is necessary in order to find the optimal conditions and hormone concentration for the reliable propagation of these species.

Table 2. Eucalyptus species that have been propagated *in vitro*.

Species	Reference	Species	Reference
E. alba	41	*E. gunnii* × *E. cinerea*	25
E. camaldulensis	5,36,39	*E. gunnii* × *E. viminalis*	25
E. citriodora	3,32,33,44,45	*E. gunnii* × *E. dalrympleana*	25
E. curtisii	36	*E. macarthurii*	25
E. dalrympleana	24,25,26,27	*E. occidentalis*	5
E. delegatensis	25	*E. pauciflora*	25,26
E. ficifolia	4,16,17,18,20,21,36	*E. regnans*	36
E. globulus subsp. bicostata	36	*E. robusta*	5
E. grandis	11,12,15,27,36,39	*E. rudis*	36,52
E. grandis × *E. robusta*	39	*E. viminalis*	25
E. gunnii	24,25,26		

APPLICATIONS IN FORESTRY AND HORTICULTURE

Micropropagation of eucalypts selected as beautiful horticultural specimens, such as *E. caesia* and *E. macrocarpa*, offers immediate commercial benefit because of the high prices people are willing to pay for them.

Essential oil production from eucalypt clones is another potential application as individual trees are known that have both a high oil yield and desirable composition (54). Selected trees of *E. radiata* and *E. polybractea* (Syn.: *E. fructiceforum*?) are two oil producing species being studied.

In forestry, large economic gains are possible by growing clonal plantations. Vegetative propagation not only enables the outstanding individuals of a population to be grown, it also

enables hybrid vigour to be exploited. Clonal plantations of eucalypts are being established in the Congo and Brazil on a scale of millions of trees per year (8,23). The clones are propagated by cuttings taken from basal coppice shoots. Large scale plantations of eucalypt clones (produced by micropropagation) are planned in Florida for the production of methanol. Commercial plantations of clones of forest trees other than eucalypts are also being established (10,42,43,47,49,55,59).

The potential gains in growth rate from using clones in plantations are very large. Seedlings from selected trees of *E. grandis* had an average volume 54% greater than routine seedlots (1). If the best individuals within these selected seedlings were propagated as clones, volume gains in the order of 100% could be realized. Very large gains in wood volume, in the order of 30 to 100% greater than routine planting stock, have been recorded from plantations of hybrid eucalypts in several parts of the world (6,8,9,22,29,57).

In continental Europe and in the USA there is a demand for cold-tolerant eucalypts. Natural hybrids have been selected and vegetatively propagated in Florida, USA, and France (25).

Since all the individuals in a clone are genetically identical they enable certain experiments to be evaluated more efficiently. For example, genotype × environment interaction is determined more efficiently with clones than with seedlings (7,46,48). A clone of *E. marginata* is being used in our laboratory to examine genetic variation in the pathogenicity of *Phytophthora cinnamomi*, the cause of Jarrah dieback in Western Australia.

Eucalypts are one of the world's most important exotic hardwoods. Plantations now exist in over 58 countries on an area exceeding 4 million ha (28). Brazil alone plants 200,000 ha each year, which is six times greater than the annual establishment rate of all forest plantations in Australia (2).

The total area planted each year to eucalypts in Australia is relatively small (2,000 ha) (2) because we still have large natural stands. However, because of the demands placed on natural forests as a source of water, recreation, and conservation, and since many of our readily accessible forests have been harvested, an increasing area of eucalypt plantations are being grown (13).

Forestry entails not only the growing of trees for wood production, but also includes rehabilitation of mining sites, agroforestry (where trees are grown at a wide spacing in association with crops and livestock), and management of shelterbelts, woodlots, and amenity plantings. In many of these situations a special type of tree is required, e.g. salt tolerant trees

for planting on saline areas, trees tolerant of heavy metals on mining sites, and trees with good form, small branches and special wood properties for agroforestry. Clones with these characteristics will find a ready market as the annual demand is now very considerable. The Forestry Commission and the Natural Resources Conservation League in Victoria each produce about one million trees a year for farm and Shire plantings, and mining companies in Australia plant several million trees each year for the rehabilitation of mining sites. A large proportion of this demand is for eucalypts.

DANGERS OF CLONAL PLANTATIONS

Plantations consisting of one or a few clones lack genetic diversity and this increases the likelihood of disease and insect pest epidemics; poplar leaf rust in Australia is a recent example. The lack of genetic diversity is not restricted to plants grown as clones as many of our important crop plants have a restricted genetic base (51).

One method to reduce the problem of genetic uniformity in clonal plantations is to plant a large number of clones (preferably of known performance in relation to diseases and insect pests) either randomly or in small compartments throughout the plantation (43,47). As many of the clones to be planted in the future will be hybrids, a large number of new genotypes will be available for selection. Genetic variation in time can be produced by planting different clones in different years.

CLONES AS A METHOD OF GENETIC CONSERVATION

Clonal plantations may represent a loss of genetic diversity, but clones also offer a simple method of conserving genes for incorporation into future breeding programs. Genotypes selected for frost tolerance and disease resistance are obvious examples.

Clones maintained *in vitro* are particularly useful in this respect as a large number of disease-free individuals can be held in a small space with a minimum of maintenance. Shoot cultures of *E. camaldulensis* and *E. grandis* have been maintained on a simple medium in a domestic refrigerator for over 8 months. When the shoots were subcultured to a fresh medium and placed in a growth chamber they grew normally.

PROPAGATION OF ADULT EUCALYPTS

Shoots taken from the upper parts of adult trees cannot yet be routinely propagated by the above techniques. Many eucalypt breeders regard this as a major disadvantage for com-

mercial vegetative propagation. This is not so, since the majority of eucalypts can develop basal coppice shoots from mature trees and these can continue to serve as a source of material for vegetative propagation. Alternatively, parent plants can be maintained as hedges and serve as a source of material for vegetative propagation (35).

If it were possible to propagate shoots from the upper branches of adult trees one would have to determine that such propagules did not display any effects of cyclophysis (53), especially with regard to growth rate. On the other hand, if clones from the tops of adult trees flowered while they were small this would be a real advantage of marketing some ornamental eucalypts.

Several eucalypts have shown a limited potential for propagation from adult shoots; *E. ficifolia* (4,21), *E. citriodora* (33), *E. grandis* (12,27) and *E. dalrympleana* (27).

TRANSFERRING THE TECHNOLOGY OF MICROPROPAGATION FROM THE LABORATORY TO THE FOREST INDUSTRY

This year the Division of Forest Research and a collaborator will be undertaking a project to produce clonal trees for experimental plantations. Eucalypts to be propagated include highly salt tolerant clones of *E. camaldulensis* and several other species. Ramets of these clones will be provided to several organizations for field trials and for planting on saline areas on farms. Clones of *E. grandis*, *E. pilularis*, *E. cloeziana* and *E. regnans*, as well as several ornamental eucalypts, that have superior growth rate and form will also be studied.

In addition to eucalypts other tree species will be included in the project. These include hybrids of *Pinus caribaea* × *P. elliottii*, *Leucaena* hybrids, *P. radiata*, and *Santalum acuminatum*.

The aims of the project are to propagate selected clones, to examine the economics of micropropagation and, in association with others, to compare the growth of clones to that of seedlings from seed orchards. Our particular role will be to micropropagate clones that have not previously been propagated, to simplify the procedures so that the costs per plant can be reduced, and to make the clones available for long-term field trials.

If the project is to succeed cooperation must exist between many organizations and individuals. We have already received a great deal of cooperation as all of the selected clones have been made available to us by other research organizations; the salt-tolerant eucalypts from the University of Melbourne, *E.*

radiata from the New South Wales Museum of Applied Arts and Sciences, *E. ficifolia* from Mr. J.H. Browne, a botanist from Red Cliffs, NSW, the hybrid pines from the Queensland Department of Forestry, the *Leucaena* hybrids from the CSIRO Division of Tropical Crops and Pastures, and the *Santalum accuminatum* clones from the Division of Horticultural Research.

The field trials are an essential part of the project. For instance, the salt-tolerant eucalypts have been selected under laboratory conditions where they demonstrate a remarkable degree of tolerance to sodium chloride. However, they have yet to be thoroughly tested in the field for additional characteristics such as growth rate, frost resistance, tolerance to insect grazing, their ability to lower saline water tables, and how they can be incorporated into grazing and cropping programmes. Field trials of the salt tolerant clones will be undertaken by a number of organizations including the Victorian Forestry Commission, the Victorian Soil Conservation Authority, and the CSIRO Division of Land Resources Management in Western Australia. A number of other organizations, farmers, and Shire Councils have also made preliminary enquiries. For species with attributes other than salt tolerance, field trials are planned by APM Forests and the State Forest Services to compare growth of the selected clones to seedlings. Cost comparisons between micropropagation and cuttings will also be made.

Clones of many other eucalypts, their hybrids, and other forest species are worth propagating; *E. gomphocephala* is a species which is adapted to calcareous sites, and clones of *E. marginata* may exist which are tolerant to *Phytophthora cinnamomi*. This latter study is being undertaken by Dr. J. McComb and Ian Bennett at Murdoch University in Western Australia.

The cost of producing plants by tissue culture can be reduced from techniques practised in the laboratory (19,30). Disposable Petri dishes have been successfully used by us to grow and transport the salt tolerant clones within Australia (Figure 5). Labour costs can be reduced if root formation *in vitro* is unnecessary. Shoots of some eucalypt clones developed roots when they were pre-treated with a rooting hormone and set as miniature cuttings. Another approach that will be investigated is to examine whether shoot multiplication and root formation can take place on the one medium.

In the future cell cultures of eucalypts (31) could be used as a tool for genetic engineering, *in vitro* selection, somaclonal variation, and haploid plants (56). Some of these techniques are already starting to play an important role in the breeding and selection of our crop plants. There is no inherent reason

why they cannot also play a role in the breeding and selection of forest trees and other woody perennials (34,40,50).

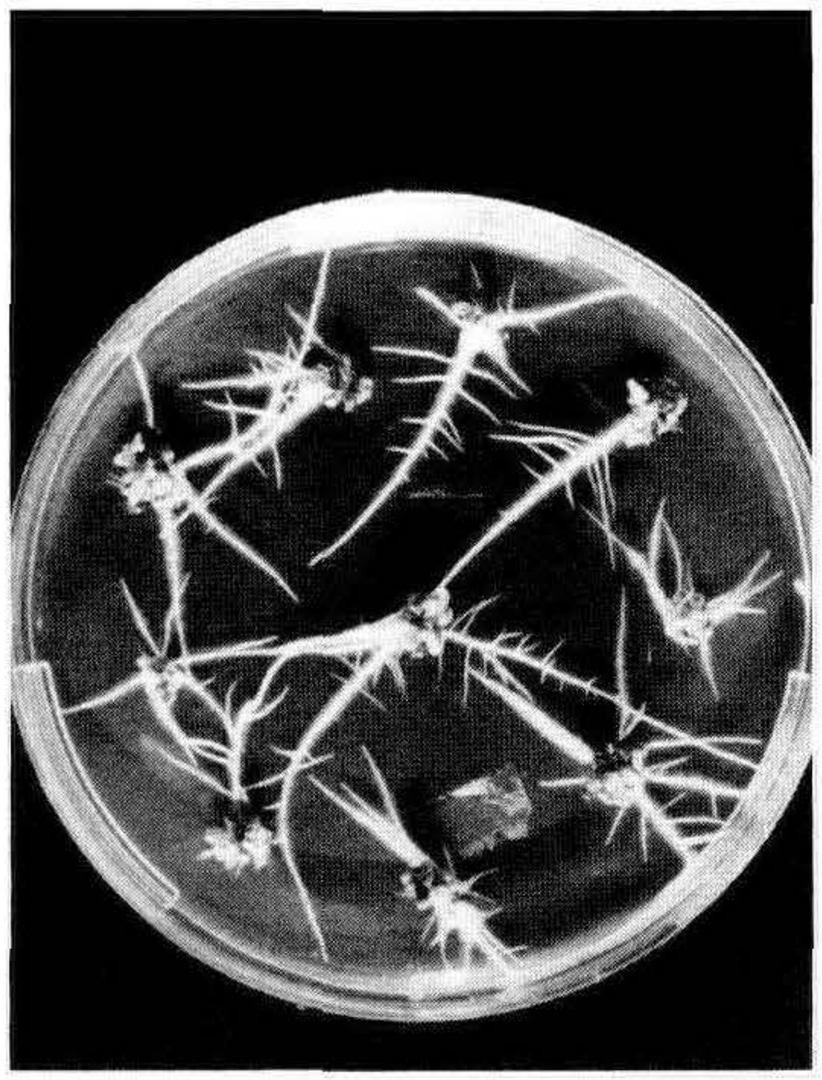

Figure 5. Plantlets of a salt tolerant eucalypt growing in Petri dishes.

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PRELIMINARY REPORT ON A TECHNIQUE WHICH PROVIDES A "MATURITY FACTOR" FOR TREES GROWN IN TISSUE CULTURE

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I would like to preface this paper with a quote from Dr. Ron de Fossard. He advises that:

"We should not lose sight of the advantage of tissue culture plants and propagation. It is not just to clonally propagate a cultivar. It is to produce a *far superior* product, free of virus, fungi, and bacteria, from a highly desirable horticultural specimen and, where yield is important, from the upper 0.1% or better of the normal curve of distribution of the species."

Good and timely advice, indeed. Anyone can produce a plant in tissue culture. Often, a little careful juggling with media can produce better yield results than those published in the literature — but, to what end? Many of the plants grown in culture originate from seed or spores. Frequently, too, tissue-grown plants are just that, and *no positive selection* has actively taken place. Consequently, these plants are of little or no value in improving the standards of that cultivar. I feel it is an essential feature of any commercial tissue culture lab to actively improve the quality of those plants chosen for culture.

Dr. de Fossard goes on to say:

"It (the tissue culture plant) should be able to outsell plants produced by other methods of propagation because it should yield a *more valuable plant* and thus sell for a higher price. It should permit all-year round propagation. It should permit the propagation of species that cannot be vegetatively propagated by any other means. It should lead to the exploitation of protoplast and haploid work. It should enable clean plants to be kept clean more easily than at present. It should enable the expedition of plants from one country to another. It should give us high multiplication rates."

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All excellent points. However, there is one more feature that a cultured plant *could* give us. That is, *a precocious and predictable yield of fruit or flowers.*

I believe that we have developed a working hypothesis which offers a very real advance in the practical utilization of tissue culture techniques. This advance utilizes that final point — "a precocious, predictable yield of flowers or fruit."

You will see from the title of this paper that it is a discussion of a potential technique. I must stress at this time that it is a laboratory technique only; one that is supported only by experimental evidence, and *not* by any large scale field trials.

I describe some of the results here and detail some aspects of my work. It is hoped that field proof and amplification of the technique will be available for the 1983 Darwin I.P.P.S. Australian Conference.

We are told by most of the conventional tissue culture exponents that an ability to rapidly multiply is a feature — an essential feature, of juvenility — conversely we are told that mature (i.e. sufficiently old fruit-bearing plants), particularly in the woody angiosperms, cannot or will not multiply "in vitro".

This is not strictly true! Under the right conditions, mature tissue can be induced to multiply "in vitro" and, in fact, can be expected to behave in a juvenile manner. As a corollary, in our experience, this tissue, when removed from culture, can *revert back* to the *mature status* of the donor parent.

It is unfortunate that most of the rapid multipication techniques used in horticulture concern soft-tissued plants. It shows a regrettable lack of insight that much of the early work done on woody plants merely adapted those techniques used for soft tissue material. Almost invariably this meant using juvenile (i.e., seedling) or quasi-juvenile (i.e., regenerated juvenile shoots from wounds on mature plants), as starting material to get any sort of response.

Techniques such as callus formation and subsequent redifferentiation of leafy shoots seemed to be most popular, closely followed by callus/embryoid production. Both techniques meant that any regenerated plantlets would be completely juvenile in morphology, behavior, and general characteristics. This, in turn, meant that they would follow a "normal" development to maturity over a period of time.

Where de-differentiation into callus, and subsequent redifferentiation into leafy plants occurs, all mature characteristics of the tissue are apparently lost.

There are a significant number of references in the literature which indicate that "sometimes" and under "certain" conditions, regenerated plantlets did not completely revert to a juvenile state, but retained some, most, or all observable mature characteristics.

Our technique depends on the development and multiplication of axillary shoots, and complete avoidance of any callus phase.

Within the scope of our work, I have defined "maturity" on a purely morphological basis, being:

(i) The immediate production of adult leaves, (if they differ from juvenile leaves) on being deflasked.

(ii) The ability to produce 'de novo' flower buds, or bear fruit in a shorter period of time than the equivalent "normally" propagated plant.

(iii) A reduced rate of growth, with more emphasis on flower buds or fruiting wood than conventionally propagated plants of the same age.

If I may digress a little, at this time, imagine the situation that could exist in the future. To an orchardist or farmer, the knowledge that stock planted out was semi- or wholly- *mature, at the time of planting* would be a unique advantage.

Consider:

(i) that such stock could commence bearing at an early age, obviating a long lead-in time for yield, and incidentally, for profit.

(ii) that such stock, because of its precocious nature or semi-mature status would not necessarily be as vigorous as seedling, cutting grown, or grafted plants. This could give benefits such as a tree of reduced size and could reduce the need for regular pruning, and

(iii) such a condition would generate great advantages when harvesting a crop — harvest could be achieved quicker and more cheaply if pickers worked from the ground or mobile picking units, rather than having to climb trees.

Our lab, over the last 2½ years has worked on a number of woody plant species. Our most spectacular results have been with roses and grapes. Other trials have been conducted with cassava, papaya, mango, bougainvillea, grevillea, and passion fruit. In the United Kingdom and Europe, I had the opportunity to test some of my ideas on such diverse plants as coconut, durian, and apple.

Other workers, working independently have published results that seem to confirm the existence of the condition I have called the "*maturity factor*".

Such indications occur with coffee, apples, peaches, and cherries. In fact, it appears that any plant which can be successfully marcotted (air-layered), can be successfully shown to exhibit the "maturity factor".

Expressed simply, this "maturity factor" states that: "providing the donor plant is mature and in a suitable condition before excision of axillary buds, those mature buds may be induced to behave in a juvenile manner "in vitro", yet return to a mature or semi-mature condition after deflàsking, in a relatively short time."

We have had miniature and floribunda roses flower from culture in 49 days after deflasking. Hybrid teas take a little longer, generally around 60 to 65 days to full opening of the blooms.

With the smaller-flowered types the blooms are generally identical with those produced on cutting-grown or grafted plants. The hybrid teas generally have only half the number of petals of a 2-year-old field-grown plant. However, in the second flush of flowering blooms are virtually normal and plant growth is similar to that of a grafted plant.

Roses are not a field crop in the tropics, they're not even a good garden subject, as our constantly warm weather provides no chilling to terminate a period. To test the plant completely then, we are setting up field trials in Adelaide, Melbourne, and Townsville. Those results and independent assessments will be available at the Darwin IPPS Conference in 1983.

Grapes are in a similar situation. We have successfully cultured axillary buds, tendrils, and stem segments and achieved commercial propagation rates from all sources. Plants raised *in Darwin have flowered and set fruit* in as little as 12 weeks from deflasking. Once again though, independent testing in a more suitable climate needs to be done for a complete assessment.

Similarly, we have achieved flowering (but aborted fruit, soon after set) on papaya at an age of only 12 weeks from the flask. Since the initial trials on random stock, we have been plagued with bacterial problems. These are mostly a diptheroid as well as *Pseudomonas putrifaciens*, which seem to be intimately associated with the clone lines we are testing on behalf of the local Department of Primary Production. We seem to have gained control of the infections now, using chloramphenicol succinate (an antibiotic of sinister reputation — extended exposure in humans destroys bone marrow). However, at 1 to 5 ppm it knocks out the pathogens and scarcely damages tissue.

Israel has reported precocious flowering in dates when, after certain field trials, cultures flowered in 3 years — instead of the more normal 15 to 25 years for seedling dates. Similarly, Italy and the United Kingdom have reported unusual and early flowering in apples and cherries during certain tissue culture trials.

In the case of passion fruit, flowering can be achieved under 12 weeks. Sampled tissues include leaves, tendrils, young stems, and flower buds. Regardless of the source of explant material, precocious "de novo" flowering occurred. On some of the larger, leafy plants derived from young stems or nodes flower initiation and, in a few cases, flower development occurred "in vitro".

With the non-woody species, we are on firm ground, with easily demonstrable examples of early flowering from mature tissue available.

These examples may be drawn from the literature and from my own work. For instance, Venus fly trap can be induced to flower within 12 to 15 weeks, "in vitro". *Drosera* and *Byblis* spp. can produce functional flowers in 4 to 6 weeks. Various researchers likewise report "in vitro" flowering of potato, hyacinth, and bouvardia. Bromeliads, grown from seed and multiplied, take a normal time span to flower, but those produced from mature tissue (our lab and several European ones) invariably produce blooms in a significantly shorter time. Potatoes can be induced to produce axillary tubers "in vitro", when tissue is taken from mature, end of the season, plants and can be maintained in this status indefinitely. Such axillary tubers taken out of culture, behave in a completely normal manner in subsequent trials.

It is my belief that any plant that can be cultured, can be induced to exhibit the "maturity factor". Further, any such plant will behave in a completely normal manner when subsequently field-grown. Differences in final height and shape are expected, as such material *will not go through the growth and formative years* of a conventionally propagated plant.

Such differences are a considerable advantage if the end objective for the exercise is to produce flowers, fruit, or seed, in as short as possible time.

THE USE OF FRESH PINE SAWDUST AS A BASE FOR INDOOR PLANT POTTING MIXES

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The potting mix currently in use at Kasteel's Nursery is the result of several years development. I intend in this paper to outline some of the more interesting facets of this development process.

About six years ago we used two basic potting mixes. The first, a peat, sand, perlite mix, was used for all plants up to 6″ pot size. The second, a mixture of soil, ash, cow manure and wood shavings, was bought premixed and delivered by the truckload and used for all plants in 8 in. or larger containers.

The decision to look for another potting mix was made when the price of German peat moss was rising almost every day and it seemed reasonable at the time to use one mix for all container sizes.

On the strength of a free sample which looked and felt good, a properietary mix based on composted hardwood sawdust and coarse sand was tried. By the time we were using the third truckload the first batch of plants had stopped growing and developed severe yellowing of the upper leaves and tips. Although I was able to correct the problem by liquid feeding with iron chelates and a high nitrogen formulation, we were not very happy.

The next mixes came from a different supplier who included milled pine bark in his mix. Very similar results were obtained and corrected the same way. I was able to prevent this from then on by delivering a special brew of fertilizer to the supplier who included this in each mix made for Kasteel's Nursery.

Although this procedure worked there were still some difficulties. One of these was the problem of waterlogging which became apparent after some time in the pot. A terrible odor was usually associated with the waterlogging. It seemed that the composting process was continuing in the pot causing very fine particles of sawdust to block the drainage and allowing the growth of evil smelling anaerobic bacteria.

This was partly solved by addition of rice husks to open up the mix. However the supplier refused to mix them through, saying they were too messy, so this extra mixing had to be done at the nursery.

Four years ago I attended a horticultural refresher course at Gatton Agricultural College and was interested to see them using raw sawdust in a mix. At that time I spoke to other nursery people who had tried using hardwood sawdust in potting mixes. I discovered that they all complained of similar problems, whether the sawdust was fresh or composted.

I put down some trials using a mixture of fresh hardwood sawdust, river sand, and rice husks plus what I hoped was a balanced fertiliser mix. Growth and vigour of the plants in the trial was equal to or better than the controls in our composted sawdust mixes from the same supplier.

One mix delivered seemed to have a more granular appearance and larger particle size than previously supplied. We found that the supplier had accidentally prepared this using fresh pine instead of fresh hardwood sawdust. Since then fresh pine sawdust has been used in all mixes for two reasons: firstly, although we had never had any trouble due to toxicity from phenolic compounds in hardwood sawdust, by using pine sawdust this possibility could be avoided. Secondly, the larger particle size seemed to give a better "feel" to the mix.

For the past two years all mixes have been made on the nursery premises from raw material stockpiles. Sandy loam has taken the place of coarse sand to provide better water retention during summer.

The present mix which has now been unchanged for 18 months seems to have met the initial requirements of: (a) low cost, (b) ready availability, (c) suitability for all plants grown by this nursery, regardless of size.

Pine mix A:

Physical components: (25 cubic yards).

56% fresh pine sawdust. (15 buckets on front-end loader)
22% sandy loam. (6 loader buckets)
22% rice husks. (3 bales)

Chemical nutrient components: for 25 cubic yards.

75 kg. Nutricote	8 kg. urea
50 kg. dolomite lime	2.5 kg. manganese sulfate
25 kg. Mo-super	1.0 kg. zinc sulfate
10 kg. potassium nitrate	400g copper sulfate
12 kg. iron sulfate	320g borax

In the past 12 months Kasteel's Nursery has used approximately 800 cubic yards of this mix, which we have called Pine Mix A.

Each new batch is tested for pH and salinity. The pH is usually between 5.7 and 6.0 while the salinity is generally about 2,500 ppm total salts. This level of total soluble salts

may seem high for some plants but we have never had deleterious effects from salinity level even when cuttings are struck directly in the mix.

The completed mix has the following physical properties of aeration and water retention for standard and squat 6" (150mm) pots. Note the difference due to the shape of the containers.

Standard 6" (150mm) pot.

	Volume	Percentage
Pine mix A	675ml	45%
Water	450ml	30%
Air	375ml	25%
Total volume	1500ml	100%

Squat 6" (150mm) pot.

	Volume	Percentage
Pine mix A	530ml	45%
Water	470ml	40%
Air	175ml	15%
Total volume	1175ml	100%

We also use a supplementary liquid feed programme, which provides the following elements:

N = 150 ppm
P = 60 ppm
K = 120 ppm
Fe = 2 ppm (as FeNa EDTA).

This is given every second watering with an average of about once a week, being applied more often in summer and less often in winter.

There are plants at the nursery which have been growing in the same mix for two years and are still growing strongly. The mix has not broken down any more rapidly in this time than one would expect from any medium having a high organic matter content, e.g. peat-based mixes.

PROBLEMS ASSOCIATED WITH PINE BARK AND HOW WE OVERCAME THEM

GORDON LAMB
Grove Nursery
Lot 31, Hale Road
Wattle Grove, Western Australia

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true. We discovered it was cheap, it was too good to be true, but it certainly wasn't simple.

At Grove Nursery we grow a variety of indoor shadehouse plants and we have an interest in growing *Ficus benjamina* and *Ficus lyrata* (Syn.: *F. pandurata*).

Our old mix prior to using pine bark was 40% German peat, 40% Jarrah (*Eucalyptus marginata*) sawdust, 20% blue metal. We had this mixed commercially by an outside contractor and it cost us $338 for 6m^3. Substituting pine bark for all the German peat resulted in magnificent savings so we decided to experiment further.

In the first season we encountered chlorosis and phytotoxicity problems in *Ficus benjamina* and *Ficus lyrata*, something we had never encountered before when using German peat. The puzzling factor here being the chlorosis was on the new growth, the old leaves remaining green. This didn't really indicate any deficiency that we were then familiar with. We contacted the Department of Agriculture who recommended a spray of iron chelate. So we sprayed with iron chelate to no avail. Our next approach was to modify the mix with a surface application of Osmocote 100 and UF38 at 1 tbsp./5 l. bucket. This cured the problem but we had lost two month's production time with two crops of *Ficus*.

In December, 1980, we decided to look at the problem from a different angle. We purchased a conductivity meter, a pH meter, a relatively inexpensive beam balance, and enlisted the help of a friendly student and attacked the problem from the back door.

Our first thoughts were what does a plant require from a potting mix and which of these characteristics were inherent in pine bark:

1. A substance to hold the plant upright.
2. A substance with a pore space at container capacity of 25 to 30%.
3. A good cation exchange capacity.
4. Dark in colour.
5. Cheaper and more economical then German peat.
6. Readily available.
7. Good water holding capacity.

We thought pine bark would give us all these qualities once we overcame the problems of phytotoxicity.

As we had had some success using nitrogen and Osmocote we first looked at the nitrogen uptake of pine bark. We constructed two cubicles out of pallets and put 1 metre^3 of pine bark in each. We learned that the C/N ratio of pine bark was

approx. 450/1 compared to sawdust 150/1, so we decided to put 8 Kg Agran 34 per m^3 and 10.8 Kg m^3 to the second m^3.

The official consensus of opinion was that we would have ammonium toxicity and have too high a total dissolved salts (T.D.S.) The pine bark started out with a pH of 3.5 and finished six weeks later with a pH of 4.5 and a T.D.S. of 150 micromhos per cm, which is almost insignificant. To this compost we added these nutrients and grew a trial crop of *Ficus benjamina*.

About this time I read an article by Thomas and Perryman (2) which gave us a hint that the pH was too low for optimum use of nitrifying bacteria. To the next trial we added lime at the rate of 6 Kg/m^3 to raise the pH to 6. This proved very advantageous. Still further research and reading brought to light a lot of helpful information. The composting process is basically an aerobic function requiring oxygen for maximum composting. This led us to believe that a stack 1.5 m deep would compost easier and far quicker than one 3.5 m deep, as seen in many nurseries. During trials and experiments we verified this fact several times. As the composting process is aerobic the less machinery used on top of the heap the better. We found the compost in the middle and at the bottom of the heap tended to have an unpleasant odour of tannic acid, similar to decayed silage. We attributed this to anaerobic fermentation rather than aerobic composting.

Cappeart, *et al.* (1) suggest that the optimum amount of nitrogen would be 0.75% of the dry weight. This amount came to 5.6 Kg NH_4NO^3 per m^3. We used up to 10.8 Kg NH_4NO_3 per m^3 in trials with no adverse affects on plants. At present we are using 7 Kg m^3 with good success.

Cappeart, *et al.* also suggest that at the proper pH the microflora can absorb more oxygen therefore speeding up the composting process. We were able to lower our amount of NH_4NO_3 from 10.8 Kg to 7 Kg/m^3 once we had raised the pH by adding dolomite lime.

It was suggested that phosphate could be added to speed up the composting process; however Cappeart, *et al.* show that the addition of phosphates do not influence the oxygen uptake of the microflora, therefore it is doubtful whether we need to add any superphosphate at all to the compost heap. In fact, if the compost is being used for native plants it could be harmful.

Many people seem to think that the hotter the compost heap the better. However Cappeart, *et al.* show that the temperature in an unfertilized heap had little to do with the speed of composting. The respiratory rate of the microflora didn't

increase with temperature. But, in a fertilized heap, the optimum temperature was around 40° to 47°C, depending on the amount of nitrogen available. This discovery also verified our suspicions that composting is quicker and more even in a shallow windrow where the centre does not reach temperatures in excess of 50°C.

Moisture is another critical factor in the composting of pine bark and there is a high correlation between moisture content of the heap and the speed at which the bark composts. Optimum oxygen consumption of the microflora occurs when the moisture content is between 50 and 70%. This again confirms our opinion that it is better to compost in a shallow heap to ensure good water penetration and drainage. Quite often in a large heap the bottom of the heap in the centre is quite dry, extremely hot, and relatively uncomposted.

Further research into literature also told us that the temperature reached in a heap of pine bark is high enough to remove *Phytophthora cinnamoni* and *P. regularii*, negating the need to sterilize or pasteurize our potting media, hence another cost saving.

Researchers in America have placed cultures of *P. cinnamoni* and *P. regularii into heaps of composting pine bark* and, in ten weeks' time, they haven't been able to find a trace of either pathogen. Similar sized heaps of sand maintained the pathogens for a period of ten weeks.

To summarize: At Grove Nursery we have had some success using pine bark compost as an alternative to German peat. In fact many of our indoor lines are grown in 100% pine bark together with the above nutrients, but for optimum success we must abide by these guidelines:

1. The heap shouldn't be deeper than 1.5 meters.
2. We add 7 Kg NH_4NO_3 (ammonium nitrate), 5 Kg lime/m^3.
3. The heap must be kept moist but not waterlogged.
4. If possible turn the heap at least once during the composting process.

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OBSERVATIONS OF CITRUS PROPAGATION IN SOUTH AFRICA

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My visit to South Africa in March and April, 1982, was sponsored by the South African Co-operative Citrus Exchange and the South African Citrus Nurserymen's Association. Terms of reference were as follows:

1. Three weeks conducted travel through the main citrus growing areas to study orchards, nurseries and research centres.
2. Attend the Citrus Nurserymen's Seventh Conference as principal speaker and cover these areas:
   A. How we produce citrus trees in one year at Renmark, South Australia, at our own nursery.
   B. Comment on impressons gained about South African nursery production and, where relevant, about the industry in general.
   C. Offer suggestions towards improving nursery technology, particularly the rapid production of clean, container-grown trees.
3. Observations on citrus production in South Africa:

The visit was extremely well organized with adequate time allotted to get a balanced view of the industry. The citrus industry is extremely well organized, heavily dependent on exports to Europe, and with a minor local juice salvage operation.

Citrus nurseries are under great pressure following a very rapid tree planting programme in the past 5 years. Traditionally, all nursery trees were field grown and took 3 to 5 years to produce giant trees which were planted out bare-root in the orchards.

Costs, delivery pressures, and pest and disease controls have forced the industry to consider better ways. Container growing has been initiated by three of their leading nurserymen, following discussions with me at International Citrus Meetings in the United States. Others are following, but the techniques to do this are as yet not fully understood, although there is a strong desire for change in most nurseries. The basic challenge is to produce trees for replant situations in existing orchards.

By comparison with Australian conditions, nurseries face

a great range of pests and diseases which include — greening, severe tristeza, *Phytopthora citropthora*, and *P. parasitica*, citrus nematodes, severe mite and aphid infestations, as well as very strong winds, to name but a few. Some nurseries have infected water supplies that need treatment, whilst others have to deal with very high salinity levels in their water.

On top of these problems, labour efficiency generally is of a very low standard, which constrasts markedly with the high standard of management's technical capability, in general.

The adoption of tree growth in bags needs a completely new approach to principles and practices. The only similarity is the crop. Many have not understood the basics of mix aeration and because of this, root decay was evident universally. Placement and size of holes in polybags require critical attention.

There is a need to change from poor draining soils to non-soil mixes which will involve consideration of cane residue, rice hulls, hardwood sawdust, or pulverised bark. Many nurseries in South Africa had polybags on, and even buried in, poor draining sites. Methods have to be developed to raise these above ground to avoid root decay, improve aeration, and raise the standard of hygiene. The need for a reproducible, freely-aerated mix is of the highest priority.

Seed tree selection, with one notable exception, was not receiving adequate attention. Nurserymen were not considering the long term consequences of poor selection, poor culling, and poor growing of seed/seedlings with the result that problems had become inbuilt before a first class end result could be achieved.

Despite these criticisms, I found a universal willingness to highlight and discuss problems and a positive desire to take steps to correct deficiencies. There were no attempts to gloss over shortcomings, and I believe this augurs well for the Industry. I would expect to see rapid technical improvements in the next few years.

INTEGRATED PEST CONTROL OF TWO-SPOTTED MITE ON ORNAMENTAL PLANTS PROPAGATED UNDER GREENHOUSE CONDITIONS

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It is a fact that over the last 30 to 40 years there has been a world-wide trend towards the complete reliance upon

a great range of pests and diseases which include — greening, severe tristeza, *Phytopthora citropthora*, and *P. parasitica*, citrus nematodes, severe mite and aphid infestations, as well as very strong winds, to name but a few. Some nurseries have infected water supplies that need treatment, whilst others have to deal with very high salinity levels in their water.

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chemical pesticides for the control of pests and diseases on all agricultural and horticultural crops. Nurserymen have become as reliant as any other group in this respect (12).

Public demand for undamaged plants from the nursery industry has resulted in the reliance upon strict pesticide control programmes. This approach has raised certain potential problems for all nurserymen.

Resistance can develop in pests following continued exposure to some pesticides. In addition to the more obvious signs of phytotoxicity, some pesticides may also interfere with proper plant function. There is the ever-present consideration of environmental contamination, very relevant to this public service industry. Finally, in most situations problems are experienced in incorrectly applying pesticides. The subsequent ineffective control encourages unnecessary repeated sprayings. This is time-consuming, which is expensive, and the added selection pressure increases any resistance problem.

With regard to plant propagation, some newly-rooted plants exhibit a greater sensitivity to some pesticides because of their immature root systems. Considering the five questions raised above certainly justifies at least a cursory look at alternative control measures, if not a serious consideration of their possible implementation on a commercial scale.

In New South Wales (NSW) the use of predatory mites in conjunction with pesticides to control two-spotted mite is being approached with some confidence.

PEST PROBLEM

Two-spotted mite, *Tetranychus urticae* (Koch), also known as red spider, is arguably the most important pest of ornamental plants in NSW. There are different criteria for assessing this importance, but on the basis of damage potential and control difficulties, this comment is true.

Two-spotted mite is very common and infests almost as many plants as are grown commercially for foliage or flowers.

Unlike some countries, in Australia two-spotted mite can occur as a pest problem throughout the year. In colder climates a diapause stage develops which neither feeds nor reproduces through the winter period. The onset of this stage is stimulated by temperature and photoperiod changes.

In Melbourne, Victoria, and in the Central Tablelands of NSW, observations have shown that a considerable proportion of the field population change to the orange-coloured diapause phase.

The incidence of this phase in Sydney and coastal areas,

especially under protected conditions, is very low. In these situations two-spotted mite can continue its normal functions and damage plants. Generally, the activity of the two-spotted mite is favoured by warm, dry conditions. In some nurseries around Sydney, populations can be noticed with the onset of heating in glasshouses. This produces a warm, dry environment.

In other circumstances, two-spotted mite can appear on plant material transported from a warmer state at a particular time each year, e.g. palms propagated in Queesland, or the pest may occur naturally each year with the onset of warmer seasons.

One way or another the pest will occur seasonally in a more or less predictable way. Spider mite regularly causes considerable damage to nursery plants and, although pesticides are currently used, the range of pesticides registered in NSW for the control of spider mite in nurseries is inadequate to solve the problem to the satisfaction of nurserymen.

THE USE OF BIOLOGICAL CONTROL AGENTS IN AN INTEGRATED CONTROL PROGRAMME

Spider mites are subject to predation by a number of natural enemies including insects and other mites. Because pesticides are essential for successful horticultural production, most of the native species are easily killed. Some, through continued exposure to sprays will develop resistances. The predatory mite, *Phytoseiulus persimilis*, (Chilean predatory mite) is one of these species which has developed tolerance to a range of pesticides.

Phytoseiulus persimilis was first discovered in Chile and recognised as a potentially useful predator of spider mites in the 1950's (3). Extensive investigations in the U.K. and U.S. in the 1960's determined that its high mobility (2,11) and relatively high prey consumption rate and productive potential (1) contributed to its greater efficiency as a predator under field conditions. At 20°C a predatory population will increase 4.6 times per week compared with 2.7 times for the spider mite.

In the U.K. and in Europe, extensive areas of glasshouse production of cucumbers mainly, plus other crops, now involves the use of *Phytoseiulus*. The extent of this usage and the success rate is given in Table 1. In recent years the area of glasshouse usage of biological control increased only in England and The Netherlands. This is attributed to these two countries having private companies producing the predators and of having the service to advise growers and actively promote the system.

Table 1. List of areas using *Phytoseiulus persimilis* to commercially control two-spotted mite.

Crop	Country	Source	Total Crop area	*Phytoseiulus* introduced on (ha)	Percent success
Tomato	Denmark	Samsøe/Holmenlund	120	6	50
	England/Wales	Gould/Ledieu	550	73	95
	Finland	Markkula	180	2	100
	W. Germany	Crüger/Hassan/ Mertens	—	10	—
	Ireland	Dunne	160	10	70
	The Netherlands	Koppert/Woets	2010	14	85
	Norway	Stenseth	63	10	—
	Scotland	Foster	20	2.5	40
Cucumber	Canada B.C.	Elliott	11	8	—
	Denmark	Samsøe	60	55	75
	England/Wales	Gould/Ledieu	216	161	95
	Finland	Markkula	55	45	100
	W. Germany	Hassen/Krüger/ Mertens	—	10	—
	Ireland	Dunne	11	4	75
	The Netherlands	Koppert/Woets	700	430	95
	Poland	Pruszynski	—	2	100
	Sweden	Nedstam	50	30	83
	Switzerland	Freuler/Städler	34	5	100
S. pepper	Ireland	Dunne	4	1	100
	The Netherlands	Koppert/Ramakers	100	37	95
Gerkin	The Netherlands	Koppert	240	30	90
Grape	The Netherlands	Koppert	45	3	100
Melon	The Netherlands	Koppert	45	2	100
	Sweden	Nedstam	7	5	80
Rose	Poland	Pruszyński	—	1,5	100
Strawberry	Japan	Nakazawa	6800	15	55

As can be seen from Table 1, efforts have been made to apply this method of control to a range of glasshouse crops. Different practical problems associated with the release and establishment of the predatory mites, plus its ability to tolerate field rates of specific pesticides associated with certain crops, have also been researched.

The use of a species of predatory mite, such as *Phytoseiulus persimilis*, to control two-spotted mite does not mean that pesticides are replaced entirely. It does, however, provide an additional input for the grower to consider in conjunction with a reduced number of miticide applications at a lesser strength, normally half the recommended rate. Sprays of this nature are used as an interim measure to lower an increasing spider mite population that may get too much of a head start on the predator under field conditions. Also, insecticides used to control other insect pests and fungicides, which will cause minimal damage to the predator populations, have to be included.

In the U.K., workers involved with *Phytoseiulus* to control two-spotted mite have been impressed both by the potential of this form of control and grower reaction to successful control by natural enemies. The technique does involve a higher technical input on the growers' part than chemical control alone

but an increasing awareness by the user provides for easier operation each year.

In the northern hemisphere the major use for this approach has been on vegetables grown in glasshouses. In Australia, it is the nursery industry which will benefit.

Although *Phytoseiulus* has been in commercial use in Europe for over 15 years (8) and in the U.S. since 1971 (10), its involvement in Australia was delayed until 1978 when it was first discovered infesting commercial strawberry farms in Sydney (6).

Table 2. The effects of some pesticides on the predatory mite, *Phytoseiulus persimilis*, and on two-spotted mite (TSM).

Pest Control	Pesticide	Registered for use on Ornamentals	Percent toxicity to life stages *P. persimilis* adult	nymph	egg	TSM adult	Safe to use with predator
TSM	Plictran		0	0	0	100	Y
TSM	Omite	Y	0	0	0	100	Y
TSM	Torque		50	0	0	75	Y
TSM	Peropal		0	10	0	100	Y
TSM	Tedion	Y	0	0	0	10	Y-poor against pest
TSM	Kelthane		100	0	5	100	N
TSM	Neoron		100	0	100	100	N
TSM	Sulfur	Y	22	0	5	0	Y-poor against pest
TSM	Pentac*		15	0	0	10	Y-poor result against pest explainable
F	Bayleton	Y	20	0	0	5	Y
F	Baycor		25	0	5	0	Y
TSM+F	Morestan		44	53	100	100	N
F	Benlate	Y	50	55	100	0	N
F	Captan	Y	16	0	0	0	Y
F	Saprol	Y	35	0	0	0	Y
F	Plantvax	Y	10	0	0	5	Y
F	Nimrod		0	0	0	5	Y
F	Ronilan		5	0	0	0	Y
F	Dithane		23	5	0	0	Y
F	Rovral	Y	42	0	0	5	Y
F	Cuprox		43	0	0	25	Y
I	Lorsban	Y	100	0	0	100	N
I	Dipterex		100	0	100	10	N
I	Thiodan		100	0	0	50	N
I	Pirimor	Y	39	0	0	0	Y
I	Cothion		38	0	0	21	Y

Y = Yes. N = No.

* Pentac acts by interference with oviposition; for initial results requires 3 to 5 days.

Phytoseiulus is particularly well suited to glasshouse environments and, apart from the list of vegetable uses, it is also being utilized overseas on ornamental plants (7,9). It is gener-

laly considered to be the best predatory mite available for use under such conditions. With glasshouse control of this pest by pesticides proving less and less reliable, it was natural for the NSW Department of Agriculture to establish a research programme to attempt to gain the acceptance of the industry for the integrated pest control concept (4,5). While *Phytoseiulus* is relatively resistant to some pesticides, it is also susceptible to others. Spray tests have been carried out with 26 pesticides to determine the susceptibility/tolerance of all stages of the predatory mite. Of pesticides tested to date, (Table 2) 73% were judged safe to use in an integrated programme with *Phytoseiulus*.

PRODUCTION OF *PHYTOSEIULUS* FOR NSW NURSERIES

Overseas, approximately 16 private companies in 9 countries rear this predator for sale to growers. In addition, other countries, e.g. USSR, have laboratories undertaking the same role.

In Australia, this concept is very new and this aspect posed a problem until 1981. A company in Queesland (Biocontrol) now provides the same service as its overseas counterparts. In addition, in NSW, the Department of Agriculture is promoting a system of the nurserymen producing their own predators (5). This overcomes a number of problems, not the least of which is the cost of regular supplies, e.g., Biocontrol charges $70/10,000 predators. Reintroduction may be necessary following the use of insecticides or fungicides toxic to the predator against a specific pest or disease. Also, *Phytoseiulus* may disappear from an area following the elimination of its food source.

For a relatively small cost in time and money any nurseryman can produce predators for his own use. Predators can be reared continuously, or according to particular seasonal requirements. The following procedure outlines for nurserymen the steps in the mass rearing of *Phytoseiulus*.

a) Germinate a dwarf bean seed grown in potting mix in each of ten 60-cell Speedling trays, or a convenient seedling tray well-stocked with bean seed. Ten trays are a nominal number only.
b) Grow-on to first true leaf stage.
c) Release spider mite infested leaves onto plants.
d) Allow 2 to 3 weeks for spider mites to spread and build-up numbers. This acts as food for the predators.
e) Release a starter culture of pedatory mite on bean plants.
f) Allow 2 to 3 weeks for predators to establish and breed-up into large numbers.

g) Transfer Speedling trays (or equivalent) to release areas and locate on benches or floor nearby. Predatory mites will eat spider mites out, then disperse onto infested ornamental plants or, cut bean foliage and distribute on plants for spider mite control. Bean foliage will dry up quickly and predators will move onto spider mite infested ornamental or flowering plants.

This procedure must be undertaken under protected conditions, either polyhouse or glasshouse facilities. Controlled temperature conditions are ideal for supplementing heat in winter to maintain the rate of production, but in a coastal climate it is not essential to have access to an air conditioned house. Temporary temperature control facilities may be required. It is essential that regular production of spider mite and predatory mite is maintained.

In releasing the predatory mite a knowledge should be obtained of the extent of spider mite infestation in the nursery. This should be done with the aid of a hand lens and a very thorough inspection, remembering that nearly all populations of spider mites are to be found on the undersides of leaves. Then release the predators systematically. Supplementary applications of reduced strength miticides may be necessary. The predatory mite is very active in moving through a poly or glasshouse; it has a large appetite and it has the reproductive capacity to build-up into large numbers. However, there are circumstances where it may require the additional help of miticides to control the pest; e.g., large infestations of spider mites will content the predator and it will not spread quickly, leaving some areas unpopulated by the predator. Also, low winter temperatures will reduce the activity and reproduction of the predator.

The benefits of the predatory mite are in the reduced usage of miticides, by applying at lower strength and less frequently. In some instances, in protected environments, no miticides will be necessary.

In applying *Phytoseiulus* in a commercial nursery, the main criteria is what kind of control is needed. Some examples are given below:

1) Fruit trees — young plants; some slight damage unimportant and predator control effective.
2) Stock plants for propagation — same.
3) Young plants with juvenile foliage — same, but heavy damage may cause plant losses.
4) Ornamental plants in pre-sale stage — infestations of spider mites must be kept *below* levels likely to cause visable damage. This level varies with the type of plant.

5) Flowering plants which will refoliate if spider mite gets out-of-hand, e.g., roses. This should not be aimed for, but it is a consideration.

The predatory mite, following the control of the pest, will seek other sources of food. This may result in the loss of the predator after one season. To counter this the recommendation to nurserymen is for the continuous production of the predator and release into the nursery area, even when it may seem as though the spider mite is absent. There is no necessity to wait until a spider mite infestation occurs. It is preferable to maintain the predator's presence and to aim to keep the spider mite at low levels or absent.

CONCLUSIONS

To be committed to using *Phytoseiulus* in an integrated pest control programme, nurserymen must appreciate the following points:

1. It does require some learning to recognise early signs of two-spotted mite infestations and damage.
2. It does require discipline in only applying pesticides compatible with the predator that will, at their worst, permit the continuation of the predator population.
3. It does require an acceptance that there are direct benefits to be gained.
4. It does require informed management decisions from the grower, faith in the value if this microscopic predator, and a willingness to persevere even if complete success isn't always achieved.

It should be noted that pesticides applied soon after the introduction of predators will be more harmful than when applied after predators are well established. That "once-off" spray will be less harmful than routine programmes. The harmful effect of a pesticide toxic to the predator can be minimised by using "spot-treatments" against other pests and diseases, e.g. mealybugs and scale insects.

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MECHANICAL HANDLING OF PROPAGATION BENCHES

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The purpose of this paper is to introduce the initial physical developments of a system in which I have been interested for several years. The developments discussed arise from the aim, which may be broken into three parts;

1. To re-think the basic approach to the volume production nursery and to develop an integrated nursery system with stock control which economically enables increased production volume and efficiency.

2. *To design* a system around the plant's growth requirements of moisture, light, temperature, humidity, and nutrition.

3. *To develop* mechanical systems and aids on a universal or multi-purpose basis, especially in the early stages of propagation — by seed, cuttings, or tissue culture — from small parent stock to 100 mm and 125 mm pot production.

A basic design criterion was adopted with regard to the species most likely to be grown, (indoor and outdoor container foliage plants), available energy sources, local engineering fa-

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cilities, and expertise and basic cost comparison of alternative systems.

A pallet handling system was selected and its eight components are described below:

1. **The Pallet Basket.** The Australian standard pallet size of 1.18 metre was chosen as it is in wide use in transport, warehouses, and allied trades. It may be handled manually by two staff persons, or mechanically by a "pallet jack" fork lift, or by a specialised carrier.

The pallet is lightweight, rigid, and compact in storage, being constructed of 5 mm guage galvanised steel mesh turned up at the sides and with 75 mm angle-iron legs welded on.

2. **Styrene Nursery Box.** Overseas experience confirms energy saving and other benefits from the use of styrene boxes on trays, so a container was designed which fits exactly 6 per pallet, and formed in styrene.

It has conical internal depressions serving each of the 308 holes in its base. Each hole runs to the peak of concave channels formed in the underside of the base to permit unblockable drainage and to channel rising heat which may enter into the box contents via the holes.

The upper edges of the box have male locating lugs with corresponding female recesses to enable stable stacking in either direction. Further, a special collar may be inserted to produce a despatch carton.

The box may be used for all stages of propagation, young growing-on, or mother stock, as well as for despatch.

3. **Heating System.** Offpeak, electrically-heated, stored hot water was installed using radiator pipes to circulate the water. Sensors and proportioning valves maintain the desired heating at the benches. Each bench may be isolated from the system.

4. **Greenhouse Structure and Ventilation.** This consists of a 2,000 square metre concrete-floored, aluminium framed structure clad with corrugated fibreglass, formed of five gable roof bays, each eight metres wide with a 2 metre automatic ridge vent system and 2 metre wide door at each end of each bay.

5. **Attached Workshed.** This houses the heating system, support equipment, and general storage. It is centrally located to enable minimum average distance of plant travel. It is spacious enough to enable access of large nursery equiment, has extensive bench area and machinery location for convenient flow of plants and media for propagation, potting, and despatch activities.

6. **Resultant Patented Bench System (P.F. 2662).** Dual level system with steel frame central support raised above the floor on legs attached to the outer end of the lower bench frame.

The levels are 1 metre apart and have radiator pipes attached on both levels. On these pallet legs rest when placed on the bench by a special handling device. This runs down the aisles between each set of benches on guide rails.

7. **Pallet Carrier.** Designed specifically for this function, it may be described as having a stable base on wheels, plus a revolving mast with motorised lift of articulated fork arms. These enable it to locate and pick up the 1.18 metre pallet in a bench row and carry it in an aisle width of 0.68 metres.

The pallet may be run out to the propagating or potting bench, despatch bench, or simply transferred to a trailer or adjoining shadehouse floor where the legs of the pallet elevate the crop above the floor.

8. **Bench Capacity.** Each 1.18 metre length or "module" of bench holds 4 pallets each with 6 styrene nursery boxes. Each module holds 48 plastic propagation trays, or over 2300 50mm conventional tubes (or 42's), or approximately 140 10-cm pots, or approximately 80 12.5-cm. pots. This system gives a bench to floor area cover in excess of 150%.

It should be noted that the only manual phase is the lifting of a styrene nursery box of cuttings onto the pallet, or the location of pots or blanket propagation material such as rockwool matting onto the pallet. The pallet is then carried and located on the bench, or brought from the bench to the work area to have cuttings removed, or be treated as required.

A boom spray, self-propelled by its own water pressure, is under investigation to run along each aisle, watering or spraying both levels and both sides simultaneously. At present we hand water with great success, watering the upper level first, then returning along the lower level. Contamination and overwatering of the lower level are the chief fears of onlooking nurserymen and I was concerned by their consistent comment.

Happily, to date, we have had no clear evidence of these problems. In fact, I am becoming aware of an increasing amount of double-layering in nurseries, not to mention overhead baskets.

Factors which I believe aid our success include:

1. Very good air flow at all points in the system under, through, and above the benches.
2. Open freely-draining, well-aerated medium which does not exaggerate potential overwetting.

3. Watering heavily and as seldom as possible.
4. Maintaining moderate humidity levels.
5. Locating crops according to growth factor needs, such as high or low light.

Note also that a level or a bench may be "Tented Off" for specialised microclimatic control such as fog propagation.

Another common comment was our light source at the lower level, not exactly overhead. Our experience is again good with most species which we have placed on the lower level, including Kentia palms, *Calathea, Spathiphyllum, Peperomia, Dieffenbachia, Philodendron, Laccospadix, Aglaonema,* etc. Species which do show directional reaction are mainly those which have "spaced internodal trunks" such as *Aralia* and *Schefflera*, and climbing species.

Some benefits not anticipated include slightly spaced internode lengths on *Syngonium* and other "tightly node spaced" species, facilitating my style of cutting supply. This is to take early smallish, main-growth cuttings, resulting in a bushy yet compact young plant for growing on. This spacing makes the taking of cuttings so much easier and therefore quicker, which in turn is more economical.

By this practical illustration of my approach to the aims stated, I hope I have at least suggested to you that alternative approaches to nursery production can be taken. If, in time, an integrated nursery system evolves using standard sizes to facilitate production processes, quality, and systems handling, including despatch, then I believe the nursery industry will be poised to take a great step forward.

Finally, I must stress the versatility of this system which enables the enterprise to discover a market need and quickly adapt the growing or production facility to enable supply of that line, thus the nursery will be better equipped all around to go into the more competitive years ahead.

SOME PROBLEMS IN SEED RAISING

JOHN H. COLWELL
Little Acre Wholesale Nursery
Montrose, Victoria

As propagators, we find at some time we must produce some plants by sexual propagation. The old cry can be heard that seed lines are easy to grow. I often wonder how many good propagators have lost a batch of seed or have failed to germinate them. When this happens a good propagator will look to find out where he has gone wrong. Seed propagation is

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easy in most instances if one understands all their requirements and have the facilities to fulfill the various needs of the species intended to be sown.

I have so often been surprised that, within the nursery trade, many failures still occur. If we take a close look at some of the failures encountered most can be traced back to bad management or shoddy workmanship. As a consultant, I am constantly asked to look at problems occurring every day with seed germination, not only from inexperienced people but from people in all branches of horticulture, including seed testing laboratories.

Many of the problems that occur could be overcome very quickly if more care was taken in the practice of seed sowing. A great number of people intending to sow seed treat all species in the same manner and just hope for the best. With the rising cost of seed and the ever growing importance of getting a good quality plant, one cannot or should not be so unprofessional in the way they plan for seed raising.

There are, of course, many problem areas which the grower has no control over, such as length of viability, poor seed quality, and the aftercare that seed are given when first collected.

PURCHASING

Firstly, let's look at purchasing: In many cases when seed is needed it will not be ordered until the last minute. You should always plan well ahead (at least six months) or the seed company may have sold out of the species or cultivar you require; this often happens with new introductions and popular cultivars. Most companies have the policy first in, first served. Lesson one — order early to avoid disappointment. While on the point of purchasing I would like to stress that if you are wanting the best results then make sure you purchase only from reliable seed companies. Price is not the first consideration. Most good seed companies have excellent storage and cleaning facilities to care for seed. If requested, most seed companies will pretreat the seed and dispatch on a date to meet your sowing dates. When ordering for the first time ask the company for a seed count chart and expected germination percentage; often these are found in their catalogues and will help you work out your needs. So often too much seed is ordered; this is both costly and wasteful.

When seed is received make sure that the order is checked; if not available, re-order immediately with another seed company. Seed should be sown as soon as possible or, if needing treatment, they are so treated. Most nursery office

staff are not aware of the importance of these facts; they must be instructed to inform propagators or someone in propagation of the arrival of all seed. Seed in packets can deteriorate very quickly if left lying on a desk. Sun shining through a window for 20 minutes will roast seed within the packet. If the seed are not to be sown on arrival they must be stored under cool conditions or losses may occur.

Any seed obtained from overseas will be subject to inspection. When ordering seed from overseas ask the company to advise you when the order is despatched so you can check with Quarantine when your seed arrives; sometimes seeds can be left in these areas for days.

CONTAINERS

For those that only sow a few seed by hand the most popular container would be the punnet or plastic tray or even the wooden seed trays. Before commencing to fill our trays we must firstly check that all holes in the trays have been pushed out. Often patchy germination is caused by these holes being blocked. The reason for this is air drainage through the medium is impaired and air space is then filled with water. If this happens the temperature in those areas of the tray will drop. Changes in temperature within the area of some kinds of seed will result in uneven germination or even loss; too much water will also reduce the amount of available oxygen, another important factor affecting seed germination.

If wooden trays are to be used care must be taken to ensure that large gaps are not in the bottom or the medium may dry out, again causing losses, or the medium may be washed through at watering, a very common fault.

FILLING TRAYS AND SOWING

Filling of trays can be carried out by hand or machine as long as uniformity is controlled. If by hand, trays should be filled to two thirds and roughly levelled, then screen the medium through a 6 mm mesh sieve. This size is recommended to avoid crusting of the surface. The tray is overfilled and a bar used to remove surplus by running it over the edges of the tray; at this stage the tray should be completely full but not compressed. If the tray is then lifted 3 to 4 cm off the bench and just lightly dropped this will settle the medium in the tray to just under full (make sure that when you drop the tray onto the bench it's kept level or you will find the surface becomes uneven).

At this stage we need a board or blade that will fit inside the tray but has edges that will run on top of the tray (depth of

inside should be 6 mm lower that top edge). This blade is then run over the tray with the medium in it; this removes the upper 6 mm making the surface very uniform. Seed can then be sown onto this surface. Some people think you should at this stage press down the surface on which you are going to sow. If that is done two things happen; firstly, if the medium is a little over-moist the surface becomes smooth and seed that are round will roll. This makes uniform sowing difficult and encourages over-sowing. Secondly, it creates a barrier for penetration of the radicle; when this occurs the radicle will run along the surface till it finds an easy access. Secondary roots will not form until the radicle moves down into the medium. What we then have is a seedling with a heel. Trees such as eucalyptus, acacias, and many others, will often uproot in winds when grown this way as the heel acts as a spring making the tree sway backwards and forwards.

If the medium is not pressed down at this stage, round seed will not roll and overcrowding will not occur. After sowing, the seed are lightly covered; depth of cover will depend on the species being sown. After covering the surface is then lightly pressed down; this keeps a uniform firmness around the seed.

When hand sowing from packets avoid allowing seed to run down the edge folds of packets as the seed will jam up; if then shaken it will cause overcrowding. It is far better to fold the centre of the packet; this allows the seed to run down from both sides. Density of sowing is then much easier to control.

TREATMENT OF SEED

Many seed purchased these days are treated with a fungicide to prevent pathogens that may be carried on the seed coat getting a start. Some diseases such as smuts may not be killed by the use of a fungicidal treatment. What is needed to control such pathogens is a hot water treatment. Seed are firstly placed in a cloth bag which is then tied at the top.

The time and temperature for hot water treatment of seed of various species plant and pathogen species will vary a little but in general smuts (*Ustilaginales*) and leaf spot diseases, such as *Septoria* and *Phoma*, may be treated at a water temperature of 50°C (122°F) for 25 minutes. The bag should only be half full of seed while treating with hot water to ensure good circulation of the water through the seed. The bag with seed in it should be suspended in the hot water on a bar across the container. Since hot water treatment may reduce germination by about five percent, a germination test should be made before and after treatment.

If you have to treat the seed yourself with a fungicide, just a little placed in the packet is all that is needed; fold down the edges of the packet twice after the fungicide has been put in and give the packet a vigorous shake. Care must be taken when dusting seed with a fungicide as most are very fine powders; if the dust is inhaled it may cause some unpleasant side affects.

Many acacia seeds are treated with hot water to promote germination. Problems of sowing the seed after this treatment may occur; for example, seed sticking together. The reason for this is that the seed coat is softened when treated with hot water. When this happens sugars and gelatinous substances are released into the water causing the seeds to stick together. These sugars also encourage the formation of moulds on the young germinating seed. Moulds use á great volume of oxygen when forming. This in turn starves the young embryo of the oxygen that is so vitally needed for germination to take place. If, after soaking, they cannot get oxygen the embryo will die. This, in turn, causes pathogens to attack; once this happens great losses will occur.

To avoid this happening, after soaking the seed, remove the sugar substances from the seed before sowing them. We can do this by gently running clean water into the container with the soaked seed in it. Running a tap slowly into one side of the container will cause the seed to suspend about half way up the container. This movement will clean all the gelatinous substances off the seed. If we then strain off all the water and add a little sand or sawdust to the seed they will no longer stick together; the sand and seed together may be sown. If you use sawdust for this be careful that it's not toxic to the seed.

An after-sowing problem that is often encountered is when trays are placed onto the benches. It is important that the trays are level; if not, water will move to the lower side; when this happens germination is poor. This also leads to overwatering or drying out of young seedlings.

WATERING

Many seedlings are lost each year by thoughtless watering; by this I mean the rose spray used to water is too coarse and the pressure too high. Large droplets of water cause much physical damage to young seedlings. When watering seedlings a very fine rose should be used and while watering it must be kept on the move while over the trays. The pressure should be turned up just enough to stop drips from forming at the end of the rose; at no time should the rose be held over the tray because if the water pressure suddenly drops large droplets of

water will occur causing a great deal of damage to the seedlings.

Always remember that all watering equipment must be kept off the ground at all times to avoid pathogen contamination.

One problem that one often encounters is under-filled trays; when this happens germinating seedlings are too low to obtain good air circulation over the surface. If in low light, *Botrytis* infection may occur; once in the glasshouse it is difficult to eradicate.

Germination may also slow down if the depth of the medium in trays is too great. When sowing seed that will be pricked off, 5 cm of medium is all that is needed; if more than this amount is used the physical properties change and movement of air and water in the medium will change. These small changes do affect germination, particularly in autumn and winter. However, there are many kinds of seed that produce very long radicles and need a deeper container in which to germinate. Many such seed are sown direct, or chitted and then planted; palms and other trees are among this group.

MACHINE SOWING

We have now come to the age of seed sowing machines for nurseries. Many of these machines require the seed to be chitted and it is here that problems seem to occur; knowing your seeds reaction to chitting is of great importance.

When we chit seed for machine sowing we must soak the seed in water up to or within a few days of the radicle emerging; seed of different species require varying periods of time in water for this to take place. Let us take a look at two genera which have different periods of time for chitting. In *Apium graveolens* (celery), the seed is small and takes about 21 days to germinate and is usually chitted for 15 days. At this stage the radicle can be seen just breaking the seed coat; if sown by a machine at this stage very little if any damage will occur. If we wait until 18 days passed the radicle will be well developed and when picked up by the pins on the machine and sown a great number are damaged. Considering cabbage (*Brassica oleraceae)*, if we chit this seed the period of radicle emerging is eight to ten days but we find that when chitting, four hours of soaking has lifted the seed coat off the young embryo. If we allow this to happen when we place them in the machine one pin picks up the embryo, the other its seedcoat. We all know that seed coats do not produce plants and when working to a given number of plants per sq. metre of nursery

space we can't afford to only have half the units filled with plants.

When soaking the seed in water they should be placed in a fine cloth bag and only half filled to allow for movement of water through the bag and around the seed. The bag must be tied at the top and suspended in the water. A very vital point when chitting in water is that after seed have been in water for 24 hours they need oxygen, the same as they would when sown in a medium so make sure that water is oxygenated from the start of chitting.

MEDIA FOR MACHINE SOWING

Most machines being used in Australia for seed sowing are those that use pins to suck up the seed from a container and eject the seed into the trays of the medium. Problems will occur at this stage if the medium used has too many abrasive materials in it; for. instance scoria or coarse sand should be avoided. Most people using these machines use peat and vermiculite, 50/50. This medium seems to cause no physical damage but one must be very careful of overwatering. With houses being filled by machine sowing care must be used in rotating the batches of different genera and species through the house.

RECORDS

There has been one problem which everyone I have consulted for has had and that is the lack of records on all aspects of propagation. There are very few people who can remember changes in weather; these conditions should be recorded because they play a great part in propagation success. Sowing dates, time of germination under your conditions, media used, treatments and pathogen control are all part of recording and become an important part of better management.

SUMMER GRAFTING OF ACER PALMATUM CULTIVARS

GRAEME CATT

F.D. Catt Wholesale Nursery
Arcadia, New South Wales

Seedling *Acer palmatum* are field-grown for one year, then dug and potted into 200 mm buckets in mid-winter (July). A few are large enough by early summer (December) for budding, but most are carried over into the following year, trimmed to make standards up to one metre high for weeping

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cultivars; these are approximately 10 to 15 mm in trunk diameter.

All understocks are grown in full sun in containers but are brought into the shadehouse to be budded and are left there for the remainder of the growing season.

In early summer scions for grafting are selected from vigorous new season's growth, preferably having three sets of nodes. Their length may be from 4 to 20 cm depending on the cultivar; leaves are trimmed back close to the bud. At the bottom of the scion a diagonal cut, approximately 3 cm long is made, I use a very sharp knife as it is very easy to bruise the very thin cambium layer.

A "T" cut is made on the side of the understock, the same as for a normal T-bud, the length of the cut to correspond with the length of the diagonal cut on the scion. The scion is inserted and then tied from the bottom right to the top of the scion with 12 mm wide plastic budding tape. Approximately 5 weeks later, or when callus appears under the plastic tape, the tape is undone to the top of the T-Bud cut and retied; then the stock is cut down to the level of the scion.

Approximately 10 to 12 days later new leaves should start to appear, and using 4 to 5 months high nitrogen Nutricote, growth of up to 50 cm on the stronger growing cultivars can be expected before autumn.

The scion "take" varies from cultivar to cultivar, around 85% I consider acceptable; however, losses after the stock is cut down account for another 10%.

I do not know of any other species of plant being propagated in this manner.

In the last two years there have been a lot of new *Acer palmatum* cultivars imported into Australia. I have 45 new cultivars from America and Japan and, along with the 40 odd cultivars already in Australia, now gives a very comprehensive list, although most of the new cultivars are not yet available in commercial quantities.

F_1 HYBRIDS — ADVANTAGES AND SEED PRODUCTION

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INTRODUCTION

Crop improvement through hybridisation of selected parent plants has been practised for many years. In its broadest sense hybridisation is simply a cross between two plants but in practical terms hybridisation is usually considered to be the crossing of individuals of unlike constitution such as species of the same genera or inbreds of species which have different genetical characteristics.

In the natural environment hybrid crosses between species of the same genus may occur indiscriminately but the number of natural hybrids which develop is limited. However in commercial species hybrid seed production utilises inbreds which are developed with certain desirable characteristics and hydridisation of these lines produces hybrids with specific advantages.

With certain vegetables, grains and flowers species different genetic systems are used to enforce controlled hybridisation in the production of commercial hybrid cultivars. In this paper I want to outline the advantages of hybrids, the basis of hybrid seed production, and some of its associated problems.

What are the advantages of hybrids? With vegetables, trial work and field evaluation has indicated that there are usually significant advantages in using hybrid cultivars. Since their introduction the number of hybrids in use has increased considerably (14); e.g. in 1976 hybrids constituted 65 percent of Brussels sprout cultivars, 69 percent of cucumber cultivars, 40 percent of cabbage cultivars, and 65 percent of tomato cultivars. Dorsman (2) summarises these advantages as including:

(i) Productivity. There may be yield advantages with onions and carrots and there are significant yield advantages with *Brassica* spp.

(ii) Earliness. With cabbages and kohlrabi the hybrids tend to be earlier in maturity.

(iii) Uniformity. Generally hybrid cultivars tend to mature uniformly which assists in reducing costs in those crops where "once-over" harvesting is not the usual practice, e.g. cabbage, cauliflower, and broccoli.

(iv) Disease resistance. Evidence is available for improved disease resistance in cabbage hybrids (13); Gabelman and other onion breeders have made significant gains in root disease resistance in onions, in particular Fusarium *(Fusarium oxysporum)* and pink root *(Pyrenochaeta terrestris)* (personal communication).

(v) Selection for quality in hybrids has shown results such as better skin quality in onions which is essential for the export trade.

With flowers, e.g. petunias and marigolds, the hybrids are more attractive with larger flowers and greater uniformity, and work is proceeding to improve disease resistance.

Basis of F_1 Hybrid Seed Production. It is possible to utilise several methods for producing hybrids based on the genetic characters of the species involved (See Table 1).

Table 1. Systems of F_1 Seed Production.

System	Crop
A. Genetic/cytoplasmic	
(i) Male sterility	Carrot
	Leek
	Onion
	Petunia
	Radish
	Tagetes
	Tomato
(ii) Self-incompatibility (sporophytic or gametophytic)	Ageratum
	Bellis
	Broccoli
	Brussels sprout
	Cabbage
(iii) Dioecy	Spinach
(iv) Monoecy	Sweetcorn
B. Mechanical or Manual	Snapdragon
	Sweetcorn
	Tomato
	Pansy
	Cucurbits
C. Chemical (male suppression or gametocidal)	Cucurbits

A. Genetic.

1. *Cytoplasmic male sterility*

Cytoplasmic male sterility is not a regular mechanism for controlling hybridity in natural populations (1). Male sterile plants have been detected, probably as the result of mutations, but they do not have any advantages. However, in domesticated plants cytoplasmic sterility can be utilised to produce hybrid cultivars.

Some species, such as onion *(Allium cepa)*, carrot *(Daucus*

carota) and *Petunia* have a specific sterile cytoplasm (S cytoplasm) which renders the plants sterile, either because the anthers are nonfunctional, or no viable pollen is produced. These sterile plants have the genotype, S msms, and an identical line with normal cytoplasm, N msms, used as the pollen parent to maintain the sterile line.

For crops where only the vegetative or floral product is required, e.g. vegetables and flowers, the resultant hybrid from a cross of the sterile inbred and a pollen parent may be fertile or sterile. However, where seed is harvested, e.g. sorghum and corn, pollen restoring genes are essential in the pollen parent. The pollen parent must have genotype, N MsMs, and the presence of the Ms gene with the sterile cytoplasm, i.e. S Msms, in the hybrid will result in fertility.

The major problem with cytoplasmic sterility is the maintenance of the male sterile line. In certain species such as carrots (2) if the temperature rises above a certain level there can be restoration of fertility which can result in sibbing during seed production. This phenomena has been suspected in onion (Pryke pers. comm.), sorghum, corn, and sunflower. In petunia cytoplasmic male sterility is known but is closely linked to flower bud abortion and the problem has not yet been overcome (5).

Another problem often encountered in maintaining male sterile lines is the usual occurrence of a low frequency of fertility restorer plants (i.e. NMsms, NMsMs) in the maintainer male, probably as a result of mutation. This causes little problems when producing stock seed but in the subsequent commercial seed production exercises, the presence of SMsms individuals necessitates extensive roguing to keep the level of inbreds in the hybrid seed to a minimum.

In recent years cytoplasmic sterility has been used experimentally for hybrid *Brassica* seed production. A sterile R cytoplasm was developed from *Raphanus* spp. (12) but it has some inherent problems. The seedlings tend to be chlorotic and the female flower, which lacks anthers, may also have poor stigma development and nectaries may be absent. The latter factors can affect hybrid seed production by reducing the attractiveness of the plants to pollen vectors such as bees, but Williams (pers. comm.) believes that these factors could be selected against.

(ii) *Self Incompatibility*

Self incompatibility is an important mechanism for maintaining cross pollination in natural communities and has been used for the production of commercial hybrids of *Ageratum* and members of the *Brassica* genus (see Table 1).

Self incompatibility reduces the ability of pollen from one plant to fertilise the ovum of the same or similar plant type and thus prevents selfing or sibbing. Prevention of selfing in natural population reduces the risk of inbreeding depression which is known to reduce the vigour and survival of species. The degree of incompatibility in species varies from 100 percent to a slight preference for foreign pollen.

There are two main types of incompatibility — sporophytic or gametophytic (1,6,9). Sporophytic incompatibility is due to pollen-stigma interaction where pollen does not germinate because of lack of "recognition" or stimulation by the stigma. With gametophytic incompatibility the growth of pollen tubes is slow and deformed and proceeds very slowly if at all and blossoms may abort before fertilisation. In addition the pollen tubes may lose direction and never find the ovule.

Nieuwhof (9) designated self incompatibility as being controlled by a series of alleles, namely $S_1S_2S_3$ .... In natural populations there are a range of S alleles which will allow for cross pollination.

With sporophytic incompatibility, as in Brussels sprouts, the pollen will only germinate if the plants possess no corresponding S factors, e.g. $S_{12} \times S_3S_4$, but will not germinate if both the parents have 1 or more S factors in common, e.g. $S_1S_2 \times S_1S_3$.

The S alleles do not always act independently and at times one S factor may be dominant over another and varying responses to the S alleles between stigma and pollen may give rise to pollination in some cases (1,9).

Gametophytic incompatibility is not as complex and with $S_1S_2 \times {}_{23}$ crosses half the pollen will be compatible and pollen tube growth will be slow and ineffective (1). With commercial hybrid seed production, selections are made so that the inbreds are homozygous for their S factor and that crosses are made between inbreds that are compatible with each other. With the wide range of S alleles this should not be difficult.

Self incompatibility in *Brassica* is strongest in freshly opened flower when the flowers are most attractive to insect pollinators. However, a few days after the flower opens the incompatibility breaks down (9) and self pollination occurs. Factors which influence breakdown include excessively high temperatures (over about 30°C, Ascher pers. comm.) and the age of the flower.

Usually *Brassica* are maintained by bud pollintation, i.e. prior to the flower opening the bud is opened manually, and pollen is transferred to the stigma. At this stage of develop-

ment the incompatibility of the flower is not complete and pollination can occur (9).

The major problem with the use of self incompatible reactions for hybrid production is the possible breakdown of the incompatibility reaction with the resultant sibbing due to poor maintenance in inbreds or due to environmental conditions. Occasionally there can be problems with insect vectors but this is not a serious problem.

B. Mechanical

To ensure cross pollination and therefore hybridisation it may be necessary to physically emasculate one inbred. With sweet corn the tassel of the female plant is removed by hand or machine and thus the pollen from the male plant is the only pollen source.

With tomato and petunia and some hybrid cotton the flowers are hand emasculated with tweezers and pollen is transferred by hand from the pollen parent and placed on the receptive stigma. Thus the F_1 hybrid seed is expensive.

C. Chemical

Hybrid cucurbit seed can be produced if one line is sprayed with ethephon (Ethrel) to suppress male flower production. Timing is critical to ensure that the female plants do not produce pollen.

Pollination as a Factor in Hybridisation. To ensure maximum seed set in both natural populations and controlled hybrid seed production units, it is essential that (i) anthesis in the donor parent coincides with the period when the stigma on the female parent is receptive and, (ii) the agent effecting pollination is available.

There are two major types of pollinating agents — abiotic such as wind and water, and biotic such as insects, birds, and bats (6). Wind pollination, which is probably the most significant abiotic agent is important in the Graminae, Cyperacae, and Juncaceae, but it is very inefficient because vast masses of pollen must be released and the efficiency of pollination depends on the wind velocity and direction. Plants adapted to this pollination process have light, smooth dry pollen and in some cases have evolved air sacs to increase boyancy (6). Pollen can only be released under warm, dry conditions and is rapidly lost from the atmosphere if rain occurs. Pollen viability in the atmosphere is short lived due to external factors, including ultra violet radiation.

Biotic agents often have a fixed relationship with the blossom to be pollinated. The pollinating agent usually is attracted to the flower because of some specific attractant such as pol-

len, nectar, or odour (6). Pollen, a major attractant, is a primary source of protein as well as fat and sugars. It is eaten directly by many insects and in cases such as bees is an intrinsic part of the diet of the larvae. Insects will actively forage for the pollen primarily as its food source but during foraging become covered with pollen (which adheres to body hairs) and pollination is achieved when the foraging insect brushes against a receptive stigma. Pollen from many insect-pollinated crops tends to be sticky and the grains adhere in lumps to the vector. In some cases the pollen may be dry but the flower structure is such that the insect's body becomes sticky from contact with the stigma and the pollen can adhere to body hairs (6).

Nectar is also recognised as a primary attractant for many insects and is found in most angiosperms (6). Nectar, which is a primary source of soluble sugars, is secreted from nectaries located within the blossoms at the base of the corolla and their secretions tend to coincide with the periodicity of the pollination process. Thus secretions are high when pollen release occurs to act as an insect attractant. Nectar gathering insects become coated with pollen in much the same way as pollen collecting insects do.

Thus pollination may be classified as an accidental process, which occurs as a result of active foraging for a food source by insects. However, plants have evolved so that they can attract specific pollen vectors so as to achieve pollination. Insects other than bees usually only benefit specific crops at specific times. Moths, butterflies, and wasps only consume nectar for their bodily requirements and not to provide for their nest (8) and thus pollen adhering to their bodies as they forage for nectar can facilitate pollination.

With commercial seed production dependant on biotic pollination it is essential to maximise all conditions to ensure that adequate pollination is achieved. Natural insect population such as ants, aphids, bees (honeybees and other colonial, gregarious, and solitary bees) beetles, butterflies, midges, moths, thrips, and wasps are involved, but the most important vector is bees (8), and their population can be controlled.

Flies have a role in pollination of open-pollinated crops such as carrot *(Daucus carota)* and onion *(Allium cepa)* and have been used by plant breeders as pollinating agents in small scale seed production cages. However flies are not of much benefit in hybrid seed production in field situations.

To achieve hybridisation in commercial fields it is essential that the insect population, espcially bees, is maintained at a high level but the level of bees in a seed production unit is

not necessarily indicative of the pollination potential. With cytoplasmic male sterility the level of bees in both male-sterile rows and pollen rows should be evaluated. Foraging bees rarely collect both nectar and pollen at the same time. Since individual bees have been programmed to collect either pollen or nectar, pollen-collecting bees are unlikely to visit the male sterile rows, except by chance, because of lack of pollen. Once bees have found a food source they will show remarkable fidelity to that row. Erickson, *et al.* (3) has studied this phenomena in carrot *(Daucus carota)* and has demonstrated that significant numbers of bees will stay on the same flower type (male sterile or normal) with only a low percentage of the population drifting onto a different flower type within a few days. To ensure that pollen transfer will occur the bee population must include a high proportion of nectar collecting bees which will forage throughout the seed crop. Where possible the visual differences between inbreds should be minimised to reduce the ability of bees to differentiate between the two inbreds.

To maximise the transfer of pollen it is essential that the female:male ratio is not too large. Erickson and Gabelman (3) found that with onion, seed set in female rows 7 feet from a pollen source had decreased by 50 percent when compared to female plants adjacent to the pollen. In *Brassica* the ratio is usually 4:2 (F:M) whilst in carrot and onion it is 3:1 (F:M).

Even with an adequate insect population in the area, hybrid seed production may still fail. Bees show marked preference for specific crops and invariably prefer to be working on clovers and lucerne (alfalfa) or native vegetation than onions (11). Thus to ensure maximum seed set it is essential to maintain a high level of native bees, i.e. bees which are new to the field, during the period of maximum seed set. Factors which may adversely affect attractiveness of onions include high nectar sugar levels which may be affected by the exposed nature of the flower, high potassium levels of the nectar, odour, and lack of visual attractiveness of the flower (Peterson pers. comm.).

If the level of nectar produced is inadequate, as can occur with the new R cytoplasmic sterile *Brassica*, then the bee population in the sterile row will be insufficient to ensure pollen transfer and seed set.

Hybrid seed, using self-incompatible inbreds, with both lines male-fertile, is not without problems. Bees are able to detect variability within colour of different inbreds of brassicas and thus may retain their fidelity for one row and not ensure hybridisation (7). The ultraviolet light reflection of the

petals differs and bees can detect this difference. A similar observation was made in carrots (Erickson pers. comm.).

SUMMARY

Utilisation of hydridisation to produce new hybrids in natural environments or under controlled conditions such as commercial seed production units requires systems to enforce pollen transfer for seed set and a mechanism for pollen transfer. In this paper I have outlined the genetic basis for hybridisation and the mechanisms for pollen transfer available to ensure effective seed set.

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INTRODUCING TROPICAL FRUIT TREES TO AUSTRALIA.

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Among the many new species of fruit trees now being introduced into Australia, I have selected twelve of potential future significance. Many exotic fruits, although native to and favoured in Southeast Asia and in tropical America, are virtually unknown in Australia.

Australia's diverse climate produces conditions which have proved quite suitable for the culture of many tropical and sub-tropical fruits. For example, litchi will grow from Cairns to Sydney, but mangosteen, durian, and rambutan will grow only in northern rainforests.

Litchi chinensis (Syn.: *Nephelium chinensis)* (litchi) is already well known in Australia where it has been cultivated since the turn of the century. It is already proving its worth as an economic crop in Queensland and Northern New South Wales. The tree bears red, warty fruits which have translucent white pulp and an agreeable sweet acid flavour. A proven method of propagation is by air layering. A 5 cm girdle of bark is cleanly removed, then a mixture of sphagnum moss, peatmoss, and sand is wrapped around the girdled area which is then completely sealed with a sheet of clear plastic. This treatment induces root growth. Clear plastic is used so we can observe root development. The air layers are ready for transplanting in 3 months. A lesser known method of propagation is by grafting. The apical wedge graft gives satisfactory results.

Euphoria longan (Syn.: *Nephelium logan)* (longan). The fruit is similar in appearance to litchi but has a darker skin. It develops into a neat tree some 10 to 20 m in height with a low trunk and spreading crown. The flowers grow in upright clusters. The flesh is white with a sweet pleasant flavour. Propagation is by air layering and apical wedge grafting. Its potential habitat extends from northern New South Wales along the Queensland east coast to Cairns.

Manilkara zapota (Syn.: *Achras zapota)* (sapodilla or chico) This tree is a native of the West Indies and Central America. It has become commercially important because of the milky latex which is used as a basis for a chewing gum. However, in Australia, the brown, egg-shaped fruit, tasting like brown sugar and honey will have marketable potential. It is propagated successfully by grafting or by cuttings. Again the apical wedge graft is used. The growing area is envisaged to be from Syd-

ney, along the coast to the Northern Territory, and in Western Australia.

Averrhoa carambola (carambola). Sometimes called the "five corner fruit" as it is a long oval or elliptic fruit with ribs arranged in such a way to make 4 or 5 sharp corners. When cut across, the outline resembles a star. It is already a popular fruit in Australia; however produced as seedlings the fruit is sour. Newly selected cultivars are sweet with a clear, watery juice. Propagation is by apical wedge grafting or by approach grafting. The East and North and West coasts of Australia are potential growing areas.

Malpighia glabra (acerola or Barbados cherry). A native of Brazil, the fruit is cherry-like, red to crimson in colour, with a thin skin. The pulpy flesh is soft, subacid, and juicy. It has a very high vitamin C content. Improved cultivars have no viable seed so propagation is by cuttings. It grows along the East, North, and West Coasts of Australia.

Garcinia mangostana (mangosteen). This is a slow-growing but long-lived tree. Mangosteen will reproduce true-to-type from seed, but it will take about 15 years to bear. Unlike most other fruits the mangosteen is parthenogenetic; that is, the fruit is produced without fertilisation. The fruits are round but slightly flattened at each end. It has a smooth, thick, firm rind which ripens to a red purple colour. Enclosed in the rind are 5 to 8 fleshly segments which are snowy white in colour. The flavour is slightly acid and indescribably delicious. It is, in fact, unique; only those who have tasted the fruit understand why the mangosteen is such a favourite. Propagation is by seed or the apical wedge graft. Its range is limited to the wet tropics of Australia.

Nephelium lappaceum (rambutan). Also termed the hairy litchi, because it has soft, hairlike spines on the surface of the rind. The white, firm flesh is juicy, sweet and subacid. Propagation is by air layering and patch budding. It is anticipated that this tree will do well along the coast north of Rockhampton.

Durio zibethinus (durian). The durian would win no popularity contest for its looks or odor. It has been compared to a "French custard passed through a sewer pipe". The flesh is enclosed in a thick skin which bears a number of rough spines. Its cream coloured flesh resembles custard in texture and colour. If the smell can be overlooked, the taste is unsurpassed. It will only grow in Australia in rainforest areas north of Townsville. Propagation is by approach graft and patch budding.

Myrciaria cauliflora (jaboticaba) is a slow growing ever-

green tree with an unusual fruiting pattern. The purple black fruits are produced in clusters along the central trunk and larger branches. The tree bears in spring and is followed by 2 or 3 lighter crops at monthly intervals. It can be propagated by cuttings or by grafting, using the apical wedge graft. Its potential growing areas are coastal regions around Australia, except in the south.

Synsepalum dulcificum (miracle fruit) is not recommended for its food value. Its unique property is that once eaten, it causes partial ageusia, so that everything eaten or drunk for about an hour afterwards tastes immensely sweet. A lime or lemon can be eaten as if it were a sweet orange. This chemical property is being researched so that it may be used as a substitute for sugar. It is propagated by cuttings or the apical wedge graft.

Chrysophyllum cainito (star apple). This is native to Central America. As well as having an edible fruit, it makes a striking ornamental tree with a silky golden brown colour under the green leaves. The round fruits, up to 4 in. in diameter are green or purple when ripe. When the fruit is cut the starlike appearance of the core gives it its common name. The flesh is white or purple and is sweet in flavour. Well known in Asia, its popularity is spreading throughout the Western world. Its propagation is by cuttings or the apical wedge graft. Its potential growing areas in Australia are envisaged to be from coastal Northern New South Wales, around Cape York to Broome.

Pourouma cerropiaefolia var. uvilla (Amazon tree grape). A native of South America, it has large racemes of purple grape-like fruit. It has a sweet white pulp and can be eaten raw or made into wine. At present, propagation is only by seed.

Quararibea cordata (South American sapote). Fast growing, medium-sized tree native to South America. Eight months after blooming "top shaped", brownish-green sapotes mature. The orange-coloured pulp has a sweet mango-melon flavour. Its propagation is by seed or cuttings. It should grow throughout Queensland, in frost-free locations.

In conclusion, I hope I have whetted the appetite of many future growers and consumers. A great deal of research has to be done before plantations of such fruit are seen throughout Australia. With many Asian people migrating to this country and with international travel, the taste buds have been titillated. A demand is developing and we now have to fill this market.

I will end with a famous quote from Thomas Jefferson: "The greatest service that can be rendered to any country is to add a useful plant to its culture".

PRELIMINARY RESULTS WITH AUSTRALIAN ROCKWOOL USED FOR PLANT PROPAGATION AND IN HYDROPONIC SYSTEMS

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This note summarizes the results obtained with Australian-made horticultural rockwool used as a substrate for the propagation of seeds, rooting of cuttings, and for hydroponics. Growth was compared against that in: Danish horticultural rockwool; in a 50:50 mix of perlite and vermiculite; and in scoria.

Seeds of various sizes (e.g., petunia to sunflower) direct sown into Australian rockwool blocks germinated and emerged normally. The only problem encountered was a temporary iron deficiency in *Gypsophila* and *Petunia*, but this was easily rectified. In one study many gerbera seedlings failed to emerge from Australian and Danish rockwool blocks because of resistance imposed by the fibres to the cotyledons. This problem was overcome by shallower sowing. Early samples of Australian rockwool blocks collapsed badly but this problem was largely overcome in samples manufactured later.

Herbaceous and woody cuttings of exotic and Australian plants rooted readily in rockwool blocks and in about the same time as compared to current commercial methods. A problem was encountered with rose cuttings but this was attributed, in part, to uneven wetting of the rockwool blocks. Once the correct managerial procedures had been developed, this problem was eliminated.

Transplanting of seedlings and of tissue-cultured plantlets into rockwool blocks was satisfactory. The only difficulty was in the transplanting of relatively large-rooted gerbera crowns into 75 mm cube blocks, probably because of the need to severely root-prune first.

In the hydroponic studies, slabs of Australian rockwool (750 mm long, 300 mm wide, and either 100 or 50 mm thick), were used to grow sugar peas, tomatoes, *Gypsophila paniculata*, kangaroo paws (*Anigozanthos manglesii* and *A. flavidus*), gerbera, rose, carnation, and the Sturt desert pea (*Clianthus formosus*). All made vigorous growth and was comparable to growth in scoria, Danish rockwool, and in a perlite:vermiculite mixture.

TRANSPLANTING CONTAINER-GROWN PLANTS INTO THE FIELD

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INTRODUCTION

There are many advantages in growing plants in lightweight mixes compared to those containing a large proportion of soil. These are:

— Easier management (e.g. better drainage, greater moisture holding capacity)

— Disease and weed problems are usually less, and

— Significant savings can be made in handling and transport costs

However, many landscapers and nurserymen believe that plants grown in "heavy mixes", i.e. those containing a large proportion of soil establish more quickly when transplanted into the field — especially into soils containing a large percentage of clay (otherwise known as the interface problem). There is also much argument as to whether tubes or advanced plants should be used.

A series of experiments were done to answer these questions, with particular attention being paid to the penetration of roots from the original potting mix into the surrounding soil and water usage by the plants in the field situation.

MATERIALS AND METHODS

(a) Soil types used were —
  (i) light sandy soil
  (ii) heavy clay soil

The soils were either in adjacent fields or in large (200 liter) containers.

(b) Potting media used were:
  (i) lightweight medium — 50% composted hardwood sawdust, 25% pine bark, 15% coarse sand, 10% pasturized loam.
  (ii) heavy medium — 50% of medium (i), 50% pasturized loam.

(c) container sizes used were:
  (i) tubes (15 cm deep, 5 cm diam)
  (ii) 5 liter plastic bags
  (iii) 10 liter plastic bags

Plants were grown for 6 weeks after being transplanted

into the field. Plants were watered when a gypsum block in the rootball indicated a preset moisture content. A range of shrubs and trees were used in these experiments.

RESULTS

1. Provided that plants transplanted into the field are watered just before they show signs of wilting (about −13 bars), extra watering has little effect on the establishment of plants in the field.

2. Tube-grown plants require only about half the number of waterings when transplanted into the field compared to plants grown in 5 liter or 10 liter containers.

3. Roots from plants grown in tubes tend to grown downwards after transplanting, and those from larger containers tend to grown outwards (Figure 1).

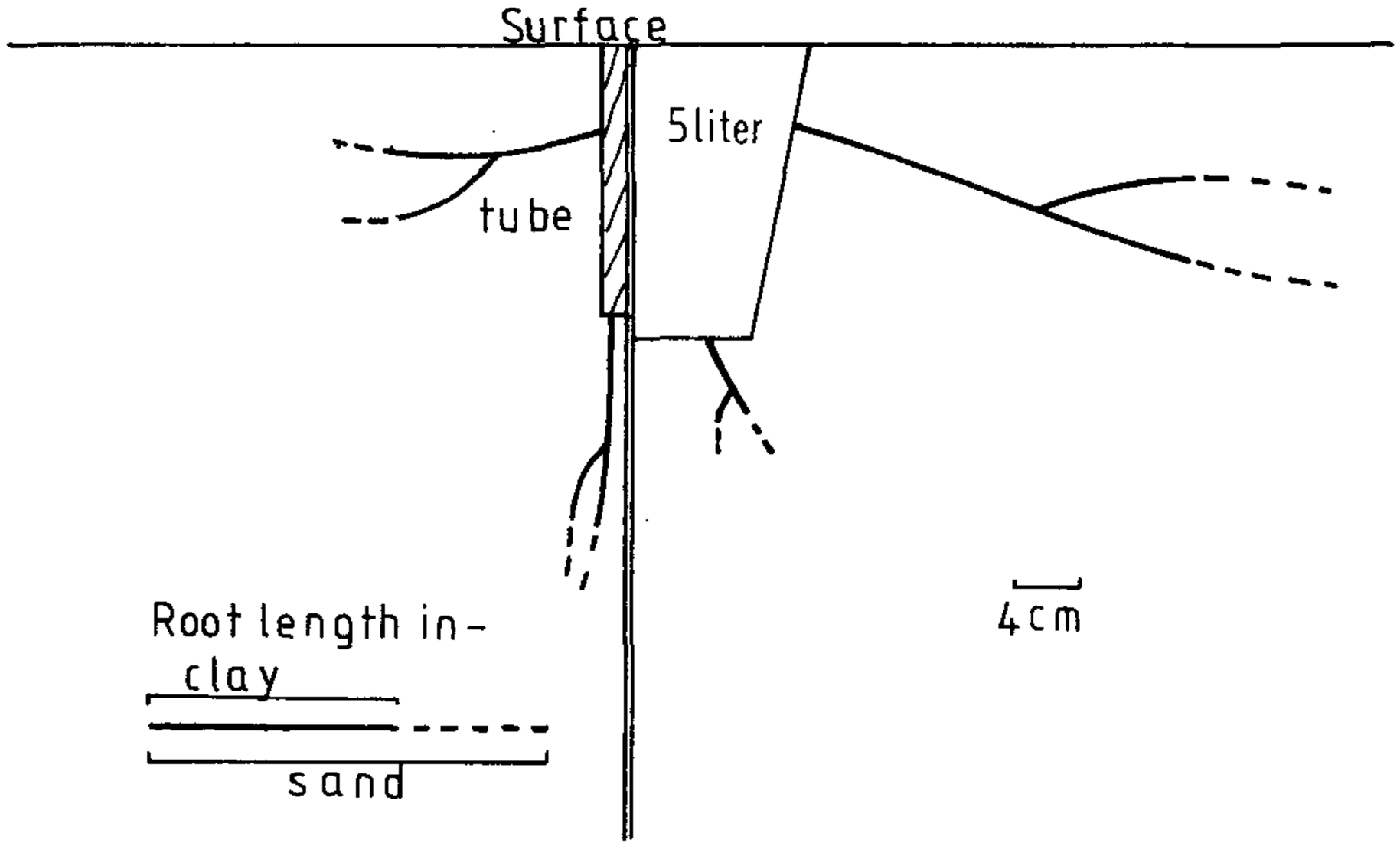

Figure 1. Average root penetration for trees and shrubs into surrounding soil from tubes and from 5 liter containers 6 weeks after transplanting.

4. Plants grown in a "lightweight" medium generally required fewer waterings than those grown in heavy mixes when transplanted into the field (Table 1). This was mainly due to the low level of available moisture in the heavy weight medium — despite the two media having similar total moisture holding capacities.

Table 1. Average number of waterings over a 6-week period for liquidambar, in either a light or heavy potting medium, and transplanted into a sandy or clay soil.

Treatment	Number of waterings
Potting Mix	
light	1.9
heavy	6.0
Soil	
sandy	3.0
clay	4.8

5. Root penetration from a lightweight medium into surrounding light or heavy soils was at least as good as that from a heavy medium, i.e. if plants receive adequate water, an "interface problem" does not exist. (Figure 2) In all instances plants were well established (as determined by root penetration) 6 weeks after transplanting in the field.

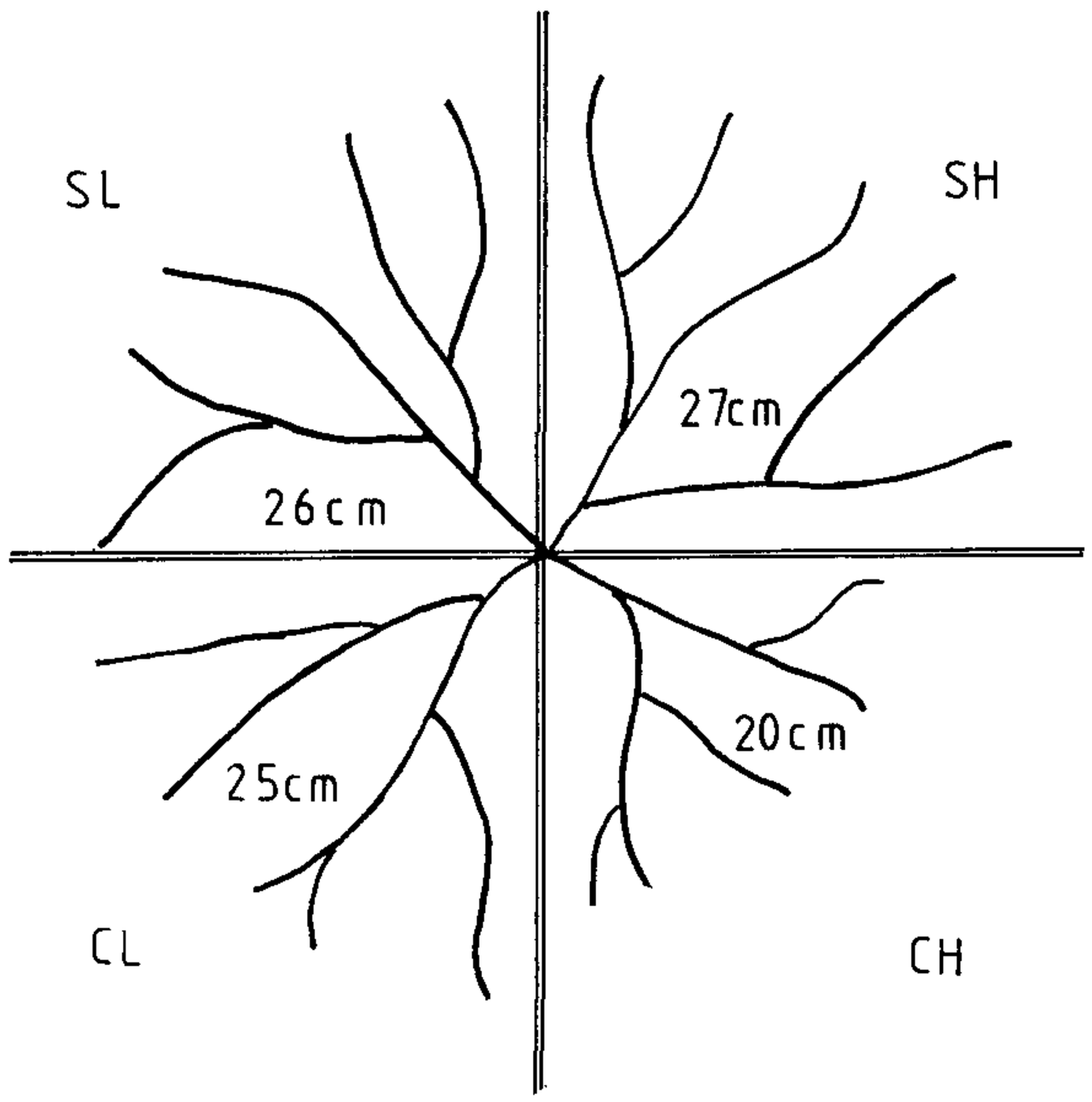

Figure 2. Average root penetration for liquidamber into sand (S) or clay (C) soils from lightweight (L) or heavy medium (H) 6 weeks after transplanting.

6. Water usage by plants transplanted into the field depends on the potting medium, pot size, soil types, species (Table 2), and weather (although for some species it

is not directly related to weather measurements, e.g. evaporation). This makes prediction of the number of waterings required by plants transplanted into the field very difficult. A better approach may be to actually measure the amount of water left in the root ball, using a relatively inexpensive device such as a gypsum block.

Table 2. Average number of waterings over a 3-week period for plants transplanted into a field soil.

Genus	Number of waterings
Ficus	2.8
Cupressus	3.1
Eucalyptus	3.5
Grevillea	3.0
Melaleuca	4.2

CONTAINER-GROWN ROSES: FIVE MONTHS FROM CUTTING TO FLOWERING

G.I. MOSS, and R. DALGLEISH

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Abstract. We have developed a method for producing rose bushes to a flowering stage in less than five months under greenhouse conditions. It can be done at any time of the year. *Rosa multiflora* cuttings are rooted and budded to required cultivars, then grown on to flowering. The percentage of saleable bushes was about the same as for field conditions. Because there is control of the environment there is considerable scope for improving the product and the method. The rose bushes produced were an attractive item, flowering in a container, and were suitable for planting.

INTRODUCTION

Rose bushes are mostly produced in the field and their production includes a significant labour component performed under uncomfortable conditions. Among the reasons for looking at the alternatives to field production are: the percentage of saleable bushes is often low (60%); garden centres and supermarket outlets probably could use an alternative product to bare-rooted dormant roses bushes, such as roses bushes already flowering in a container and suitable for planting out. Initially the method we describe was developed because we needed rapid production of disease-free, uniform rose bushes for use as test plants in experiments.

METHODS AND RESULTS

Experiment 1

Producing the rootstock. Cuttings of *Rosa multiflora* were

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METHODS AND RESULTS

Experiment 1

Producing the rootstock. Cuttings of *Rosa multiflora* were

taken in early summer (December), consisting of semi-hardwood material 22 cm long; all leaves and eyes were removed except for the top two. They were rooted in 50/50 peat-sand mixture adjusted to pH 6.5 in 15 cm pots, with 10 cuttings per pot. A white plastic cover was used over the mist bench to increase humidity and reduce light intensity (Figure 1). Approximately 75% of the cuttings were rooted by 8 January, and no hormone was used.

Figure 1. *R. multiflora* cuttings in the mist propagator.

Other rooting media were tried including 5 mm scoria and perlite/peat moss (1 part perlite to 1 part peat, plus 3 kg limestone per m^3). Other workers have noted that perlite/peat mixture is a good rooting medium (4). A comparison of cuttings in scoria with one in perlite/peat after one month in the propagator is shown in Figure 2.

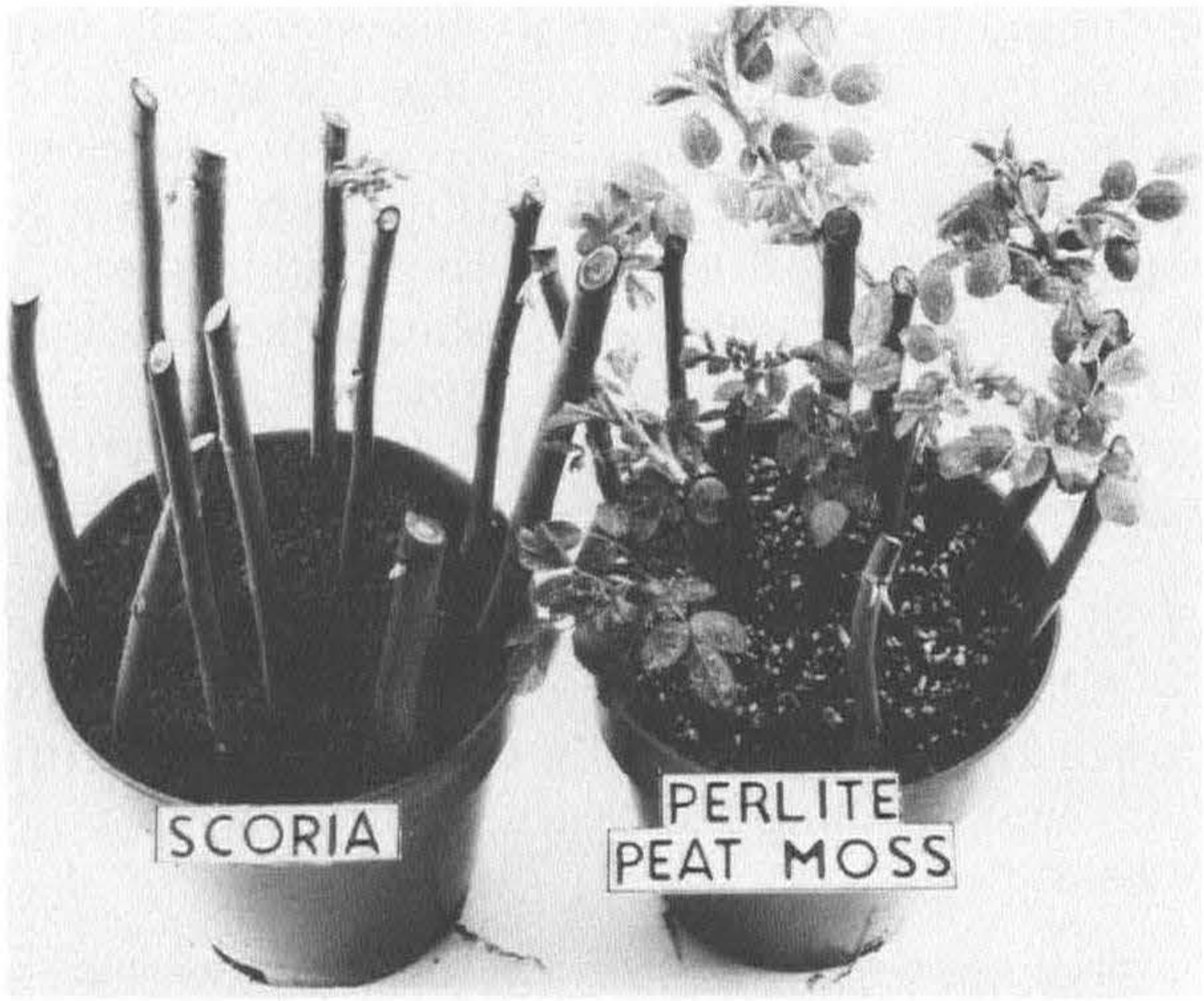

Figure 2. A comparison of the performance of *R. multiflora* cuttings after 4 weeks under mist in 5 mm scoria and in a 50/50 perlite-peat mixture.

The rooted cuttings were transferred to another glasshouse and using sprinklers controlled by a time clock they were hardened-off gradually as the daily maximum temperatures were above 35°C. Two weeks later all cuttings were transplanted into individual 150 mm pots containing U.C. Mix C. Of the original batch of 500 cuttings 412 were planted out and a further 88 either died or were discarded (Table 1). After repotting, plants received a liquid feed each week, because the success of rapid propagation in pots depends upon maintaining a healthy growth rate; the pH of the medium was checked periodically to this end.

Table 1. Dates of procedures and success rates for container propagation of roses.

Procedure	Experiment 1		Experiment 2	
	Date	Numbers	Date	Numbers
Cuttings taken	12 December (early summer)	500	15 June (early winter)	500
Rooted cuttings removal from mist	8 January	412	24 July	386
Cuttings budded	14 February	412	31 August	386
Stock headed	23 February	404	10 September	371
Bushes selected for use (sale)	10 May	300	5 November	280

Producing the scion. On 14 February all stocks were 'T' budded, and the buds tied with plastic tape. The scion culti-

vars were: Ilona, Mercedes, Sonia. The stock top growth was reduced by ⅓ five days after budding, reduced further by ⅔ nine days after budding at which time the plastic ties were cut (Fig. 3). Under greenhouse conditions it is important to remove the ties early before callusing of the bud occurs. The bud "take" was 98% for all cultivars. Further treatment consisted of rubbing out all new *R. multiflora* growth until the scion had attained several true leaves; the stock was then headed back to the bud union. The rose bushes were maintained in the glasshouse with a minimum temperature of 18°C (Fig. 4b) and pinched at the 4th leaf stage (Fig. 6). Fifty days after budding there were 300 good quality bushes (Fig. 5), and these commenced flowering by 10 May. The root system was fibrous and would have been suitable for planting out, or as a plant for a larger container.

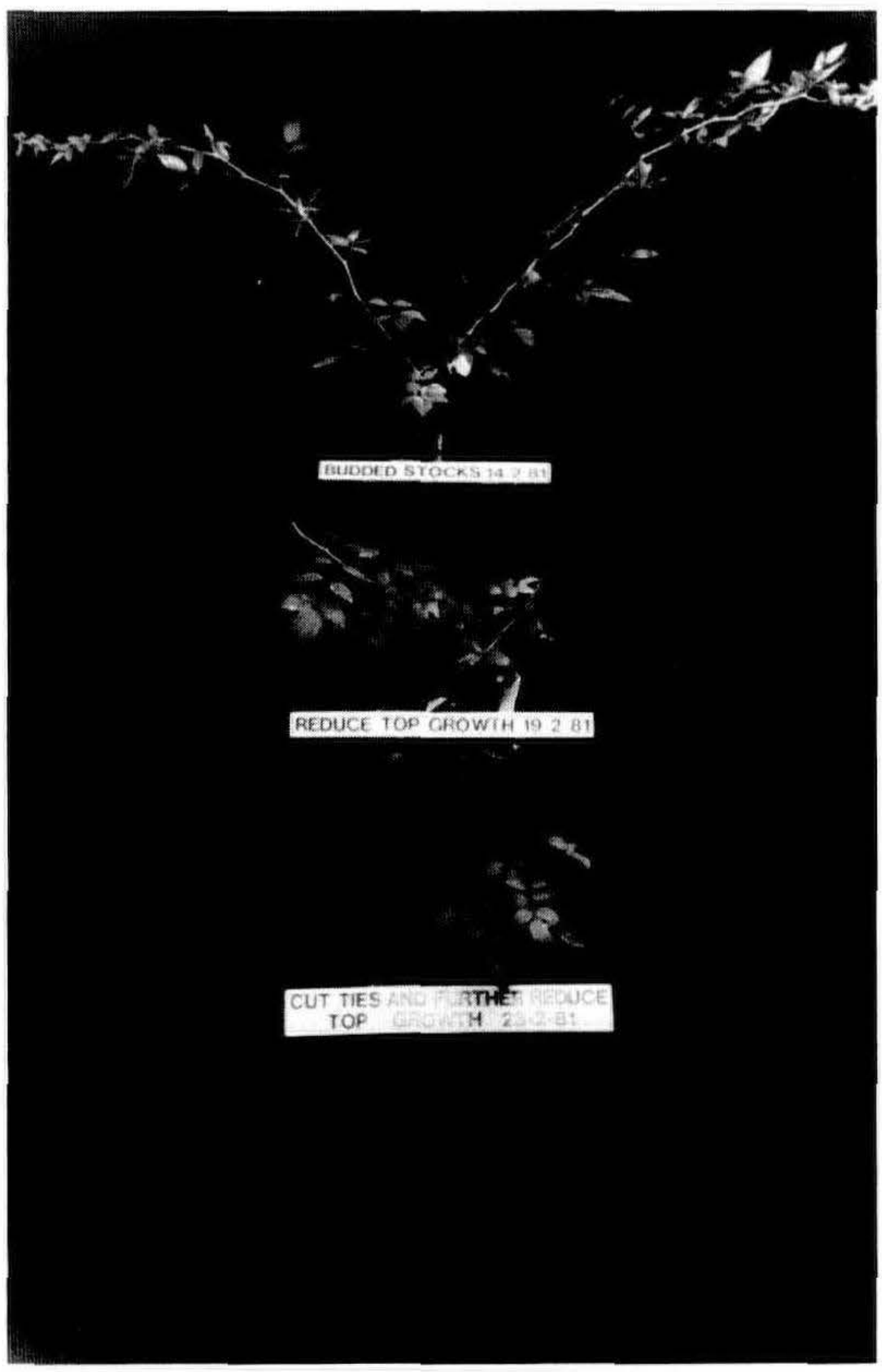

Figure 3. Reduction of rootstock growth after budding. *Top*. Rootstock budded on February 14, 1981. *Center*. Top growth reduced on February 19, 1981. *Lower*. Tie cut and top growth further reduced on February 23, 1981.

Figure 4. (a) Scion pinched at the fourth leaf (left). (b) Scion growth developing after heading the stock. (right).

Figure 5. Rose bushes in 150 mm pots 50 days after budding.

Figure 6. The final product: rosebush, cv. Sonia on *R. multiflora* rootstock in a 150 mm pot 67 days after budding.

Experiment 2

By taking cuttings in the autumn it would be possible to have two crops a year in the greenhouse (Table 2, alternative method). *R. multiflora* cuttings were taken on 15 June, rooted in the mist propagator, potted on 24 July, and budded on 31 August. Flowering rose bushes suitable for spring plantings were produced some 67 days after budding (Figure 6).

Table 2. Comparison of container-grown rose propagation with traditional field methods.

Field-grown roses, procedures	Approx. date	Container-grown roses, procedures	Experimental date	Alternative date
Soil preparation	May (late fall)	Soil mixture prepared	December (early summer)	June (early winter)
Cuttings of rootstock taken	June	Pots filled	December	June
Buds cut out	June	Cutting of rootstock taken	December	June
Cutting callused	June-July	Buds removed (except top 2)	December	June
Planted in field	August	Cuttings rooted under mist	Dec-Jan	July
Cuttings, hilled up to 2 buds	August	Potted on after rooting	January	July
Herbicide and fertilizer applied	Sept.	Drip irrigation installed	January	August
Hills knocked down after rooting	Oct.	Rootstock budded	February	August
Head back stock	June-July	Top growth reduced	February	September
Cultivate ground	August	Ties cut; remove more top growth	February	September
Clean stock	August	Head back stock	March	September
Apply herbicide	August	Pinch out tip of scion	April	September
Pinch out growing tip	Oct.	Sprays	Feb-May	October
Fertilizer applied	Oct.	Growing on	Mar-May	October
Spraying	As required	Plants ready for sale	May	November
Plants lifted	May-June			
Plants prepared for sale	June			

DISCUSSION

There is world-wide interest in improving rose propagation methods (2). Rapid propagation in containers under protected conditions offers considerable advantages. These are: ease and efficiencies of working; soil-bourne pest and disease avoidance; production of a more attractive sales item. A direct comparison of field production with container production is made in Table 2. The chief difference is that container growing is completed under 6 months, compared to field growing which takes two years.

One problem we encountered was obtaining good rootstock material. To obtain good rooting and ease of budding the rootstock cuttings should be semi-hardwood and the diameter of a pencil. For spring propagation in the future we intend to keep stock plants of rootstocks in the greenhouse so we have plenty of growth when we need it. The choice of rootstock depends on local requirements. Some cultivars grow well on their own roots; our experience with 'Sonia' is that cuttings appear to grow better than the budded plant on *R. multiflora*; this cultivar might be used as a rootstock.

We used semi-hardwood cuttings of the rootstock with at least 6 buds per cutting; this size has been demonstrated to produce more roots than smaller cuttings (1). Roses can be produced as cuttings from either 4 leaf or 1 leaf cuttings (5), or from softwood cuttings (6). Single rose buds can be stimulated to grow *in vitro* and the resulting shoots rooted normally (2). Another alternative method is to graft a short length of scion onto a short length of rootstock and place this in the mist propagator (7). With rose cuttings in early spring a mist propagator may not be necessary; a sheet of plastic over the cuttings to preserve humidity can be sufficient.

We feel that there is considerable scope for improving container propagation of roses. Our wastage rate was high (Table 1), the main areas being failure of cuttings to root and unsatisfactory development of the rose bushes. Rooting might be improved by the use of IBA at 750 ppm (1). Selection of better rootstock material from plants grown in the greenhouse would probably give superior results.

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MECHANISED NURSERY PRODUCTION

ROBERT MILLER

Broadhouse Farm Nursery
Cutnall Green, Droitwich, Worcs.

I want to show you how we produce cuttings, on the understanding that we are a young nursery, and have only been in existance for five years, four years on a full time basis. We started with an empty field and built a nursery to suit ourselves, so in theory we have no hangover of old habits and practices. After two years we built a purpose-designed barn which incorporates a separate propagation room. It is built of brick and fully insulated, with tiled floor and walls, so that it can be heated and easily washed down and sterilized. There is a bench and comfortable chairs for the workers, and good lighting conditions.

The only "mechanical propagation" is knives and secateurs, the tools of the trade. We employ two girls full time on propagation, and we hope they will do 2000 cuttings per person per day, which includes insertion and putting out the trays on the benches. In twelve months we do 600,000 cuttings, on a 300 working day year. Secateurs are used more than knives as the girls find them easier to handle.

We keep a full record of every batch of cuttings with dates of propagation, potting on, and numbers of plants at each stage, etc. The staff do this themselves, and the records are kept through to point of sale.

The plastic trays we use are made by Allibert in France, and are not common on English nurseries. They measure 24″×18″ and are easy to handle. We like this tray for the number of cuttings it holds, and, more important, is the 32% space area in the base which is physically in contact with the sand on the propagation bench. There is very good heat transfer, and at any one time there is only a 2° to 4° difference in the bench and compost temperature. With the traditional seed tray the base is solid and this temperature differential can be 12°, so up to 8° is wasted in achieving the right temperature in the compost. The French trays have very good drainage, and can easily be sterilized by dipping or fogging in a sealed chamber. They are very tough and we expect a 10 year life, whereas similar trays from Holland at half the price are not UVI inhibited and break sooner.

We have a typical mist house with a three foot bench each side and a six foot wide one in the centre. These beds are laid out to take our trays exactly, so that no space is wasted. There is a conventional Macpenny mist system, and electric heating cables are buried on each bench, controlled by two thermo-

stats per bed; which allows us to switch off part and save heat. The beds are lined with polystyrene and this has given good control of heat.

The centre bed is watered from a coarser nozzle operated by a timeclock, and this has been quite suitable for broader leaved and evergreen cuttings. We put 40% shading over the roof, with an extra Lobrene shade cloth on the south end of the house. In the winter months we use polythene over the beds instead of mist. Paths are such a width that we can balance a tray across on the bench walls to make inspection easier.

A Robinson house has been put up for propagation, and the bottom heat in this is provided from hot water pipes buried at 6¼" centres and 6" depth. The water is heated in a domestic hot water boiler of 120,000 BTU capacity burning 28 second oil. Nobel control units operate circulation pumps which pump water at 120°F through the flow pipes, and it returns at 115°F. The heat control is very accurate; even in the last cold winter we had only a half degree variation, while we had 12° variation within beds heated by soil warming cables. More significantly, the hot water system costs only half that to run compared to electricity.

A bench in this house is 8 feet wide and 91 feet long. It is constructed with walls of 9" concrete blocks, and is lined throughout with 2" polystyrene, and filled to a depth of 7" with sand, the hot water pipes buried at 6". Polythene is draped over the beds, as so far we have no mist. It is used for shading and as a thermal screen, and we use different types and densities at different times of the year. In winter it makes an effective thermal screen, and temperatures under the polythene have been 6° to 7° higher compared with the glasshouse temperature. We maintain the latter at a minimum of 1°C. In winter we lay Xirofilm directly on conifer cuttings, but support it on hoops over softer material.

For our potting operations peat is stored in the barn, and a conveyor takes it to our Alvan Blanch soil mixer so one person can do the mixing. We make a peat/sand mix and use Q4 fertilizer, and the mixer delivers it directly on to the potting bench behind.

The cutting trays are stacked 20 high on plastic dollies with four wheels; with an iron handle attached we can pull these trollies over concrete floors. Another mechanised handling trolley is based on a hospital trolley, and holds 10 Allibert trays which can be slid in at the sides so there are two side by side. There is one pair of wheels on the front, and the

back pair are fixed, and it will turn in its own length. Two wheels on each side guide it along the walls of the concrete paths in the glasshouse.

Once cuttings are rooted they are brought on a trailer to the potting shed. We handle the potted cuttings in Empot carriers which take either 7cm or 9cm pots, and we developed a racking system which can be simply transferred on a track to the trailer. We pot by hand, and pots are transferred to the Empot racking. The trailer will hold 2000 pots, a morning's work for our two women. In the polythene houses we have more tracking for unloading racks from the trailers, or for loading up customer's orders later.

For weed control in the containers we have designed a boom to span a 7'6" bed; this has been an adaption of an old sprayer.

N. ROBERTS: Do you have any restrictions on the use of secateurs for cuttings of certain subjects?

R. MILLER: We do not use them on brooms or any *Cytisus spp.* or any soft material such as *Hypericum*, *Cotoneaster* and *Cornus*. With *Senecio* knives make a better cut, and for skilled labour I feel knives are better.

N. ROBERTS: Do the people doing cuttings collect their own material, and does this affect the rate of work?

R. MILLER: They collect if we have our own stock plants; the rate depends on material. We use shears on some species, but for difficult subjects such as *Berberis* it is a morning's work. We expect to do 2000 per day; taking and making cuttings is done in one stage and sticking is done outside the propagation room.

S. FRASER: With a temperature of 120°F in the bench heating pipes, what is the temperature at the base of the cuttings?

R. MILLER: 18°C (68°F). With 6" of sand over the pipes we get a very even and constant spread of temperature. Shallower sand means hot spots.

D. WHALLEY: Could you give more details of the shading?

R. MILLER: We have 40% net shading on top of the glasshouse, then a thermal sheeting 6' above the beds, but this is only on in hot sunny weather, making a total shading of about 62%.

A. WOOD: What is the cost of the trays?

R. MILLER: In small quantities, the Allibert trays cost £3 each, and the similar Dutch tray £1.39.

B. RIGBY: Did you make your own trolleys, or were they made by an engineer who could supply to the industry?

R. MILLER: Most roller conveyors clog with peat, so we consulted an engineer when we decided to build a system around the Empot carrier. It is too expensive to patent the idea, but I am prepared to sell the drawings. The handling time to unload the trailer is 20 minutes for 2000 plants; this is impossible to do by hand.

R. EVISON: Do you overwinter young plants in the trays, and do they get starved?

R. MILLER: We use no fertilizer in the compost, but we now top dress Q4 as soon as the cuttings are rooted and water it well in. Most get one application before they are potted.

R. EVISON: We are using smaller but deeper trays with a potting compost in the base and a normal cutting compost on the top. It has been very successful, but we shall have to see how they overwinter.

COST EFFECTIVE PROPAGATION USING POLYTHENE STRUCTURES

ROBIN B. TACCHI

Tacchi's Nurseries
Banks End, Wyton, Huntingdon

When I left college some 13 years, or so, ago; with ambitious plans to turn a small family retail firm into a production orientated wholesale business, there were three factors which determined our propagation set-up:

Firstly, large amounts of money were not available;

Secondly, the lack of any existing conventional propagation systems, which allowed me to start from scratch with a fresh approach. People are reluctant to change what they already have!

Thirdly, the reluctant realisation by horticulturists that polythene did have applications other than wrapping sliced bread, and that it might even be used as a glass substitute.

Using this magical substance it became apparent that not only did it work, it enabled one to erect large areas of propagation covering, simply and with a low initial expense.

I say initial because, over a period of time, re-cladding

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Using this magical substance it became apparent that not only did it work, it enabled one to erect large areas of propagation covering, simply and with a low initial expense.

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labour and material costs mean that there must be a point where the cost of glass versus polythene evens out. But it is the low initial cost which was important.

With the high capital outlay and high running costs with glass, concrete paths, raised beds, mist and timers (I never could understand the concept of heating a bed and at the same time drenching it with cold water), and all the other electronic paraphernalia, which always seems to break down during the hottest day of the year, leading to "propagator's palsy".

Simplicity is the key; nothing could be simpler than going with the seasons, using the sun as free heat with polythene as the uncomplicated tool.

Now with the high capital outlay in misted glass, bench space is at a premium. There must be a constant flow of rooted material through the propagation house to justify the high costs.

Grouping of plants with similar rooting times becomes critical, making the use of trays essential. Trays are costly; they need sterilizing and filling. The labour costs in handling the trays from propagation room to propagation house, and then from rooting to the weaning or over-wintering house are considerable. Trays also take up space.

With "poly-houses", without mist or heat, one can afford to root one crop per year and leave it sitting there undisturbed over the winter, ready for spring potting when teams of part-time workers lift the crop en masse for the potting team. (Autumn potting can be discounted as being too risky, and there's no point in doing this with us, anyway.) This eliminates trays (although we do use trays for about 10% of our production, which I'll explain later).

Having large areas of propagating space at one's disposal is a definite asset. For example, the majority of evergreens under polythene root best without bottom heat, from mid-August to the end of October. This major peak in propagation can be met by employing more part-time cutters, and production can really be achieved in a big way, without the worry of having to find more space.

I won't go into the importance of having large stock beds on a hedgerow system, or time and motion in the cutting room. I'm sure this has been covered adequately before.

Our propagation year starts after potting, which is the last week of June, and continues with fluctuations in the labour force, to the end of January, after which the potting cycle commences once again.

We have two 28′×100′ wide Filclair houses with vents for

propagation extremes. By "extreme" it is meant that one is used for mid-summer propagation where the hottest temperatures are achieved; the other in the depths of winter when one experiences the coldest temperatures. Both houses are designed to deal with these extremes and they account for about 30% of our total propagation.

From mid-August to December we have a series of 14′ to 16′ wide polyhouses. In all houses, with the exception of the winter house, cuttings are stuck into a 10cm peat/grit layer, which is laid directly on black polythene. All beds are at ground level. The peat/grit ratio varies according to season. (Osmocote, frit, and dolomite are incorporated in the mix at ½ potting compost rates). Rockwool and other multi-pot aids are also being used.

A trolley for the "sticker" is used to cut out most of the arduous bending work involved, and to increase production.

SUMMER PROPAGATION

The greatest hazard of propagation under polythene between June and August is the excessive heat build-up. There are several ways to deal with this. When we start in July with deciduous softwood cuttings, our vented Filclair house is used. A 60% shade plastic netting is suspended across the eaves and along the sides. Under this at ground level are low tunnels covered with 150 gauge white polythene. Each low tunnel is fitted with a series of high pressure nozzles which are used either manually, or on a time-clock at week-ends. These high pressure nozzles are only used on warm clear days, giving an 8 second burst every hour between 9 am and 5 pm. They are used purely as cooling devices but they also ensure that 100% humidity is achieved. This is our only concession to the "mist" principle and the actual volume of water used is minute; it is turned off completely during dull weather.

We aim to experiment with fine sprays actually directed over the top of the tunnels, which would induce cooling without over-saturation of the compost.

In mid-August we move into the 16′ wide polythene house clad in white film. As an additional precaution in hot weather, a 20′ wide Nicofence is draped over the house, which can be removed or erected in minutes, as the weather dictates. In the houses themselves the low polythene tunnels are now dispensed with and white 150 gauge polythene is laid directly on top of the cuttings.

We believe direct polythene gives better results at this time of the year and into the winter months, especially with evergreens and small-leaved subjects.

One word about shading: at one time netting was laid directly on top of the polythene clad inner tunnels. We found very little, if any, reduction in heat inside these. There must be at least a 1' gap between the netting and the polythene.

We are now looking at lathe type shading — like Paraweb, which breaks the light into parallel bars of deep shade and bright light. As the sun moves these bars of light and shade move steadily across the house giving each strip no more than 10 minutes before heavy shade, thus giving a boost to the food production in the leaves of the cuttings, but without scorch.

In September/October, whilst still using the white out-covers, the 150 gauge white is replaced by a light opaque 75 gauge film directly on the cuttings and then by November, a clear 75 gauge polythene is used.

From late November through to mid-December we use a clear polythene house with the clear 75 gauge inner covering. During November and December all the easy ground-cover types are rooted, i.e. *Hypericum*, *Vinca*, ivies, etc. We find that even in mid-winter there is still enough heat in the sun to promote slow rooting without heat.

So we are having a flexible shading routine which varies according to the light throughout the different seasons.

From mid-December to the end of January we move into our winter Filclair, where cuttings of × *Cupressocyparis leylandii*, *Ilex*, and certain conifers do require some bottom heat. The beds are heavily insulated with styrofoam using Nobel probes.

We also, reluctantly, have to use trays because of unequal rooting times to make best use of the house.

Low polythene clear tunnels are hooped over the crop with Pillasol laid directly over this, and on clear sunny days white polythene is placed over this, creating a sandwich.

The bed temperature is kept at between 60° and 65°F; we have found higher temperatures unnecessary.

No air heating is used in any of our houses during the winter. During cold spells we do cover rooted cuttings with bubble glaze and polythene laid directly on top.

Last winter we recorded −20°C inside our tunnels and had very few losses, even with tender species whose mother plants were killed outside.

B. LOCKWOOD: Could you tell us more about the use of Osmocote, and nutrients in general in the rooting media?

R. TACCHI: We have tried for two to three years using long release Osmocote with trace elements (Micromax) and

dolomite limestone on summer-rooted cuttings, and they are left until the following spring.

M. SCOTT: Don't you run into problems with release of nutrients in hot summer weather?

R. TACCHI: No, not really.

A. WOOD: Initially you chose polythene houses for your nursery, but during the long term these incur high replacement costs for polythene. If you started again, would you choose glass or polythene?

R. TACCHI: It would be a difficult decision; I haven't done any definitive costs and examined the grant position.

W. MATTHEWS: I chose glass and built ¾ acre. There are breakage and washing problems, but I would stay with it. It is easier to control temperature and there are no drip problems. With the increasing cost of oil polythene replacement will get more expensive.

SIMPLE BUT EFFECTIVE PROPAGATION IN NORTH AMERICAN NURSERIES

ALAN E. DOWN

Hillier Nurseries (Winchester) Ltd.

Ampfield, Romsey, Hampshire

Last summer, I toured the United States and Canada as a Nuffield Scholar fully funded by the Studley Trust. My prime interest was in the production and marketing of container plants but, as I visited over forty container producing nurseries, I gained an insight into their propagation methods.

One cannot fail to be impressed by the vast open-air mist units of the South and Southwestern states. The progressiveness of the growers in the Pacific Northwest with tissue culture of ornamentals is equally impressive.

However, the humbler propagation techniques used by some growers set me wondering whether we in Europe are employing over-complicated and unnecessarily sophisticated methods for the propagation of easy subjects.

For instance, in the Midwest, millions of *Taxus* and *Juniper* cuttings are produced annually employing a technique which is really no more than an adaption of the old coldframe. Instead of frames, walk-in polytunnels are used to enclose the cuttings stuck in raised ground beds. No bottom heat is provided at all and the only air heating that is done is to prevent irrigation lines from freezing in winter. Large cuttings are

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inserted during winter when severe freezing brings most other nursery work to a standstill. The cuttings are 20 to 25cm long, wounded, and dipped in hormone before inserting into raised peat and sand beds on the floor of polyhouses, 2.5 to 3m wide. After filling, houses are sealed up and the cuttings are misted over just two or three times a day with a coarse mist. Rooting is slow and it is normal practice to leave the cuttings *in situ* for 15 months before lifting for lining out or potting off. This may seem a long time to wait to get a liner by our standards but the costs are low and the system is extremely simple and easy to operate.

The second low cost system which impressed me is one which is currently receiving renewed interest on both sides of the Atlantic. Work conducted by Dr. Milbocker at the Virginia Truck and Ornamentals Experimental Station has caused a revived interest in the use of foggers for propagation of cuttings. This technique has, I believe, been covered in depth at a previous IPPS Conference and I will therefore not dwell long on it. The principle is to provide constant 100% humidity in a polyhouse or glasshouse. The leaf surface of cuttings is cooled by ventilation instead of by evaporation with the mist system. Less water, it is claimed, passes through the rooting medium and one assumes that this, in turn, leads to a heat saving. The system is relatively inexpensive, costing in 1981, just $500, plus cost of installation.

Undoubtedly, rapid rooting can be achieved by this technique. An added advantage appears to be that fewer leaves need to be removed from cuttings and this results in a reducting in cutting preparation costs. For a low cost installation, this technique would appear to have distinct advantages.

In the Pacific Northwest, a number of growers are successfully rooting shrubs directly into the containers in which they are sold. This direct rooting drastically reduces production costs. Three cuttings are inserted per pot in polythene clad tunnels. Rather than applying mist to aid rooting, heavy irrigation is applied for one minute in every fifteen. A very open compost mix is used to avoid water-logging. This is usually composed of at least 60% bark. Cuttings of easily rooted subjects are stuck in June, relying on the sun's heat to warm the tunnels. Rooting hormones are rarely necessary and the loss percentages are extremely low. The major crops produced in this way are *Arctostaphylos uva-ursi*, ground cover *Cotoneaster* and *Euonymus*, *Potentilla* and *Pyracantha*. *Photinia* × *fraseri* is also rooted in this way but with the assistance of hormones. After rooting, the polythene covers are removed for the summer and stock is fit for sale during the autumn of the same year.

Finally, a technique which is probably very old but is certainly now neglected and which impressed me, is used in Oregon. There, growers are reducing the time required to produce a specimen grafted plant by framework grafting. Large, field-grown *Acer palmatum* trees are lifted and containerised prior to grafting the main branch framework with many scions. A large, grafted specimen is rapidly produced, often with an interesting habit imparted by the framework of the understock. Occasionally, a mixture of scions are worked onto the same framework. This could lead to poor results later on if vigour is not carefully matched.

Conifers are frequently worked onto stems to produce small standards and half-standards for the patio market. This is, I believe, a growing market in Britain and one which provides an additional outlet for hardy plants and nurserymens' grafting skills.

J. GAGGINI: Can you tell us more about topiary Piceas grown as standards and half-standards? Where are they sold, and what is the price differential?

A. DOWN: The market is the high quality garden centre. They are often sold with an expensive container, and obtain up to double the price of the usual plant.

S. FRASER: A 6′ *Sciadopitys* would make $280, and $90-$150 would be a good price for a spruce, which would retail in the East for up to $350.

D. HATCH: How many scions are used on grafted trees?

A. DOWN: One scion for standard conifers, but others are multi-scion.

A. WOOD: What is the compatibility of *Picea* cultivars worked on *P. sitchensis*?

A. DOWN: There is no problem, the *P. pungens* cultivars are on Sitka spruce.

E. BATE: Can fungicides be used in the fogging mist?

A. DOWN: It was a new unit and I did not discuss this, but there was very little disease in the cuttings as less leaves are removed with this system.

R. CURRIE: How do American nurserymen handle growth of plants in bark composts with regard to stability, watering, and nutrition?

A. DOWN: At Brigg's Nursery, Olympia, Washington, cuttings were struck directly into containers, and these are kept pot thick. Later the polythene covers are removed from the houses. There is no shortage of water and plants are fed and

watered heavily. The aim is for a low cost landscaping product, not the higher quality garden centre trade.

A. HARGREAVES: Has any work been done in this country using wood chips as a mulch and for weed control in small containers?

M. SCOTT: Efford E.H.S. worked with peat mulches which were best for weed control, but were expensive and difficult to apply in small containers. Spraying is more cost effective.

D. GILBERT: There seems to be some contradiction in shading and outdoor misting; has outdoor misting any place in the U.K.?

A. DOWN: In the U.S.A., outdoor mist is used for evergreen cuttings, but there are large areas of shaded mist. It would not be feasible here because of wind.

NURSERY STANDARDS AND QUALITY CONTROL IN SWEDEN

LARS RUDIN[1]

Malmö, Sweden

Like most countries the nursery industry in Sweden has its own standards for nursery stock. These standards however have, by tradition, been adapted to the unofficial international standards for nursery stock in Northern Europe.

The difference between Sweden and other countries is that our standards were made compulsory some years ago. This means that today no single woody plant might be sold unless it complies with The New Official Standards for Nursery Stock. The official and the former trade standards are very close in their requirements. This means, in practice, that the new official rules are a revision and an elucidation of the former nursery standards and are furthermore made into law.

The purpose of this law is to create a consumer's protection. The background for this is that the trade with nursery stock changed drastically during the last 10 to 15 years. Briefly, the distance between the producer and the consumer has increased. Earlier nursery stock was produced and sold locally but today plants are shipped over long distances, from abroad into Sweden and from the southern part of the country to the mid- and northern parts. Furthermore, nursery stock is today sold through many new non-professional channels.

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[1] Extension Specialist in Nursery Production.

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Until now I have only spoken about nursery standards but these are only one part of The Total Quality Control of Nursery Stock in Sweden.

Quality Control of Nursery Stock. The mainpoints of The Total Quality Control of Nursery Stock are:

1. The rules comprise all woody nursery stock, except forest trees (for lumber production). Also strawberry plants are included in the control.

2. The plants must comply with certain *minimum requirements* in regard to quality, health, and labelling.

The requirements for healthy plants states that they must be free from serious pests and diseases like Dutch elm disease, fireblight, and other bacterial diseases, as well as virus. On the other hand, stock with minor attacks of less harmful pests and diseases like mildew, scab, aphids, etc. might be accepted after controlling measures are taken.

The requirements of labelling plants are mainly connected with retail sales and states that every plant (or bundle) should be marked with Latin name, cultivar name, Swedish name, name of the garden center, rootstock of fruit trees, and hardiness zone. The requirement for hardiness classification is due to the great variation in climate within Sweden.

In the wholesale trade the requirement of labelling is limited to bundle-marking with Latin name, or cultivar name, and rootstock of fruit trees.

3. The authority that is carrying out the quality control is The Plant Inspection Service, which is a branch of The National Board of Agriculture. With a staff of 20 plant inspectors they are trying to control the plants in about 700 nurseries, garden centers and other retail outlets. Besides that they are controlling the imported nursery stock. The import is very big, today about 50% of the total sales in Sweden.

If plants do not meet the requirements, the plant inspectors have the authority to prohibit sale. This means that the plants might not be sold but are allowed to grow on in the nursery to reach acceptable status of quality or health. Plants in very poor condition, mainly due to serious pests or disease attacks, can be destroyed. Imported plants which do not meet the requirements are not allowed to come into the country.

Nursery Standards. I am now going to talk about quality of woody plants in respect to nursery standards. Few questions might be as controversial as those connected with quality. Professional nurserymen, however, can easily judge good plants from bad. But I guess it is a little more difficult if you ask them to write down what they mean by good quality. Our

experience in Sweden is that you might be able to describe in words maybe 70% of the quality criterium for a group of plants, like roses, but the remaining 30% is your own personal judgment based on plant knowledge. This is due to the fact that you are dealing with a biological material with genetic variation.

If you are regarding the quality conception you can easily find two mainpoints, viz external and internal quality of a plant. The external or anatomical quality describes things like height, width/diameter, number of canes/branches, caliper, branching height, habit, and root system. The internal or physiological quality of a plant describes things like vitality and genotype.

When you are dealing with quality control you must keep both the anatomical and the physiological quality in mind. But when you are going to write rules for nursery standard you must, for practical purposes, mainly work with anatomical criteria which are easy to measure. The Swedish Nursery Standards are, for this reason, mainly a question of certain minimum sizes and number of canes or branches. This, in spite of the fact that a small plant physiologically could be of the same good quality as a bigger plant.

The Swedish Standards consist partly of General requirements for all groups of plants and partly of specific requirements for different groups of plants.

A. General requirements. These are:

— the plants should have a normal development according to species or cultivar.
— the plants should be in good physiological condition.
— etiolated shoots must not be more than 1 cm.
— the root system should be well-developed.
— plants grown in glasshouse should be hardened off.
— plants should be free from perennial weeds.
— bareroot plants should have mature shoots, without shoot or root development; species with an early vegetation might have new shoots to a length of 5 cm.
— packed plants should have their roots in a moist growing medium; shoot development is allowed to a length of 5 cm.
— container grown plants should have the growing medium interwoven with roots and transplanted every second year.

— plants with rootball should have a natural rootball; the size of the ball should match the rest of the plant, transplanting or root cutting at least every third year.

Specific requirements. The specific requirements below cover the following groups of plants: roses, ornamental trees, ornamental shrubs, vines, hedgeplants, conifers, fruit trees and small fruits:

1. **Roses**

Type 1, Grandiflora, floribunda, polyantha, climbing and bush roses:

The plants should have at least 3 strong canes with a length of 25 cm. Two of the canes should come from the bud union and the third not higher than 5 cm above the bud union (with some exceptions). Bare rooted roses must not be older than one year from budding and container-grown 2 years. Container size, min 2 liter.

Type 2, Tree roses:

The plants should have at least 3 strong canes from the bud unions with a length of 20 cm. The stem should be at least 60 cm. Container size, min 3.5 liter.

2. **Ornamental trees:**

Trees are divided into three main types: standard trees (with a crown and an unbranched stem), branched trees and clumps.

Type 1, Standard trees should have a well-developed crown consisting of at least 3 strong, well-directed side-branches and a leader. Branching height should be at least 80 cm and the caliper min 1.3 cm (4 cm, circumference) measured half way up the stem. Street trees should have a branching height of 180 cm and a caliper of 1.9 cm (6 cm circ) measured 100 cm up from the ground. Examples: *Acer, Aesculus, Malus, Prunus, Sorbus, Syringa, Tilia.*

Type 2, Branched trees have a natural form with developed side branches which start close to the ground. Minimum height is 100 cm and the branching must start higher than 50 cm up. Examples: *Betula, Carpinus, Fagus, Magnolia, Salix.*

Type 3, Clumps are trees with at least two main stems starting from the ground or max 40 cm up. Examples: *Acer, Betula, Prunus.*

3. **Ornamental shrubs**

This group includes both deciduous shrubs and broadleaved evergreens. It covers a large number of plants and is of this reason divided into 6 subgroups or main types, depending on habit of growth.

The specific requirement for all shrubs are that they should have at least 3 strong canes emerging from the rootneck or maximum 10 cm above. Exceptions are *Aralia* and *Pyracantha* which are accepted with only one cane, and *Hamamelis, Magnolia,* and *Rhus,* which are accepted with only two canes.

The requirement of length of the canes for different shrubs varies from 15 cm to 60 cm depending on habit of growth and type.

Plants in the first three subgroups or types are allowed to be sold bare root. Plants in the following subgroups should be sold either container-grown or with a rootball. The requirement of container size varies from 1.5 to 3.5 l, depending on group.

Type 1, Shrubs: Strong growing; may be sold bare root; canes should have a length of at least 60 cm. Examples: *Acer campestre, Amelanchier*

canadensis, *Syringa vulgaris*. Container-grown shrubs: container sizes 3.5 l; canes min 50 cm.

Type 2, Shrubs: Medium growing; may be sold bare root, canes should have a length of at least 40 cm. Examples: *Berberis thunbergii*, *Cornus alba* 'Argenteo-marginata' (Syn.: 'Elegantissima'), *Hydrangea paniculata* 'Grandiflora'. Container-grown shrubs: container size 3.5 l, canes min 30 cm.

Type 3, Shrubs, Dwarf and Semi-Dwarf; may be sold bare root, canes should have a length of at least 25 cm. Examples: *Deutzia gracilis*, *Potentilla fruticosa*. 'Tangerine', *Spiraea bumalda* 'Anthony Waterer'. Container-grown shrubs: container size min 2 l, canes min 20 cm.

Type 4, Shrubs: Medium growing; may only be sold container-grown or with rootball; canes should have a length of 40 cm. Container size min 3.5 l. Examples: *Buddleia* spp., *Cytisus* × *praecox*, *Rhododendron* spp. (30 cm).

Type 5, Shrubs: Semidwarf; may only be sold container-grown or with rootball; canes should have a length of 25 cm. Container size min 2 l. Examples. *Cotoneaster* 'Skogholm', *Lonicera nitida*, *Pyracantha* spp.

Type 6, Shrubs: Dwarf; may only be sold container-grown or with rootball; canes should have a length of 15 cm. Container size min 1.5 l. Examples: *Berberis candidula*, *Cotoneaster adpressus*, *Cytisus decumbens*.

4. **Vines**

Vines may only be sold container-grown or with rootball. Exceptions are *Aristolochia*, *Parthenocissus*, and *Wisteria*, which can be sold bare-root. Container size 1.5 l. The shoots or runners may be cut back to 20 cm.

Type 1 Clematis hybrids should have 1 shoot or runner.

Type 2 All other vines should have 2 shoots or runners.

5. **Hedge plants**

Hedge plants are divided into 3 types, depending on habit of growth. Age and transplanting should be stated. They should also be marked "Hedge plants".

Type 1 The plants should have one cane with a length of 30 cm. Examples: *Alnus* spp.: 1/1, *Fagus sylvatica* spp: 1/1, *Populus* spp.: 0/1.

Type 2 The plants should have a length of 30 cm and have side shoots from the rootneck or maximum 10 cm above. Examples: *Berberis* spp.: 1/2, *Cotoneaster* spp.: 1/1, *Ribes alpinum*: 0/1/2.

Type 3 The plants should have a length of 20 cm with side shoots from the rootneck. Examples: *Buxus sempervirens*: 0/1/2, *Rosa nitida*: 0/1/2, *Taxus*: 2/2.

6. **Conifers**

Conifers are a very large group of plants and are of this reason divided into 5 main types depending on habit of growth. They may only be sold container-grown or with rootball. Container size: min 3.5 1 for strong growing conifers, min 2 1 for semi-dwarf or dwarf conifers. The size of conifers is measured as average height and average spread.

Type 1. Upright, strong growing types; height: min 40 cm. Examples: *Abies concolor*, *Chamaecyparis lawsoniana* 'Alumni', *Taxus* × *media* 'Hicksii'.

Type 2. Upright, semidwarf to dwarf types; height differs from 15-30 cm. Examples: *Abies koreana* (25 cm), *Juniperus chinensis* 'Blaauw' (20 cm), *Picea omorika* 'Nana' (15 cm).

Type 3. Spreading, strong growing types; spread/height: min 25 cm, general requirement: at least 3 well-directed branches. Examples: *Juniperus chinensis* 'Pfitzerana', *J. horizontalis* 'Douglasii', *Taxus* 'Densiformis'.

Type 4. Spreading, dwarf types; spread/height: min 15 cm. Examples: *Juniperus* 'Blue Star', *Picea abies* 'Nidiformis'.

Type 5. Pinus mugo; *Pinus mugo*, with cultivars, should be evenly grown with 4 well-directed shoots or, alternatively, a leader and 3 shoots. Spread/height 20 to 25 cm, depending on cultivar.

7. **Fruit trees**

Fruit trees are generally sold as standard trees which should be 2 years old. The stem should be straight with a branching height in the interval of 40 to 100 cm. The caliper measured half way up should be 1.3 cm. The crown should be well-shaped with at least 3 well-directed side branches and a leader. (Sour cherries: 4 side branches without leader.) The length of branches and leader should be 40 cm. Apple trees should be raised on vegetatively propagated rootstocks. If container-grown the container size should be 10 liter.

Espalier and cordon trees have special standards.

8. **Small fruits**

8.1 *Black and red currents and gooseberries.* The shrubs should have at least 3 strong canes and not be older than 3 years. The length of the canes should be: 45 cm for black currant, 35 cm for red currant, and 30 cm for gooseberries. If container-grown the container size should be 3.5 liter.

8.2 *Raspberries.* Raspberries must not be older than one year. The diameter of the cane, 5 cm above the rootneck, should be 8 mm. Length of the cane should be 40 cm.

8.3 *Blackberries.* Blackberries should be container-grown. The plants should have at least 1 cane with a length of 40 cm. Container size 1.5 liters.

This has been a summary of The Swedish Standards for Nursery Stock. How do all these new rules work in practice? After a period of three years I dare to say very well. One reason for this was the close and good contacts with the nursery industry during the work with the New Standards and the Quality Control. Of course, there have been some initial problems but today most of them are solved.

Even if the goal has been to create a consumers' protection the nursery industry has also had benefit of the new system. This because the new rules have turned into a standardisation and a reconstruction of the trade with nursery stock.

E. BATE: What happens to those nurserymen who do not comply with the standards?

L. RUDIN: If the plants do not meet the standard required on inspection they may be allowed to grow on. However, if they don't comply at the second inspection they must be destroyed. If plants are moved from the nursery the owner is fined.

B. LOCKWOOD: Who initiated the idea of statutory control?

L. RUDIN: The nursery industry made the request in an effort to overcome the competition from imports, which at that time made up 50% of total sales. There was collaboration

between the authorities and the industry and, as an extension officer, I wrote the first draft. For the scheme to work in practice rules must be practical for the producer and the consumer, and it is necessary to find a compromise.

D. GILBERT: How is the nursery inspection carried out?

L. RUDIN: It is illegal to sell plants that are insufficiently developed, so if plants are too small they are allowed to stay. It is up to the nursery to grade properly as there is a quality control at trade outlets. I have not discussed health inspection; this is only carried out at the nursery.

J. GAGGINI: Who pays for the inspectorate, as twenty inspectors cost a lot of money. Is it on a levy basis?

L. RUDIN: It is a combination of government and nurseries. Nurseries pay a levy according to size. The inspectors are on a part-time basis and would equate to ten full time.

W. MATTHEWS: Do we need plant standards? Should we let market forces decide standards? In the long term will standards remain the same, and will the multiple retailers stipulate quality standards in the future?

B. LOCKWOOD: Certainly the present standards have changed since the bad winter.

B. HUMPHREY: I agree market forces will determine grades, but a huge volume of sales are still on tenders which demand standards.

W. WATKINS: Is there a standard price for the product in Sweden?

L. RUDIN: No, there is no government interference in pricing.

R. EVISON: Are there standards for liners traded between nurseries?

L. RUDIN: Only a general requirement; there are no specific specifications for liners.

K. HAMILTON: How significant is the nursery industry in Sweden for the government to take an interest?

L. RUDIN: The primary value of nursery stock is less than that of food crops. A result of the regulations is that now there are no cheap imports of poor quality stock coming in from Holland through mail order. There are 1200 hectares of nursery stock in Sweden, with a value of £10 million.

P. WOOD: Are inspectors selected from bureaucratic or practical sources?

L. RUDIN: They need a practical background for the job.

PROPAGATION OF ELAEAGNUS BY CUTTINGS

JEREMY C. BEESLEY

John Hill and Sons, Spot Acre Nurseries
Stone, Staffordshire

The advantages of propagating *Elaeagnus* from cuttings are that it is cheap, there is no problem of suckering, and good growth can be achieved. Strong cuttings are taken between October and December from the current year's growth. Terminal cuttings root better than the thicker basal cuttings although the basal cuttings, when rooted, produce more vigorous plants. The cuttings are made about 12 cm long, wounded at the base, and treated with 4% IBA in talc mixed with an equal quantity of Captan. Ten cuttings are placed around the edge of a 5″ clay pot filled with a mixture of five parts 2 to 3 mm grit to one part fine moss peat. The pots are plunged in moist peat on benches heated by electric cables; these are controlled by electronic thermostats using semi-conductor sensors. These sensors are placed in the rooting medium, level with the base of the cuttings, and the temperature is set for 65°F.

The cuttings are covered with 150 gauge clear polythene which is removed once a week and left off overnight to be replaced the next morning after a light watering. Rooting takes about 12 to 16 weeks depending on cultivar. The heating is turned off and the cuttings left *in situ* until they are potted in early spring. By this time a fibrous root system has developed and these are trimmed before potting into 3-inch peat pots. Our standard compost is used which consists of 45% peat, 45% pulverised bark, 10% grit, 5¼ lb per cu yd 18:11:10 Osmocote, ¾ lb per cu yd superphosphate, 12 oz per cu yd F.T.253, 1 lb per cu yd ferrous sulfate, calcium and magnesium limestone, and Aldrin. Dimilin is added to control sciarid fly.

The plants are kept moist in a polythene tunnel until established; if possible slight bottom heat is helpful. Once new growth takes place, regular pinching at an early stage ensures a bushy plant. Further potting into two litre pots and grown under polythene, *Elaeagnus* × *ebbingei* makes 30 to 45 cm in height. *Elaeagnus pungens* 'Maculata' grown on for another year makes saleable plants the following autumn.

With this method of propagation approximately 90% take is achieved. Previously, when cuttings have been placed in plastic seed trays, very poor rooting occured. Better drainage and aeration together with a greater depth of rooting medium would explain the success rate in pots. One species we still find difficult to root is *Elaeagnus macrophylla*.

R. THURLOW: Have you tried rooting *E.* 'Limelight', and how successful were you?

J. BEESLEY: We had good results when rooting cuttings taken from some bought in plants in October, but were unsuccessful with cuttings taken from another source.

B. LOCKWOOD: Do you wound cuttings?

J. BEESLEY: Yes.

P. WOOD: Have you tried rooting cuttings taken in January or February? We tried this and had results similar to October cuttings, but the advantage is they occupy the bench space for a shorter time.

J. BEESLEY: No, we haven't tried that late.

B. HUMPHREY: The Clonal Selection Committee would welcome additional clones of *E.p.* 'Maculata' for testing if anyone has a good one.

PROPAGATION IN DENMARK OF SOUR CHERRIES BY CUTTINGS

OLE NYMARK LARSEN

Institute of Landscaping Plants
Hornum, DK-9600 Aars, Denmark

There is, in Denmark, a long tradition for the growing of sour cherries and this has expanded rapidly in the last few years.

Sour cherry is now, after apple, the most grown tree fruit in Denmark. Sour cherries requires relatively little regular care and are often grown by farmers. The rapid expansion is in part due to a high demand for juice by the processing industry and in part, to the development of machine harvesting.

Sour cherries belong to the species, *Prunus cerasus L.*, and all cultivars which are grown in Denmark are self fertile. By far, the most planted cultivar is 'Stevnsbaer' which has been grown in Denmark for at least 200 years. It is preferred by the processing industry because the fruit is strongly coloured and has a high content of sugar and of acid.

The well-known Danish rose breeder, D.T. Poulsen, has bred two cultivars 'Kelleriis 14' and 'Kelleriis 16'. These are little grown in Denmark but 'Kelleriis 16' is quite frequently planted in Germany.

As machine harvesting requires relatively more space, the normal planting distance is 5×3 metres, which gives about 670 trees per ha.

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As machine harvesting requires relatively more space, the normal planting distance is 5×3 metres, which gives about 670 trees per ha.

The rootstocks are either seedlings of *Prunus avium* or the *P. avium* clone, F 12/1. As the trees are machine harvested there is, however, little need to control the size of the tree through the rootstock.

There seems to be a big difference in the yield of different trees and, in the last couple of years, a selection programme has been carried out, and there are now several high yielding clones available. At the same time some growers have selected their own high yielding clones.

Some 10 to 12 years ago a few trees which were propagated by cuttings were planted in an orchard alongside a row of trees which were grafted on the rootstock, F 12/1. The growth and yield of these own-rooted trees has been very satisfying and inspired the experiments about which I am now going to report.

EXPERIMENTS AT HORNUM

At the Institute of Landscaping Plants at Hornum there has for several years been work with the propagation of sour cherries by cuttings.

The initial experiments were designed to investigate the rooting potential of 'Stevnsbaer'. They were also designed to investigate the need for a rooting hormone treatment.

The cuttings were harvested from stock plants grown in 10 litre containers in a glasshouse. The cuttings were terminal cuttings about 10 cm long.

Some of the cuttings were treated with different concentrations of IBA by the concentrated dip method.

The cuttings were rooted in 3.8 cm stonewool blocks in which the temperature, by bottom heat, was kept at a minimum of 21°C. The cuttings were kept moist by a misting system controlled by an electronic leaf.

After two weeks the cuttings were assessed weekly for root development. A cutting was recorded as having rooted when at least one root had penetrated the bottom or sides of the stonewool block.

One experiment was started in April and another in May. In the experiments several concentrations of IBA were used but in Table 1, only the results for 1000 ppm IBA is given as this concentration was superior to both lower and higher concentrations.

As shown in Table 1 the rooting was accelerated by the IBA treatment. After two weeks there were more rooted cuttings among the IBA-treated than among the untreated control. After 3 weeks, however, the difference was small, and after 4

Table 1. 'Stevnsbaer' sour cherry. Percent of cuttings rooted after 2, 3, and 4 weeks. Mean of two experiments.

	Weeks		
	2	3	4
Control	40.0	95.0	98.4
1000 ppm IBA	66.7	100.0	100.0

weeks there was little difference. From Table 1 it can be concluded that a hormone treatment is unnecessary and that glasshouse grown cuttings will root in 4 weeks.

To assess the growing-on of the cuttings, 30 cuttings were placed in 1 litre stonewool blocks and grown in a glasshouse all summer. In October the height of these plants was about 150 cm.

It is well known that cuttings harvested from stock plants forced in a glasshouse root faster and better than cuttings harvested from stock plants grown in the open. Table 2 shows the percent rooting of cuttings harvested from fruit bearing trees.

The cuttings of 'Kelleriis 14' and 'Kelleriis 16' were inserted in the stonewool blocks June 28 while the 'Stevnsbaer' clone 24 (a clone selected for its high yield) was inserted in the stonewool blocks July 26. The rooting procedure was as mentioned earlier. The number of rooted cuttings were recorded August 30 and the results are seen in Table 2. It must be noted that 'Kelleriis 14' and 'Kelleriis 16' are much slower rooters than 'Stevnsbaer'.

Table 2. Three cultivars of sour cherries. Percent rooted; recorded August 30.

'Kelleriis 14', inserted June 28	60.0%
'Kelleriis 16', inserted June 28	73.0
'Stevnsbaer' (clone 24), inserted July 26	70.8

After recording, the cuttings were potted in 10 cm pots and overwintered in a frost-free glasshouse. In the spring the plants were repotted in 1 litre pots and grown on an outdoor container bed during the summer. Table 3 records the height of the plants at the end of the growing season.

Table 3. Sour cherries. Rooted mid-summer 1978. Mean height, fall 1979.

'Kelleriis 14'	72 cm
'Kelleriis 16'	89
'Stevnsbaer' (clone 24)	134

The most commonly used method in Denmark for propagating easily rooted cuttings is a 1 metre wide tunnel covered with milk-white polythene. The tunnel is equipped with a mist line which is normally operated 2 to 3 times a day, either automatically or, more often, manually. This method was in-

vestigated for rooting 'Stevnsbaer' cuttings.

In early July cuttings were harvested from mother stock grown in the open on a container bed. The cuttings were not treated with rooting hormones. For the first 6 weeks the mist line was operated daily.

It was obvious that the cuttings rooted more slowly than in the glasshouse. However, when the cuttings were lifted in November, 95 percent had rooted. This is quite satisfying and the method can be said to be quite suited for 'Stevnsbaer' sour cherry.

From these experiments the conclusion can be drawn that 'Stevnsbaer' cherry is easily rooted and that several methods are available for propagating it by cuttings.

COMMERCIAL PROPAGATION

The nursery industry has, so far, shown very little interest in propagating 'Stevnsbaer' sour cherry by cuttings and, in fact, hardly propagates it at all.

The cherry growers themselves have, however, shown a keen interest, and we have had many inquiries from growers who wanted advice.

That the growers shows such keen interest may, in part, be due to the fact that many of them are farmers, and have no traditional feelings concerning the merits of rootstocks. Also, the rapid expansion in the area planted with 'Stevnsbaer' has created a heavy demand for trees, and this has encouraged the growers to do their own propagation.

Most growers have been experimenting with one or two thousand cuttings but only one grower has propagated on a really commercial scale. Because of lack of equipment and experience some growers have experienced failures of one kind or the other.

Also the weather conditions have been most unfavourable and, in the spring of 1981, caused heavy losses among cuttings which had been propagated in polythene covered low tunnels and had been overwintered in the tunnels. 'Stevnsbaer' is an earlier leafer and, as the temperature on April 22 very quickly dropped from a plus temperature to minus 7°C, many cuttings were killed.

The above mentioned grower, who works on a commercial scale, was hard hit by this frost. With cuttings propagated in 1979 the same grower had a much more satisfying result and he has in 1981 sold two-year-old trees to several other growers.

For instance, one grower in the fall of 1981 planted 6000

trees, that is enough for about 10 ha. These trees are now well established.

A glasshouse grower rooted cuttings in 9 cm pots in August 1980. The cuttings were overwintered in a glasshouse and, in the spring, repotted into 16 cm pots. The plants were, during the summer of 1981, grown on a container bed in the open and overwintered on this container bed. In the spring of 1982 the plants were planted. About 75 per cent of the original cuttings were planted. I think the grower would have done even better if he had started rooting the cuttings a month earlier, that is about July 1.

To sum up, experimental as well as commercial experience shows that the 'Stevnsbaer' sour cherry can be propagated by cuttings. It is also known that 'own-rooted' trees can yield well. The propagation methods may need some adjustments so that they are more suited to the growers' equipment and experience. We are at present working on these problems at Hornum.

ESTABLISHMENT IN CONTAINERS OF WOODY ORNAMENTALS PROPAGATED FROM DORMANT LEAFLESS CUTTINGS

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Abstract. Data are presented on the rooting of February-taken, dormant, leafless cuttings in heated bins and on their subsequent establishment in containers.

Both rooting in the bin and survival at the end of the season were highly correlated with the degree-weeks of temperature which the cuttings had experienced in the bins.

The survival of *Acer saccharinum* cuttings markedly decreased with increase in the number of degree-weeks. This response was not as marked for *Laburnum* × *vossii* and *Platanus* × *acerifolia*, suggesting that *Acer* cuttings rapidly become depleted of their carbohydrate reserves.

Survival of *A. saccharinum* cuttings in containers was markedly increased by placing them under mist enclosed by polyethylene in a netting tunnel.

Difficult-to-root species such as *Acer platanoides* 'Drummondii' and *Prunus* 'Shirofugen' responded poorly even when mist was used to assist cutting survival.

REVIEW OF LITERATURE

The propagation of woody ornamentals from dormant, leafless (hardwood) cuttings is a traditional technique for easily rooting genera in cold frames or the open ground (see Sheat,

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REVIEW OF LITERATURE

The propagation of woody ornamentals from dormant, leafless (hardwood) cuttings is a traditional technique for easily rooting genera in cold frames or the open ground (see Sheat,

19). The rooting of more difficult species and cultivars, some of which are traditionally grafted, in heated compost in insulated bins, has been attempted by a number of workers and recently reviewed (24). The technique was developed for fruit rootstock production by Garner and Hatcher (8,9,10) following observations that cuttings lined out in the field rooted well when soil temperatures were high. Initially they constructed bins of straw bales with thatched covers, where the rooting compost was heated by soil warming cables to a temperature of about 7°C. Subsequently a higher temperature (21°C) for a shorter period was found to be advantageous, Howard and Garner, (14).

Howard then went on to investigate the factors contributing to the success of the technique such as management of stock plants, type of cutting, time of taking cuttings, hormone concentrations, rooting temperatures and storage requirements of cuttings (11,12,15).

A major modification was the raising of the rooting-medium temperature (14). This allowed a greater throughput of cuttings but subsequently presented problems associated with planting and establishment in the field. Two major rooting periods were clearly identified, i.e. October-November and February-March (16). Optimum treatments and times for the successful rooting of a wide range of fruit rootstocks have subsequently been listed (13).

Cuttings of many woody ornamentals, for example *Ribes*, *Forsythia*, *Salix*, root readily when inserted in open ground in the autumn. It was assumed that genera more difficult to root would respond to the heated-bin technique as used for fruit rootstocks (17,18,20). This proved not to be the case and it became evident that for ornamentals more accurate control of rooting medium temperature, irrigation of cuttings in the bin, and lower hormone concentrations were required (21,22,23).

Furthermore, ornamentals are in general more difficult to manage (1) — not surprisingly as fruit rootstocks have been bred and then clonally selected over long periods of time. Fruit rootstocks often contain preformed root primordia; indeed, preformed roots occur on the stems of stock plants of some genera. *Malus* rootstocks appear to tolerate a wider range of conditions during rooting when propagated alongside ornamental species (21).

A problem with field production of fruit rootstocks has been carbohydrate depletion (13). This may well contribute to some of the poor establishment observed with field-planted ornamentals (21). One method of alleviating the problem has been the use of a shorter rooting period, even as little as two

weeks. Plants so rooted usually have fewer roots. This is beneficial as the majority of the roots will be produced into the medium in which the cuttings will grow undisturbed for the first season.

As ornamentals appear more sensitive to desiccation and carbohydrate depletion than fruit crops, they should benefit from being grown in an environment which can be more easily regulated than a field one. As a large number of species are now grown in containers it seemed appropriate to grow rooted dormant, leafless cuttings in such a system. Initially plants were grown in a sheltered situation only (25) and subsequently under protected environments in a netting tunnel structure. The experiments reported were done over four years. The objectives were twofold: to investigate the physiology of the rooting of dormant, leafless, woody cuttings and to attempt to develop a commercially useful technique.

MATERIALS AND METHODS

Propagation procedures. Cuttings of the species listed in Table 1 were taken from the basal 30 cm of branches, after Garner and Hatcher (8) of hedge-pruned stock plants (six years old in 1979) in February of each year. The bases of cuttings were trimmed and dipped for 15 sec 10 mm deep in 1500 ppm 4-(3-indoyl)butyric acid (IBA) in 50% ethanol. Fifty cuttings per treatment were generally used, although this number did range from 40 to 90 cuttings per treatment for some experiments.

Bundles of cuttings were then inserted 15 cm deep in a rooting compost of equal parts of Irish moss peat and Chichester grit (maximum particle size 5 mm). The bases of cuttings were then 9 cm above the heating cables. The temperature of the rooting medium was measured by four semiconductor diode junctions (Nobel Engineering Ltd) per m^2 of bin area and controlled electronically (26). The temperatures achieved were independently monitored by a Honeywell Versaprint 12-point recorder using platinum resistance sensors in 1979 and 1980, and by a 20-channel Grant recorder using type C thermistor probes in 1981 and 1982.

Experimental designs. Four bin temperatures (5°, 10°, 15° and 20°C) were factorially combined with three lifting times (2, 4 and 6 weeks). The combinations differed from one year to the next according to the nature of the experiments, which are listed in Table 1. The cuttings were tied and inserted into the rooting medium in bundles of five. The treatments were randomly allocated to plots within each bin and, on each lifting date, two adjacent bundles of cuttings were lifted and scored.

Table 1. Rooting temperatures, growing-on environments, and species used in the experiments.

Year	Rooting temperature	Object of experiment	Growing-on regime	Species and cultivars used
1979	5°, 10°, 15°, 20° C	Comparison of rooting temperatures and lengths of times in the bins	Outside, but sheltered on 3 sides by glasshouse structures	*Acer saccharinum* *Laburnum* × *vossii*
1980	5°, 10°, 15°, 20° C	Detailed investigations into water and carbohydrate relationship of cuttings	same as above	*Acer saccharinum* *Laburnum* × *vossii* *Prunus subhirtella* 'Autumnalis' *P.* 'Shirofugen' *Acer platanoides* 'Crimson King'
1981	20° C	Plant survival as affected by duration of time in the bins and subsequent growing regime	"Nicofence 31", 40% shade tunnel. With mist and shaded polyethylene (as described in text)	*A. saccharinum* *Platanus* × *acerifolia* *P. subhirtella* 'Autumnalis'
1982	20° C	Plant survival as affected by duration of time in the bins and growing regime. Rooting of more difficult genera	As above, but with additional shading over "misted" treatments	*Acer* spp. *Prunus* spp. *Betula* spp. *Sorbus* spp. *Crataegus* spp.

The cuttings were scored for root development on a 0-5 ranking basis and potted into 14 cm diameter black polyethylene containers of 3 liter capacity. The compost used in the containers was 75% Irish moss peat and 25% sand, with fertilizer additions (per m^3) of "Osmocote" slow release fertilizer (18-11-10), 750 g; single superphosphate, 750 g; magnesium limestone, 2400 g; and fritted trace elements (WM 255), 300 g.

Growing-on environments. In 1979 and 1980, containers were placed in blocks on a gravel base, in open outdoor frames, sheltered from wind by adjacent glasshouses on three sides. During 1981 and 1982 they were placed on drained subirrigated sand beds inside a tunnel structure clad with "Nicofence 31", 40% shading material, to allow for greater environmental control. Within the tunnels the cuttings were given different environments i.e. 1) control (no additional protection), 2) shaded polyethylene, 500 gauge (125 μ) polyethylene as an enclosed tent and shaded with "Rokelene" 40% shade cloth (1981 only), and 3) "mist" under a similar polyethylene structure. Except for a few days at the start of the growing on period of the experiments in April and May, with high radiation (daily integrals ca. 18-26 MJ/m^2), the mist was unshaded in 1981. During 1982, 40% shade cloths were used over the mist as the radiation was about 30% higher than in the previous year during April, May, and June. Mist control was by timeclock set to operate from about 1.5 h after sunrise to 1.5 h before sunset.

Recording and analysis of data. Measurements of temperature at the base of the cuttings showed that the values achieved were sufficiently close to the set ones to use the latter in all experiments. Examples are given in Whalley and Loach (25). Mean air temperatures 1 m above the bins gradually increased during propagation; for example, in 1979 the mean temperature for the first two weeks of February was 3.1 °C, whilst for the first two weeks of March it had reached 7.5 °C. The effects of bin temperature on temperatures experienced by the above-ground portion of the cuttings were minimal. Sensors placed in the centres of bundles of cuttings, 5 cm above the rooting medium, differed by only 1 degree C from the coolest (5 °C) to the warmest (20 °C) treatments and differed little from air temperatures 1 m above the bins.

On lifting from the bins in March, cuttings were scored for root number, degree of callus, and of any basal browning. During the growing season bud development and extension growth were recorded, together with the numbers of the cuttings which survived.

RESULTS

Results of the first year's experiments were interpreted using the product of time and temperature (degree-weeks). Similar results were obtained from combinations of low temperatures for long durations and from high temperatures for short durations; Thus, for *A. saccharinum* 4 wks at 15°C gave closely similar rooting to 3 wks at 20°C (both 60 degree weeks).

Rooting clearly correlated with accumulated temperature expressed in degree-weeks (Figure 1). For both *Acer* and *Laburnum* 50 to 60 degree weeks were required for rooting.

Plant survival (assessed at the end of the season in November) was closely and negatively related to rooting in the bin (Figure 2). A steep decline in percentage survival was associated with increasing percentage rooting, probably indicating a rapid depletion of reserves during rooting and the importance of such reserves for subsequent growth. Different patterns of survival of *Acer* and *Laburnum* were apparent when plotted against accumulated temperature (Figure 3). *Acer* showed a steep decline in survival beyond 40 degree-weeks, but there was less evidence for a decline with *Laburnum*. Cuttings which rooted well survived poorly in *Acer*, but rather better in *Laburnum* (asterisked values, Figure 3). However, the mean survival percentages were low, being 38 for *Acer* and 32 for *Laburnum*. In the best treatments just over 50% survived in both species.

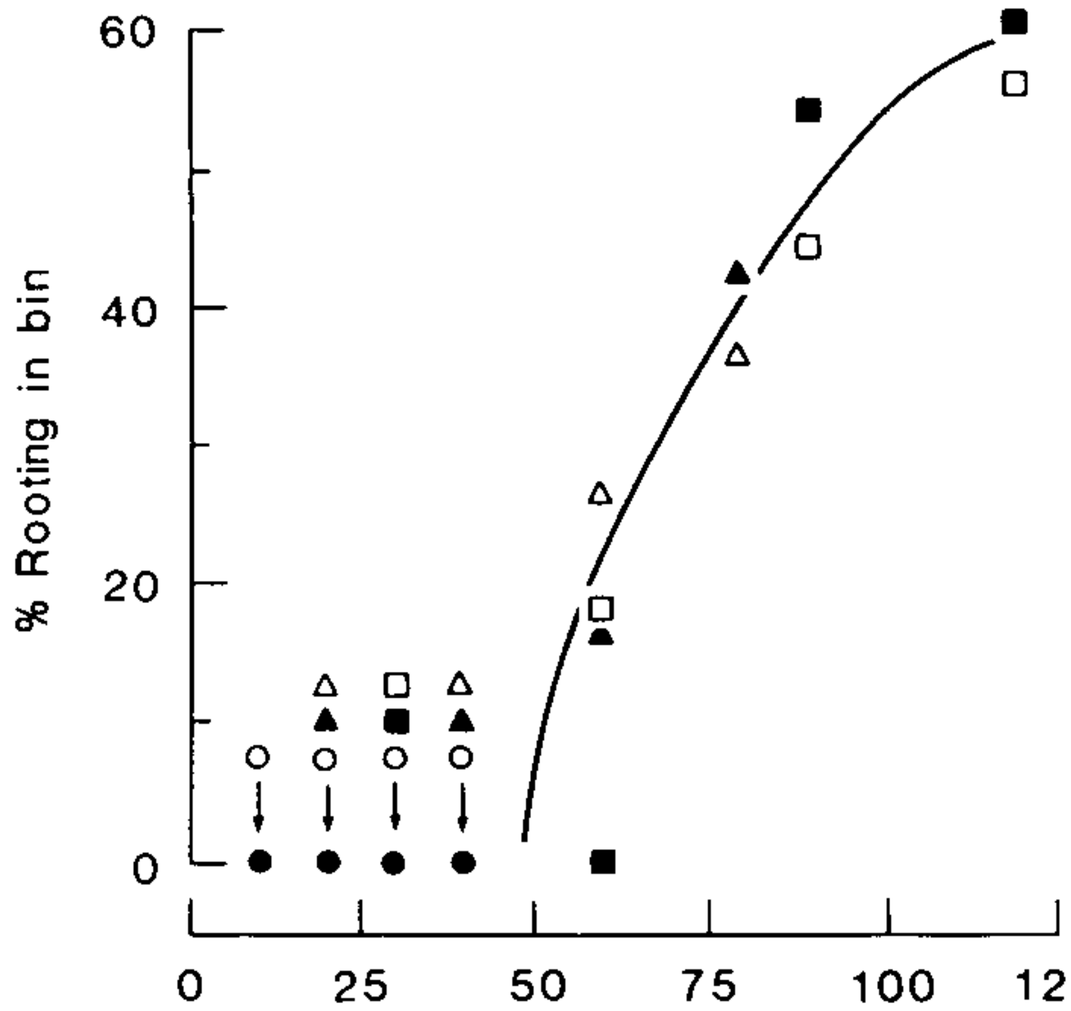

Figure 1. Relationship between percentage rooting and accumulated temperature (degree-weeks) in the bin. *Acer* shown by open and *Laburnum* by closed symbols. (O●) 2 weeks, (Δ▲) 4 weeks and (□■) 6 weeks. (No rooting occurred prior to 50 degree-weeks.)

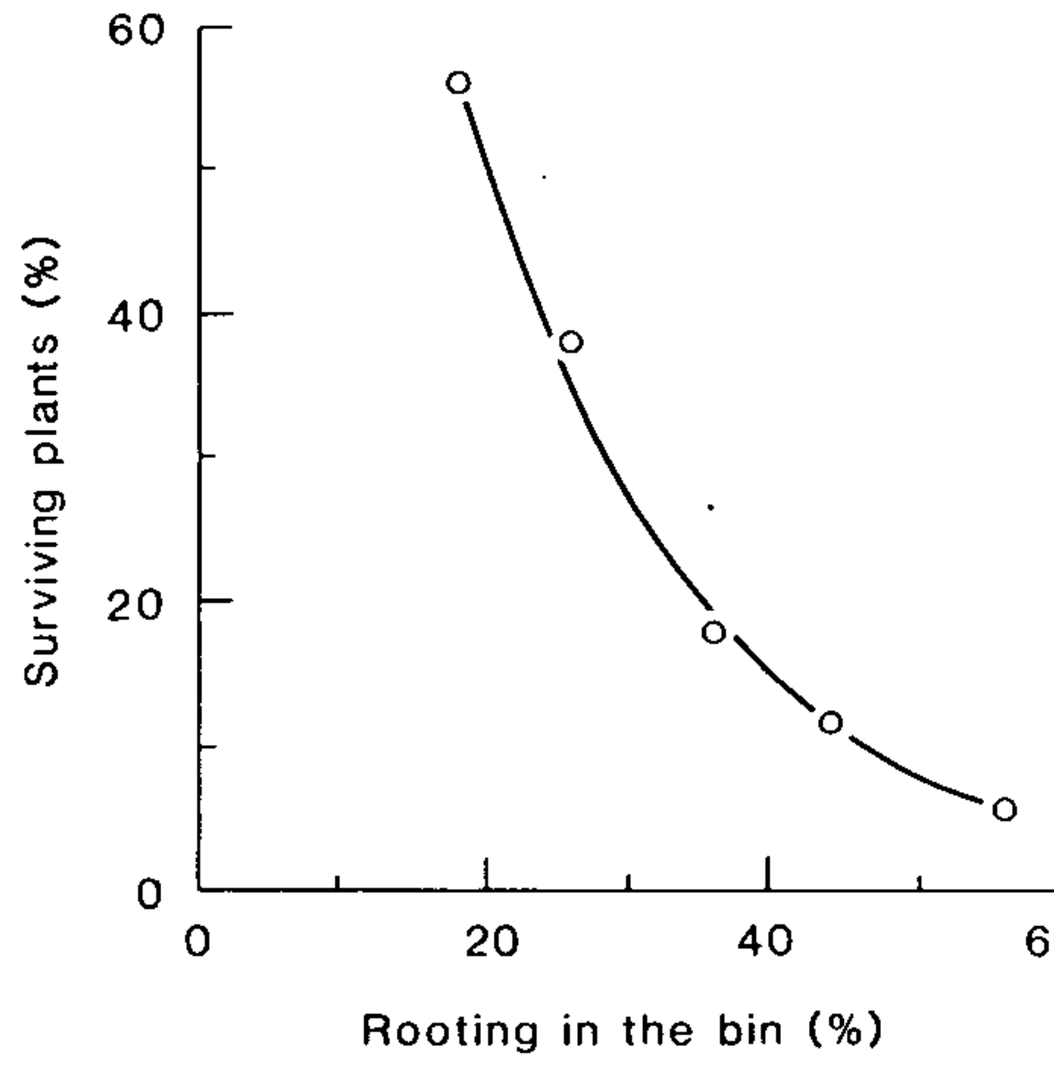

Figure 2. Survival of plants in November as a function of rooting in the bin. All data for *Acer saccharinum*.

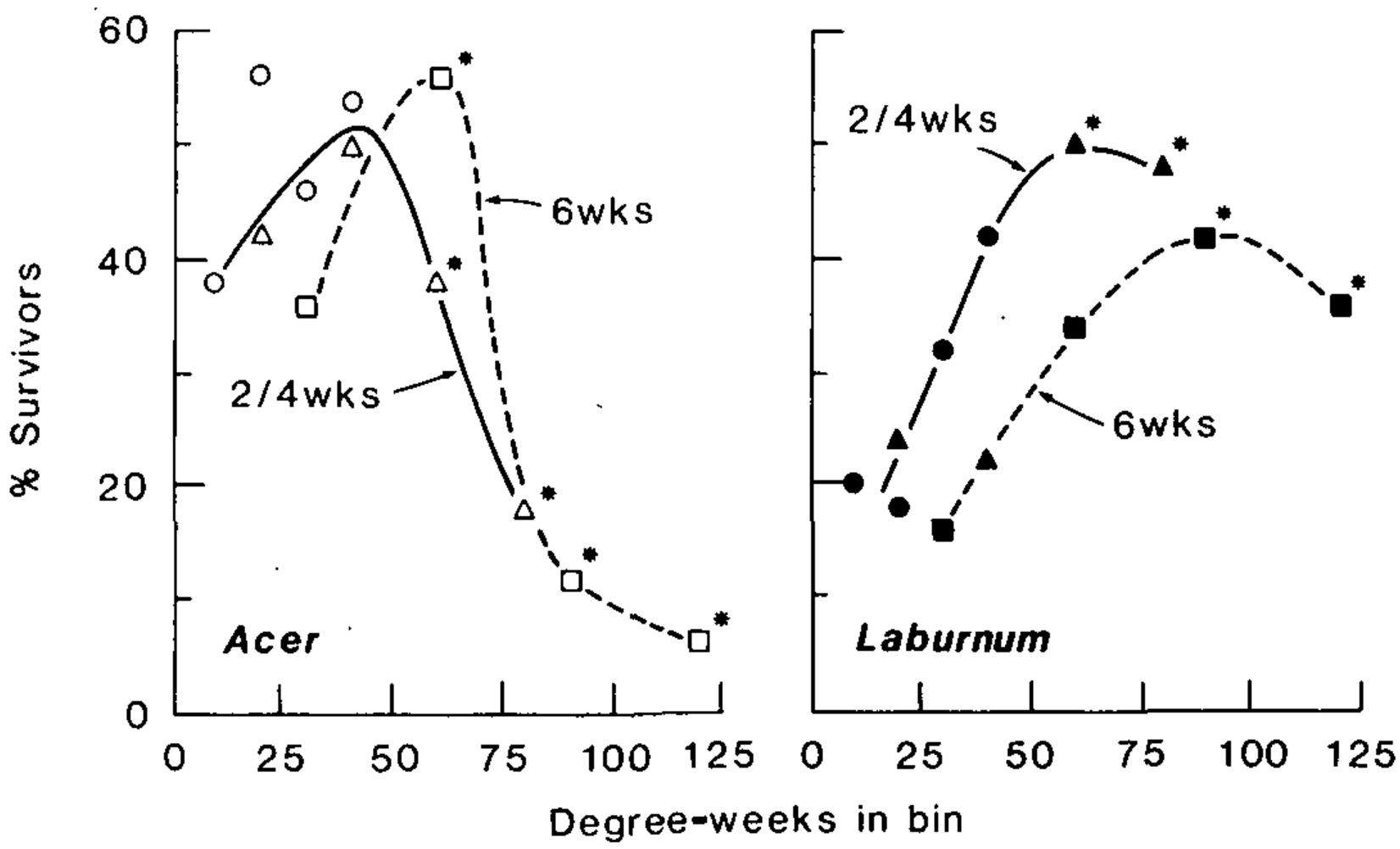

Figure 3. Relationship between percentage survival (assessed on 5 November 1979) and the number of degree-weeks the cuttings received in the bins. Symbols for *Acer* (O) 2 weeks, (Δ) 4 weeks, and (□) 6 weeks, (Left). Symbols for *Laburnum* (●) 2 weeks, (▲) 4 weeks, and (■) 6 weeks (Right). *: = treatments with rooted cuttings at potting.

There was a definite separation of the 2/4-week and the 6-week treatments (see Figure 3). Similar separations were also seen for bud development data (25).

The 1980 experiments investigated water and carbohydrate changes in greater detail and will be separately reported (Loach and Whalley, in preparation). However, some of these results are described briefly here.

To obviate the carbohydrate depletion observed in *Acer*, cuttings were supplied with sucrose in solution during and after rooting via small wells made in the top of the cutting. Surprisingly, this resulted in 100% plant mortality, possibly the result of damaging high osmotic potentials, assuming the sugar was mobilised.

Laburnum cuttings gained in fresh weight when propagated at high temperatures, mainly because of water uptake by the roots (Figure 4). Respiratory depletion at high temperatures was found to be negligible (25). The curves for rooting obtained when the data were plotted against degree-weeks were similar to those of the previous year (Figures 1-3). Overall percentage establishment figures for *Acer* and *Laburnum* were again low, being 48% and 28%, respectively. In the best treatments, 58% survived in *Acer* and 95% in *Laburnum*. However, subsequent extension growth was poor in *Laburnum*, probably as a result of the "fuzzy-top" syndrome. This disorder affected all of six clones submitted to a clonal selection scheme, (2) and its cause is unknown.

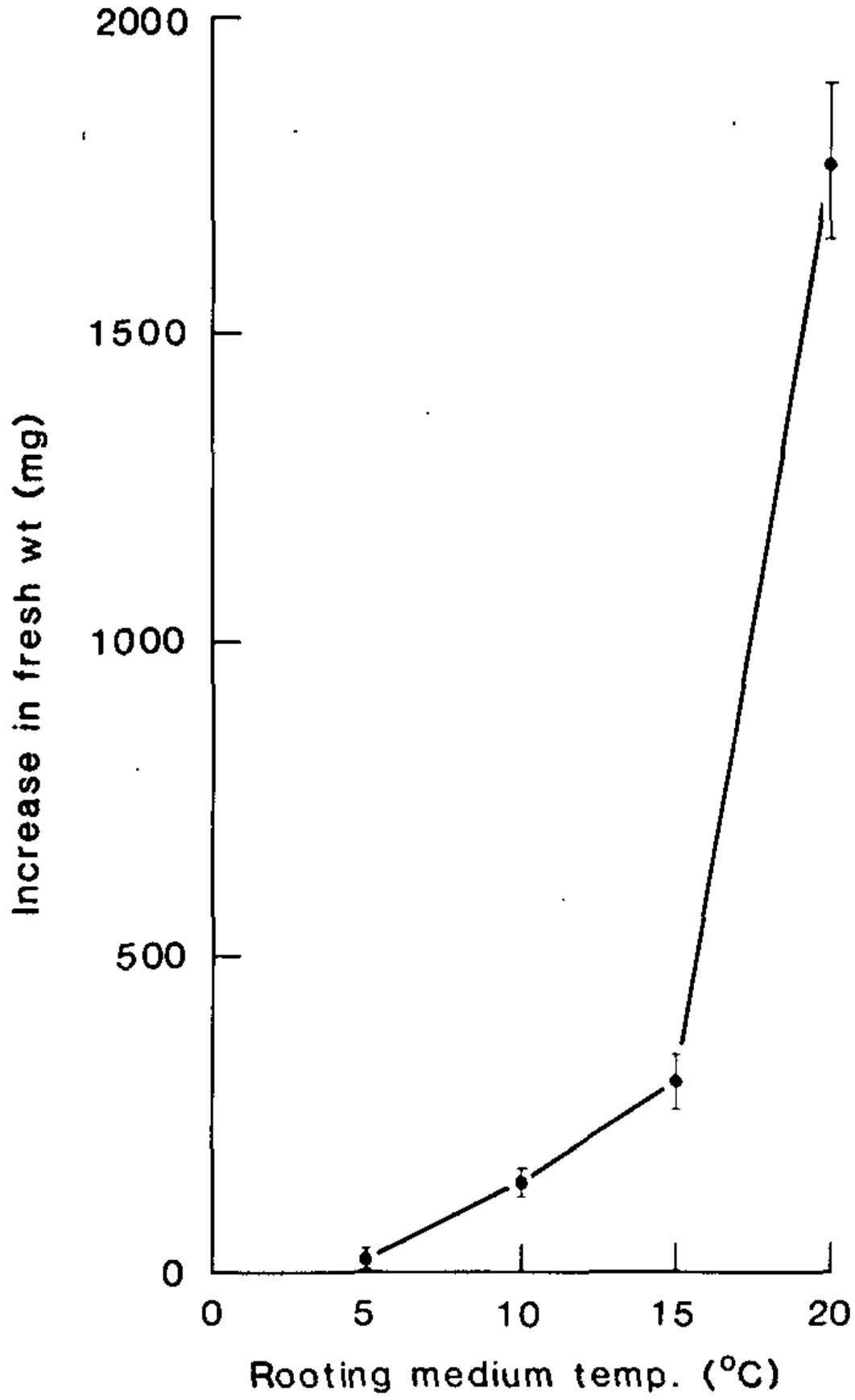

Figure 4. Change in fresh weight of *Laburnum* × *vossii* cuttings after four weeks in the rooting medium at 5°, 10°, 15°, and 20°C. Vertical bars represent standard errors of means.

The 1981 experiments concentrated on post-bin treatments designed to protect the developing foliage of cuttings with little or no root development.

Results for the three systems: Control, Shaded Polyethylene, and Mist under Polyethylene, are given for *Acer* in Table 2. This shows the superiority of the misted system and also the decline in survival with a longer duration in the rooting medium.

By contrast, plants of *Platanus* in the same experiment had a much higher percentage survival (mean 89%) although the misted system was still superior.

As providing a suitable environment for cuttings of this type by misting at an early stage appeared to be beneficial, the 1982 experiments compared more difficult-to-root species against *Acer saccharinum* as a standard. Table 3 again shows the superiority of the mist under polyethylene system for *A. saccharinum*. These data clearly illustrate that the post-rooting

Table 2. Percentage survival of *Acer saccharinum* and *Platanus* × *acerifolia* under three different systems (recorded September, 1981).

a) Overall percentage survival in the three systems

	Control	Shaded polyethylene	Mist under polyethylene
Acer	25%	27%	60%
Platanus	78	94	94

b) Percentage survival of *Acer* after different lengths of time in the bin

	Control			Shaded polyethylene			Mist under polyethylene		
Weeks in bin	2	3	4	2	3	4	2	3	4
Degree-weeks	40	60	80						
Percentage survival	45	19	11	41	30	11	76	58	45

Data based on 74 cuttings per treatment for Acer and 90 cuttings per *treatment for Platanus.*

environment is the most important factor. Of the cuttings which had not been placed in the heated bins, but had been directly inserted into the compost of the containers, 84% survived to form good plants, compared with 30% of the controls. Furthermore, of all the controls, those without bin treatment established best, a steady decline being seen with increased duration of the time in the bins.

Table 3. *Acer saccharinum* - percentage survival of good quality plants (August 1982).

Rooting period (weeks)	Holding period (weeks)	Control plants in "Nicofence" tunnel only, no additional protection	Mist under polyethylene within plastic structure in "Nicofence" tunnel
0	0	30%	84%
2	0	28	88
2	1	24	78
4	0	16	54
4	1	2	58
	Mean	20	72

Data based on 50 cuttings per treatment.

A platanoides 'Drummondii' cuttings survived poorly (overall mean 11%; highest was the mist under polyethylene treatment, 30%). Early lifting of cuttings from the bin to minimise carbohydrate depletion was effective to a limited extent for *Prunus subhirtella* 'Autumnalis'. Misting was ineffective for *P.* 'Shirofugen' (Table 4).

Leaching of nutrients from leaves was found to be a slight problem in both the years the mist was used, despite the use of supplementary liquid feeding when deficiency symptoms appeared.

Rooting of cuttings of species normally grafted was disappointing. *Betula pendula* 'Youngii', *B. pendula* 'Dalecarlica',

Sorbus cvs 'Red Tip', 'White Wax', and 'Scarlet King' all failed to root or did so to a minimal extent. *Crataegus oxycantha* 'Paul's Scarlet', and *C. oxycantha* 'Rosea' callused but failed to root as observed previously (21).

Slightly more promising results (best treatment 18%, mean of all treatments 8%) were obtained for *Acer platanoides* 'Crimson King'.

Table 4. Percentage survival of *P. subhirtella* 'Autumnalis' and *P. serrulata* 'Shirofugen' as a function of accumulated temperature in the rooting medium.

P. subhirtella 'Autumnalis' (recorded April 1980)*					
Degree weeks in bin	20	40	60	80	120
Percentage survival	13	23	53	13	0
P. subhirtella 'Autumnalis' (recorded August 1982)†					
	Control		Mist under polyethylene		
Degree weeks in bin	40	80	40	80	
Percentage survival	24	4	22	4	
P. serrulata 'Shirofugen' (recorded August 1982)†					
Degree weeks in bin	40		40		
Percentage survival	20		8		

* 40 cuttings per treatment.
† 50 cuttings per treatment.

DISCUSSION

The leafless (hardwood) cutting technique for ornamentals offers simplicity, low-cost, rapid growth rates and managerial convenience. However, problems remain both at the rooting stage and in the subsequent establishment of bin-treated cuttings in the field. Despite many refinements in bin technique, species found to be difficult to root a decade ago (21), still present problems, as evidenced by our 1982 rooting results for *Betula*, *Sorbus* and *Crataegus* supp., *Prunus* 'Shirofugen', *Acer platanoides* 'Drummondii' and our 1980 results for *A. platanoides* 'Crimson King'. Further, there are problems of inconsistency; species rooted easily in one year can root poorly in others (Table 5). Weather-induced variations in the endogenous hormone levels of the stock plant and/or uncontrolled variations in the rooting environment are presumably responsible.

Establishment problems have been attacked in several different ways, e.g. by planting cuttings in more protected conditions than the open field or nursery beds, (7), and by retaining cuttings in the bin, with the heat switched off, for some weeks after the root-inducing heat treatment (6). Cheffins (3), and Cheffins and Howard (4), demonstrated that the level of carbohydrate remaining after heated-bin treatment influenced establishment. Active buds on rooting cuttings appeared to be a

Table 5. Yearly variability in the rooting percentage of dormant, leafless cuttings.

	Year		
Subject	1972	1973	1974
Ulmus hollandica 'Commelin'	90%	92%	12%
Viburnum × *bodnantense* 'Dawn'	23	84	92

In all years, the two cultivars were rooted in the same bin controlled at 15°C, after dipping with 1500 ppm IBA; 30 cuttings of each species in 1972, 25 cuttings in 1973 and 1974.

preferential sink for carbohydrate, so Cheffins and Howard (5), recommended planting cuttings before buds became active, either by timely handling or propagating at low ambient air temperatures.

Ornamentals may well have less stored carbohydrate than the fruit rootstocks used in Cheffins and Howard's experiments, so that establishment problems could be correspondingly more severe. The clear inverse relationship between rooting percentage and percentage survival in *Acer saccharinum* (Figure 2) strongly suggests carbohydrate deficiency as a cause. Since bud growth was negligible at the end of the heated-bin treatment, the drain on carbohydrates was most likely to have been principally caused by root growth. If carbohydrate deficiency was responsible for this decline in survival, it would appear to be less of a problem for *Laburnum* and *Platanus* than for *Acer*. The green *Laburnum* stems might contribute sufficient photosynthate to affect survival but this seems unlikely for *Platanus*.

The difficulty then is to synchronise root and shoot growth so that root growth does not outstrip shoot growth, which could severely deplete the cuttings of carbohydrates; nor should shoot growth outstrip root growth as this may lead to problems of an adequate supply of water to the shoot, resulting in desiccation. The extreme situation occurs when bin-formed roots die after potting into containers. This has been observed by Whalley and Loach (25) and the roots may well have been non-functional before death. Removing cuttings from the bin after 50 degree-weeks of heat treatment brings them to the point of incipient rooting which gave best survival (Figure 3).

To ease any ill-effects caused by a sharp drop in soil temperature from the heated bin (20°C) to the netting tunnel (around 9°C), some cuttings were retained in the bin for one week after switching off the heat. This treatment proved detrimental rather than beneficial (Table 3).

Beyond this point, further protective treatments were

evolved to support the soft, new bud growth in cuttings with few roots. A simple, inexpensive mist line under a polyethylene tent proved extremely effective for *A. saccharinum* (Table 2) and *Platanus* × *acerifolia* (though untreated cuttings also gave reasonable survival in this species), and somewhat effective for *A. platanoides* 'Drummondii'. However, in the latter species, the problem of initiating roots remains paramount.

In *A. saccharinum* the bin treatment proved non-essential if the cuttings were placed in a mist/polyethylene tunnel (Table 3). For this species, root initiation is clearly less of a problem than survival, and the data for control plants, where cuttings with least bin treatment survived best, support this conclusion.

The mist/polyethylene tunnel treatment was quite ineffective for *P. subhirtella* 'Autumnalis' and was detrimental for *P.* 'Shirofugen' (Table 4). Neither rooted very strongly and it may be that conditions under the tunnel were unsatisfactory, with the high air temperatures in spring causing rapid and early bud break, suggesting a possible corresponding carbohydrate depletion at a critical time for root development.

There have been other reports from time to time of individual species rooting well, i.e. Adam (1) and Ward (20). For these, the merits of the post-bin treatments outlined in the present experiments need testing as aids to survival. The evidence suggests that such treatments could prove beneficial where survival presents the major problem and rooting is less difficult (e.g. where carbohydrate reserves are inadequate or cuttings are susceptible to desiccation).

For easier species, such as *P.* × *acerifolia*, or the slightly more difficult *Hibiscus* and *Ulmus* (22,23) and *Sorbus intermedia*, *Tilia cordata*, *T. platyphyllos*, and *Prunus padus* (1), the benefits may be less cost-effective.

Although in some seasons plants grown in the tunnels for the duration of the experiment were of good quality, there was some inconsistency with *A. saccharinum* and *P.* × *acerifolia*. A problem may well be the gauging of the correct transfer time from the shade tunnel to an unshaded, non-wind-protected environment. Earlier removal than our end-of-season practice might allow for greater stem strength and improved quality in the final plant.

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1982 IPPS ORDINARY NATIONAL DIPLOMA PRIZE

(Two students, Hilary Schonbeck and Tracy Lunn, shared the 1982 award presented by the G.B.&I. Region for the best Ordinary National Diploma in Horticulture student project. The reports of their projects follow).

IS STRIPPING OF CUTTINGS NECESSARY?

HILARY SCHONBECK

Merrist Wood Agricultural College
Worplesdon, Guildford, Surrey

This project was secondary to a main college project, and I decided to examine the need for stripping cuttings before insertion, as the topic had been questioned at last year's Conference. As it had to commence in September, of necessity I worked with evergreens, but did do some successful work with soft-woods.

I questioned the three main reasons normally given for stripping cuttings, and my findings were as follows:

(1) "The lower leaves decay and this decay spreads to the stem."

Largely this was not true. Either there was no decay (examples *Spiraea* × *bumalda* 'Goldflame', *Viburnum tinus* and *Hebe* 'Eversley Seedling') or decay did not spread (examples, *Pernettya mucronata*, *Erica herbacea* (Syn.: *carnea*), and *Elaeagnus pungens* 'Maculata'). An exception was autumn struck *Ceanothus*, where decay from decaying stems did not spread to the stem.

(2) "Cuttings are difficult to insert."

This statement is true of large, thick-leaved species such as *Rhododendron* and *Skimmia*. It even takes longer to insert unstripped cuttings of heathers, *Pernettya*, etc., but this time

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factor is more than equalled by time taken to strip the cuttings. It depends on composts; I used peat blocks which hold cuttings well, but there is possibly a problem with peat/perlite composts.

I concluded that one need not strip small leaves, but big leaves must be stripped if there is a problem of insertion.

(3) "Wounding aids rooting."

Most cuttings root quite well from the base. Others will root from nodes either when the leaves are still present, e.g. *Viburnum tinus*, or when the leaves have decayed, e.g. *Pernettya mucronata*. Maybe wounds will allow pathogens to enter and accelerate decay. I found *Elaeagnus pungens* 'Maculata' rooted better when not stripped. An exception was *Hebe rakaiensis*, which rooted mostly from leafless nodes.

My reasons for not stripping:

Time saved — it is possible to miss out an operation. Cuttings of the required length can be removed from the stock plant and dipped in a hormone and inserted. Time in the preparation shed is avoided.

Discomfort avoided — prickly species such as *Berberis* and *Pyracantha* are painful to handle, so the less handling the better. Less time is wasted examining wounds.

Better aeration around the stem — a bigger hole is made when cuttings are inserted with leaves, and the compost is propped open allowing more oxygen at the base for rooting. Examples are spring struck *Ceanothus*, heather, *Pernettya*, *Berberis*, and *Viburnum tinus*.

Conclusions. Do a pilot test before embarking on anything, because nature is so variable.

Consider the characteristics of the plant; i.e. susceptibility to decay, size of leaves, rooting habits, thorniness, ease of stripping with a knife or fingers.

STUDIES IN THE PROPAGATION OF CERTAIN DECIDUOUS ORNAMENTALS BY HARDWOOD CUTTINGS

TRACY L. LUNN
Hadlow College of Agriculture and Horticulture
Hadlow, Tonbridge, Kent

The object of my project was to compare the effects of different rooting composts and rooting hormone treatments for *Acer palmatum* 'Osakazuki', *Hibiscus syriacus* 'Woodbridge', and *Magnolia* × *soulangiana*.

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MATERIALS AND METHODS

Preparation of cuttings. The first batch of cuttings was collected in January and a second in February. All the cuttings were collected from stock plants grown in the outside border soil. The cuttings were cut into 150 mm lengths of pencil thickness and the base of the cutting cut to a node of the previous year's wood. They were divided into basal and non-basal groups and wounded by splitting the base of the cutting to a depth of approximately 2.5 cm. Hormone treatments were applied.

Because of the length of the cuttings and the small number of individual treatments, I used 125 mm 'Long Tom' plastic pots as these hold a reasonable depth of compost to support the cuttings. I inserted 10 cuttings per pot around the edge and in the centre. After insertion, pots were placed on a heated bench with a constant basal temperature of 18°C.

Compost. Peat and perlite 2:1
Perlite and grit 2:1 } by volume

Drainage of the compost is very important and the media should feel almost dry to the touch; at no time during the trial did I water the compost. The porosity of the compost materials was chosen deliberately as they are free draining; this allows for a better supply of oxygen to the base of the cutting which aids in the production of callus.

After insertion, cuttings were not watered-in as compost was prepared to the right moisture levels. The basal substrate on the heated bench was kept well watered, but there was no mist.

Hormones.

1) Indolebutyric acid (IBA) at 2500 ppm 5-second, quick-dip. The dip is to the top of the wound and then the cutting is placed on blotting paper for 15 to 30 minutes to remove excess liquid.
2) Acetone and Seradix No. 3 (0.8% IBA). To obtain maximum response from the powder preparation the cutting bases were wetted with 50% acetone and the excess shaken off before coating with powder.

RESULTS

Acer palmatum 'Osakazuki'

The trial looked to be fairly promising in the early stages after insertion, but because of over-caution on my part (not watering the media from above), the cuttings that had callused and rooted died from the dryness of the compost.

When knocking out the cuttings on the 21st April, the compost of the first batch was very dry and all the cuttings were dead. Most of the cuttings of the second batch inserted on 4 February had broken into leaf in the first week of April. All of the cuttings that had rooted later died due to lack of water. The best medium, as indicated by results, was perlite and grit, using the 50% acetone/Seradix No 3 rooting hormone.

Hibiscus syriacus

Although some cuttings had rooted in the control it was observed that the delicate balance between shoot growth and root development indicated that the majority of the unrooted cuttings may well have run out of stored food, as the shoot growth was rapid. It would, therefore, seem that the use of rooting hormones on hardwood cuttings of *Hibiscus syriacus* cvs. is very beneficial if roots are to be produced well before shoot development.

The 2500 ppm IBA five-second dip treatment was found quick and easy to use and generally produced a good rooting response in both composts. It was observed that Seradix No 3 talc formulation seemed to attract too much moisture at the base of the cuttings. It was thought that this may have been one of the contributing reasons why so many cuttings in this treatment showed basal decay.

Magnolia × *soulangiana*

The trial has shown that the rooting of *Magnolia* × *soulangiana* by hardwood cuttings is not impossible but, unexpectedly, the two cuttings which rooted were of non-basal material.

Most of the cuttings were found to be dead when they were removed for potting off. The peat and perlite compost was dry to the touch in most cases, contrasting with the perlite and grit compost which remained moist, probably because of the compatible capillary action between the compost and the basal substrate.

Conclusions. Because of the poor rooting results, it is difficult to come to any definite conclusions regarding treatments for *Magnolia* × *soulangiana* and *Acer palmatum* 'Osakazuki'. Rooting of *Hibiscus syriacus* was improved with the use of rooting hormones, regardless of compost used.

ACID TREATMENT OF SEEDS OF *CRATAEGUS MONOGYNA* AND OTHER *CRATAEGUS* SPECIES

STUART ST. JOHN

No 2 Cottage, Kirby Lodge Farm
Kirby Bellars, Melton Mowbray, Leics.

Is it worth growing hawthorn (*Crataegus monogyna*) from seed in the U.K.? Liners are always available in quantity from abroad, usually at unrealistic prices, whereas they are fairly expensive to produce here, with a necessity for regular sprays against mildew.

Points against imported plants are the chances of dried out roots, and problems developing where the liners have been raised on peat soils and have developed fine roots which do not transplant well on heavier soils. The quality is unknown until the plants arrive. There may come a time when imports are banned because of disease such as fireblight. So perhaps it is useful to know how to grow this utility plant, and a "home-grown" label may help to sell it.

From a smaller nurseryman's point of view, I have always had excellent sales of this plant, and by producing it myself can offer it at reasonable prices. For the smaller grower it is not worth buying in small numbers, and there is a self satisfaction of home-grown stock.

It is easy to produce a well-graded seedling of 45/60 cm in one year if attention is given to water, nutrients, sprays, and seed bed density. Mildew is little of a problem in the first year.

My reasons for adopting acid treatment for the seed is to reduce the pre-sowing traditional stratification period from 18 to 4 months with the acid treatment. Also there is a loss in viability with age, and imported seed could be more than one year old when it is received. In bad seed years one must rely on imports and resort to breaking down the seed coat artificially with mechanical abrasion or acid. It is advisable to collect two year's seed supply in good seed years.

By abrading the outer seed coat by 80 to 90%, a higher percentage germination is obtained, bearing in mind that with traditional stratification many seeds will not be sufficiently broken down by autumn to allow the ensuing chilling period to be effective. It is for this reason that the Dutch sow *Crataegus* seed at very high densities. Imported cleaned seed, artificially dried for lower postage, causes very hard seed coats. It may take up to two years normal stratification to get through, by which time seed viability is reduced. If the temperature is

raised many seeds are killed, as they have already been subjected to stress when artificially dried.

It is not necessary to be a scientist to undertake acid treatment, but common sense and general care are needed. Equipment required is concentrated sulfuric acid obtained through a laboratory supplier or a chemist, rubber gloves, overalls, shallow containers (plastic, glass or enamel), a thermometer, ⅛" mesh sieve, and washing soda. The work area should have access to cold running water and a stone sink with plastic drainage pipes.

Small quantities of seed are easier to handle than large; I use 1 kg for each treatment, but can have many treatments going at once.

Seedcoat thickness in *Crataegus* can very considerably from tree to tree and season to season. Trees can be picked separately or they can be mixed, with a representative sample taken for testing. Take four representative samples of 50 seeds each; samples must be clean and dry, placed in separate containers and labeled 1 to 4.

Note the time and add sufficient acid to coat the seeds so that they slide around easily when stirred without sticking or swimming. Give an occasional stir and if the temperature reaches 80 to 90°C either immerse the container in cold water or add more acid. Heating is not normally a problem if the seed is dry and the batch is not too big; keep the seed in the container flat and avoid splashing with water.

To test the effectiveness of the treatment, remove samples at ½ hour intervals from ½ hour to two hours after starting the acid soak. Cover the seed sample with water and then, using rubber gloves, rub the seed together and over the sieve to remove charred particles and to clean the seed. Rinse thoroughly and then immerse in clean water plus washing soda to neutralise the acid.

The next step is to inspect the seed by cutting open with a knife or secateurs and checking how far the acid has penetrated the outer coat. There should be 80 to 90% penetration in the majority of the seeds in one of the samples. It is possible for the acid to have reached the embryo, blackening it but still not affecting its viability. The acid usually penetrates through the joint of the two halves of the seedcoat, but sometimes there are weak spots where it may break through. At this stage the outer coat will appear much thinner and become very brittle.

Once an optimum treatment period has been established from these tests, one kilogramme batches can then be treated accordingly. In doing several batches at the same time, allow

15 to 20 minute intervals between batches to allow cleaning time. Occasional stirring is very important to prevent hot spots and give uniformity to the treated batch.

After the seed has been treated, cleaned, washed, and inspected and passed satisfactorily, it can be mixed with an equal quantity of moist peat and grit and given a warm period of two to four weeks at 20°C to break down any remaining parts of the seedcoat. This will also help to mature the embryo. After this, place the seeds in a polythene bag in a refrigerator for 10 to 12 weeks at 2 to 4°C, turning once a week to aerate and prevent mould development.

Ideally, give 10 weeks chilling then sow at the end of February or early March; this will finalize the chilling and the damp atmosphere is ideal for maximum germination. Frost damage is unlikely in our locality at that time.

I have found that *Crataegus monogyna* seeds require between 30 minutes and 2 hours acid treatment and *C. crus-galli* and *C. prunifolia* up to 4 hours. I treated a batch of imported seed of *C. coccinea*, received in late December 1981, and with a 2-hour acid treatment, followed by 4 weeks warm and 12 weeks chill treatment, achieved 80% germination.

PLANT STANDARDS FOR FRUIT NURSERY STOCK IN THE U.K. — AN UPDATED RESUMÉ

JOHN TURNBULL

Ministry of Agriculture, Fisheries and Food
East Malling, Maidstone, Kent

In my advisory career I have always found that economics are an extremely potent incentive for new technology to be adopted. If we take this point in the context of better quality fruit nursery-stock I am sure it is the improved results of using this certified stock which has led to its rapid acceptance by the industry.

At the recent "Fruit Focus Exhibition" in Kent, the Ministry of Agriculture's Fruit Certification Schemes were featured in the Agriculture Development and Advisory Service (ADAS) Exhibit and whilst I was there two very well known fruit growers were discussing the subject with me. One of them who has been around long enough to have known the situation prior to certification said, "John, it was like the Irish Sweepstake when we used to buy stock before certification standards put reliability and confidence into fruit production."

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I propose to outline my talk with an examination of why improved health standards in fruit tree production are so important to the fruit industry and then, look at some of the factors which influence this. And finally, to show you how these standards are maintained at present.

The basic reason why first class trees are required and demanded by fruit growers is because it is sound economics. When you consider it costs £4500 to £8,000 per hectare to establish an orchard, to plant poor quality trees is a very poor investment. The variable costs of production in the first year show that the trees themselves account for over 53% of the establishment costs, indicating the economic significance of the tree.

It is also worth emphasizing that the orchard is there for probably 20 years and the ongoing costs in that period are extremely high; if you are putting resources into an orchard of poor trees economic losses are likely.

Over the years an enormous amount of work and research has gone into cleaning up fruit stocks from virus diseases and we can clearly see the value of that improvement (Table 1). In plums and cherries there was a dramatic improvement, with crop yield increases of between 28 and 42% and, in pears, there was a similar improvement in cropping. Apples varied from 7 to 26% improvement in both cropping and fruit quality. Orchards with greater productivity were, in fact, a tribute to the better stock that was supplied from reputable nurserymen of yesteryear, such as Rivers and Bunyard, household names in horticulture. One might go back still further and discover that fruit growers always consulted the nurseryman in order to get the best stock that was available; reputable nurserymen based their success on their ability as plantsmen and their ability to select quality as well as their ability to know their customers. Obviously orchards planted with trees of doubtful origin, of doubtful health, and doubtful cultivars often had to be grubbed out because they were so unproductive.

Table 1. Effects of Virus on Cropping in Fruit Crops.

	Age	Average percentage decrease
Plums	10 yrs	−28
Cherries	10	−42
Pears	15	−28
Apples:		
Cultivars on M.2	16	−26
Cultivars on MM.104	9	−20
Cultivars on MM.106	9	−16
Cultivars on MM.26	9	−7

Research has also shown the value of increased yield from better branched trees which arise from good healthy material.

Yield increases from 26 to 60% have been recorded. Such trees can produce up to 11 kilograms of extra fruit in the first 4 years of production, which more than pays for a better quality tree. The improved tree structure is also an advantage over the whole life of the orchard.

Summary of Benefits of Certified Healthy Stock — EMLA

1. Trees are of higher and more consistent quality, generally producing better branching.
2. Better yields of quality fruit are produced.
3. Greater productivity during the life of the orchard.

East Malling and Long Ashton with their combined efforts managed to clean up apple mosaic and other complex viruses, such as "rubbery wood" and "chat" fruit, which were common in cultivars such as Lord Lambourne. "Star crack" virus was also present in other apple cultivars. Good nursery management backed by sound research work has provided the key to raising and improving standards of fruit stock. These high standards are now expected and demanded in the U.K. fruit industry.

It must also be emphasized that it is the combined efforts of research stations (East Malling Research Station and Long Ashton Research Station), the Nuclear Stock Association, and MAFF which has led to the cleaning up and release of this certified stock to the industry. As you will appreciate, this is an on-going exercise and to maintain this health status we cannot afford to be complacent with the imminent threat of diseases such as plum pox and fireblight, which lurk in the background. The extra vigour from this healthy material also requires adjustment management techniques to harness the full cropping potential of this stock.

If we examine some of the other factors which are involved in fruit tree propagation we can see that it is not just the health standards that must be considered. If we are to consistently produce the high standards that are required, there are basic principles which we ignore at our peril. For example, to plant any nursery stock in badly drained land can lead to disastrous results. Similarly, soil analysis and tests for SARD (Specific Apple Replant Disorder) are equally important, bearing in mind, that repeated planting of *Malus* can soon lead to a decline in tree vigour. Good rotation, good soil structure, and isolation are also part of this whole exercise of giving first class technical management to get first class results.

Just as we have moved on in terms of health standards we have also moved on in terms of technology in propagation. For example, chip budding and rootstock production by hardwood

cuttings are now accepted commercial practices. Similarly, growth regulators such as M&B 25105 (a feathering agent) is now being used by nurserymen to produce better branched trees. This not only improves tree structure but also encourages earlier and heavier cropping. These certified well-branched trees are the very foundation of the future of the fruit industry and are an extremely sound investment, fully justifying the costs involved in growing and certification.

The recently introduced Plant Health Propagation Scheme is an "umbrella" scheme covering all the existing certification schemes of fruit crops and other crops and the schemes are administered by the Plant Health Administration Unit of MAFF based in London; the inspections are carried out by ADAS. These schemes are completely voluntary, the nurserymen fully accepting the regulations associated with the schemes. The ADAS inspectors assess the health, vigour, and trueness-to-type of the stock and the isolation requirements concerned. From time to time the fruit stocks are retested for virus in order that the health standards are maintained. This is done in close collaboration with East Malling, Long Ashton, Plant Health Branch, MAFF, ADAS and, of course, the Nuclear Stock Association, and the nurserymen concerned.

I must also stress that the health status must be combined with the improvement and selection of better clones of the stock and this is very much an on-going affair. In the EMLA scheme we have already seen the improvement in yield and quality by the introduction of better clones and this work is still proceeding.

There are times when we get variation or off-types occurring within this biological process. We had, for example, an off-type showing abnormal characteristics from one of the 'Bramley' mother trees.

In mentioning marketing we must constantly be aware of the sovereignty of the customer. Only the satisfied customer will come back for more and they will only do so if the quality is of a high standard and produces good results.

For this reason, and with the every increasing competition from overseas producers, I feel we must constantly strive to improve our standards of nursery stock production and increase our self sufficiency in this important sector. We must accept that the customers' needs are changing; they certainly are in the fruit industry and the nurserymen in the U.K. must be flexible enough to respond to these changing needs. If they fail to do so, there are other nurserymen elsewhere who I am sure will step in and help themselves to our home market. As you know, the hardest competition that first class U.K. stock

has to face is low grade U.K. nursery stock which does nothing to establish customer confidence.

I have tried to show that this confidence and reliability is not dependent on one factor, but the inter-relationship of many factors, not the least of which is the nurseryman. Only he can weld together these very essential ingredients to make the whole operation successful. This requires skill and a great deal of business accumen. A fundamental principle of both fruit crops and ornamentals is the basic law of economics. Therefore, may I congratulate the organizers of this conference with their very appropriate title "Cost Effective Propagation" because as specialists you are well aware that much time and effort go into the techniques used in propagation. Equally, land, time, effort, and capital can be wasted unless at the outset the very best clones for propagation are selected, which are both healthy and true-to-type.

BRITISH STANDARDS FOR NURSERY STOCK

R.J. GARNER

East Malling, Maidstone, Kent

The establishment and maintenance of standards has long been a laudable objective of trade guilds and associations. It arises from a wish to standardize nomenclature and quality.

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The primary concern of any standards scheme is with trueness-to-name, as in the rootstock certification scheme introduced in 1946, and in the health schemes for bush and soft fruits, which are so important to the U.K. fruit industry.

In 1960 the Horticultural Trades Association, jointly with the National Farmers Union, published descriptive standards for nursery products. At the same time the Institute of Park Administration issued specifications for trees for roads and gardens, as did the Road Beautifying Association. A year later the H.T.A. and N.F.U. asked the British Standards Institution to consider standards for nursery stock. They convened a conference in 1962 and gathered representatives from a dozen organizations including the Horticultural Trades Association, the Horticultural Education Association, the Institute of Park and Recreation Administration, the Ministry of Agriculture,

has to face is low grade U.K. nursery stock which does nothing to establish customer confidence.

I have tried to show that this confidence and reliability is not dependent on one factor, but the inter-relationship of many factors, not the least of which is the nurseryman. Only he can weld together these very essential ingredients to make the whole operation successful. This requires skill and a great deal of business accumen. A fundamental principle of both fruit crops and ornamentals is the basic law of economics. Therefore, may I congratulate the organizers of this conference with their very appropriate title "Cost Effective Propagation" because as specialists you are well aware that much time and effort go into the techniques used in propagation. Equally, land, time, effort, and capital can be wasted unless at the outset the very best clones for propagation are selected, which are both healthy and true-to-type.

BRITISH STANDARDS FOR NURSERY STOCK

R.J. GARNER

East Malling, Maidstone, Kent

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the National Farmers' Union, the Royal Horticultural Society, and other bodies. By the end of 1963 four drafting sub-committees were set up: (1) Trees and Shrubs; (2) Roses; (3) Fruit; and (4) Forest Trees. Throughout the next two years there were frequent meetings and discussions and in 1965 the first British Standards Specifications for Nursery Stock were published. The best example of these and the most firmly based upon present knowledge and legislation is (3) Fruit.

This part of the standard specifies requirements for fruit trees, bushes, canes, and plants which are suitable to be transplanted and grown for food. It covers origin and marking, root system and rootstock, age, condition, packaging, and certification schemes operated by the Ministry of Agriculture and the Departments of Agriculture for Scotland and for Northern Ireland.

Whilst it is true that the use of a British Standard is a voluntary undertaking, once there is a declared adherence to it any departure therefrom invokes a ready means of redress. Against that, a clear declaration of intention to keep to a British Standard, by itself, invariably indicates reliability of the goods.

Put quite simply the goods must be labelled informatively and truthfully, in the same way as are proprietary medicines. If of certified material, the certificate number should be given. If of grafted material, the rootstock used must be stated. For example, not just 'Cox's Orange Pippin' but 'Cox's Orange Pippin' on 'M.9' or 'Cox's Orange Pippin' on seedling.

Any departure downwards from the British Standard Fruit (Bs. 3936: Part 3: 1965) is to be condemned. To quote a vital part of this: "Fruit trees shall be worked, or double-worked where necessary, on a fully compatible and approved rootstock for the type of tree. The rootstock used shall be declared. The height of working shall not be less than 5 in. (130 mm) above ground level, to avoid risk of scion rooting. To escape certain diseases, higher working is desirable for some cultivars of apples, plums, and cherries." Again, regarding the use of certified material: "Material and cultivar covered by one of the certification schemes of any of the U.K. Departments of Agriculture shall be of certified stock."

Any who take part in a standards scheme, whether plant raiser, merchant, retailer, or customer, must be able to rely on the quality of the product, its health and trueness-to-name and of a type and form suited to his own particular conditions. It is disastrous for him to plant his apple trees closely on a vigorous rootstock thinking they were on a dwarfing rootstock, such as 'M.9' or 'M.27', or similarly his pear on vigorous pear root-

stock instead of 'Quince C' and, likewise, myrobalan is no substitute for 'Pixie' when allocating space in the garden for a plum tree.

British Standards is, therefore, not merely an advertising scheme to trade doubtful material but, properly conducted, will build confidence in the trade. It is a skilled and highly complex trade. We must not try to run before we can walk. Let us begin first with the most clear-cut fruit plants, the most detailed, the most frequently inspected in regard to trueness-to-name and health. Then, when we have perfected these schemes we can adapt them to a wider range of trees and shrubs.

Remember, the British Standards Scheme is purely voluntary. If we wish to trade doubtful material we can still try to do so, but surely this is not in the long term interests of the industry.

MY VIEWS ON NURSERY STANDARDS

STEPHEN J. HAINES

James Coles and Sons (Nurseries) Ltd.
Thurnby, Leicester

Not many years ago it would have been frowned upon to have a session such as this at an I.P.P.S. Conference. In fact, at the inaugural meeting at Syon Park I remember being worried as to whether I would be granted membership when our first president defined "propagators" as, "those who put roots on cuttings and grafted in a controlled environment" or some such words, as against "despised" field workers and growers. Being in the latter category, I never really forgave him and the hurt must have been deep for me to remember his words. Greenhouse propagation has always had a certain mystique, unwarranted in my opinion, about it and those engaged in it tend to consider themselves superior to the peasants who graft in the fields. However I rejoice in the words of John Steinbeck in his book, "The Grapes of Wrath". He says, "The men who graft the young trees, the little vines, are the cleverest of all, for their's is a surgeon's job, as tender and delicate, and these men must have surgeon's hands and surgeon's hearts to slit the bark, to place the grafts, to bind the wounds, and cover them from the air. These are the great men."

When I first agreed to take part in this session it was, I thought, to discuss with our second illustrious President, Robert Garner, the standards of nursery production today. That

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could have been great fun and, to me, a great privilege for he is a man of great wisdom whom I have always admired and revered.

Looking at the nursery trade I think it must be conceded that in the last decade there has been a decline in standards, particularly of field-grown stock. There are still nurseries, usually the more specialist ones, which attain superb standards year after year. On many other large nurseries there are craftsmen of the highest calibre, but many of the most skilled people are now carrying managerial responsibilities and are less able to spend time working among their crops and passing on their skills to younger employees. These skills are precious and I fear that insufficient intelligent young people are taking them up and practising them to their highest standards. It is not just a matter of learning to bud, or to graft, or to stake; it requires a long period of experience of producing a crop in our strange climate when there are so many unpredictable elements. It is a matter of having foresight, of knowing how to apply one's knowledge to best advantage to achieve maximum response from plants and employees, of being self disciplined and pretty single minded, intent only on producing a crop as near perfection as is humanly possible.

Before I attempt to give reasons for this, I hope, "temporary decline in standards of field-grown stock", I think it right to say that the introduction of British Standards to tree crops has greatly improved the quality and grading of material received by the customer. It is the lower percentage of the crop which is marketable about which I am concerned.

Now for a commercial view of why standards for tree crops have declined:

1) Over-expansion of tree growing by the trade in the 1970's.
2) Decline in demand from New Towns and local authorities; also a period of reduction of orchard planting.
3) Inflationary costs allied to uncertain demands.
4) Growth of container production.
5) Several difficult growing seasons.
6) Methods of training/educating young entrants.

My first two points can be bracketed together; most nurseries have now come through the period of over-production, a period which has had a very bad psychological effect on persons who have spent time in producing and then wasted time in clearing drifts of unwanted stock. It is far better to be slightly under-produced and feel that each tree will find a market. Clearing unwanted stock is expensive and an extra

burden on those who are already overstretched during most of the year.

3) Inflationary costs allied to overproduction and falling demand have created a position where prices have failed to keep pace with inflation. There has been uncertainty over income and profitability and, consequently, a reduction in recruitment into the trade. Despite higher than usual annual increases in wages the trade is still low in the wages league and skilled staff are very poorly rewarded by comparison with others in far less onerous occupations.

4) Rise of containerized tree and shrub production, with it's high labour input, tends to draw staff from field work, especially in April and May. The peak sales season for Garden Centres is the spring. Garden Centres buy in response to demand, often in smaller quantities, but more frequently; while these sales are welcome they do occur at a very busy time of the year.

5) I am sure that most growers would agree that we have had, on top of other problems, a series of difficult seasons for field production. I could give several instances of very poor stands of rootstocks and transplants, part of our own plantings this year being a good example. We have a local rose grower admitting to weeping over his field of lost briars and roses and saying that it is the worst he has had in 50 years. These are all problems to be sorted out by the trade but my point has been that through various pressures over recent years, the burden has increased on key staff and the very best men have a point where they have to compromise standards in order to get through a work programme.

Earlier I said that the skills are still there but were being overstretched and that the real problem was to see that these skills are passed onto intelligent young people who have a love for growing and will not shy away from work.

6) There is no shortage of young people wanting to take up horticulture as a career. There must be something radically wrong with the industry and the method of training when so few become qualified to take responsible jobs in practical horticulure. A man, who many of you know, recently told me that he was under no pressure in his job and certainly would not want the pressures of commercial horticulture. Many young people must be learning that this is true and so they look for the easier road.

I still believe that growing is a great way of earning a living and gives great satisfaction and fulfillment among the heartbreak and frustration. I also believe that few good field growers will come out of the college system unless that system

is radically changed. In my opinion, college staff are not qualified to train young nurserymen. Over and over again I have seen, during National Proficiency Test Council standard setting sessions, standards accepted by college examiners which would not be acceptable to the trade. Taking proficiency tests at college is a soft option and should no longer be tolerated by employers.

What is required is for the trade to spend more time in "on the job" training, backed by lectures on the theory of growing, with a further raising of the standards of proficiency tests so that the word "craftsman" once again has a true meaning.

My conclusion is that the trade must make haste to see that the skills of senior employees are not lost; it is no use relying on any other source for the craftsmen of the future.

At the same time it is necessary to ease the burdens which have been placed on the people on whom we rely for the maintenance and improvement of the standards of nursery production.

B. RIGBY: I agree with Steve, colleges are not the best place to train students as craftsmen. It needs to come in the "sandwich" year, or as part of pre- or post-college training in the industry.

J. STANLEY: The training board does use examiners from the industry.

D. CLARK: Mike Dunnett's I.P.P.S. project on rates for cutting production are an example of I.P.P.S. involvement in improving standards. As an industry we need to see standards are set and maintained in proficiency tests, and to feed information back to colleges and to give them some objectives.

L. DICK: May I make a plea from the colleges to the nurseries taking sandwich students, to allow the students to participate in budding and grafting?

D. WEGUELIN: Why not let students add a second bud higher up on worked stocks to give them practice without jeopardizing the bud take?

R. EVISON: Young people need to have more time for in depth practical training; they need four to five years to gain real experience, and not to flit from job to job.

B. HUMPHREY: Students now are of higher calibre and interest, and we expect more of them in a short time.

I would also suggest that the fact is that our standards have risen, which would account for less stock reaching the required standards.

N. DUNN: Standards haven't improved compared to improved techniques; we could have done better.

A. WOOD: In an age of specialization, we should concentrate on one aspect to improve quality.

D. WHALLEY: We cannot afford to grow poor stock. In the 1970's there was an increase in area of stock, but not in the amount of available labour.

GRAFTING OF PINUS, PICEA, AND ABIES

DON HATCH

Chantry Nursery
Honiton, Devonshire

STOCK PLANTS FOR SCIONS

The most important procedure before any grafting can be undertaken is the establishment of stock beds of true-to-name cultivars. Stock plants need to be planted with plenty of space for full development. Even the dwarfs can soon fill out to take more space than allocated. Good cultivation is important, as is a regular spraying programme, for the control of conifer spinning mite on spruce and adelges on *Pinus sylvestris* forms. It must be appreciated that, with the dwarf cultivars especially, some years must elapse before commercial quantities of scions become available, dependent upon the number of each cultivar planted.

UNDERSTOCKS

We produce a few of these ourselves because of the wide variety of cultivars we produce and a need for stocks of varying thickness. The bulk are bought-in and can be acquired, graded for grafting purposes as two-year transplants. These arrive in spring and, after potting in 3″ pots, are placed in a net tunnel. We use *Pinus sylvestris* for all two-needle pines, *Pinus strobus* for five-needle pines, and *Abies grandis* for *Abies*. I suspect that *Abies alba* is a better understock, but it is not grown much now because of disease and is, consequently, difficult to obtain from forest tree nurseries. *Abies* are, however, compatible within the range and do not present much of a problem.

Methods. Somehow the idea that understocks should be dried off appears to be fairly widespread and, although this may or may not be true with angiosperms, it is not in our experience a critical factor with conifers.

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Understocks are brought into a glasshouse or slightly heated tunnel in batches; the first in mid-December ready to start grafting soon after the Christmas break. Ideally, root tips should be showing white indicating root development, and the root ball should be uniformly moist.

We normally begin with the pines, followed by firs, and then the spruces. A side graft is used, except where the stock is much thicker than the scion, when we make a cut leaving a flap. The end of the scion is then cut to a thin wedge, covered with the flap; one side of the scion should be aligned with the cambium on the same side of the stock. The tie is made with ½" polythene tape, which is a tying and sealing medium. Some practice is required to become proficient and speedy but I think it is well worth the effort. The grafts are best plunged in moist peat just above the pot. They are inserted at a 45° angle with the scion at the top, then covered with thin polythene over wire hoops and sealed down if possible. Gentle bottom heat is applied.

AFTERCARE

Now we come to the most important phase of the entire grafting process; however good the carpentry, success or failure is governed by aftercare. Careful watch must be kept for drying out, which will inevitably lead to losses, more especially in the firs and spruces than the pines. The effective sealing by the use of polythene tape means that quite heavy watering can be applied when necessary without harm. After five to six weeks the grafts can be looked through and those that are showing movement of the terminal bud of the scion can have the rootstocks headed back by half. Grafts must be regularly inspected for pests. A mild winter can lead to a quick infestation of aphis when stocks are brought into warmer conditions. As in all cases, prevention is easier than cure so we spray once or twice with Metasystox, which controls both red spider mite and aphis. At twelve weeks most grafts will have made their extension of growth; when the terminal buds on the new growth are visible the stocks can be headed back to just above the union. At this stage we cut the polythene tie to release it. When training staff I try to impress upon them the importance of aftercare and draw the analogy with a hospital patient who has just undergone an operation. It is the careful nursing afterwards which ensures the success of the operation.

A propagator with a batch of grafts in his care must also look to proper shading onwards from the end of March. A sunny weekend in early April without sufficient shade will kill many grafts; it is imperative not to be caught unawares.

SUMMING UP

Successful grafting of *Abies*, *Pinus*, and *Picea* then, along with most other species, depends upon:

1. Ample supply of healthy scions.

2. Pot-grown understocks of the correct stem thickness with some root activity at the time of grafting.

3. Use of a good sharp knife and correct carpentry.

4. Dedicated aftercare. By this I mean, amongst other things, before the propagator disappears for the week-end at the end of March, he should pause to think whether the grafts require shading in case the weather changes. Careful attention must also be paid to the pest control programme.

BENCH GRAFTING UNDER HEATED GLASS

C.G. LANE

Hadlow College of Horticulture
Hadlow, Tonbridge, Kent

This paper covers the bench grafting of deciduous trees which have proved, in the past, to be very difficult to propagate by conventional field propagation techniques. This mainly covers the production of ornamental cultivars or species of *Alnus*, *Betula*, *Fagus* and *Quercus*.

SOURCE OF SCION MATERIAL

Scion material is procured from specially established stock "mother" trees. These are planted at a spacing of 12 ft between the rows, and 6 ft apart in the row. This allows tractor access for grass mowing, strip herbicide application and spraying for pest and disease control. A branch framework is established at a height of 3 ft like a bush apple tree. The trees are pruned hard back to the framework each year once the required scion material has been removed. Cuts are then painted over with a fungicidal paint.

SOURCE OF ROOTSTOCKS

Basically there are two methods of producing good well-established pot grown stocks.

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SOURCE OF ROOTSTOCKS

Basically there are two methods of producing good well-established pot grown stocks.

1) For *Alnus* and *Betula*, 1-year old field-grown seedlings are selected during the winter months. Ideally they should have straight stems of 3 mm diameter and good fibrous root systems. For *Fagus* and *Quercus*, 1 + 1 field-grown seedlings of 5/6 mm diameter are selected because they are slower growing. The stocks are root pruned and then cut down to 35 to 40 cm with any side shoots removed. They are then potted into 10 × 12.5 cm containers during the winter, using a fairly high (35%) loam-based compost. These are grown on for one season to produce well-established stocks to graft the following winter.

2) For the fairly rapid growing *Alnus* and *Betula*, a method of raising stocks of sufficient size for grafting from seed in one growing season has been used. Seed is sown in trays in March under heated glass, having had 3 weeks stratification at 2° to 3°C. During March and April the seedlings are pricked off into plastic units made up of 40 compartments which fit into a standard seed tray. Each seedling has an individual container which allows easier potting on. Repotting into the same compost and container is carried out, as in the first method, when the seedlings are 8 to 10 cm high; they are then stood down under polythene protection. They will grow away without any check to make good 5 to 6 mm diameter stocks for grafting the following winter. During the course of the growing season the growth is stopped to encourage thicker stem development.

PREPARATION OF THE ROOTSTOCK

At the end of December the pot-grown stocks are brought into the glasshouse 3 weeks prior to grafting. The glasshouse temperature is maintained at 8 to 10°C. Water application is restricted so that the rootball can be dried off from excessive moisture. This stimulates the stocks into activity and also prevents flooding of the union which is important, particularly with *Alnus* and *Betula*.

GRAFTING PROCESS

Two types of grafting technique are employed, side veneer for *Alnus* and *Betula*, and splice for *Fagus* and *Quercus*.

Side veneer graft. The stocks are cut down to 15 to 20 cm and the base of the stem cleaned up to make tying easier. Only strong, well-grown material should be used for the scions which are prepared 12.5 to 15 cm long, cutting flush above a bud at the top. A 3-4 cm sloping cut is made at the base of the scion with a small nick on the opposite side. A corresponding cut is made on the stock, as low down as possible. The stock and scion are placed together ensuring close matching of the

cambiums; they are then tied together using 4 × 150 mm rubber strips ensuring that the correct tension is maintained. The strip should lie flat and the basal nick is left exposed as bruising could occur here with subsequent loss. Next the union and tip of scion are waxed over using molten paraffin wax.

Splice graft. The stock is cut down to 5 to 6 cm with a slightly sloping cut. The scion is prepared 10 to 12.5 cm long, cutting flush above a bud at the top and making a 4 cm long sloping cut right through the scion at the base. A corresponding cut is made on the side of the stock from the top of the sloping cut. The stock and scion are then tied in as before but ensuring some of the cut surface of the scion is visible above the stock. This ensures a stronger cambial union.

AFTERCARE

The grafts are placed pot thick on an open bench in the glasshouse. No basal heat is given, relying on the ambient temperature being maintained at 8 to 10 C. In my experience grafts which callus more slowly form better unions than those which are forced too much. An open bench makes observation of the grafts more easy, especially for spotting those which are getting too dry. In sunny weather the grafts are shaded and sprayed with water to maintain humidity and prevent the compost getting too dry. *Botrytis* is not a problem on the open bench, compared with a closed case or polythene tent where it is a major problem.

Sucker growth is removed as it appears, and once scion growth is 5 to 6 cm long the grafts can be watered quite liberally. Heading back starts once the shoots are 10 cm long. Secateurs are used and it is necessary to leave a small section (3 to 4 mm) of the cut surface on the scion exposed. The cut is waxed over. The union will then heal over the top of the cut, thus giving a much stronger union. At this point, a 70 cm split cane is put to the plant on the opposite side to the graft, and the growth is tied in. With the splice grafts it is important to rub out sucker growth when it is small, otherwise it will take over and the scion will fail. These grafts are also caned and tied in when growth is 10 cm high.

GROWING ON

Providing field irrigation is available, grafts can be planted out in early June to become well established and make some growth before winter. Alternatively, grafts are kept in a frame until autumn and then planted out. If there is evidence of root curl at the base of the container this should be cut away at the

time of planting, particularly with *Fagus* and *Quercus*, which are very long-lived trees.

PESTS AND DISEASES

Aphids are the major pest which can attack and damage young growth, and these should be controlled as soon as they are seen. Routine fungicidal sprays can be given, especially one which prevents mildew on *Quercus*.

SOME COMPATIBLE ROOTSTOCK/SCION COMBINATIONS

Stock	Scion
Alnus glutinosa	*Alnus glutinosa* 'Imperialis'
A. incana	*A. incana* 'Aurea'
Betula pendula	*Betula pendula* 'Dalecarlica'
	B. jacquemontii
	B. ermanii
Fagus sylvatica	*Fagus sylvatica* 'Riversii'
	F. sylvatica 'Rohanii'
Quercus cerris	*Quercus castaneifolia* 'Green Spire'
Q. robur	*Q. frainetto*
Q. rubra	*Q. rubra* 'Aurea'

All birches are compatible on *Betula pendula*. With oaks one must graft within one section, e.g. *Q. cerris* section type onto *Q. cerris*. All the *Alnus* appear to be compatible, but as stocks are readily available it is best to work on the same species.

S. FRASER: Why is it necessary to graft *Betula nigra* — in America they are grown from cuttings?

C. LANE: No nurserymen in the U.K. are successful in rooting cuttings or, if some do root, the root systems are poor. It is essential to have a good root system on trees.

B. HUMPHREY: They, perhaps, have better rooting clones in the U.S.A. I have seen clones there which root from two-year-old wood.

BENCH GRAFTING ORNAMENTALS AND FRUITS

PAUL BRADLEY

Swallownest Nurseries, Sheffield

The aim of our bench grafting is the production of pot-grown whips for growing on into small sized, container-grown trees suitable for Garden Centre sales. We only grow the more

time of planting, particularly with *Fagus* and *Quercus*, which are very long-lived trees.

PESTS AND DISEASES

Aphids are the major pest which can attack and damage young growth, and these should be controlled as soon as they are seen. Routine fungicidal sprays can be given, especially one which prevents mildew on *Quercus*.

SOME COMPATIBLE ROOTSTOCK/SCION COMBINATIONS

Stock	Scion
Alnus glutinosa	*Alnus glutinosa* 'Imperialis'
A. incana	*A. incana* 'Aurea'
Betula pendula	*Betula pendula* 'Dalecarlica'
	B. jacquemontii
	B. ermanii
Fagus sylvatica	*Fagus sylvatica* 'Riversii'
	F. sylvatica 'Rohanii'
Quercus cerris	*Quercus castaneifolia* 'Green Spire'
Q. robur	*Q. frainetto*
Q. rubra	*Q. rubra* 'Aurea'

All birches are compatible on *Betula pendula*. With oaks one must graft within one section, e.g. *Q. cerris* section type onto *Q. cerris*. All the *Alnus* appear to be compatible, but as stocks are readily available it is best to work on the same species.

S. FRASER: Why is it necessary to graft *Betula nigra* — in America they are grown from cuttings?

C. LANE: No nurserymen in the U.K. are successful in rooting cuttings or, if some do root, the root systems are poor. It is essential to have a good root system on trees.

B. HUMPHREY: They, perhaps, have better rooting clones in the U.S.A. I have seen clones there which root from two-year-old wood.

BENCH GRAFTING ORNAMENTALS AND FRUITS

PAUL BRADLEY

Swallownest Nurseries, Sheffield

The aim of our bench grafting is the production of pot-grown whips for growing on into small sized, container-grown trees suitable for Garden Centre sales. We only grow the more

popular kinds of ornamentals and a range of fruit species.

Established potted stocks are used for *Acer*, *Fagus*, and *Betula* cultivars.

Bare-root stocks are used for all the fruits, i.e. apples, pears, plums, damsons, cherries, and peach. Of the ornamentals, *Syringa*, cherries, *Malus*, *Prunus cerasifera* 'Atropurpurea' (Syn.: 'Pissardii'), *Crataegus*, *Laburnum*, *Pyrus salicifolia*, *Sorbus*, and *Robinia* are also grafted bare-root.

We do not find it convenient to grow our own stocks, so these are bought from a reliable source during the autumn. The potted stocks are put straight into a tunnel or glasshouse.

It is vital that the bare-root stocks are the best quality, freshly lifted, transplants available — preferably 7 to 12 mm. Undercut seedlings and one-year layers are not good enough.

When the bare-root stocks are delivered they are immediately trimmed, both stem and roots, to facilitate easier potting later on. The stems are shortened to about 12 in. The trimmed stocks are then plunged into crates of moist to dry peat. We use the Continental type plastic crate which is approximately 9 in. deep and 15 in. × 2 ft., into which we get approximately 250 stock plants. The crates are then put into a frost-proof building, not necessarily a glasshouse. This is to make sure that they will not be frozen when needed for working in the first week of January. All preparation is completed before Christmas.

Grafting commences the first week in January. The early growing species, such as double lilacs on *Syringa tomentella*, or *Prunus cerasifera* 'Atropurpurea' on Myrobolan B, are grafted first, ending with *Robinia pseudoacacia* 'Frisia'. I aim to complete all bare-root grafting before the end of January. I find that stocks worked in January produce a larger tree by the end of the growing season and take better than stocks worked in February. It is also a useful job to do during the bad weather of January. This year the temperature was approximately −15°F and all other nursery operations were at a standstill.

The splice graft is used for all the bare-root stocks, this being the quickest and most simple type. The ornamentals are worked as low down the stock as possible, or even the root itself.

The scionwood is usually the prunings taken from the previous year's growth, which is cut and used immediately. The scion has three buds. Virus-free material is used wherever possible.

The grafts are tied-in with Rapidex rubber strips without any sealing. I find that polythene tape also gives excellent

results, but needs removing by unwinding rather than slitting up the back with a knife. This job usually must be done in early June when we are very busy with other work and is very time consuming. However I still use polythene tape for *Robinia* 'Frisia'.

The completed grafts are re-plunged into crates of moist dry peat. This time they are placed almost horizontally with the union and scion completely buried. This keeps the union and the scion moist and seems to aid callusing.

The next important step is slow callusing. The crates of completed grafts are placed in a cool, shaded building. It does not have to be a glasshouse; a temperature of about 34 to 40°F is ideal, although no heat is used to control the temperature.

The timing of potting is very important. The stocks worked in early January are usually ready for potting in early February. I find the ideal time to start potting is when the leaf bud scales begin to show signs of swelling and expanding. If potting is delayed and long white roots develop on the stocks then losses will be heavy. It is better to pot early when the buds are dormant rather than wait too long. Our potting of grafts is a continuous process at this time, the early grafts being potted first. But even grafts that were worked perhaps a week earlier are also potted at this time as growth is much more active.

The ornamentals are potted into 8 in. (6 litre) poly bags, potted deep to disguise the graft on the final finished tree. Fruit trees on dwarf stocks are potted into 4 litre poly bags. These are worked higher to preserve the influence of the stock. *Robinia* 'Frisia' is potted into rigid 4 litre pots. They have a naturally poor root system, but we find it is improved in a rigid pot, which also improves the presentation of the tree and usually makes quite an acceptable saleable one-year plant.

The potting compost is the conventional peat/sand mix with full strength Osmocote added.

The potted grafts are then placed in an unheated polythene tunnel which is shaded with 10 ft. wide strips of black polythene on the outside, zebra fashion. This is another critical stage in the process. It is most important to keep the air temperature low until plants are well established to assist the slow callusing and to prevent premature bud development which will lead to failures.

The next phase, which is the growing-on, will determine the profitability of the crop. It is one thing counting the take at the 6 in high stage, and another counting the number of first class trees at the end of the growing season.

During spring the grafts are watered as required taking care not to over water until growth is well established. Suckers are removed promptly. When growth is 10 to 12 in high an application of Temik 10G at the recommended rate, is applied with a hand applicator. We find this gives us complete freedom from aphids and red spider for the whole of the growing season and no further insecticidal spraying is necessary.

In early June the trees are caned with 5 or 6 ft canes and spaced as required. When growth reaches the top of the cane it is stopped to encourage branching. I find that by letting the leader run on 6 to 9 in extra, then pruning back rather than pinching, this removes the apical dominance and produces better branching. This is most noticeable with plums and damsons.

The pot-grown stocks are grafted after all the bare-rooted stocks are finished. We put them onto an unheated glasshouse bench and wait for the natural activity of the sap. A veneer graft is used on these. Scionwood is collected and cool-stored until required.

If all the cultural procedures have been carried out as soon as necessary and the trees have not been under stress for any reason, then a large number can be selected for Garden Centre sale at competitive prices.

In conclusion, we are satisfied that our method of grafting bare-root stocks is a viable proposition and gives an economical one-year tree.

If we did not use this method it would mean our buying-in field-grown stock.

COSTINGS

Average cost of bare-root stocks		20p	
Preparation of stocks		3p	
Cost of grafting, 400 per day at £5. pr. hr.		10p	
Cost of compost, 3p per litre in 6 litre bag		18p	
Cost of potting and putting down		3p	
Cost of plant pot		6p	
	total	60p	(assuming 100% take; If 80% take this becomes 72p)
Growing on		12p	
Cost of 6 ft. cane tying and spacing		12p	
Insecticide, watering, and weeding		9p	
	total	93p	

Allowing for unforeseen costs, the total cost is about 1 pound

Having looked in a few English and Dutch catalogues, the current cost to buy in 6 to 8 ft whips is about £2.00, plus carriage. In other words, one can grow their own for approximately half that of buying in.

N. CLAYTON: Do you use wax when you bind with rubber ties?

P. BRADLEY: No, we just bury grafts in peat.

BENCH GRAFTING METHODS AT CROWDER'S NURSERIES

RONALD THURLOW

W. Crowder and Sons Ltd.
Thimbleby Nurseries, Horncastle

GRAFTING FACILITIES

We have four grafting benches, each 45 ft long and 6 ft wide and having 9 in high wooden sides. These benches are supported by small 2 ft 9 in high walls, made of concrete blocks. The floor of the benches consists of corrugated zinc sheets covered by a layer of polystyrene for insulation. On top of the polystyrene there is a layer of sand in which we have soil warming cables embedded. Only three benches have bottom heat.

Each bench is covered by a 3 ft high polythene tent with lift up sides. These benches are housed in a double span greenhouse, two benches each side.

Across the roof and partly down the sides of the greenhouse we have a movable Netlon type shading. This shading was stitched by a sheet maker and is made to measure fit. It is held in place by wire and can be easily slid to the sides when not in use.

Also three tunnel houses are available, measuring 50 ft by 14 ft. These are used by the propagators in summer and have soil warming cables in them if we need them.

ROOTSTOCKS

We use mostly pot-grown rootstocks and have two methods of obtaining them.

First method: One year seedlings are graded in February or March from our own seed beds, or they are bought-in transplants for machine planting. These are cold-stored then potted when time allows. They are ready for grafting the following spring. Examples of genera whose rootstocks are handled this way are *Fagus*, *Prunus*, *Robinia*, *Picea*, and *Chamaecyparis*. For *Picea* and *Chamaecyparis* we would probably use two-year-old seedlings, or 1+1.

Second method: These rootstocks are bought in ready for grafting. They have been grown from seedlings propagated in seed trays and then pricked out into pots. Examples are *Betula*

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Second method: These rootstocks are bought in ready for grafting. They have been grown from seedlings propagated in seed trays and then pricked out into pots. Examples are *Betula*

spp., *Cupressus macrocarpa*, and *Syringa vulgaris*. We bare-root graft *Hibiscus* and sometimes *Prunus* and *Robinia* species. The pot size we use is usually either 3-in (7.5 cm) plastic or 4 in (10 cm) plastic long toms.

TREATMENT PRIOR TO GRAFTING

About six weeks before grafting the rootstocks are brought indoors to dry out. This helps to prevent flooding of the union in plants such as *Betula*. The greenhouse is washed out with a power wash and then disinfected.

GRAFTING TIMES

We graft from mid-January to the end of March. *Fagus* plants are the first to be grafted, then the *Betula* and the conifer plants. After this we try to graft the cultivars that come into leaf early.

GENERAL HYGIENE

All grafting operations have to be carried out in clean conditions. The pots and any parts of the rootstock which are to be cut are rubbed with a clean cloth if they are dirty. As a disease precaution and to keep knives clean, especially when grafting conifers, they are dipped in methylated spirits.

ROOTSTOCK AND SCION SELECTION

For good results we need healthy, strong rootstocks with a good root system. The scion material should be last season's growth, disease-free, and selected from the best plants. It should be firm and plump, not weak and straggly.

Scion material from such evergreens as *Picea* is taken, if possible, only from the terminal shoots. These grow better and retain the truer shape of the parent than would scions taken from lateral shoots.

TYPES OF GRAFT USED

We use two types of graft. One is what many people now call the modified whip graft, where the rootstock is cut down to about 2 or 3 in (5 to 8 cm) from the soil. We then make a cut about 1½ to 2 in (3.5 to 5 cm) long down the side of the rootstock. This cut can be longer if the scion and rootstock are quite thick. At the bottom of this cut we make a nick. On the scion we make one long cut on one side (behind a bud) and a short cut on the other side at the bottom to fit into the nick of the rootstock.

Like other types of grafting, it is necessary that the cambium layers on the scion and rootstock match each other when

tied. This may mean putting the scion on one side only if the rootstock is thick and the scion thin.

When the graft is tied a small portion of the cut on the scion should project up above the rootstock top. This portion then heals together with the rootstock top helping to make a strong union and preventing dieback of the rootstock top. Do not leave too much of this cut showing through as it may weaken the graft at this point. Some people call this cut the "church window" because that is what it looks like.

The second type of graft is the side-veneer graft; it is used on conifers but can also be used on deciduous plants. With this graft remove only a third of the rootstock to start with, then clear the bottom branches. A cut about 2 in (5 cm) long is then made as near to the bottom as possible. At the bottom of this cut a small nick is made. It is easier to make the small cut (the nick) first. The scion has one long cut on one side and a small cut at the bottom on the other side.

After about five weeks half of the remaining rootstock above the graft is removed. Around five weeks later the rootstock can be cut down to the graft union. This last piece of rootstock can remain for longer if the union is not that strong or if the scion has not made much growth.

TYING MATERIAL

We use ½ in (13 mm) wide polythene grafting tape; 1 in (26 mm) wide tape is sometimes used for thick stocks and scions. We use Arbrex to protect exposed cut surfaces on the rootstock and scion. We hope in the future to try rubber strips and paraffin wax. Polythene tape seems good for conifer and *Fagus* grafts but rubber strips may be better for *Betula* because the callus can expand easier and make a stronger union.

SUBSEQUENT TREATMENT

After grafting, the plants are stood out in the benches and labelled. The air temperature in the glasshouse is set at 40° to 50°F (5° to 10°C) depending on the species. Soil warming cables are set at 50° to 55°F (10° to 13°C). Each morning the polythene sides of the tent are lifted up for 2 or 3 hours to dry off the condensation. Sometimes the sides are left up longer if we want the plants to grow slower. On warm days the greenhouse is ventilated and shaded. The benches are sprayed over with cool water, especially the ones containing conifers.

WATERING

To start with the grafts are kept fairly dry, with only spot watering of the odd pot that dries out. We test how moist the

grafts are by lifting them out of their pots from time to time. This way we can make sure they do not dry out too much.

PEST CONTROL

As a precaution against diseases like *Botrytis*, we spray the grafts every 10 to 14 days with a fungicide. Usually we alternate with Benlate (benomyl) and Rovral (containing Iprodine). Both of these are applied at 1 gram in 1 litre of water. Each bench is sprayed from both sides so that the spray makes contact all around the graft. We spray with Malathion to eradicate greenfly, whitefly, etc. If we are troubled with caterpillars we use Fenitrothion. Slugs, which seem to appear every year, are destroyed with Draza G micropellets (containing Methiocarb).

TIE REMOVAL

The ties are removed either when they are just starting to cut in as the rootstock and scion swell, or when the grafts have made quite a bit of growth and they have callused well.

N. DUNN: Does Arbrex inhibit callusing?

R. THURLOW: We only paint the cut surfaces to protect from fungus. We get a 90% take.

B. HUMPHREY: The fungicide in Arbrex inhibits callus. Hilliers use Bituproof 3, which appears to be quite satisfactory.

C. LANE: Arbrex dries from the outside inwards and this can mean a mess seeping around the union. We use hot wax that dries immediately on contact.

P. GAUT: Has anyone used Mildothane canker paint?

B. HUMPHREY: We used it in the past but it is more expensive than some others.

J. GAGGINI: We use petroleum jelly and have no problems. We wipe it on with the finger and it is perfectly adequate in reducing transpiration from cut surfaces.

P. BINGHAM: Do you have any tips on keeping the knife clean?

D. HATCH: I use surgical spirit on a cloth to wipe the knife, and then wipe the knife on a piece of wood to avoid contamination.

B. HUMPHREY: We use methylated spirits and have no problems, although we don't wipe it off.

J. EDGEBY: An observation, at Writtle we use wallpaper paste with IBA to paint cuts and add a fungicide such as Mildothane.

DISEASE CONTROL IN ERICAS AND CALLUNAS

DAVID HUTCHINSON
Ministry of Agriculture, Fisheries and Food
Winchester, Hampshire

INTRODUCTION

The diseases *Phytophthora cinnamomi, Pestalotiopsis spp., Pythium spp.*, and *Cylindrocarpon spp.* can cause significant crop losses in *Erica* and *Calluna* production and, in recent years, the disease *Rhizoctonia solani* has caused appreciable losses to specialist growers especially in wet growing seasons.

Having specifically identified *Rhizoctonia* as a problem with a specialist producer, nursery trials were carried out using the fungicide Iprodine (Rovral) to contain the disease. (Rovral had the necessary clearance and recommendations for the control of *Rhizoctonia* in lettuce and bedding plants).

The nursery practice is to grow 1 year Ericas and Callunas in ½ litre containers under high polyethylene tunnels (the polyethylene being removed in May/June and replaced in September/October). Overhead irrigation is used with a fibre capillary mat on a black polyethylene sheet base.

METHODS AND MATERIALS

Trial 1. A drench of 2 grams of Rovral 50% a.i. in 5 litres of water per m^2 was applied at 2, 4 and 6 weekly intervals. There was a non-treated control. The four treatments of 25 plants were replicated 4 times in 10 cultivars of callunas. Results are given in Table 1.

Table 1. Fungicide Control[1] of Rhizoctonia on *Calluna vulgaris* Cultivars. 1981 Drench Trial.

		Rovral drench every:		
Cultivar	Untreated	2 weeks	4 weeks	6 weeks
J.F. Letts	*	**	**	**
J.H. Hamilton	*	**	**	**
Gold Haze	**	***	***	***
Darkness	**	***	***	***
Golden Carpet	*	**	**	**
Elsie Purnell	**	**	***	**
Multicolour	*	***	***	***
Sister Anne	*	***	***	**
Serlei Aurea	**	**	**	**
Cupryea	***	***	***	***

[1] Disease control: *poor, **moderate, ***good

Trial 2. A compost incorporation of 400 g Rovral 1.25% dust (mixed with 1.1 kg of dry sand) per m^3 in addition to the normal nursery practice of incorporating 75 g Etridiazole (Aaterra) was used. This was followed up in the most successful treatment by 4 weekly interval drenches of Rovral at the rate of 2 g Rovral in 5 litres of water per m^2. There were six treatments of 24 plants replicated 4 times. Results are given in Table 2.

Table 2. Fungicide Control[1] of Rhizoctonia on *Calluna vulgaris* Cultivars. 1981 Compost Incorporation and Drench trial.

Cultivar	Untreated	Aaterra in Compost	Rovral in Compost	Aaterra + Rovral in Compost	Rovral drench every 4 weeks	Aaterra + Rovral incorporated, + Drench every 4 weeks
Sunset	*	*	**	**	***	***
Joy Vanstone	*	*	**	***	***	***
Kinlochruel	**	***	***	**	**	***
Orange Queen	*	*	**	**	***	***
Beoley Gold	**	**	**	**	***	***
Robert Chapman	**	**	**	**	***	***

[1] Disease Control: *poor, **moderate, ***good.

Trial 3. To establish whether a drench or a spray at high volume would be effective, a trial was established to compare the two methods. It was replicated 4 times and had a control of clear water.

Results obtained were:

1. No significant difference between the two methods of application.
2. The 2 g Rovral treatment was similar to the 4 g Rovral treatment.

Trial 4. To establish whether a Rovral treatment of 2 g per 1 litre of water per m^2 would be an effective control in the propagation stage, trays of *Erica vagans* 'Valerie Proudley' cuttings were treated. Results are given in Table 3.

Table 3. Effect of Rovral on root vigor and weight and on cutting weight.

	Percentage		
	Poor	Moderate	Good
Root vigor			
Untreated	4	76	20
Rovral on Insertion	12	24	64
Root weight	Grams		
Untreated	0.30	—	—
Rovral on Insertion	0.40	—	—
Cutting weight			
Untreated	0.74	—	—
Rovral on Insertion	1.17	—	—

Cost of Treatment (1 year plants)	**per 1000 plants**
Aaterra incorporated	£3.50
Rovral, 1.25% dust incorporated	1.00
Rovral drench — 3 week intervals, 14 treatments	2.50

CONCLUSIONS

1. Drenches every 3 weeks would be ideal.
2. Compost incorporation was very effective, especially after potting and before drenching programmes could commence.
3. Drenches, when combined with compost incorporation, gave excellent results.
4. Treatment of the propagation trays was very effective and resulted in superior plants for later potting on.
5. Trials work suggested that the volume of drenches could be reduced.

Recommendations. The Agriculture Department and Advisory Service (ADAS) is currently in discussion with the manufacturers of Rovral, who are interested in extended the recommendation of Rovral to include Ericas and Callunas as a label recommendation in the future.

THE ECONOMICS OF GRAFTING

BILL MATHEWS

Mill Race Nurseries, New Road, Aldham
Nr. Colchester, Essex

REASONS FOR GRAFTING

I am committed to grafting as a way of propagating plants because:

I worked in Boskoop for 2½ years and, during this time, I went to Sweden doing contract grafting roses for the glasshouse industry. The money I received for this work purchased the liners and stock plants which helped to start my business ten years ago.

It is ideal for the small nurseryman.

There is a need for a quick turnaround of plants.

I consider that grafted plants produce a better end product if handled properly in containers, i.e. grafted Viburnums are superior to Viburnums produced from cuttings.

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COSTS INVOLVED IN GRAFTING

Materials and labour		Cost range, pence/plant
Grafting stock		
handling on arrival (varies with type of stock)		10 to 20
trimming prior to potting (100 plants/40 minutes)		2 to 2
Potting		
pot		¾ to ¾
compost, laying out	machine potting 1300 plants/hour	1½ to 2
Empot trays at 26p (written off over 3 years)		½ to ½
Spraying		
weed and pest control — chemical £4, 2 hours at £5	£14	
Picking up ready to dry out		1 to 1
Collection of scions		
home produced, 5p		
purchased from Holland, 5 to 9p		5 to 9
Grafting		
preparation of stock — drying out		
trimming/heading back		6 to 7
grafting ties		
putting on to bench after grafting		
Aftercare		
airing, spraying water and fungicide, removal of dead material and suckers, hardening off after callusing		1 to 1
Removal to over-wintering quarters		1 to 1
Heading back, grading for potting, planting		2 to 2
	Totals	30½ to 46
Assumed loss, 30%; say 10p (14p) added to costs		10 to 14
		40 to 60
Assume 20% of grafting stock re-usable, subtract from costs		2 to 4
	Final total costs:	38 to 56

These costs can be compared with the following, taken from two French and one Dutch nursery catalogues:

		£
Cedrus atlantica 'Glauca'	12-20 cm	1.00
Chamaecyparis obtusa 'Nana'	8-12 cm	0.87
Viburnum × *carlcephalum*	2 year cutting	0.77
Hibiscus	1 year	0.51
	2 year	0.63
Cedrus atlantica 'Glauca'		1.09
Chamaecyparis obtusa 'Nana'		0.90
Viburnum × *carlcephalum*		0.86
Hibiscus		0.57
Corylus avellana 'Contorta'		1.09
Cedrus atlantica 'Glauca'	transplant	1.26
	graft	0.90
Chamaecyparis obtusa 'Nana'	transplant	1.08
	graft	0.82
Viburnum × *carlcephalum*	transplant	0.90
	graft	0.58
Hamamelis	transplant	2.16

It is the only way to successfully produce certain types of plants such as *Hamamelis* and *Picea pungens* 'Koster'.

I have committed 25% of my new propagation unit to bench grafting, an outlay of £12,000, therefore, in my case, grafting must be economical.

Is grafting economic? In short "Yes" — if handled by *production line techniques, because grafting is really living* carpentry, with a bit of know-how, which you learn rapidly after you lose a few pounds.

One further comment is that you must know your glasshouse or tunnel or frame before attempting any grafting.

To adopt production line techniques it is necessary to consider the following:

Minimize handling. Use Empot trays; plastic pots instead of clay pots; and shelved trolleys, enabling you to move 360 grafted plants at one time. Cover trolleys with polythene to make a tent, and to stop drying out before moving into grafting benches.

Planned work area. Have a sturdy bench and good seating, in good light but not in direct sunlight. Organize the grafting materials in front of you, and handle with trolleys or pallets.

Organization of work. Scions pre-collected or bought in and stored at +2°C. Potted stocks are headed back, pre-trimmed, and brought in on a trolley ready for the grafter. Scions are pre-prepared, i.e. cut ready for grafting. Materials are all put to hand — scions in an open bag in front of grafter, grafting strips/ties in a container and not spread all over the place. Stocks for grafting are on the left, empty tray on the right, scions and ties in the centre of the work position. A multi-shelved trolley is made into a tent for holding grafted plants in a turgid condition until the trolley is filled. Grafted plants are then put into a peat bed at an angle of 45°. One grafter needs one sweeper/learner to assist. The grafter must not move at all except for meal breaks. I expect him, after a period of two weeks, to have grafted a total of 20,000 plants, depending on cultivar and condition of stocks.

J. STANLEY: What are the indirect costs of grafting?

W. MATHEWS: The glasshouse cost £12,000 and I am writing it off over seven years. I reckon the indirect cost per plant is about 1p, if we do 20,000 grafts each year; that is, 140,000 grafts in the seven years.

B. RIGBY: What is the rate of pay for the Dutch grafters?

W. MATHEWS: £250 net per week; they work a long 11 hour day and we expect them to do 12 to 1500 grafts per day, so that all the grafting is completed in two to three weeks. We expect our own staff to do 50 grafts per hour.

WINTER PROTECTION AT YOUR NURSERY

DAVID HILL

Boningale Nurseries Ltd.

Holyhead Road, Boninghale, Albrighton, Wolverhampton

After spending 5 years in northeastern America, and with our experience in this country of the coldest winter on record, I decided it would be relevant to discuss methods of protecting plants used at two different nurseries in the U.S.A., and to discuss what we plan to do at our nursery in Boningale.

My first 3 years in the states were spent at Jim Wells Nursery as a student and then manager. The Wells Nursery was located 30 miles south of New York on the East Coast with temperatures ranging from 100°F (38°C) in July to −15°F (−26°C) in January and February. Wells specialized in growing rhododendrons and azaleas, which were subject to damage by the extreme cold if unprotected, therefore every precaution had to be taken to minimize the risk of damage.

The first thing Jim Wells did was to select a hardy range of rhododendrons and azaleas able to survive harsh East Coast winters. Rhododendrons he selected for their hardiness were the 'Iron Clad' group, including the cultivars English Roseum, Roseum Elegans, Nova Zembla and the Catawabiense cultivars — Catawabiense Album and Boursult. The deciduous azaleas chosen were the Exbury and Ilam groups: 'Gilbraltar', 'Balzac', 'Klondyke', 'Red Velvet' and 'Fireball'. The evergreen azaleas were chosen from the Kurume group — 'Hino Crimson', 'Polar Bear' and 'Lorna'. Although proven hardy cultivars, all these required some protection. The very first operation each year was to cover all the tunnels with 6 ml clear polythene (by December 10th). This was sprayed with paint to exclude strong sunlight and to reduce high temperature. Next, plants would be graded into selling sizes and containers moved up, pot-thick, leaving unsaleable plants on the two outer edges to give protection to saleable material. Plants were then well watered and the watering system drained down to the lowest point to prevent damage to pipes. Watering was then carried out when needed, each time draining the system completely afterwards. The polytunnels were closed top and bottom at both ends by a

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"stable door" arrangement. They were opened during the hottest part of the day to prevent a build-up of heat, which frequently occurred on days when temperatures would rise to 50°F (10°C) inside and be at freezing point outside. The major problem caused by this variance was that the compost in the container would freeze solid yet, at the same time, the plants would experience moisture loss due to high temperatures inside, with the roots unable to take up frozen moisture. To overcome this, watering was done at the warmest part of the day in the hope that some moisture would reach a thawed part of the root system and maintain plant turgidity. Often it would necessitate watering a tunnel for half an hour or more and, with the exception of the driest plants on the edges, it usually proved effective. During the winter of 1976/77 in one range of houses, the water pipes did freeze and we had to resort to dragging yards of hosepipe from the single mains tap to water the fifteen houses by hand. We did this three times in two weeks and it made the difference between saleable and frozen/burnt plants.

Liners were in litre pots in 150 × 21-ft (45.8 × 6.4m) double-skinned houses covered with two sheets of 6 ml U.V.I. polythene, kept apart by a small electric blower. This was advantageous in two ways — the polythene was kept taut and an insulation layer was formed. The houses were heated by forced air hot water heaters set at 32°F (0°C) at each end, plus a conventional fan placed on a table centrally in the house. This ensured that air was kept moving — important to prevent air freezing. All the fans were connected to the thermostat. The doors were covered with a layer of 6 ml polythene to increase insulation and burlap was packed against the bottom of the doors. Opening and closing of the doors at the right time was essential. Despite these precautions some stem split was encountered with the azaleas in the coldest years. All houses had alarms connected to the thermostats in case of boiler failure. Over evergreen azaleas an extra layer of 6 ml polythene was laid in the coldest months.

Field plants were pre-dug by December 1st and transferred to 50% shade wooden lathhouses, where they were well mulched in with leaf mulch. Plants were spaced so that the leaves of adjacent plants just touched, after which they were well watered with a low concentration liquid feed — 20:20:20, to retain a good colour throughout the winter. Finally, the lath panels were re-installed and a layer of 6 ml polythene placed all around the lower section to exclude freezing winds.

Constant checking of moisture content of the rootball was essential. In general, checks on all plants, in response to changing conditions, were very important to ensure that water

was applied at the correct time and ventilation of houses adjusted. These were the two most important measures.

Weather forecasts were obtained daily by phone by the person on duty that week, plus every tunnel was thoroughly inspected each Friday for holes, loose polythene or any other problems. The cutside of the propagation glasshouse was covered with a layer of 6 ml polythene to conserve heat and preclude draughts. Alarms and thermostats were normally checked weekly, daily in severe conditions. The boiler was checked visually every day and oil levels checked weekly by "rodding" the tanks. Rodent bait was put down to prevent another type of winter damage — as described further on.

My last two years in the states were spent in the propagation department of Weston Nurseries (located 250 miles northeast of Jim Wells' nursery) in Massachusetts, where winter temperatures were between −20°F (−29°C) to −30°F (−34°C). The frost depth averaged 3 ft, but in extreme conditions up to 5 ft (1.5 m), with an average of 3 to 4 ft (9 to 1.2 m) of snow. Weston Nurseries has 500 acres under cultivation with a wide range of landscape trees and shrubs including 500,000 containers on 5 acres.

The average age of saleable material was seven years. Before sale, plants were subjected to extremes of temperatures and other climatic conditions which therefore produced fully hardy stock. Protection was required from the liner size until plants were two to three years old. The containers were protected in 96-ft (29 m) by 14-ft (4.3 m) tunnels covered with two layers of 6 ml polythene, base layer being clear white polythene on top, nailed securely, with the covering completed by 14th December. All plants required this protection except the *Juniperus* species. Added protection was given by a thermal blanket laid over the top and sides of the containers after packing them in pot thick. Tunnels were ventilated daily when necessary by a door at either end. Container plants from the Garden Centre were stored in large barns on pallets on a huge shelving system during the winter, as were root-balled plants. Material for spring flower shows were stored the same way but in the most accessible position in the barn for early use. Once again, sufficient watering before storage was important in conjunction with regular checks. Using this method, drying out was not common as the barns remained dark and cool.

Pre-digging of *Kalmia*, *Pieris*, *Rhododendron*, and *Ilex* species was important to prevent wind burning, which made plants totally unsaleable. These were pre-dug and stored in all available barns, sheds, and garages in leaf mulch.

Liners planted out that year on a bed system were protected by a substantial layer of salt marsh hay, protecting roots, foliage, and stems. This was carried out every year before the onset of cold weather. If an early fall of snow arrived before this then covering was only done if a thaw occurred. After Christmas the nursery would buy up unsold cut Christmas trees locally and lay these on the windward side of plants in susceptible positions to provide additional protection against chilling winds. This was a cheap and effective method.

All potted liners were stored on shelves in relatively frost-free barns, watered, and checked regularly. Survival rate was good but liners had to be moved out at the beginning of spring to prevent rotting. Liners outside were heeled-in in frames and covered with saltmarsh hay. Rhododendron and azalea liners were in large polythene tunnels, similar to Jim Wells system.

All propagation glass houses were covered with a layer of 6 ml polythene for increased insulation, the polythene being kept away from the glass by a small electric blower which kept it tight so that snow would slide off. Along the sides of the propagation bench, near the heating pipes, were reflective galvanized foils to improve energy efficiency. Ventilation was by a polythene blower tube down the centre of the house to blow cold air in on high light intensive days when temperatures would reach 50°F (10°C). Draining of all outside pipes was undertaken and done before 1st December.

Rodent baits were very important in view of the hay used and was a routine operation annually. Winter conifer cuttings were pre-cut in the last week of November and stored in moist burlap bags and kept in a cool barn for final preparation in December. This prevented damage by low temperatures and gave instant "bad weather" work.

After my 5 years in the States I returned to work at Boningale Nurseries as Propagation and Liner Manager convinced I had seen the last of sub-zero temperatures and winter protection procedures. Then came last winter and once again it was "closing houses up tight and lining doors with polythene".

When it became apparent in mid-December that it was going to be a very cold winter we checked the water system and drained it completely after a thorough watering. All liners in the poly tunnels were covered with another layer of 2 ml polythene tucked in at the sides. This required pulling back each day when the temperatures rose, a repetitive job but it paid off in terms of high survival rate of liners inside the tunnels. Liners outside were protected by double layers of polythene and Serran Windbreak around the frame yard.

Losses were higher outside but were minimal in comparison with other growers on account of additional protection. We started daily checks of all houses and thermostats in the mist unit and rhododendron house. In the mist unit all cuttings were covered by a single layer of 2 ml polythene with all beds heated to 20°C to help raise the temperature of the house to just above freezing. When frosts of −15 to 20°C occurred we added another layer of polythene on top. Rooting of conifers was not too adversely affected. A large number of liners were saved by the extra covering and constant checking but our 3-litre plants suffered.

What can we do in preparation for future winters? Following are some ideas we plant to implement at Boningale:

1. To sell as many of the less hardy genera as possible by Christmas, e.g., *Ceanothus*, *Escallonia*, *Hebes*, *Senecio*, etc.

2. Remaining plants to be moved up, pot thick; saleable material protected by less readily saleable or taller plants.

3. Stock straw bales ready for use in the event of extreme temperatures.

4. More "choice" plants to be in poly tunnels, e.g. rhododendrons, azaleas, and camellias of all sizes.

5. Erect more windbreaks in and around the nursery.

6. Provide greater insulation in and around tunnels and propagation houses, e.g., a layer of polythene on mist house walls.

7. Daily maintenance and watering checks stepped up in adverse conditions.

8. Water system to be drained by 15th December (unless unusually mild).

9. Liners and rooted cuttings to be kept in polythene tunnels.

10. Make full use of all sources of weather information, e.g., local radio, farmer's forecast, Automatic Television Weather Service (A.T.W.S.), telephone services, plus Teltext.

MICROPROPAGATION IN NORTHWESTERN AMERICA

TED LEWIS

2, The Gallops, Green Mile Farm
Babworth, Retford, Notts.

This paper is a report of my trip to America using the 1981 Travel Award.

The aim of my trip was to look at some micropropagation being practiced commercially, and to make practical recommendations to British nurserymen interested in the technique. I also wanted to find out about any new knowledge in mycorrhizal relationships that could benefit the nursery trade in the U.K. While focusing on these two areas, I took the opportunity to visit some nurseries of more general interest, a chance not to be missed.

Undoubtedly rhododendrons are the most successful subject for micropropagation developed so far in the American northwest. Dr. Wilbur C. Anderson of the Northwestern Washington Research Unit at Mount Vernon estimates that at least 10% of rhododendron production in Washington State now is done by micropropagation. He has done a lot of research and development of rhododendron microculture and explained some of the practical problems to me. The majority of micropropagation work requires dexterity but is somewhat tedious and Dr. Anderson recommends having one qualified person of high calibre to run the laboratory, recruiting the rest of the laboratory staff from nursery workers already employed. This was certainly evident at the facilities I visited, where the tedious division of plantlets, the "cooking up" of culture media, and the delicate placing of plantlets on the media were all carried out by female staff trained in tissue culture on the nursery and without any previous experience.

Dr. Anderson also warned against over-investing capital. A very serviceable laboratory can be equipped without buying a lot of very expensive gadgets; for instance, an ordinary domestic washing machine and refrigerator, open shelving as used in offices or stores, and plain Formica work surfaces are all quite adequate. However, he suggested that it was well worth buying a really good autoclave and top quality chemical reagents.

A point that Dr. Anderson stressed was that of competitiveness; this seems to be the cornerstone of many American success stories. He saw this as a real stumbling block for micropropagation of rootstocks, which would have to compete with stooled stocks at 25¢ each; obviously the higher unit price of rhododendrons allows for higher production costs.

However, he estimated that problems of production that tend to raise costs should be overcome within 10 years, but that the solutions involved more than just tinkering with the ingredients of culture media, etc., and thus were too much for small commercial laboratories to tackle. Clearly, therefore, large scale research is still required, funded either by the government or a large firm.

In developing microculture of rhododendrons Dr. Anderson has been in close contact with Bruce Briggs, who propagates a large range of rhododendrons by tissue culture at his nursery at Olympia, Washington. Bruce has a standard tissue culture laboratory and uses the standard three phases of culture in vitro; multiplication, shoot growth, and root growth. Each phase has a different culture medium. When the plants are taken out of the laboratory they are treated rather as seedlings, being "pricked out", hardened off, and potted on as for conventionally raïsed plants.

Bruce is optimistic about the returns on his investment. One obvious advantage is that stockplants are no longer required, as material is taken from growing stock.

Another is that stocks of a new introduction can be rapidly bulked up from a small amount of plant material. While they are happy with results so far, Briggs Nursery has tried to extend their range of tissue-cultured plants to include ornamental plums, crabapples, and conifers but, so far, have not gone into production.

Briggs Nursery also has a water chlorination plant, which means that they do not have a problem with moss in their containers. In contrast, Clay's Nursery, Langley, British Columbia, do not chlorinate their water, and do have a moss problem. However, they find that Ronstar gives satisfactory control of this.

A more conspicuous difference at Clay's is that the tissue cultured plants are not rooted in vitro as at Briggs. Instead, rooting takes place in paper tubes using a peat-perlite medium. (Sand cannot be used in the medium due to soil requirements for export.) The tubes are placed in a polythene tent in a glasshouse. Humidity is controlled by conventional fine mist nozzles; temperature is controlled by a fan that brings cooled air into the tent. Air cooling is by an ingenious device similar in appearance to a car radiator, which contains circulating cold water which takes heat from air being drawn through it. Sterilization of benches is simple, as all benches in the glasshouse at Clay's are concrete and have the heating calbes embedded in them, giving a smooth surface for swabbing down. While Clay's mainly clone rhododendrons they also produce some

Kalmia, *Amelanchier*, *Photinia*, *Sequoia*, and *Hypericum*.

Different subjects again are microcultured by Microplant Nurseries of Gervais, Oregon; for example, *Malus* 'Royalty', *Betula* 'Dalecarlica', and 'Newport' plum. The laboratory is a sophisticated one, on the site of one of Oregon Rootstock's nurseries, and is funded by them, in partnership with McGill and Son of Fairview, Oregon, among others. Some material from Microplant is sent to McGills for growing on under glass and then in the field. McGills have found that plum plantlets grow away better after a cold period of about 3 weeks. They have tried tissue culture of Norway maple but, at the moment, have problems with rooting.

I got the impression that setting up the Microplant Laboratory has been costly, and that there was spare production capacity not being fully used. Gayle Suttle, the manager, said that they were looking hard for sales to recover funds to meeting running costs. I felt that this experience at Microplant backed up Dr. Anderson's advice to be very careful about costing a tissue culture unit before investing.

The British nursery stock trade can, therefore, learn this lesson from the American experience: Technically, tissue culture has great potential to become a major tool for our industry, but caution is needed. Before embarking on a microcultural program it must be proved to be competitive as investment of capital and time are considerable. For many plant subjects there are still problems to be overcome before they can be produced successfully in vitro, but there is a good prospect that solutions will be found, and found in the foreseeable future, say five or ten years.

SOME IMPRESSIONS OF CURRENT PROPAGATION AND PRODUCTION TECHNIQUES IN THE U.S.A.

JOHN EDMUNDS

Valeford, Bransford, Worcester

I hope by the time I finish I will have frightened you a little, because during my tours abroad in recent months I have become scared. I could begin with the story of a French micropropagation concern who propagated 500,000 M27 apple rootstocks, and when they were out in the field it was realized that there had been a swapping of flasks in the laboratory and they had 500,000 MM 106!

In the U.S.A. they have reached a stage of very considerable over-production. I could tell you about the American

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nursery stock industry in deep trouble, partly because of economics but partly because of over-production. In some cases the latter is due to micropropagation. An example is of ferns in 4 litre pots transported 7000 miles from Oregon to sell at 40p. There are twenty-one micropropagation units in Florida, many doing ferns.

I could tell of dumping of nursery stock. A large nursery is dumping daily. Well-trained pyracantha plants are being dumped to make way for younger stock, but the frames and containers are saved. I could frighten you with an account of one nursery with 1¼ million *Juniperus sabina* 'Tamariscifolia', and 1⅓ million *Picea glauca* 'Conica' 1 to 7 feet high, all on one nursery.

In Holland recently I met an American who intended to dominate the nursery stock industry. In the first 18 months he had planted 1200 acres of containers, and in the next five years aims to put in 14,000 acres.

Our natural advantage in the U.K. is proximity to our customers. I ask you to consider the story of A Y R chrysanthemums, where propagators have now moved abroad to areas of better light. I hope the same does not happen to nursery stock. One can be devil's advocate. I.P.P.S. has been a blessing to the nursery industry, but a disaster for some individuals who were specialists in propagating some difficult species. Knowledge has now been shared, so they no longer have a special advantage. The real danger on the horizon is micropropagation, so there will no longer be any difficult-to-root plants. We shall then have a system of costing our plants according to the production costs, rather than subsidizing the cheap plants by more difficult to propagate plants for which we can ask an over-economic price.

On the West coast of America I saw many micropropagation units. I saw two specialists in Washington and Oregon, and one specialist vine producer. In California I visited the Oki Nursery in Sacramento, who installed the first micropropagation unit with an initial annual output of two million plants, and it has been extended since then. I saw other more specialist units as I travelled down the U.S. West Coast. It seems many are aiming at one item; for example, Bruce Briggs with rhododendrons, and another down near Santa Barbara doing over a million staghorn ferns a year. With one exception the most successful are nurserymen, rather than people set up specially to do it. Many nurseries started in a small way. Bruce Briggs started in a kitchen and now has a commercial set up.

Micropropagation is a commercial technique and it will affect this business of ours. I checked the I.P.P.S. literature to

see what various Regions were doing with micropropagation. G.B.&I. has been lagging behind. In the Proceedings for 1978, 9 out of a total of 106 papers given in other Regional conferences were in micropropagation; for G.B.&I. the figure was nil in 15. In 1980 we had two papers on micropropagation in a total of 17; other Regions 9 out of 127. We have been falling behind and we must not.

In the July issue of the French equivalent of "The Grower", there are 16 advertisements for plants and seeds, and three are for micropropagated material. We must not be ostrich-like.

Micropropagation will save time in producing a plant. In the commercial bulking-up of rhododendrons it can save between 9 and 17 years. It means we can propagate rhododendrons like roses and roses like grass. We can now produce 200,000 rhododendrons of one cultivar to launch such a cultivar, with a potential of a million. The potential is there as it will be worthwhile promoting a cultivar and building up a marketing and selling organization.

There are a number of problems with micropropagation. I know in the Joint Consultative Organization we had considerable discussion on the possibility of genetic variation. The Americans agree that in a batch of 100,000 there may be a few dozen variable plants, but the same would happen with other methods. The methods might be slightly wrong, such as nutrition and hormones, but this would only be a small percentage. It could be a problem with timber trees, for example if a genetic defect was propagated and this did not become evident until after cutting for timber.

To quote from the 1979 edition of the I.P.P.S. Proceedings, Bruce Briggs did a lot to pioneer the technique and share his knowledge. He still does it on the cheap. I recommend reading another article in the same edition, which advises starting with simple equipment and building up. It seemed to me these were the people doing a successful job in the United States.

P. GAUT: How do you see the development in the U.K. with regard to specialist micropropagation laboratories for nurseries?

J. EDMONDS: I hope the nurserymen will do it themselves; if not the potential could come from abroad. There will be an enormous surplus in the U.S.A. and, perhaps, in France. We need to develop small units on nurseries and do it soon.

J. GAGGINI: What about the disease situation in micropropagation?

J. EDMONDS: It could be serious; there is every potential for disease, but development could overtake us. We need to get in and start now.

J. GAGGINI: A range of 20,000 kinds of plants can be grown in the U.K. and another 3 to 4000 imported. How will micropropagation units cope?

J. EDMONDS: There is a danger of over-production, as with hybrid rhododendrons in the U.S.A. We have reached this stage with common things in this country. I feel micropropagation could be used to develop new cultivars, with an opportunity to build up larger stock numbers for promotion of some lines with a guarantee of supply. It will alter the business for several plants.

J. COSTIN: Are those in the U.S.A. doing a range?

J. EDMONDS: Nurserymen are doing single lines or a small range.

P. BROOKING: Why do nurserymen do a better job than specialist propagators?

J. EDMONDS: I don't know.

R. MARTYR: Has Bruce Briggs got one blueprint formula for all cultivars of rhododendron?

J. EDMONDS: He varies the cytokinins, and has to find out the specific requirements for each cultivar. There is no rhyme or reason.

R. MARTYR: This might be difficult for small nurserymen specializing in one group but a large number of cultivars.

P. ALDERSON: There are differences in normal propagation so why the surprize.

D. GILBERT: There are tremendous facilities and resources in the U.K. and these ought to be recognized by the I.P.P.S. Long Ashton has recipes for woody ornamentals and these will be extended when the unit is moved to East Malling. There is enough scientific work going on in the U.K.

J. EDMONDS: I can't judge the scientific scene but, as a nurseryman, I know the commercial scene, and I want nurserymen to do something about it.

P. GAUT: Do American nurserymen do their own research and development?

J. EDMONDS: Bruce Briggs is an exceptional person. A number of people are spending money on graduates, who are doing work for two or three years.

C. KAYANGE: How does growth from tissue culture propagation compare to that from cuttings?

B. HUMPHREY: Rate of growth from tissue culture is faster.

P. ALDERSON: There is increased vigour in tissue cultured plants.

1982 G.B.&I. ROSE BOWL AWARD

The Rose Bowl, given to G.B.&I. in 1974 by the Eastern Region, is presented annually by the G.B.&I. President to someone who has made a special contribution to plant propagation. This year the award was made to Tom Wood, currently Secretary of the G.B.&I. Region.

Tom joined I.P.P.S. in 1974 and has always been a very active member, becoming Vice-President in 1978 and organizing an excellent conference at Bristol University. During his Presidency in 1979 the Region's varied range of activities were consolidated and our links with the International organization were further strengthened during his term as International Director in 1980-81. Tom took over the Secretariat on Bruce MacDonald's departure for Vancouver, British Columbia in 1980.

He trained at Kew Gardens and, on his return from Uganda in 1965, joined Oakover Nurseries in Kent, specializing in seedling production, a subject on which he is a recognized authority. He is a Governor of Hadlow College, which has a strong nursery stock department; he is involved in many aspects of the nursery industry and its promotion, hosting many groups of international visitors. In presenting the Rose Bowl, the President said that Tom's contribution to our knowledge of plant propagation epitomized the I.P.P.S. motto of "Seeking and Sharing", and it was a privilege to be allowed to present the Award to him this year.

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1982 G.B.&I. ROSE BOWL AWARD

The Rose Bowl, given to G.B.&I. in 1974 by the Eastern Region, is presented annually by the G.B.&I. President to someone who has made a special contribution to plant propagation. This year the award was made to Tom Wood, currently Secretary of the G.B.&I. Region.

Tom joined I.P.P.S. in 1974 and has always been a very active member, becoming Vice-President in 1978 and organizing an excellent conference at Bristol University. During his Presidency in 1979 the Region's varied range of activities were consolidated and our links with the International organization were further strengthened during his term as International Director in 1980-81. Tom took over the Secretariat on Bruce MacDonald's departure for Vancouver, British Columbia in 1980.

He trained at Kew Gardens and, on his return from Uganda in 1965, joined Oakover Nurseries in Kent, specializing in seedling production, a subject on which he is a recognized authority. He is a Governor of Hadlow College, which has a strong nursery stock department; he is involved in many aspects of the nursery industry and its promotion, hosting many groups of international visitors. In presenting the Rose Bowl, the President said that Tom's contribution to our knowledge of plant propagation epitomized the I.P.P.S. motto of "Seeking and Sharing", and it was a privilege to be allowed to present the Award to him this year.

PHIL PARVIN: Aloha. I am Phil Parvin, your Conference Chairman. It is a distinct pleasure to welcome the Western Region of the International Plant Propagators' Society to our fair island state of Hawaii. We sort of "hang loose" here in the Islands. We are rather informal and I think we fit in quite well with what I have seen of the International Plant Propagators over the years.

I would now like, first of all, to bring on our President, Stan Sorenson. Stan, would you open the meeting?

STAN SORENSON: Thank you. It is very nice to have you all here. Without further ado, we are now going to move right into the program. Phil Parvin will introduce the first speaker, Dr. William Theobald, Director of the Pacific Tropical Botanical Garden.

A TROPICAL GARDEN FOR THE NATION[1]

WILLIAM L. THEOBALD

Director, Pacific Tropical Botanical Garden
P.O. Box 340, Lawai, Kauai, Hawaii 96755

Over the past decade-and-a-half a little known garden has been developing in the Hawaiian Islands which is unique in its origin, mode of operation, and scope. It is the Pacific Tropical Botanical Garden; the only national, privately supported, tropical botanical garden chartered by Congress. The charter (P.O. 88-449) was granted on August 19, 1964 and gave the organization the following purposes:

a) to establish, develop, operate, and maintain for the benefit of the people of the United States an educational and scientific center in the form of a tropical botanical garden or gardens, together with such facilities as libraries, herbaria, laboratories, and museums which are appropriate and necessary for encouraging and conducting research in basic and applied tropical botany;

b) to foster and encourage fundamental research with respect to tropical plant life and to encourage research and study of the uses of tropical flora in agriculture, forestry, horticulture, medicine, and other sciences;

c) to disseminate through publications and other media the knowledge acquired at the gardens relative to basic and applied tropical botany;

d) to collect and cultivate tropical flora of every nature and origin and to preserve for the people of the United

[1] This an up-dated version of an article published in *Pacific Horticulture*, Summer 1980, entitled "The Nation's Tropical Garden".

States species of tropical plant life threatened with extinction;

e) to provide a beneficial facility which will contribute to the education, instruction, and recreation of the people of the United States.

Since its inception the Pacific Tropical Botanical Garden has been rapidly developing with these objectives in mind and it should become one of the most important centers in the world for the study of tropical plants.

The world's tropical and subtropical vegetation covers a vast area of the globe's surface from the equator north and south to approximately the Tropic of Cancer and the Tropic of Capricorn, respectively. Within this area are over 75 percent of the earth's plant species and many scientists have estimated that there are several times the known number yet to be discovered. Up until recently most botanical research has been concerned with plants of the temperate regions and the tropics and subtropics have been sorely neglected. Yet it is in these little-known regions that we have nature's greatest floristic and functional diversity.

In the tropical regions of the world live a large number of the world's peoples and it is among them that we have some of the most rapid increases in population. This rapid population increase has been accompanied by exploitive "cut and burn" methods of agricultural land clearing and with the destruction of forests for fuel. The latter has become even more prevalent in the past nine years because of the high cost of oil and the need for these countries to reduce imports. To the local needs for land and fuel have been added the demands of countries outside the tropics, where timber and other crops do not grow as rapidly or where certain minerals available in tropical areas are not found.

These same regions of the world have provided man with innumerable plants of benefit. These have included those of nutritional and medicinal value as well as those used for such things as timber, spice and shelter. Never to be forgotten are the vast numbers of plants yet undiscovered and those whose value remains unknown or unexploited. It is true that extinction is forever and efforts must be made to study those plants no matter how limited the studies may be compared to the vastness of the undertaking.

THE GARDEN'S DEVELOPMENT

Botanists and plant scientists have long felt the need for a tropical, botanical research garden within the United States. Most of the major tropical gardens of the world were devel-

oped in former colonial territories of European nations and today difficulties of access and unstable political situations have created the need for our own national tropical garden.

Hawaii provides the ideal location for such a garden. The island chain contains a number of extremely varied habitats with distinctive rainfall and temperature patterns over small areas. Great numbers of tropical and subtropical plants from many countries of the world can be grown and there is reasonable access for scientists from all areas and especially for those from the continental United States.

During the 1950s and 60s, the dedicated efforts of a great number of individuals and organizations, in Hawaii and elsewhere, led to a Congressional Charter being granted. A private, nonprofit corporation was founded and a Board of Trustees apponted to establish the Garden's programs. The initial generous financial support of the late Robert Allerton helped to make the organization a reality and in the late 60s a site was chosen in the Lawai Valley, Kauai. On January 1, 1970, Dr. William Stewart, the Garden's first director and his wife Maria, symbolically turned the first shovelful of soil to start the Garden and on January 30, 1971, the Garden's first temporary headquarters was officially dedicated.

Today the Garden is guided by a distinguished national Board of Trustees, a series of International Scientific Advisory Committees, and a dedicated staff. Although Congressionally chartered, the Garden is privately supported through the contributions of individuals, foundations and corporations. Over 800 people are now members and the Garden needs and welcomes the help of all.

The 186 acre site of the Garden is of great natural beauty and is being developed into a center for research, education, and the living collections. The staff now operates from this headquarters complex but plans have been prepared for a greatly expanded facility on the west side of the valley. The first increment of the new complex consists of laboratories for staff and visiting scientists and is now complete. The Garden recently received a challenge grant of $200,000 from the Kresge Foundation towards the one million needed for the completion of the second increment (Administrative offices, Library, and Herbarium) and landscaping at the site.

At present the Garden maintains two satellite gardens. Kahanu Gardens (120 acres) near Hana, Maui, is the center of ethnobotanical plants and breadfruit, coconut, and loulu palm collections. It also has on its grounds the largest ancient Hawaiian place of worship, the Piilanihale Heiau, a National Historical Landmark.

On the northern coast of Kauai there is a magnificent new satellite Garden and Preserve in the Limahuli Valley (1,000 acres). This lush area contains many newly discovered rare native Hawaiian plants and a portion of it will be developed to contain collections of ethnobotanical, economic, medicinal and other plants of interest. This site complements the Headquarters Garden at Lawai by providing ideal conditions for plants needing more moisture.

The Garden is fortunate to have the use of an office and laboratory on Oahu through the courtesy of the Department of Botany, University of Hawaii. Preserves on Maui and the island of Hawaii are maintained to conserve areas containing rare and endangered species. Hawaii has the greatest number (over 800) of acknowledged rare and endangered species of any place in the world and the Garden is ideally situated to work towards their study and preservation.

LIVING COLLECTIONS

The living collections are among the most important aspects of the Garden's development. The vast array of tropical plants to be grown will include representatives from many groups. Special collections being developed include: Plants of Nutritional Value; Plants of Ethnobotanical Interest; Plants of Medicinal Value; Rare and Endangered Species in need of Conservation; Plants of Unexploited Potential; Tropical Fruits; Spices; as well as Special Groups such as palms, erythrinas, gingers, breadfruit, coconut, taro, aroids, banana, vanilla and tropical ornamentals.

Seeds, cuttings or living plants of approximately 1000 species are accessioned each year. These plants come from all areas of the world and the Garden encourages plantsmen from throughout the world to send their material. All of the information concerning each accession is kept on computer records and each plant is given a number when planted at any of the Garden's sites. Records can then be kept on every plant of every species for use by any persons interested in that particular plant. Several thousand specimens have already been planted and they represent a wide range of species. A program is being developed whereby the magnificent tropical species of the genus *Erythina*, which are not cold hardy, will be hybridized with those grown on the U.S. West Coast with the object of producing new horticultural hybrids for use elsewhere.

GARDEN PROGRAMS

Research. One of the Garden's major roles is to serve as a center for the study of tropical plants. Plans have been drawn for the construction of an extensive laboratory, library, and

herbarium complex for use by staff and visiting scientists and part of this is now completed. A consortium of U.S. universities and institutions is being formed to help make the Garden a truly national center for tropical research. In view of the unique nature of the Hawaiian flora, the Garden plans to undertake the sponsorship of a new floristic study of the islands with the cooperation of scientists from throughout the world.

Education. As part of the Garden's developing role in education, several programs have been initiated which appeal to groups of all ages. A 9-month Professional Gardeners' Training Program in Tropical Botany and Horticulture is offered to post-high school students from throughout the United States and abroad. The apprentices receive two hours of daily instruction followed by six hours of paid work experience on the Garden's grounds. During the summer there are Summer Internship Programs for college and university students interested in working in a tropical garden. In addition, there are public lectures, publications of general interest, and guided tours.

Publications. The Garden has a publications program which, although primarily oriented towards the scientist, also contains items of general interest. These include: *Allertonia, A Series of Occasional Papers; The Flora of Fiji*; a new edition of *Hawaii: A Natural History*, by Dr. Sherwin Carlquist; A Memoir Series; Rock's *Indigenous Trees of the Hawaiian Islands; Coastal Flowers of the Pacific Islands*, by Dr. Arthur Whistler; and pamphlets on various subjects.

Na Lima Kokua (Helping Hands). A volunteer organization serves as an integral and vital part of the Garden's operations. These dedicated individuals give freely of their time as tour guides, hosts and hostesses, and Garden helpers. Their annual plant sale is a major island event. In addition they have published a series of recipe books (breadfruit, taro and coconut) and have printed and prepared various types of notepaper.

ALLERTON GARDENS

No discussion of the Pacific Tropical Botanical Garden would be complete without mention of these gardens. The Allertons' private 100-acre estate at Lawai-Kai is a tropical garden of great beauty and tranquility. It was started by Queen Emma, wife of Kamahameha IV, in the 1870s and has been greatly expanded over the past 40 years by the late Robert Allerton and his son John. The grounds contain numerous plants of interest, outstanding examples of garden design, and Queen Emma's original summer cottage. Higher up the Lawai Valley behind the Pacific Tropical Botanical Garden there is

an additional garden area known as Three Springs. Both Lawai-Kai and the latter will one day become part of the Pacific Tropical Botanical Gardens.

When joined with the Allerton Gardens the Pacific Garden will consist of some 450 acres, with the main area devoted to research and education and the Allerton Gardens to beauty and garden design. In order to preserve the bay, research studies will also include marine plants. The Garden will then extend from below sea level through the Lawai Valley back for over 1½ miles. It will truly become a great garden for a great nation.

A HISTORY OF IPPS MEMBER SHARING

RALPH B. SHUGERT
John Zelenka Evergreen Nursery
Grand Haven, Michigan 49417

For the benefit of the guests in the audience this morning, the motto of the IPPS is "To Seek and To Share", and all members adhere to this creed. In discussing any topic, the origin is always quite fascinating. When one reviews the Proceedings of the first Plant Propagators' Society, held on November 8-9, 1951, in Cleveland, Ohio, there are some interesting words presented by several important people relative to the formation of our Society. Words which the late Ed Scanlon wrote are certainly appropriate today. I particularly enjoyed one sentence in his opening statement, "no man should ever entertain the thought that he is omnipotent". This, of course, was one man's view of the interchange of ideas which has made this Society the success that it is today.

Several people showed a tremendous amount of foresight in those early years of the 1950's. For example, the committee which was apointed to draw up the Constitution and By-Laws, consisted of three scientists, three nurserymen, and three active plant propagators. With us today at this meeting is a gentleman who was appointed to that committee; he is none other than our illustrious International Secretary-Treasurer, William Snyder. Bill Snyder, in 1951 through today, has certainly shared with all IPPS members.

Another gentleman, well known to all of us, was extremely active in not only the philosophy of the Eastern Region but later instrumental in the regional and chapter development which we have today. That gentleman was the first speaker of the formal program on November 8, 1951, speaking on the

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topic, "The Plant Propagator — the Basis of Our Industry"; he was, of course, James S. Wells. Many comments which Jim Wells stated on that November snowy day in Cleveland, was the importance of the plant propagator as a professional and definitely as a craftsman within our industry. Jim was very strong in those days on using the word Guild and, in fact, he suggested that a Guild of Plant Propagators be established following the century-old Guild organizations in Europe. I would dare say that Jim's United Kingdom background allowed the word Guild to flow smoothly from his lips. One point he mentioned throughout his talk was this: requirements for full membership, after a practical experience period and a high standard of integrity, are a "ready willingness to freely share knowledge and skills with other members". So here in the early days of the Society, we have two gentlemen who were saying the same thing but in different words.

The founding of the Western Region is a history within itself. For the edification of our new members and guests, and to recall pleasant memories of the older members of the Society, a committee was appointed from the Eastern Region and that committee met at Asilomar, California on October 14, 15, and 16, in 1960, being the organizational meeting of what would become the Western Region of the IPPS. At that organizational meeting, there were about 150 people in attendance and, I am sure, that several people in the room this morning fondly recall that organizational meeting. Again, we had a keynote address at that meeting by a gentleman previously mentioned, Jim Wells. Dick Fillmore chaired this Eastern Region committee and, in his words, "We can give you the benefit of 10 years of very successful experience in operating an organization of this kind." He later added a comment, "They, however, can do more for us than we can do for them." My good friends, again, throughout all of the background words and philosophy in the founding of our various regions and chapters, our motto comes forward loud and clear — "To Seek and To Share".

In preparing these words, for this 22nd Annual Meeting of the Western Region, I reread all of the words from our Proceedings which was the first Combined Proceedings of the East and West. It is interesting to reread those words and observe names of members who were appointed to various committees. Again, it would be folly to mention all of the names, but it is fitting that the chairman of the organizational committee, who later became the first president of the Western Region was Don Hartman, who worked hard and diligently in putting together all of the infinite details to form an organization of this magnitude. Also one reads of questions from

members as to how the two Regions were going to work together, what was going to formulate the founding of the International Society as we know it today, and there was much wisdom in all of the discussion which came forth at Asilomar.

It is also interesting to read of another name, a gentleman who has been extremely active and beneficial to this Society over the years. In the summer of 1958, several members living in the West contacted various people to explore the feasibility of establishing a Western Region. One of the most active people in this endeavor was Hudson Hartmann, who, of course, today is our International Editor, and a man that has given much to this Society.

I have often reflected that we all are extremely fortunate to have the total guidance of a Hartmann and a Snyder, sitting on the International Board, offering their wise words of counsel as new International Board members take their position to serve the Society above their Regional affiliation.

It is interesting if one reads all of the words from the first meeting of the Society in 1951, and then read the keynote address given on Saturday morning, October 15, 1960, by James Wells. The title for the two papers was identical, "The Plant Propagator — The Basis of Our Industry". Jim Wells' words were well received, and most certainly filled with the philosophy of a gentleman who definitely has the Society at heart and is warmly genuine with his comments. He closed his address with a sentence, "We should follow your development with keen attention, wishing you well in every way, and hoping that your activities can further enhance on mutual desire to establish and maintain the plant propagator as a craftsman of the highest order." It is difficult to put those thoughts in any finer form.

One final comment is in order relative to the October, 1960, meeting, in words which I could never forget. Dick Fillmore in his opening remarks at Asilomar made this comment, "The Plant Propagators' Society has meant a great lessening of professional loneliness." Dick Fillmore was making the point that prior to the founding of the Society, there was indeed considerable professional loneliness throughout the entire nursery trade. Not only has the Society eliminated this loneliness, but the Society was very instrumental throughout the United States in removing locks from greenhouse doors. Again, for the benefit of the younger members, the locks were not on the doors to guard against theft, but to guard against the theft of propagation techniques. It is almost uncomprehensible to think that such a condition existed, but I have personally seen locks on greenhouse doors, and I am sure others in the

room have witnessed the same phenomenon. A mutual feeling of professional people sharing, and we are back again to the motto of the Society, aren't we?

In reviewing my Historian's files, it is interesting to read the minutes of the 1966 meeting of the IPPS Board, held at Anaheim, California. The International president of the Society at that time was our own Bill Curtis, and he instructed the Secretary, Bill Snyder, to write a letter to James S. Wells, in reply to Jim's inquiry concerning the Board's attitude towards foreign chapters. This is the first record I have of a formal approach to the founding of foreign regions. The Board directed Bill Snyder to draft the letter and that the responsibility of such a Region formation would rest entirely upon the foreign members of the Society in the interest they could generate in the various geographic areas.

From that period on, the Region of Great Britain and Ireland was indeed established, and they held their first meeting on September 18, 1968. The keynote address at their first annual meeting of this region was given by a familiar name, James Wells. At the second meeting, on September 12, 1969, IPPS International President, Pete Vermeulen, was present to sit in the business meeting, as well as the formal program which followed. It was at this meeting that some of the "loose ends" were tied together and it is now history that the G.B.&I. Region is strong and active. It would be folly to mention all of the names of members who were active in the founding of this Region, but names such as Garner, Humphrey, McDonald, Evison, Martyr, and Clark should receive recognition. I hestiate to mention names due to the possibility of missing those members who are worthy of noting, but I believe all would agree that this nucleus of members did, indeed, bring this Region into reality.

The G.B.&I. annual meeting in 1973, had the International Board of Directors in attendance, as well as a total of about 140 overseas members, wives, and other family members who attended the annual meeting, as well as the pre- and post-Conference tours. This was, for all of us present, an outstanding visit and certainly did strengthen the ties separated by a large body of water. It was also at this meeting that Robert Garner was issued Honorary Membership. In rereading the International Board minutes of this 1973 meeting, it is interesting to note that the considerable effort of James S. Wells to establish both the New Zealand and Australian groups was acknowledged with gratitude by all officers and Board of Directors. Today we are honored to see Ray Evison, our International President, and Margaret Scott the Regional Director from G.B.&I. in the attendance with us.

Following the calendar in the growth and development of our Society, on September 26, 1972, a group of plant propagators met at the University of Waikato, in Hamilton, New Zealand, to discuss the formation of a chapter of the Society in that country. Again, the move to start this chapter was initiated by Jim Wells, and the inaugural meeting was carried out by Ellaby Martin and Ron Lycette. Jim Wells explained the philosophy behind the IPPS and contributed to that meeting by showing slides and explaining some techniques of propagation conducted at his own nursery. This Chapter-at-Large, will conduct its 11th Annual Meeting in 1982, and is a viable arm of the International organization. Terry Hatch is their representative attending the 1982 International Board Meeting.

The Australian Region had its inaugural meeting in New South Wales, and Jack Pike gave the opening remarks on behalf of the Federation of Australian Nurserymen, an organization which at that time he chaired. As Jack mentioned in his opening remarks, the history of horticulture in Australia did not have the longevity of that either in the United States or in their mother land of England, and he was very appreciative of the gesture by Jim Wells to again give a keynote address. Jim's title at the Australian Inaugural meeting was, "The Plant Propagator Holds The Future In His Hands". Needless to say, Jim's words were listened to with great attention. He delivered his address with the concept that he had great hopes that the Australian members would help themselves. The purpose of the IPPS was to put all of us in touch with people interested in plant propagation everywhere. He again stressed a philosophy which the present International Board believes in, that each Region or Chapter-at-Large will run their own affairs and meetings, but the stimulus of new ideas from all over the world will give all of us a formula for success which is unbeatable. I am sure that Peter Smith, who is the Director from the Australian Region to the International Board, and Terry Hatch, who is the representative from the New Zealand Chapter, present with us today, fondly look back on the founding of their respective organizations as an important part of the entire International Society.

Those same comments would certainly be applicable to the gentlemen who are present with us today, from the newest Region of the Society. The Southern Region today is represented by the International Vice-President, Charlie Parkerson, Regional Director Jake Tinga, and Alternate Director, David Byers. Charlie Parkerson, who was a loyal hard-working member of the Eastern Region, along with other members living below the Mason-Dixon line, was instrumental in the founding of the Southern Region. The Southern Region held its inaugu-

ral meeting in December 1976, in Mobile, Alabama. There were two devoted IPPS members who shared the keynote comments at this meeting. Bill Curtis, from Oregon, and Jim Wells, from New Jersey. Both these gentlemen have served this Society well and they are certainly dedicated members. The remarks of both these gentlemen were to explain the background and the history of the Society, and they were ably assisted by Bill Snyder, who also was a guest at this meeting. The presentations at their first and second meetings are printed in the Combined Proceedings, Volume 27, dated 1977. The Southern Region is growing rapidly; the International Board met with them at Huntsville, Alabama, in 1980.

We have seen the Society's history in a brief summary of the founding of Regions and Chapters-at-Large. The agenda for the International Board Meetings for the past 4 to 5 years has shown interest from other propagators throughout the world, as to the establishment of a Region in their locale. Hours of deliberation and counsel have gone forth to these interested parties and, in fact, such a topic was on the agenda of the International Board meeting yesterday.

Our Society is strong and viable due, in part, to a blend of the academic and the commercial member. Each benefits the other for obvious reasons. We practicing propagators need the results of testing and experimental work done in various university laboratories. The scientist member needs the application of his or her research conducted in the field under commercial practices. The one key to the success of our beloved Society is member sharing. So we have come 360 degrees around again to our motto, "To Seek and To Share".

Pertinent to this topic, Henry David Thoreau, writing in 1854, said as well as anyone possibly could: "I wish to live life deliberately. I wish to learn if life proves mean, why then to get the whole and genuine meanness of it; or if life were sublime, to know it by experience". That, ladies and gentlemen, is the International Plant Propagators' Society creed in words written long before the development of the Society. We all share one common goal — by bettering ourselves, we enrich all mankind.

PLANT PROPAGATION FROM A UTILIZATION VIEWPOINT

JOHN A. WOTT

Center for Urban Horticulture, AR-10
University of Washington
Seattle, Washington 98195

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ronment. Even though these environmental concerns have fluctuated along with the reorientation to our economic and resource management issues, the concern for our environment continues into the 1980's. Let's begin by thinking about the changes which have affected the horticulture "world" (6).

First, we have witnessed a return to home fruit and vegetable production. This interest has helped to spawn such organizations as "Gardens for All" and the new "American Community Gardening Association". Then too, land for parks and "green areas" for everyday enjoyment is now a commonly accepted part of community and residential planning.

Those of us who work with the public have witnessed the almost overwhelming demand for information on the selection, use, and maintenance of plants in our everyday lives. Plant societies, many with specific plant identities, have appeared in large numbers.

Never before have Americans bought and used more bedding plants for summer color. Today we see a renewed interest in perennial flowers, as well as a concern for low maintenance landscaping. Also the rapid growth of suburbs and business complexes has created a demand for landscape architects who can design a more pleasing atmosphere in which we live and work.

We are all aware of the tremendous growth in our nursery production industries, many of which now produce thousands of identical plants in efficient complexes. Once planted, there developed the need for maintenance companies to keep these landscapes esthetically and functionally alive. Many municipalities, e.g., Seattle, have hundreds of maintenance companies ranging in size from "one-man, one-truck" operations to large sophisticated companies.

Urban Horticulture. One of the newest changes in horticulture is the number of academic and public institutions which are creating programs called "urban horticulture." It is described by Harold B. Tukey (5) in remarks at the XXI International Horticultural Congress in Hamburg, West Germany.

> "A new science of horticulutre — Urban Horticulture — is emerging spontaneously in many parts of the world. It is concerned with research and education on the functional uses of plants to maintain and enhance urban areas. Whereas most horticultural departments and institutes emphasize production of horticulture plants and products, urban horticulture is concerned with the problems of those who utilized landscape plants."

Since an increasing number of people will be living together in more confined areas, the science of urban horticul-

ture will have implications that will affect most aspects of production horticulture; thus, urban horticulture will need to concern itself with plants for beauty and ornamentation as well as functional use. For example, the science must consider which plants are suitable for screens against wind, headlights, and unpleasant views (3). Which plants will reduce noise and air pollution? Which plants can be grown for both esthetic and culinary purposes? Are some plants more suitable for improving the human psyche in densely populated areas? Thus, the urban horticulturist will be seeking plants based on their specific useability.

In most modern departments of horticulture, the research deals with relatively few economic crops. Furthermore, little research has been conducted on the large number of landscape plants. There has been even less research on how these plants grow in landscape situations. It's interesting to note that academic institutions such as the University of Washington, as well as botanical gardens such as the New York Botanical Garden, have both recently established urban horticulture programs.

In urban horticulture programs, some emphasis will be placed on traditional-type research and teaching. But a vital part of these programs will be the mechanism to disseminate appropriate information to the people who will utilize as well as produce the appropriate plants. The flow of information must be a "two-way" street, aimed at the producer and consumer at similar times. It makes no sense to recommend a plant, only to find it is not available in the nursery trade. Likewise, it's not economically feasible to grow a plant which will not sell.

Much of the research in urban horticulture departments may differ from that now used in production agriculture. In production agriculture, uniform plants of a single cultivar are grown in large numbers in controlled conditions. This provides plants of similar size, flowering, and harvest time so that efficient production systems can be determined. This has been the mechanism by which our large nurseries now grow.

But in urban settings, plants are grown alone or in small groups in constantly changing environments. Many garden plots may contain over 100 species. In these sites, research on individual species is virtually impossible with conventional techniques. However, the computer modeling technique for individual plant growth may prove to be the method by which plant growth and response can be predicted for urban environments.

Plant Materials and Breeding. One of the most important

areas of concern in urban horticulture will be plant materials and breeding, where the plants will be studied for their beauty and function (4). This will include the traditional areas of horticultural taxonomy, plant collection and dissemination of new introductions, and plant evaluation. But in urban landscapes more attention will be given to cultivars and botanical varieties than to species. This will help to organize the myriad of "introduced" plants now offered to the gardening pubic.

We must also recognize the importance of amateur horticulturists who collect and often breed new cultivars. The trained taxonomist is needed to study and categorize these plants so they can be introduced, successfully classified, then propagated and used in the urban areas.

The increasing need for specific landscape materials will also cause landscape architects to need further assistance in selecting landscape plants to fit more defined requirements such as color, texture, form, size, low maintenance, pest resistance, and tolerance of environmental conditions. Again, the computer-age with its databased management systems may be of utmost help in categorizing what we already know or will need to know about plants in order to quickly select appropriate plants for design.

The Plant Propagator. What are the implications for the production industry, or more specifically, what are the implications for the plant propagator? First, we have noted that urban plants must be esthetically pleasing. Artisans and knowledgeable horticulturists have long extolled the enriching and therapeutic virtues of plants. The time has arrived when horticulturists will combine forces with the psychologist, the artist, and the landscape architect to quantify in scientific terms the total effect plants have on humans.

For example, horticultural therapists use plants in rehabilitation programs for the physically and mentally ill. Growing plants has a positive effect on social interactions in ghettos and prisons. Also, initial studies show lower absenteeism in offices with plants. Thus, a landscape design of the future may list the therapeutic requirements of the plant along with its seasonal and cultural requirements. This entire aspect of plant acceptance is almost totally unexplored. For the propagator, he or she will be asked to propagate those plants which have therapeutic value.

Esthetically Pleasing Plants. Along with the therapeutic considerations of the plant is its general esthetic appearance. The weird and often grotesque characteristics which graft incompatibilities form are often esthetically displeasing. For example, the rootstock used on certain flowering Japanese cher-

ries often outgrows the scion. As the public becomes more sophisticated in its knowledge and taste, they will be more critical of such plant growth habits. This means that if we desire to continue the use of the scion cultivar, we must find a more satisfactory, probably self-rooting method, for its propagation and subsequent growth in the urban environment.

Graft Incompatibilities. Another problem arising from the use of grafts is the long-term stability of the graft union. Trees used in the urban environment must meet the rigors of the people-pressure syndrome. For example, can the tree (or shrub) withstand the constant "tugging" on its branches by children? We are all familiar with the desirable new cultivars of *Acer rubrum*. Esthetically, they are marvelous. However, from the useability viewpoint, the eventual breakdown of the graft union limits their use in an urban planting. Will propagators need to produce it on its own roots?

Environmental Conditions. The environmental conditions within the city limits are composed of many microclimates. For example, the city of Seattle is built on many hills, hedged between Puget Sound and the Cascade Mountains and sheltered by the Olympic Mountain range. Add to this already complicated natural environment the man-made buildings, tunnels, and roads. Thus, the number of microclimates in this city becomes even more complicated.

Research will eventually tell us the best plants for even these many varied microclimates. In order to do this, we will need to return to a larger base of plant materials, selected from many seed sources. A flowering dogwood in a specific city microclimate may need to be from a specific geographic seed source. This may explain why dogwoods from southern collection sources may survive on south, protected slopes, but will suffer damage on north or higher slope elevations.

In the urban environment, plants will be selected to meet very specific growing conditions. As William Flemer III recently indicated in *The American Nurseryman* (2), the following are some of the concerns for environmental selections:

1. the width of the mature tree, and more specifically, the crown area,
2. the root space needed to support the crown growth,
3. how to maintain proper soil oxygen levels in heavy compacted traffic areas,
4. tolerance to de-icing salts and other soil/plant applied pollutants,
5. plant selection of size and type to avoid vandalism and urban destruction,

6. protection of trunks from people and their "mechanical toys",
7. tolerance of utility lines, construction, repairs, and
8. tolerance of air pollutants, and temperature-light effects.

Narrow Selection Base. As indicated, one of the greatest concerns for the urban horticulturist is the narrowing selection base for plant materials. In a survey published in 1981, James Clark (1) contacted 12 large nurseries about their shade tree production. Between 1960 and 1985, the average number of trees produced will increase by 109%. However, the percentage of the trees produced by seed will decrease from 41% to 29%. Clearly there is a steady trend away from seed propagation. In red maple, for example, 80% of those grown in 1985 will be of six genotypes.

This trend away from seed propagation will narrow the genetic base of material left to us for selection and use in landscape planings. How many of us in our nurseries have actually increased the number of cultivars of a specific plant available over the last decade? Probably not many. This means that the genetic base of plant material kept at the many arboreta, botanical gardens, or even amateur enthusiasts will be of even greater importance to urban plantings in the future.

In urban areas where trees may already be stressed, foreign organisms may cause devastation. Consider the implication of the Dutch Elm disease. In most cities, city arborists are now advocating the planting of many different kinds of street trees rather than avenues and avenues of the same kind of tree.

Modern Technology-Efficiency. The trend away from seed propagation has arisen because improved cultural techniques and research results have facilitated the use of asexual propagation methods such as grafting, cuttings, and most recently, tissue culture as a propagation tool. Equally, the demand for specific desirable clonal cultivars has stimulated interest in these asexual propagation methods. Our industry has basically been concerned with the ease of propagating, i.e., the best (or the least expensive) method for putting roots on a plant. We have generally streamlined our production facilities to handle thousands of a limited number of kinds of plants. In contrast, in the future, plants used in the urban environment will also be selected for their useability. The challenge for all of us is how to use the commonly accepted methods of propagation to produce the desirable plants for urban environments.

Monitoring of Modern Methods. As with the long-term desirability of grafted plants, so too will continued testing be needed on all forms of modern propagation, specifically on

tissue-cultured plants. We hope that after years of growth in the urban environment plants produced through tissue culture techniques won't "break apart" like some graft unions.

Plant Quality. The user of plant material is very much concerned about the quality of the plant materials which are propagated, grown on, then sold to them in the trade. A general survey of plants sold still shows too many plants with "curled" roots, too many pot-bound plants, and too many which are improperly pruned. If each of us is doing the proper job of propagating and producing plants, then why does the biggest loss of plants occur when they change hands from the retailer to the customer? Is it all the fault of consumers mishandling them? I think not!

CONCLUSIONS

Propagation from a utilization viewpoint will necessitate that we again move into other areas of plant selection in order to widen our base of plant availability. This implies then that attention will again be focused in greater depth on producing "difficult-to-root" types which have largely been eliminated from most plant propagation operations. True, the total number of these plants which will be needed may be small, but it will necessitate the re-establishment of specialist producers. Thus, there will be a need for producers who will produce large numbers of a limited number of kinds of plants, and also smaller producers who will produce a smaller number of a larger variety.

In addition, we will also need to develop superior trees and shrubs through selection and breeding, so the advantages we desire in a conal cultivar can be incorporated into a seed-producing plant.

Growing plants or gardening is one of the safety valves of society, particularly in the pressure atmosphere of modern cities. The basis of gardening in urban areas includes knowledge about plant selection, culture, pests, maintenance, and ecology. As people are increasingly crowded into dense clusters, the need for understanding growth of plants within cities and the effects of these plants on human beings becomes critical.

Thus, the plant propagator will need to concern his/herself with providing plants that are suitable for the people-pressure urban areas. The modern propagator will consider not only the rootability of the plant but also its useability. In urban areas the useability is fast becoming a very important factor in plant propagation and selection.

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SETTING OBJECTIVES IN A PLANT PROPAGATION COURSE

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One educational principle is that learning is a function of perseverance, time, and teaching. The first component, perseverance is largely a personal characteristic of the learner as modified by his personal experiences and motivation. The second component, time, can be a limiting factor both when there is too little time or when there is too much (procrastination). This factor is elastic in that we can modify it.

The teaching component is complex. Whole curricula are based on the development of teachers. There are many aspects which must be studied, and the application of education theory to educating students is a practical result.

In agriculture, and specifically horticulture, we do not teach in formats designed by professional educators. Our methods follow a basic lecture and laboratory format and only occasionally do we reach out for different ways of doing things. Our clients in industry (= employers), on the other hand, are bombarded with new concepts: zero based budgets, management by objectives, systems analysis, etc. The feedback we receive from them is often contradictory to what we "educators" perceive as necessary in our product, the student.

How should we cope with the multitude of needs as perceived by us, by the employers, or by the student?

Those who have studied the processes of learning tell us, not unreasonably, that people learn best when they know

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Those who have studied the processes of learning tell us, not unreasonably, that people learn best when they know

what they are supposed to learn about. In other words, we ask, what are the objectives in a given learning situation?

Our plant propagation courses function at different levels: What to do; How to do it; Why we do it; not to mention, Where and When. At each of these levels, objectives can be specified to make a task identifiable and the outcomes of performance measurable.

Almost anyone long involved in plant propagation would say that to be both proficient and efficient at making cuttings, for instance, requires a lot of practice. How much practice is enough? Is an appropriate objective that a student make 100, or 600, or 1600 cuttings? Should a time limit be imposed? Do we need to specify just how the cuttings should be collected, handled, and prepared for sticking in the propagation bed? Is it necessary to understand the difference between terminal and stem piece cuttings, or the effects of polarity on rooting?

The more we analyze the task, the more concerns we have about organizing a correct approach to teaching it. Education is notorious for ambiguity, while the "real world" functions by knowing how to measure its product, and the efficiency with which it was produced — the good old "Bottom Line."

Looking back at our instruction problem — teaching the student to make cuttings — we find a greater need to define what we are attempting to do. One very good approach is to ask, "What should the student be able to do after completing the exercise?" The answer to this question can be rephrased as an objective.

Possible statements of objectives:

1. The student shall produce 100 terminal cuttings of oleander.
2. The student will collect and prepare 100 terminal cuttings of oleander.
3. During a two-hour laboratory, the student will collect plant material from stock plants of oleander and prepare 100 terminal cuttings.
4. During a two-hour laboratory, the student will collect plant material from stock plants of white oleander, cut the terminals to 5-inch lengths, remove leaves from the bottom 3 inches, and dip the base into a prepared rooting hormone to produce 100 uniform cuttings.

As we examine the statements, the "Do what?" question is fairly obvious for all 4, increasing in specificity from 1 to 4. However, the conditions under which the student will work are lacking in statements 1 and 2 while we are aware of a time constraint in 3 and 4. Between 1 and 4 there is also a clarifica-

tion of the performance level we are seeking, from "produce 100 cuttings" to a description of which oleander (the white one), how long a cutting (5 inches), what preparation (terminals, basal leaf removal, rooting hormone treatment), and importantly, that the resulting product be 100 uniform cuttings (measurable component of the objective).

The statements could go into greater detail, and statement 4 may be more of a set of directions than an objective. Still, careful statement of an objective based on *outcome* of the exercise should have three elements: The performance required of the student, the conditions under which this performance takes place, and the minimum acceptable level of performance. This last is the measurable component of the task.

This all seems simple enough except that we have really only thought the problems through on one level, the "hands on" level. If all we want is a technician to produce hundreds of uniform cuttings, these statements may suffice in designing a laboratory exercise in plant propagation by means of cuttings.

The choice of verb is important to the wording of the objective and to our understanding of how "deep" we want to go.

Mechanical aptitude can be expressed by verbs such as cut, strip, remove, trim, prepare, collect, etc. Some of these require sub-skills. Basically, however, they do not require much more than *doing*. One has to be careful at this level not to put in an excessive amount of time developing instructional units for simple manipulative tasks.

Do we really want to teach only HOW to make cuttings? At our university level we do not have the facilities and the time to turn out efficient practitioners of the art of making cuttings. Thus, a major part of our effort is devoted to giving the students an understanding of why certain tasks are performed. For this, objectives are established which require *knowledge*, and these objectives will use verbs which reflect the complexity of use of this knowledge.

Some objectives may relate to memory and recall: to *know* and be able to *label* the parts of a plant, to *identify* the cambial zone, to *list* the procedures for making cuttings, to *recognize* an axillary bud.

More advanced objectives require comprehension and the ability to inter-relate concepts: to *distinguish* between wounding and scarifying, to *explain* polarity of shoots, to *give examples* of practices which minimize desiccation, to *compare* mist and high humidity systems.

When students begin to associate complex ideas and to analyze and synthesize new patterns of ideas, high level objectives can be constructed: to *interpret* the results of a rooting experiment, to *relate* a plant's physiological status to its ability to root, to *integrate* principles and practices into a system for pathogen-free production.

This last part overlaps with skills which we would like to see our students develop in the area of organization. The emphasis is on comparing, relating, and synthesizing concepts, resolving conflicts, and organizing or developing systems. For example, objectives might require that the student *develop* year around schedules for propagation to keep a propagation area full, or *create* a flow chart for nursery operations or *identify* the bottlenecks to maximum productivity.

Whether we are setting forth tasks for students or for employees in a nursery, we can do a better job by asking ourselves whether our objectives are clearly stated and if they are formulated at the appropriate level of generality. Careful wording is necessary, and it is helpful to have others read the statements we prepare as a check on the meanings we think we have tried to communicate.

A checklist for evaluating objective statements may include the following points:

1. Select and state the desired learning outcome while taking into account such questions as:
   a. What is the importance of students possessing this skill or knowledge?
   b. What does the student know already about this task? Or, what does he have to learn for entry at this level?
   c. What are the desired competencies in this area?
2. In your statement, is the desired outcome clear and unambiguous?
3. Is the minimum acceptable performance required of the student stated?
4. Is there a means for measuring accomplishment of the goal?
5. Limitations which may be imposed are stated.
   a. If time or space limits attainment of the goal, can the task be sub-divided into logical major parts and reworked as separate objectives?
   b. If the task is too small or too simple, can it be fitted into a larger concept and associated with related ideas?

AN APPROACH TO PLANT PROPAGATION

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Every generation has a need to state things in its own way. Let us look at some examples: "It is well, in fact it is necessary, that the seasons be considered (for grafting and budding) in which new growths are generally made, namely fall, spring, and the period of the Dog Star." Describe time by the Dog Star, and you are not in the 20th century of scientific writing unless you are an astronomer. "The following is a good method of grafting olives, figs, pears, or apples: Cut the end of the branch you are going to graft, slope it a bit so that the water will run off, and in cutting be careful not to tear the bark. Get a hard stick and sharpen the end and split a Greek willow. Mix clay or chalk, a little sand and cattle dung, and knead them thoroughly so as to make a very sticky mass." This description goes on to state how the bark grafting is done and how to protect the newly made graft from rain and cold. Because of the unique substance used to seal the graft, you know this is not 20th century writing. "In Italy, a widely used method is to bark graft small seedlings (of olive) in the nursery row in the spring. The stocks are cut off several inches above ground, and one small scion is inserted in each seedling, followed by tying and waxing." This last quote is more like the terminology of modern day.

The first quote comes from Robert E. Dengler's translation of Theophrastus: De Causis Planitarium, Book I. The second quote is from Marcus Porcius Cato On Agriculture, written around 160 BC. The last is from the third edition of *Plant Propagation* by Hartmann and Kester.

These quotes point out that even with technological development, a lot about plant propagation has remained constant. Instead of cattle dung and clay, we use beeswax and resin or asphalt and water. Instead of split Greek willow for tying the graft, we use rubber bands or plastic ties or sticky tape. Yet the method for bark grafting has not changed much. "Take your split willow and tie it around the cut branch to keep the bark from splitting. When you have done this, drive the sharpened stick between the bark and the wood two fingertips deep. Then, take your shoot, whatever variety you wish to graft, and sharpen the end obliquely for a distance of two fingertips; take out the dry stick which you have driven in and drive in the shoot you wish to graft. Fit bark to bark, and drive it in to the end of the slope. Wrap the Greek willow thicker,

smear the stock with the kneaded mixture three fingers deep . . ." In 160 BC, this is the way they grafted olives in the spring in Italy. How different is it from the procedures used today?

If procedures have remained fairly constant, aside from exchanging beeswax for cattle dung, what has changed over the centuries? We like to think that we have a more fundamental understanding about plants and plant propagation and that we can describe the phenomenons in chemical and physical mathematical terms, that we can put our formulas and numbers into computers and analyze complex relationships, that we can use the marvels of microprocessors to monitor environments and control processes and that we more fully understand the relationships of seemingly isolated occurrences.

The Holistic Approach. Each generation likes to think that it is applying the latest technology and that it is considering holistically all of the ramifications of the separate processes. In the main, each generation is.

The system approach is an holistic approach. By examining the relationships, we will concentrate on those areas where improvements will have large payoffs. It will also help to understand why different systems are essential.

The payoffs — where are they and why? First, we must consider how we are to judge payoff. This leads one to answering the question — why are you propagating plants?

To expand our understanding in chemical or mathematical terms and write a paper about it is payoff to the scientist. It means we look for an interesting or intriguing phenomena to study and describe. For example, crown gall bacteria causes proliferation of undifferentiated cells. What are the chemicals and how do they act? Can this information be used to increase callus growth for propagation by tissue culture? Here we are involved with information to more fully understand the biological system involved in plant propagation.

On the other hand, if we are studying plant propagation because our livelihood depends upon profit from it, then the system involves biological, human, mechanical, and environmental considerations. The payoffs would be in terms of dollar returns and profitability. Rearranging work stations may have a larger payoff then instituting a procedure that increases rooting percentage by a small number. Controlled atmosphere storage of rooted cuttings or seedlings may be more profitable than increasing the size of the propagation facilities. Rather than studying a biological phenomena alone, we study the man, machine, and biological interactions.

Developing New Systems. Analyzing a system and developing replacements is one of the great values of a systems approach. By this, I refer not to simply replacing cattle dung with beeswax, but rather to developing an entirely new system. Take field budding of roses — there must be a better way, and there is. True, each plant must be handled one at a time, and each plant will probably be handled by a human with mechanical aids. But there is a better way than squatting or lying in the hot sun hour after hour and hoping that nature does not play tricks.

The commercially used procedure goes somewhat as follows:

1. Stock blocks may be maintained for understock and for the budwood. This is especially true where virus-free plant materials are used. Otherwise, the necessary cuttings are harvested from plants to be dug for market.

2. Understock is harvested in the late fall. Canes are cut to lengths and the lower buds are removed. Fungicide and other chemical treatments are applied.

3. Understock is stored under refrigeration until they are lined out in the field during the winter.

4. Meanwhile, budwood is collected, treated, wrapped in moist newspaper, and stored at slightly below freezing.

5. Understock is irrigated as necessary.

6. In the late spring, the budding process begins. Budwood is removed from the storage as needed, and the budder inserts each bud, one at a time, into the understock. The buds are tied in by the budder or by another person.

7. Water, fertilizer, and other cultural practices are applied on a continuing basis.

8. Once callusing has occurred, various steps such as bending over the top of the understock are undertaken. The exact step depends upon the type of rose being produced. By type, we refer to greenhouse started eye, two-year garden roses, etc.

Is there another way to arrive at the same end point — a #1 rose plant ready for the world gardens? The system developed must take into consideration these necessary parts:

1. An understock and a scion must be joined by some grafting or budding procedure.

2. Optimum yield of #1 roses is necessary.

3. Costs must be such that the profitability is equal to or better than the present system.

4. People must be able to control the system.

5. Suitable machinery is available or can be developed.

Some possible systems suggest themselves — they should be developed:

Possible System 1. Dormant scion buds are chip-budded upon dormant understock. Suitable machinery can be used. These are then placed through a series of physical environments to effect healing of the bud union and initiation of roots in the understock.

A few years ago, Don Luvisi, a Farm Advisor in Kern County, California, and I chip-budded dormant rose scion buds on rose understock. These were coated with grafting wax, then lined out in the field. Some of these buds took and grew into budded plants.

Possible System 2. Rather then chip bud, one-eye scions and grafting machines might be used. These grafts then would be subjected to various environments for union to occur and for rooting to be initiated.

This system is applying the information on propagation of grapes to another crop. It should be relatively simple to make the procedure pay off handsomely.

Possible System 3. Understock and scion stock plants are maintained in controlled environment conditions, i.e. greenhouse, so that vegetative growth can be maintained around the year. The buds or grafts are made each day — possibly microbudding, or some similar procedure can be used. Callusing of the graft and initiation of roots is stimulated. The grafts are then stored in controlled atmosphere storage until all are transplanted (lined out) into the field. Lining out occurs during one optimum period.

There are other possible systems to explore. These alternative systems maintain the essential parts, remove much of the chance element, and put the work into more pleasant surroundings. These descriptions are in broad strokes — many details must be inserted, investigated, and many procedures must be tested and adapted. However, the process comes into focus — the area where payoff would be greatest begins to appear. For example, of the three possible alternative systems, I am drawn to the third because the work load is spread out over the year, permitting maintenance of a capable staff. The other suggested systems require a lot of concentrated effort in the winter when harvesting, packaging, and shipping stretches the management ability of the company to the limit.

Many possibilities begin to appear as we anticipate problems and develop alternative solutions. Perhaps the understock and the budwood should be stored until after the ship-

ping season. Still the work could be highly seasonal, but it overcomes the major problem of too many important tasks all at once.

Could understock and budwood be stored all year and taken out for budding and callusing, then returned to storage to be then lined out all at the same time?

A lot has remained constant, until now. As long as we continue to make grafts or buds outdoors or to stick cuttings into rooting media, not much will change over the years. However, an holistic approach and a lot will change. Propagation by tissue culture is a good example. Other examples will come. We have just begun ----.

THE DEVELOPMENT OF FOAM PROPAGATING SYSTEMS

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INTRODUCTION

Propagating systems continue to evolve from the introduction of Jiffy-Pots in 1954 (1). These and other peat pots are made in round and square shapes, in a range of sizes for the propagation and growing on of individual units. Propagators familar with peat properties find few difficulties in growing plants in these biodegradable units and buyers like the concept of planting pot and all. While others less familar with peat technology, encounter difficulties in watering procedures and observe restricted root development. We see the "wicking action" problem when plants are set a bit high in the final container. Individual peat pots tend to fall over on the propagation bench. They are difficult to efficiently handle during packing and shipping processes.

The buyer of plants rooted in these pots must also deal with single units which can be difficult for him to manage. From the individual peat pot or plastic pot we see the development of Jiffy-Strips and a whole array of vacuum-formed plastic "packs". These thin walled plastic "packs" are low cost and adequately do the job for the propagator. They allow for multiple unit handling, ease of handling during propagation and packing, but getting a rooted plant to the customer in one piece can still be a shipping problem.

POLYSTYRENE FOAM TRAYS

The California Rooting Tray developed by Paul Ecke Poinsettias in the early 1970's was a further improvement in low

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POLYSTYRENE FOAM TRAYS

The California Rooting Tray developed by Paul Ecke Poinsettias in the early 1970's was a further improvement in low

cost, multiple unit handling, ease of handling system concept (2). This polystyrene foam tray was molded from the same commercial egg container material we see in grocery stores. Each tray was 16 in. in length, 1½ in. tall, and 1 in. wide. Cross protrusions divided the tray into nine cavities. A top closure was designed into the tray to reduce the likelihood of soil mix and plants from falling out of the tray during air or truck shipment. The primary objective of Paul Ecke Ranch is to ship high quality rooted plants to buyers and have these plants arrive in excellent condition.

Propagation benches at Paul Ecke Ranch are actually wooden framed beds of peat plus sand. These were used for the rooting of cuttings which are dug and shipped as bare-rooted plants. Beds were and still are dibbléd to hold cuttings for callused cutting production. These benches require pasteurization through steaming every 9 to 11 day cycle of callused cutting production, an energy and labor intensive sanitation measure. The California Rooting Tray propagation system reduced this need because benches were covered with new 1 mil poly film between each cycle. Furrows made into the sand plus peat beds gave added support to the California Rooting Trays which during the last week of each propagation period became unstable as plants grew in height. Rooted plants also required overhead watering and these furrows helped to support the trays.

California Rooting Trays were loaded into wire frames and mechanically filled with a soil, peat, sawdust, and perlite propagation mix. Filled trays came off the conveyor belt, were loaded on flat bed trucks, and taken to propagation houses.

In propagation the trays were spaced in the furrows. The trays were watered overhead to settle the propagation mix in the cavities and make dibbling possible. Best results occurred when cuttings were placed in dibbled holes and not watered in until callus formation had occurred.

The California Rooting Tray system of propagation and shipping yielded acceptable high quality rooted plants, but variability in plant growth and continued shipping problems were persistent. Variations in soil mix quantities within each cavity during the propagation cycle contributed to rooting and plant growth differences. Changes in peat, sawdust, and perlite physical characteristics and blending techniques made significant changes in the propagating mix characteristics. Variations in these ingredients added to the nonuniformity of mix during the year which paralleled growth differences. Plants continued to root in the lower half of each cavity. Loose soil mix did spill out during shipping. Plants could also become dislodged dur-

ing transport. Printed labels and arrows to direct handlers to keep loaded shipping cartons upright help, but do not eliminate this on-going problem. A very different approach to the production of rooted poinsettia plants for shipment throughout the United States was needed.

PHENOLIC FOAM STRIPS

The Smithers Company, the leader in floral foam technology and manufacturing capability recognized this need. Researchers developed a phenolic foam product #0903 from the regular Oasis Floral Foam which is too closed cell for propagation work (4). Water is taken up, but no exchange occurs. A balance of open and closed cells govern saturation and drainage which gives proper moisture levels for rooting. To achieve this balance in #0903, some foam cell membranes were left intact. A wide range of drainage possibilities were evaluated before determining 26 to 38% drainage by weight was best. Low pH was increased to 5.5 to 6.0 by adding neutralizing salts during the foaming process. The strength of product #0903 was evaluated from a heavy-walled cell structural foam that would not receive a cutting, to a very fine structure that would not support a cutting. After drainage, pH and strength characteristics were determined for the product, numerous growth trials were performed to determine size and shape of the propagating unit.

Foam strips 16 in. in length were cut with varying widths (¾ in., 1 in., 1½ in.) and heights (1 in., 1¼ in., 1½ in., 2 in.). Initially holes on 1¾ in. centers were made by punching the foam units with a sharpened pencil or dowel before settling upon ⅜ in. holes, punched to within ½ in. of the bottom of the strip, the lower ½ in. of each hole tapered to nothing. To facilitate breaking apart each plant, scores were made between units approximately ½ in. into the surface of the strip.

Growth trials were performed to determine callus initiation, root development, watering requirements, holding time on bench, shipping weight, and transplanting success before deciding upon a strip 16 in. long, 1 in. wide and 1½ in. high. Handling of these strips after plants had rooted proved difficult because the water heavy foam broke apart too easily. Therefore a 0.080″ thick liner was designed from the egg carton polystyrene foam to act as a sleeve for the strip. The liner was secured around the strip by a brass staple. Growing tests with or without the sleeve/liner showed that cuttings in strips with liners rooted ahead of those without.

These trials also indicated a need to leach or flush the neutralizing salts from the foam prior to sticking cuttings, otherwise basal stem injury occurred. Fungicide drenches

were tested and were found to cause basal injury at the recommended rates. Additional tests at The Ohio State University indicated that poinsettia cuttings stuck in Rootcubes® will root faster and better when no fungicide is applied. Applications of all fungicides caused an inhibition of rooting. The extent of rooting inhibition varied among the four fungicide treatments examined (3).

During the development of the phenolic foam growing medium, many of the earlier practices associated with the use of California Rooting Trays were incorporated to improve plant handling. Since foam strips were placed in the plastic lined furrows and the benches were sloped, a furrow irrigation system for watering the rooted plants was developed. Fertilizer solution trickled into the beginning of each furrow could flow along the furrow and through the foam. This eliminated individual strip overhead hand watering. Packing frames were designed so workers could efficiently load entire groups of rooted plants in an upside down manner. This facilitated placing the carton over the plants without breaking the plants. Alternative packing methods have since been devised where workers gather up strips of plants in the plastic liners of each shipping carton. The entire group of plants is gently dropped into the shipping carton.

In 1976 Paul Ecke Poinsettias adopted Oasis® Rootcubes® Growing Medium for the propagation of all rooted plants for shipping to customers as well as in-house stock plantings. The Strip and Liner system allows for the efficient annual production of several million plants at the Paul Ecke Ranch. Besides meeting the objective of getting a rooted poinsettia plant to the customer in one piece, the use of Oasis® Rootcubes® Growing Medium reduces the need for stockpiling soil mix ingredients, preparing soil mixes, pasteurizing mix and beds, and drenching with fungicides. It speeds clean-up operations after each propagation cycle.

Since the commercial introduction of Oasis® Rootcubes® Growing Medium in 1976 by The Smithers Company, propagators of poinsettias throughout the United States have adapted this growing medium system to their greenhouse propagation needs. Continued development of phenolic foam into other shapes and sizes has occurred to meet the needs of other propagators, propagators of chrysanthemums, geraniums, foliage plants, and woody ornamentals who require consistent uniform results.

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FUEL ECONOMY IN THE PROPAGATION BENCH

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Efford Experimental Horticulture Station (EHS) is part of the Ministry of Agriculture Fisheries and Food's Agricultural Advisory and Development Service and has responsibility for work with propagation and container production of hardy nursery stock. Work on propagation has been in progress for 4 years and has considered aspects of fuel economy, improving speed of rooting, and maintenance of cutting quality. The scope of this paper reviews the work aimed at reducing electricity fuel costs for heat-assisted winter propagation. Economy measures investigated can be categorised under four headings:

1. Efficient heat control.
2. Efficient heat transfer to rooting medium.
3. Reduction of heat loss.
4. Plant requirements.

EFFICIENT HEAT CONTROL

Most nursery stock is propagated in trays stood on the heated base; the important temperature to consider is that at the base of the cutting within the rooting medium. The advent of electronic controllers with probes which can be inserted into the rooting medium has provided a more accurate means of control than rod thermostats which can only control from a fixed point in the sand base. Optional temperature read-out scales linked into the electronic system provides an important, easily monitored, temperature check. Where rod thermostats are used compost temperatures need checking by thermometers inserted into the tray, and the thermostat must always be covered by a tray, otherwise temperatures will be very different from those desired.

EFFICIENT HEAT TRANSFER

Usually there is no problem in achieving the required temperature in the rooting medium, but efficiency of heat

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transfer from the base can markedly influence fuel usage. The greater the contact of the rooting medium with the heated base the less heat required to maintain a given temperature, and the most efficient system was by use of cell pack units. However, these take up more space than trays; reasonable results can be obtained with standard polypropylene seed trays, though their performance could have been improved by increasing size and number of holes in the base.

REDUCTION OF HEAT LOSS

The three major areas of heat loss are: into the surrounding air, from the base of the bed, and from the structure itself. The comparative work on these aspects was undertaken in unheated polythene clad tunnels with ground level heated propagating beds.

Propagation under polythene covers. Propagation under low polythene covers provides a major fuel economy measure for winter propagation, since the necessity to continually heat cold mist applications is avoided. Work at Luddington EHS (1) demonstrated that during an August/September period, for every 100 units of heat used by a misting system, only 36 were required under a polythene cover. At Efford EHS the polythene (38μ) is supported just above foliage height by hoops across the bed, allowing easier management for regular inspections (Figure 1). Clear polythene is used in the winter, changing to opaque white, with shading as necessary with increasing light intensities. A routine fungicide programme at 10 to 14 day intervals, together with removal of plant debris, maintains health status.

Bed Insulation. Insulation of beds using sheets of expanded polystyrene has produced significant savings in fuel consumption. The sheets are either wrapped or sealed in polythene to prevent loss of efficiency from water logging; it is also important to line sides and ends of beds as well as the base, since 10 to 15% heat can be lost here from narrow beds (1.25m). Results given in Table 1 show fuel savings achieved at different thicknesses of insulation, with the potential of 50% economy from a 50 mm thickness, which is now the general recommendation. However, on narrow beds, reducing to 25 mm on the sides and ends will avoid too great a loss of effective bed area.

Poor drainage of insulated beds is avoided by cambering the polystyrene sheeting on ground level beds (Figure 1), allowing drainage from the edges. Benching is more difficult and polystyrene sheets must not be fitted in too tightly so water can drain between the sheets. Additionally, a drilled alkathene pipe laid on top of the polystyrene has provided excellent

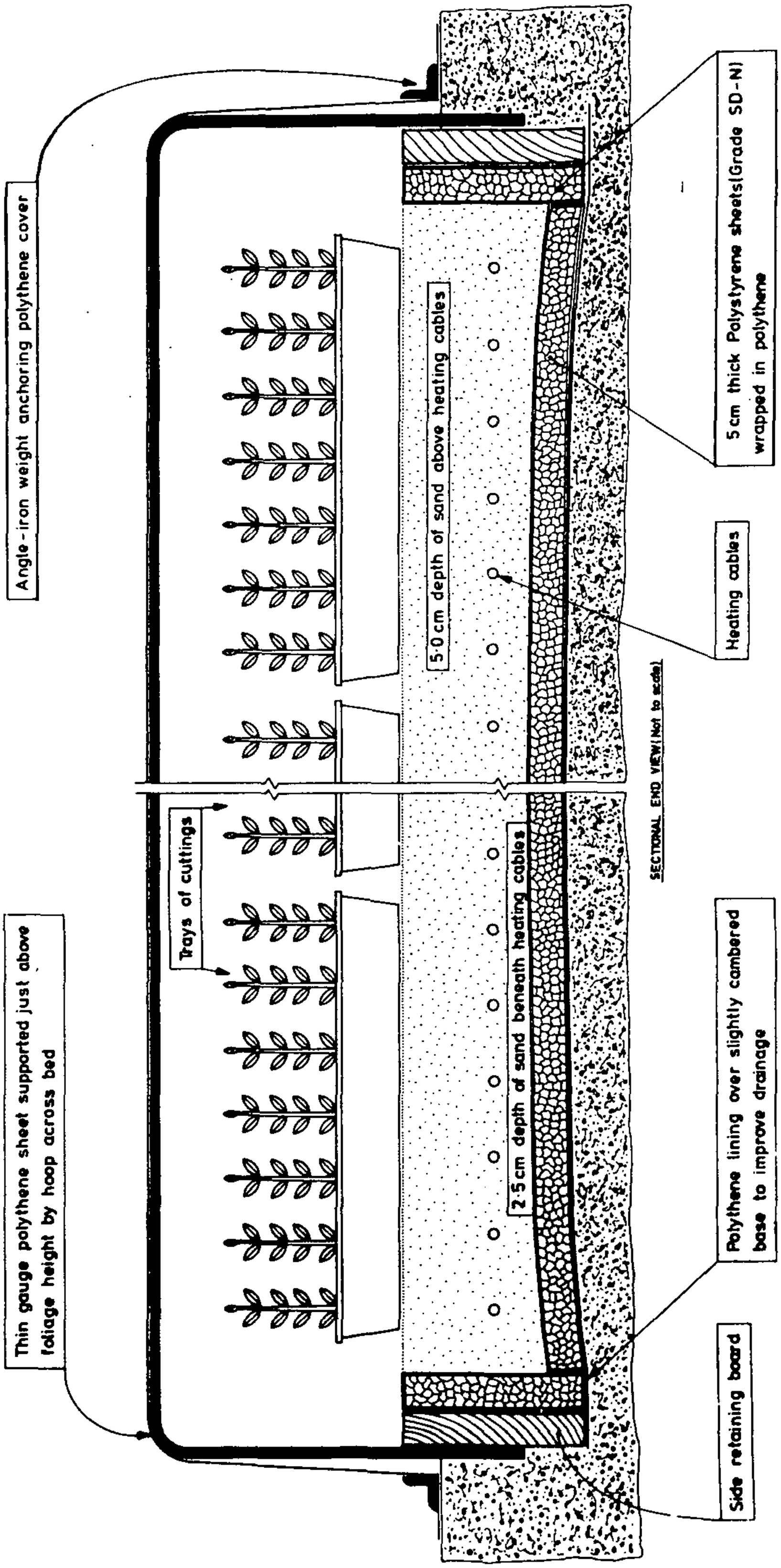

Figure 1. Insulated propagation bed

Table 1. Effects of bed insulation on electricity consumption.

Insulation (polystyrene sheets)	Electricity used kwh/day/m^2	Percent saving over uninsulated bed
1979 (March-April)		
Single Clad Tunnel		
Uninsulated bed	1.2	—
25mm insulation, base only	0.8	32%
25mm insulation base, ends and sides	0.5	49
50mm insulation, base only	0.7	42
1980/81 (Nov-Jan)		
Double Clad Tunnel	2.03	—
Uninsulated bed		
25mm insulation base, ends and sides	1.35	34
50mm insulation base, ends and sides	0.97	53

drainage from 75 mm of sand above. Covering the polystyrene and drain pipe with a layer of fabric (capillary matting) has prevented escape of the sand.

Use of Thermal Covers. Having minimised heat loss from the base of the bed, further fuel savings can be achieved by use of thermal covers over the bed to reduce loss to the air. Both an aluminised polyster cover, which has to be removed during the day, and a bubble polythene (Pillosol) left on permanently, have been compared over beds already insulated with 50mm polystyrene sheeting. Use of the bubble polythene gave the potential for a further 15% fuel savings, while the aluminised polyster cover over the clear polythene cover at night produced a 10% saving (Table 2). There is concern, however, that light levels may be becoming limiting for some species under the bubble polythene and further trials are in progress to monitor rooting response of a range of species.

Table 2. Effects of thermal covers on electricity consumption under a double clad polythene structure. (All beds have 50mm polystyrene sheet insulation)

	Single clear polythene	Bubble polythene	Single clear polythene + Aluminised Polyster sheet (night)
Electricity used, Dec-Apr. (kWh/day/m^2-1981/82)	0.94	0.75	0.83
Percent saving over clear polythene cover	—	15%	9%

The economics of thermal covers needs careful consideration, the fuel saving needing to more than compensate for their costs, although their useful life should extend over several seasons.

Reduction of Heat Loss from Structures. A structure used very successfully at Efford for propagation has been an unheated 4.25 × 14m tunnel clad with two sheets of 500g (125μ) polythene sheeting blown apart by a small fan sited in the middle of the tunnel. Using air from within the tunnel minimises internal condensation since it collects mainly on the colder interface of the outer sheet, running to the base inside the air gap. Since the structure is by no means air tight, consisting of sheeting merely wrapped round lath and nailed to a base batten, water escapes easily. Our original covers are now in their fourth season of use and stand up particularly well in wind gales, the air between the sheets merely displacing from one area to another, preventing their buffeting against the hoops as happens on the single clad structures.

The insulating air gap has provided up to 5°C frost protection compared with a single clad structure, as well as reducing fuel consumption in the propagation beds by up to 30%.

Table 3. Electricity consumption under single and double clad polythene tunnels (beds lined with 50mm polystyrene sheeting)

	Single clad tunnel	Double clad tunnel
Electricity used in beds, Dec-Apr. (kWh/day/m^2-1981/82)	1.33	0.94
Percent saving over single clad tunnel	—	29%

The extra sheet cuts out a further 15% light and while this has not affected rooting at Efford, where winter light is reasonable, it could be a consideration further north. In this situation the mobile thermal screen developed for tunnels by the Lee Valley E.H.S. (2) could be worth considering since it could be drawn back on its internal hooping during the day.

PLANT REQUIREMENTS

The work presented so far has been concerned with ways of reducing energy consumption while maintaining a "standard" compost temperature (18°C). However, running concurrently with this work were detailed environmental studies to determine air and base temperature requirements for propagation of a range of species and their effects on electricity consumption. These trials were in compartmented glasshouses on insulated benching. Over the four year period, cuttings taken in December have been rooted under low polythene covers. Results for the four years follow a similar pattern and are discussed in respect to plant requirements for air and compost temperatures and duration of the base heat.

Air Temperatures. Providing propagation is under polythene covers, air temperatures can be reduced to a minimum

with no apparent adverse effect on rooting. In fact, results indicated that better rooting was achieved at a 5°C air minimum compared with 10°C and, in 1980/81 and 1981/82, equally good results were achieved where the only heat input was for "frost protection." (Table 4). While costs of heating the bench increase at the lower air temperature, theoretical calculations suggest that cost of actually heating the house would be greater than the extra cost involved in heating the bench.

Table 4. Percent rooting at different air temperatures. The base (compost) temperature was 15°C.

	1980		1981			1982	
Air Temperature	5°C	10°C	"Cold"	5°C	"Cold"	5°C
Hypericum calycinum	96%	96%	89%	87%	—	—
Pyracantha 'Orange Glow'	90	84	—	—	87%	98%
Elaeagnus pungens 'Maculata'	—	—	—	—	98	100
Chamaecyparis pisifera 'Boulevard'	71	48	98	93	100	100
Camellia 'Donation'	90	91	91	98	100	84
Units of electricity used /m^2 (averaged over all species)	81	34	88	72	88	71

Compost Temperatures. Results over the four years have shown conclusively that high compost temperatures of 18 to 21°C are unnecessary for successful rooting of a wide range of species and could, in fact, adversely affect rooting of some (Table 5). In addition, quality of rooting of some species was reduced at the higher temperatures which led to poorer establishment and early growth on potting (*Hypericum*, conifers). *Botrytis* was a greater problem at the higher temperatures. In general, a compost temperature between 12 and 15°C appeared suitable for most species and cost less than half that required to maintain the 18 to 21°C regime. Whether heat assistance is necessary has been questioned and results showed that, as

Table 5. Effects of compost temperature on rooting percentage. (1980 — *minimum* 5°C *air*; 1981 *and* 1982 — *air only "frost-protected"*)

	1980		1981			1982			
Compost Temperature	15°C	21°C	Cold	15°C	18°C	Cold	12°C	15°C	18°C
Hypericum calycinum	96	93	91	89	100	71	98	87	97
Pyracantha 'Orange Glow'	90	71	—	—	—	—	—	—	—
Elaeagnus pungens 'Maculata'	—	—	—	—	—	100	98	89	98
Chamaecyparis pisifera 'Boulevard'	71	84	38	98	96	100	98	100	93
Camellia 'Donation'	90	85	2	91	93	67	100	100	100
Units of electricity used /m^2 (Averaged over species)	81	222	—	88	168	—	61	88	106

expected, this varied with species and season. On the average, some base heat appeared beneficial for winter propagation for all but the easier and faster rooting species. Rooting was considerably slower without base heat.

Duration of Base Heat. For the majority of species used in the trials, limiting the duration of heat input to an 8-hour night period (2300 to 0700) gave equally good results to the continuous regime (Table 6), with only a slight delay in speed of rooting of the slower species (*Camellia*) in the poorer seasons. Thus manipulation of duration of heating appeared to be a means of achieving further fuel savings without adverse effects on results. Monitoring the proportion of heat used in the day/night periods of a continuous regime indicated that 60% was used during the day-evening (16 hours) with 40% used in the cheaper night period (8 hours).

Table 6. Effects of limiting duration of base heat on rooting percentage (1980 — minimum 5°C air, 15°C base; 1981, 1982 — air frost protection only, 15°C base)

	1980		1981		1982	
Duration of Base Temperature	24h	8h	24h	8h	24h	8h
Hypericum calycinum	96%	93%	89%	91%	—	—
Pyracantha 'Orange Glow'	90	83	—	—	87%	100%
Elaegnus pungens 'Maculata'	—	—	—	—	89	96
Chamaecyparis pisifera 'Boulevard'	71	61	98	100	100	100
Camellia 'Donation'	90	88	91	100	100	100
Units Electricity used /m² (averaged over species)	82	72	88	94	88	65
Costs/m² (using current tariff prices appropriate to each year)						
Standard tariff	£3.43	—	£3.92	—	£4.30	—
Economy 7 tariff (on continuously)	—	—	£3.17	—	£3.45	—
Off Peak tariff	—	£1.29	—	£1.83	—	£1.35

1982 tariff prices: "Standard": 4.88p/unit (24 hours continuous)
"Economy 7": 1.09p/unit (7 hours night); 5.24p/unit (17 hours)
"Off-Peak": 2.06p/unit (8 hours night only).

In England, where an 8-hour "Off-Peak" tariff is available between 2200 and 0800 hours, costs of heating were considerably reduced, even though in 1980/81 this regime appeared to use as much or even more electricity to bring the bed back up to temperature after it had been off for 16 hours. In the 1981/82 winter the propagating house itself was thermal lined and screened and, despite a very cold period, the "Off-Peak" treatment used consistently less electricity than the continuous regime. However the "Off-Peak" tariff is only available at night

whereas the "Economy 7" package offers the greater flexibility of 7 hours cheaper heat at night with the option of 17 hours at a more expensive rate, which could be used for a few hours boost during the day if required.

DISCUSSION

Results from the four year's trials support the old adage "warm roots/cool tops" for propagation and, in terms of energy saving, it was encouraging that the combination of low temperature regimes (minimum air, 15°C compost) produced the best overall results. While only relatively easy rooting species have been used in the trials they have included a range of fast to slower rooting species, as well as conifers. However, other species such as *Rhododendron* may well have high temperature requirements. Nevertheless, the results underline the magnitude of savings possible by taking the measures discussed and, compared with the old 'standards' of non insulated beds at 18°C - 21°C compost and 10°C air, savings approaching 75% are possible. In addition, improved rooting is achieved since the higher temperatures appeared to have been too high for best results. For winter propagation the "economy package" includes:

1. Propagation under low polythene covers
2. Beds lined with 50 mm polystyrene sheet insulation, including sides and ends for maximum benefit
3. Use of thermal covers over beds
4. Propagation under double clad polythene tunnel or thermal screened glasshouse.
5. Accuracy of temperature control
6. Efficient heat transfer to rooting medium from heated base.
7. Reduction of house temperature (air) to a minimum (frost protection). This is only possible when propagating under polythene covers which create a microclimate less influenced by external factors.
8. Reduce compost temperature (15°C)
9. Limit duration of heat input.

While this experimental programme used electricity as the heat source, the same principles would apply to other heating systems.

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MASS PROPAGATION OF FRUIT TREES IN ITALY BY TISSUE CULTURE: PRESENT STATUS AND PERSPECTIVES

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Abstract. The present status of mass fruit tree micropropagation in Italy is reported. Information is given concerning species, clones, and the amount of trees of various rootstocks and cultivars produced by several laboratories. Methods, materials, and main characteristics of the laboratories, as well as perspectives of this technique are discussed.

In recent years plant tissue culture techniques have been adopted to an increasing extent for the commercial propagation of plants. The success of these techniques is due to important well known advantages over the traditional methods of vegetative propagation.

The tremendous number of studies carried out in a short time on this subject have revealed many improved technical methods and physiological phenomena. Thus, much information is now available on the media and environmental requirements, so the number of species and cultivars currently propagated *in vitro* is continually increasing.

In Italy, as in other countries, tissue culture is a commercially applied practice for propagating a large number of species such as medicinal plants, ornamentals, vegetables, forest and fruit trees. Progress in micropropagation of fruit trees over the past 2 to 3 years has been remarkable.

The satisfactory results obtained by preliminary experience have increased interest in this technique. Today hundreds of thousands of fruit trees are being produced by micropropagation.

The economic and agronomical consequences resulting from the application on a commercial scale of this technique may be of great value for both nursery and fruit-growing activities. In this paper an estimate of the situation concerning fruit tree micropropagation in Italy is made as well as of its perspectives.

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Species and number of trees micropropagated. So far, micropropagation has been used mainly to produce apple and peach rotstocks (Fig. 1). This is, firstly, attributed to the great economic importance that these two fruit species have in Italy. Secondly, the need for propagating some difficult-to-root rootstocks, recently introduced in Italy which could overcome problems such as the low resistance of plants grafted on peach seedlings to chlorosis and to water-logging. The number of apple ('M27', 'M26', 'M9', 'MM106', 'MM111') and peach ('INRA GF677', 'INRA GF1869', 'INRA GF43', 'INRA GF655/2') rootstocks produced by tissue culture since the beginning of its application on a commercial scale today is about 2.5 and 8.5 millions, respectively.

Among peach rootstocks, the hybrid peach × almond 'INRA GF677' and Damas 'INRA GF1869', are the most widely propagated ones; 'INRA GF43' and 'INRA GF655/2' are micropropagated to a smaller extent. Clonal rootstocks of plum ('Pixy') and cherry ('Colt') are also giving satisfactory results with this technique. In early 1982, the interest in propagating apple rootstocks increased because of the restrictions imposed by the Italian Ministry of Agriculture relative to the importation of apple trees from other countries: these measures were applied in the attempt to avoid introduction of fireblight into Italy.

Very recently laboratory research showed the possibility of propagating certain apple, pear, peach, plum, cherry and kiwi cultivars (Table 1) on their own roots. Some of them are produced in very small amounts (500 to 2,000 trees) but others, such as 'Armking' and 'Sunred,' 2,000 and 8,000 maiden trees on their own roots were produced, respectively. In 1981, tens of thousands of kiwi plantlets were produced .

Table 1. Fruit tree cultivars of different species propagated by *in vitro* culture.

Species	Cultivars
Peach and nectarine	'Flavorcrest', 'Suncrest', 'Maycrest', 'Sunred', 'Armking', 'Maria Bianca', 'Firebright'.
Apple	'Golden Delicious', 'Golden Delicious B', 'Perleberg 3'.
Pear	'William', 'Decana del Comizio', 'Abate Fetel', 'Conference', 'Kaiser'.
Plum	'Santa Rosa', 'Stanley', 'President', 'Laroda', 'Early Golden', 'Shiro', 'Sorriso di Primavera', 'Ente 707'.
Cherry	'Vittoria', 'Gemella', 'Durone I', 'Durone II'.
Apricot	'S. Castrese', 'Defarges', 'Reale d'Imola', 'Caldesi I'.
Almond	'Ferraudel', 'Tuono', 'S. Caterina'.
Kiwifruit	'Hayward'.

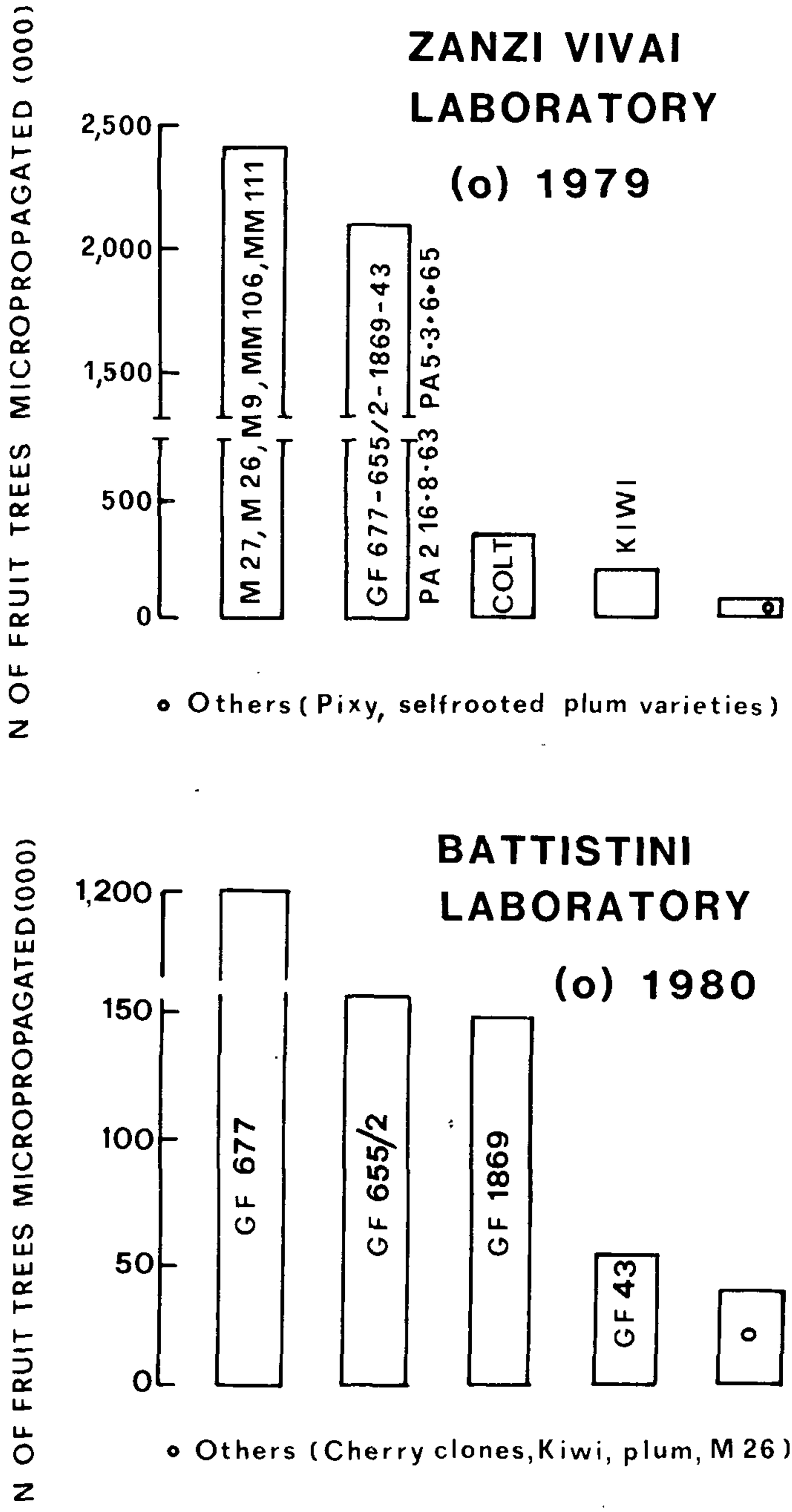
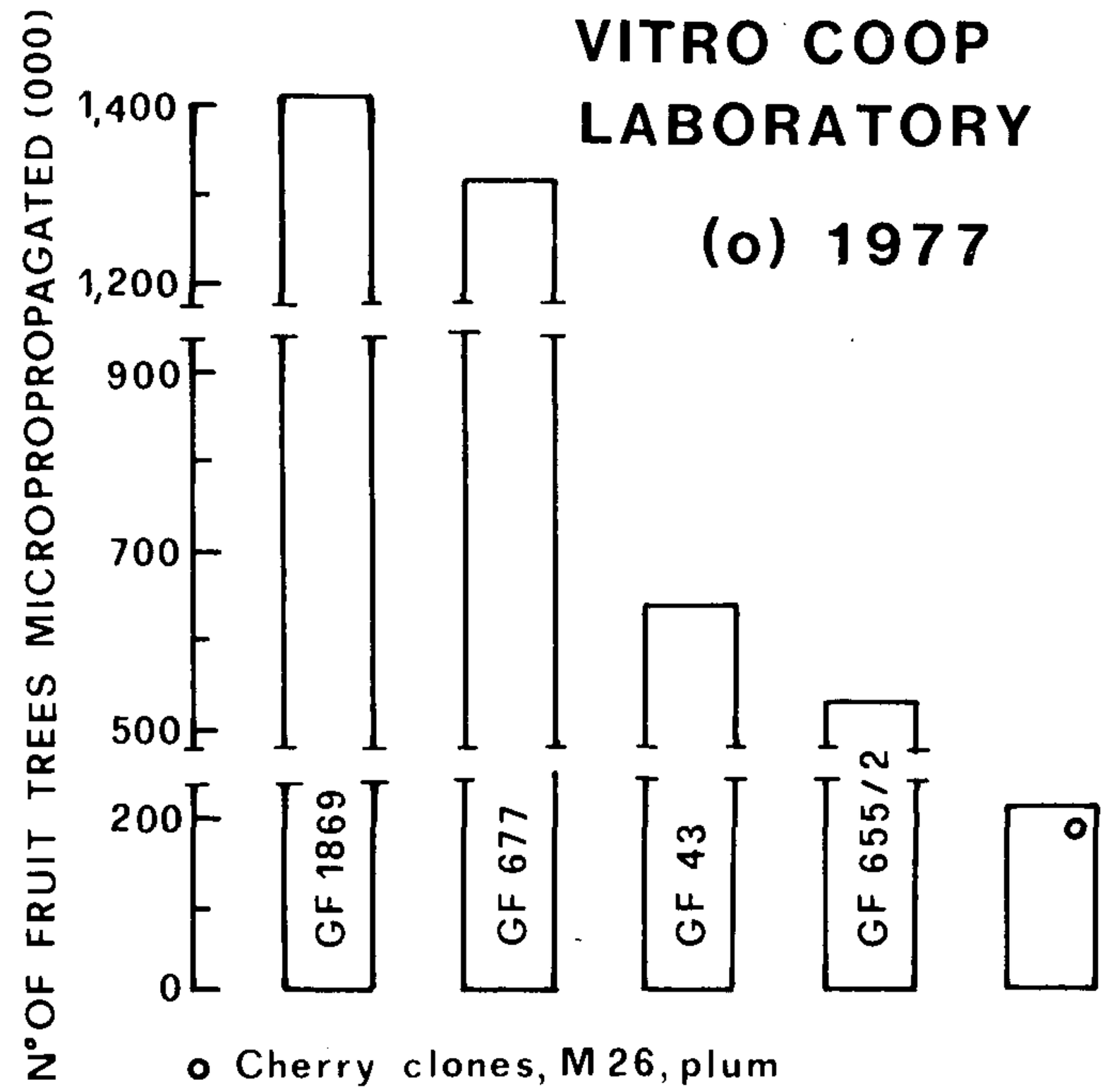


Figure 1. Number of plants produced *in vitro* by different laboratories from the beginning of their activity (0) on commercial scale to today.



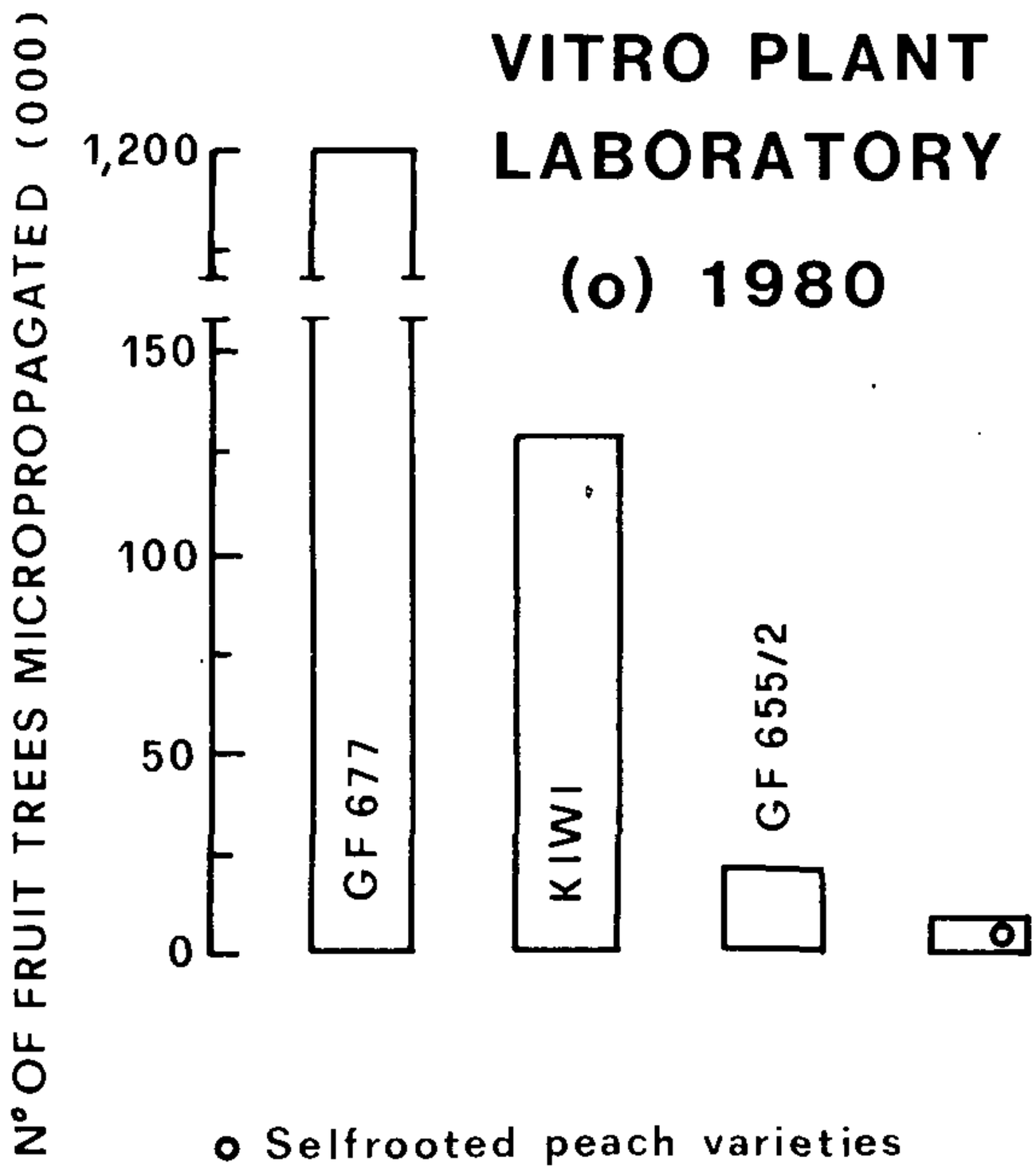


Figure 1. (Continued)

Micropropagation techniques used by different laboratories. In various laboratories, micropropagation is preceded normally by specific experimentation to determine the medium requirements for each species and cultivar. With these trials only a few thousand plants are produced.

In general, whole dormant buds, meristems, and shoot tips have been tried; the latter is preferred because it is easily handled and has given better results. Each laboratory has chosen one or the other method based on these experimental results.

Sterilization was accomplished in different ways depending on the type of material used and based on the experiences of the laboratory. Washing in alcohol or in sodium or calcium hypochlorite solution has been used successfully. In some cases an antibiotic is added to the medium to prevent bacterial growth.

Each laboratory has determined its own balance of the various media components starting with the formulae published in the literature. Media found most suitable for particular clones were determined by accurate experimentation in which the material to be propagated was collected at different times.

The shoot proliferation phase can be carried out in different ways:

1) Rapid multiplication through rapid sub-culturing every 2 to 3 weeks. In this way a large number of shoots are produced but they are usually too short. Under such a situation an elongation phase is necessary to obtain good shoot development in preparation for rooting.

2) Multiplication is obtained at a modest rate by transferring to a fresh medium every 3 to 4 weeks. By this method, longer shoots are produced which are most suitable for handling and are prone to rooting. In this case, the shoots can go onto rooting medium while the bases of the explants can be recultured on a fresh proliferation substrate. The method chosen depends on the requirements of the laboratory or the nursery and on the market.

The various species and clones have differing potentials for shoot proliferation (Table 2); these potentials depend, in part, on the appropriateness of the medium and on biological factors not yet defined clearly.

Subcultures are made every 15 to 30 days; e.g. with 'INRA GF 677' it is possible to subculture the material 14 to 16 times per year. New apices from the mother tree are being explanted each year to initiate new cultures.

Table 2. Potential rates of proliferation of some species starting with 100 sterile apices (based on data from Zanzi Vivai laboratory).

Period of culture (weeks)	A kiwi fruit	B apple	C INRA GF677	D Pixy
0	100	100	100	100
4	200	300	400	500
7	400	900	1,600	2,500
10	800	2,700	6,400	12,500
13	1,600	8,100	25,600	62,500
16	3,200	24,300	102,400	312,500
19	6,400	72,900	409,600	1,562,500

After the proliferation has been completed, an elongation phase on a different medium may be necessary to obtain shoots of desired lengths for rooting. This last phase requires 2 to 4 weeks, depending on species and cultivar. In some cases, such as 'INRA GF 1869' and GF 677', 8 to 12 days are sufficient to reach 80 to 100% rooting. Usually light and temperature conditions during the rooting phase are the same as in the proliferation, although in some laboratories and with some species, light and temperature may be increased.

Acclimation is normally carried out in 30 to 40 days. Some species, e.g. pear, may grow slowly or stop and then resume growth later.

An important aspect of acclimation is the choice of medium, especially the source of peat used. The source of peat and the ratio of peat in the potting mixture may determine the survival and the growth of young plants. Experimental work is continuing to define the optimum chemical and physical attributes of the medium.

The best period to minimize the costs of acclimation is from March to September. Plants produced during winter are refrigerated and acclimated in the spring prior to transplanting to the nursery.

Laboratory organization. Micropropagation of fruit trees is practiced by four commercial laboratories whose production is shown in Figure 1. They are located in Central Italy in the most important area for the cultivation of fruit trees. In each laboratory about 7 to 12 persons are employed of which 2 or 3 prepare media. Besides the facilities which are needed for setting up the *in vitro* culture, each laboratory is supplied with growth rooms and greenhouses for acclimation as shown in Table 3.

These values are, at this time, the maximum capacity of each unit but they are not all designed for fruit tree multiplication. Many vegetable species, ornamental and medicinal

Table 3. Amount of growth room and greenhouse space available at the four micropropagation laboratories.

Laboratories	Illuminated shelving in the growth room (m^2)	Greenhouses for acclimation (m^2)
Zanzi Vivai	345	2,500
Vitro Coop	190	1,600
Vitro Plant	180	1,600
Battistini Vivai	140	2,000

plants as well as forest trees are also micropropagated by these firms. However, fruit trees are the main production which may reach 60 to 80% of total.

Concerning the facilities for eleminating viruses from plants Zanzi Vivai laboratory has been provided since 1962 with heat treatment chambers, glasshouses for indexing, and repository for maintaining the mother plants in a healthy condition. In a short time all the other laboratories will set up these structures; now they utilize virus-free material available at some laboratories belonging to Italian universities or, sometimes purchased from foreign countries.

An important point to be underlined is the collaboration between private laboratories and universities and other Italian and foreign research institutions. Due to this cooperation, the laboratories may have assistance with particular problems of micropropagation and be brought-up-to-date on new developments in this field.

The destination of micropropagated fruit trees is different among the various laboratories. Zanzi Vivai utilize the plants, principally clonal rootstocks, for their own use. Thus the nursery, of which the laboratory is part, utilizes the stocks for their grafted maiden trees of several species. Some plantlets represent material for establishing mother plants (especially apple rootstocks) from which cuttings are collected for conventional propagation. A part of the acclimated plants are sold to nurseries and fruitgrowers or exported to many European, Arabian, and African countries.

Vitro Plant laboratory sells 90% of its production. Normally the plants are sold in an acclimated state but at times, for instance with 'INRA GF677', small lots may be sold at the end of the rooting phase. Last year a few thousand 'INRA GF677', representing about 10% of total production, were exported to Spain.

Battistini laboratory utilizes 20 to 30% of its production for its own nursery activity; 70 to 80% is sold to other nurseries, fruitgrowers and cooperatives. In 1981 about 3 to 4% was exported to other countries.

Finally, Vitro Coop Laboratory, founded by a cooperative

of 4,100 fruitgrowers, supplies principally its members and nurseries. Recently this laboratory has begun to sell nonacclimated plants; in this case the purchasers generally provide the necessary structures to carry out this operation. This allows the laboratories to reduce the risks related to acclimation which represents one of the most expensive phases of micropropagation.

It would be very interesting to talk about micropropagation costs, comparing them with those of conventional methods. Unfortunately many factors make this very difficult to do. One of these factors is the expertise and structures available to the laboratory needed to increase its efficiency.

Another factor is the variability of response of different species. Moreover, the laboratories propagate various species and clones at the same time and it is hard to distinguish the costs for producing a plant of each one. Last, but not least, is the reticence of nurserymen to discuss economic questions.

It is only possible to compare some aspects common with conventional propagation methods. Table 4 shows that micropropagation has a better adaptability from different points of view than conventional propagation.

Table 4. Comparison between micropropagation and conventional methods in relation to some production factors (+ = favourable).

	Micropropagation	Conventional methods
Original stock	+	−
Space necessary	+	−
Time for propagation	+	−
Sanitary conditions	+	−
Unexpected events	−	+
Market response	+	−

Perspectives. The results obtained so far on fruit tree micropropagation can be considered very satisfactory and the perspectives of further spread of this technique are related to the possibility of reducing the production costs and to put on the market trees at a lower price than those conventionally propagated.

The exclusion of a grafting or budding operation and the production of a large amount of self-rooted trees could represent an important step in reducing the production costs. This possibility could only be feasible after the biological and agronomic behaviour of self-rooted trees of the various species and cultivars has been evaluated.

The possibility of propagating by micropropagation rootstocks which are difficult-to-root by traditional methods, could

permit reconsidering some of them which may have superior characteristics and be particularly suitable for specific conditions.

To date the micropropagation laboratories now existing in Italy seem to be sufficient to satisfy the demand of the Italian market for material difficult to root by traditional methods, and also to supply some exports to foreign countries.

If production costs can be conveniently reduced by further perfecting the procedures now used by laboratories of micropropagation, and major distribution and testing of self-rooted trees occurs, it is reasonable to assume that in the near future micropropagation can be more widely adopted for the multiplication of various species of agricultural interest.

ACKNOWLEDGEMENTS

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— Azienda Agricola Battistini, Via Ravennate, 1522 — 47020 Martorano di Cesena (Forli).

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— Zanzi Vivai — 44040 Fossanova S. Marco — (Ferrara).

PROPAGATION OF 'Mr. S. 2/5' PLUM ROOTSTOCK BY TISSUE CULTURE

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Abstract. Observations were made on the behaviour of 'Mr. S. 2/5' rootstock propagated by "in vitro" culture on a modified MS substrate. Shoot tips were collected in February from actively growing shoots kept in a growth chamber. Numerous shoots were produced from the shoot tips during the proliferation phase but many of them did not develop (only a few millimeters in length) even when subjected to the elongation phase. Shoots, elongated on a medium with reduced BAP concentration, gave better results but their rates of rooting were slower and their numbers less than those of shoots elongated on a medium without hormones and with half strength MS nutrients. Plantlet survival was not satisfactory.

During the last two decades the Institute of Fruit Science of the University of Pisa, has carried out clonal selection on some *Prunus* species in an attempt to select rootstocks with better agronomic characteristics and rooting capacity. In this work seedlings of *Prunus insititia*, *P. domestica*, and *P. cerasi-*

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fera were evaluated and promising ones selected. In addition to good rooting as evaluated by trench layering, they were characterized by high vigour, satisfactory growth after transplanting, and graft compatibility with some peach and apricot cultivars.

One of these, 'Mr. S. 2/5', selected among Myrobalan seedlings, has been delivered to nurseries and will be put on the market under a trademark. In order to satisfy demand of nurseries and fruitgrowers it would be very useful to produce quickly a sufficient number of trees to establish mother plants. Research carried out to date on micropropagation shows that this technique provides the methodology to make this possible. In this paper the results of "in vitro" propagation trials of 'Mr. S. 2/5' are reported.

MATERIALS AND METHODS

Cultures were established using actively growing shoots 1 to 2 cm long which were collected in February from 1-year-old shoots. These had been held for a few weeks in a growth chamber in order to promote bud burst and shoot elongation.

Shoot apices were surface sterilized with sodium hypochlorite at concentrations of 0.8% and 1.2% for 15 minutes; a surfactant was added at 0.2%.

The explants were rinsed three times in sterile distilled water and aseptically cut back to obtain 10 to 12 mm length shoot tips. Each was placed on a 10-ml culture medium in glass tubes (2.4 × 16 cm).

To stimulate shoot tip growth, different media were used (7): A) for shoot proliferation; B) for shoot elongation; and C) for shoot rooting. All contained the MS macro and micro elements and were characterized by different levels of growth regulators. The medium A) contained (mg/l): nicotinic acid 0.5; pyridoxine HCl 0.5; glycine 2.0; thiamine HCl 0.1; myo-inositol 100; ascorbic acid 10; NAA 0.01; BAP 0.6; GA_3 0.1; sucrose 30,000. B): the same components as A) but with BAP at 0.1 mg/l and GA_3 at 0.5 mg/l. The effects of B medium were compared to those of R, which did not contain growth regulators but with macro and micro elements reduced by half (5). Medium C) contained the same components as A but without BAP and GA_3; IBA was added at 1 mg/l.

The media were adjusted to pH 5.3 before adding 0.6% of agar; they were then sterilized at 120°C for 20 minutes. IBA was sterilized by passage through a 45μ millipore filter.

Culture room temperature was maintained at 24 to 26°C with 16-hour day and with a light intensity of 3,500 lux.

At three week intervals the cultures were transferred to fresh media. At this time explants which had produced several shoots were subcultured.

Rooted shoots were rinsed under tap water to eliminate any residual agar from the roots. Plantlets were potted in a mixture of soil, perlite, sand, and peat (1:1:1:1), which had been previously sterilized.

Initially the potted plantlets were put in a glass-case where humidity was very high. The case was then gradually opened and the plants were transferred for a few days to a conditioning chamber and afterwards into a greenhouse.

RESULTS

Shoot tips sterilized with 0.8% and 1.2% Na hypochlorite had survival rates of 23% and 37%, respectively. In both trials about 25% of explants were damaged by hypochlorite and did not grow normally. 'Mr. S. 2/5' apices appeared to be more sensitive to hypochlorite than other plum and peach rootstocks (1).

Proliferation of shoot tips started quickly but many of the new shoots appeared to be very short, less than 10 mm (Fig. 1). After about 100 days of growth and after 2 subcultures were made, half of the explants were transferred to medium B and the others to medium R, in order to promote shoot elongation. After 22 days of culture on B or R, the average number of elongated shoots per explant was much higher with medium B than R (Table 1).

Table 1. Average number of shoots elongated in 22 days on two elongation substrates (B and R) and estimate of the average number of shoots which could be produced in 122 days of culturing by an initial shoot tip.

Substrate	Average number of shoots (> 1 cm length) per explant	Average number (x) of shoots (> 1 cm length) per shoot tip
B	8.0	33.1
R	4.4	18.2

(x) These values have been estimated considering the total number of the explants obtained at the end of proliferation phase as cultured on the substrate B or C.

During proliferation and elongation phases some explants produced shoots with abnormal morphology (Fig. 2); shoots axes were thick and leaves were small, light green, and folded downward.

'Mr. S. 2/5' was slower in initiating roots in comparison with other rootstocks cultured on the same medium. The high-

est percentage of rooting (75%) was obtained in 54 days while 'GF 677' required only 20 to 25 days to reach values between 75 to 100%. The abnormal shoots mentioned above rooted as well as the others and formed normal leaves during the rooting phase.

Figure 1. Proliferation phase of 'Mr. S. 2/5' plum rootstock.

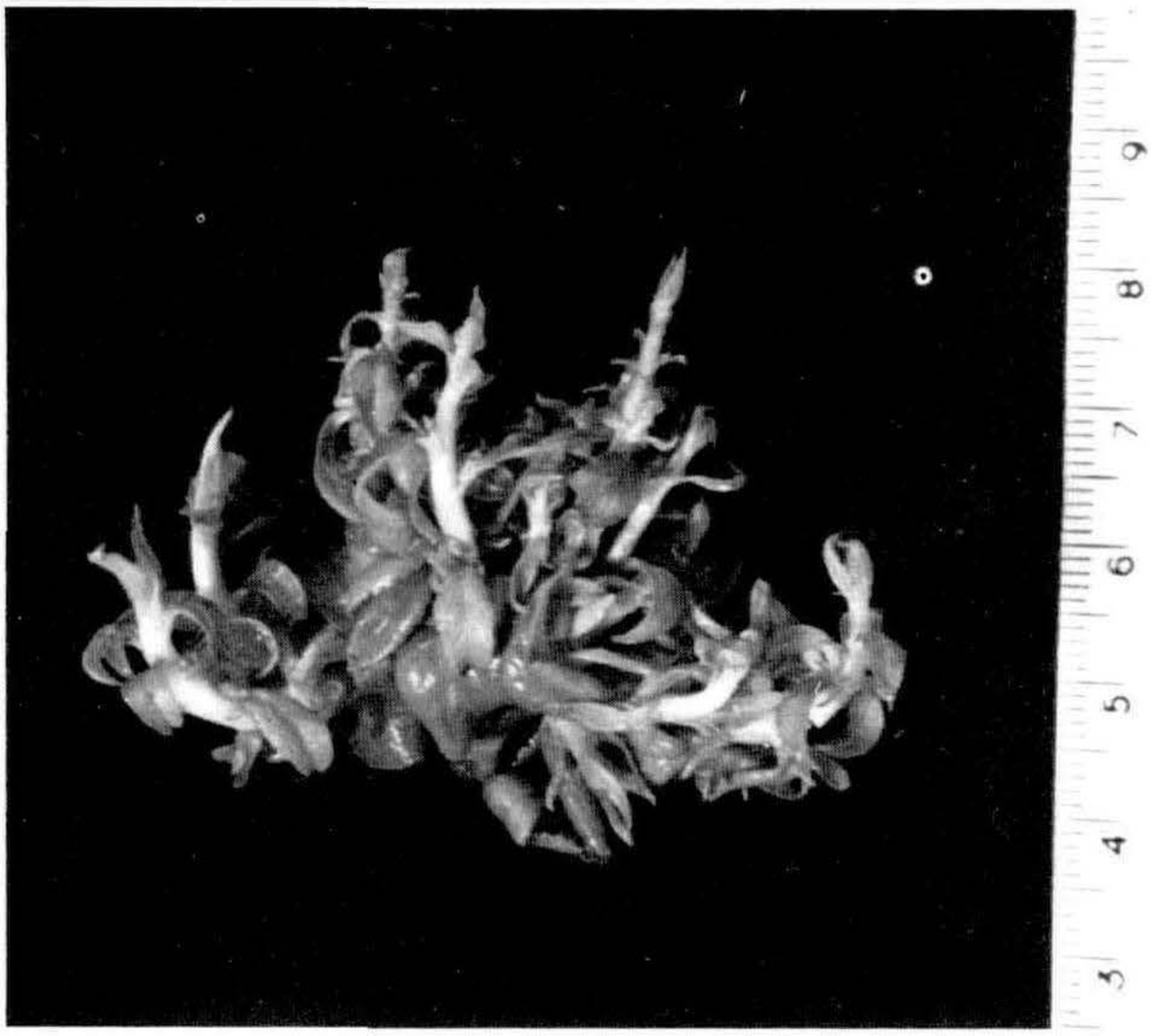

Figure 2. Abnormal shoots produced during elongation phase.

Different rooting results were obtained between shoots elongated on media B and R. Shoots, elongated in the absence of hormones, and with macro and micro elements reduced to half concentration (medium R), gave better rooting (Fig. 3). After 30 days in a rooting medium, 55% of shoots elongated in R had rooted while those elongated in B needed 54 days to reach a similar value of rooting.

Each shoot produced about 3 to 5 well-formed roots (Fig. 4). In spite of the good appearance of plantlets, the establishment after transplanting from the test tubes to peat-pots was not always very satisfactory.

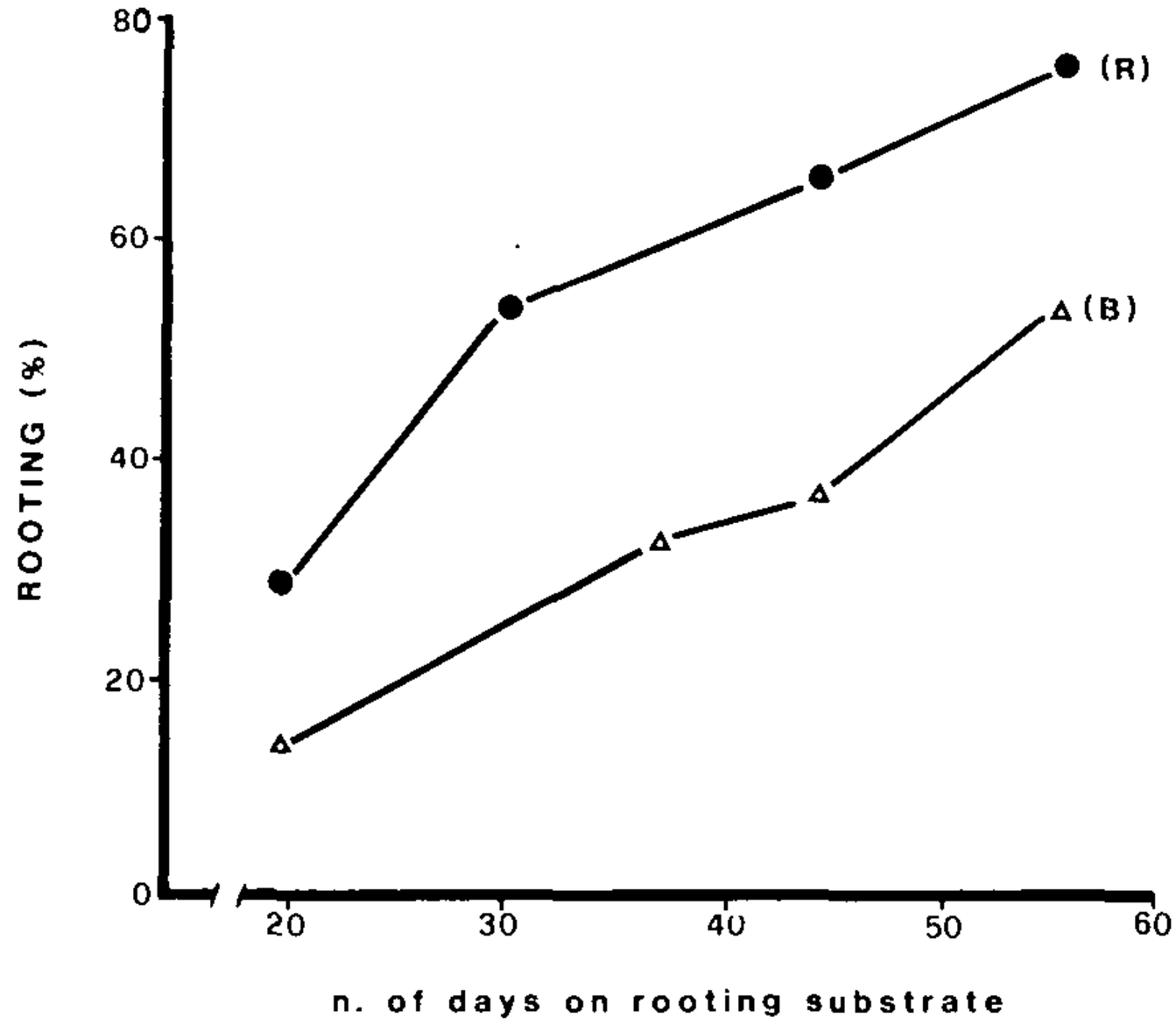

Figure 3. Different rooting percentages observed on medium C of shoots coming from B and R elongation substrates, respectively.

DISCUSSION

The results obtained in this preliminary trial have pointed out the possibility of propagating 'Mr. S. 2/5' by in vitro culture. Nevertheless, further investigations are needed to improve the survival rate of this rootstock to assure mass propagation. A problem to be solved is the shortness of shoots produced during the proliferation phase, which could be attributed to an excess of BAP. The concentration used on this rootstock, even though similar to that used by other experimenters (2,4,6,7), probably stimulated the shoot multiplication to the detriment of shoot elongation. The explants produced a very high number of shoots which grew only to a few millimeters in length, even after 3 weeks of culturing on the elongation medium. The values reported in Table 1 represent the

number of shoots longer than about 1 cm but the shorter ones were even more numerous. From our observations it seems that elongated shoots inhibit the development of others on the same explant. Short shoots present on the explants coming from the elongation phase grew normally after 3 additional weeks when the previously elongated shoots were excised.

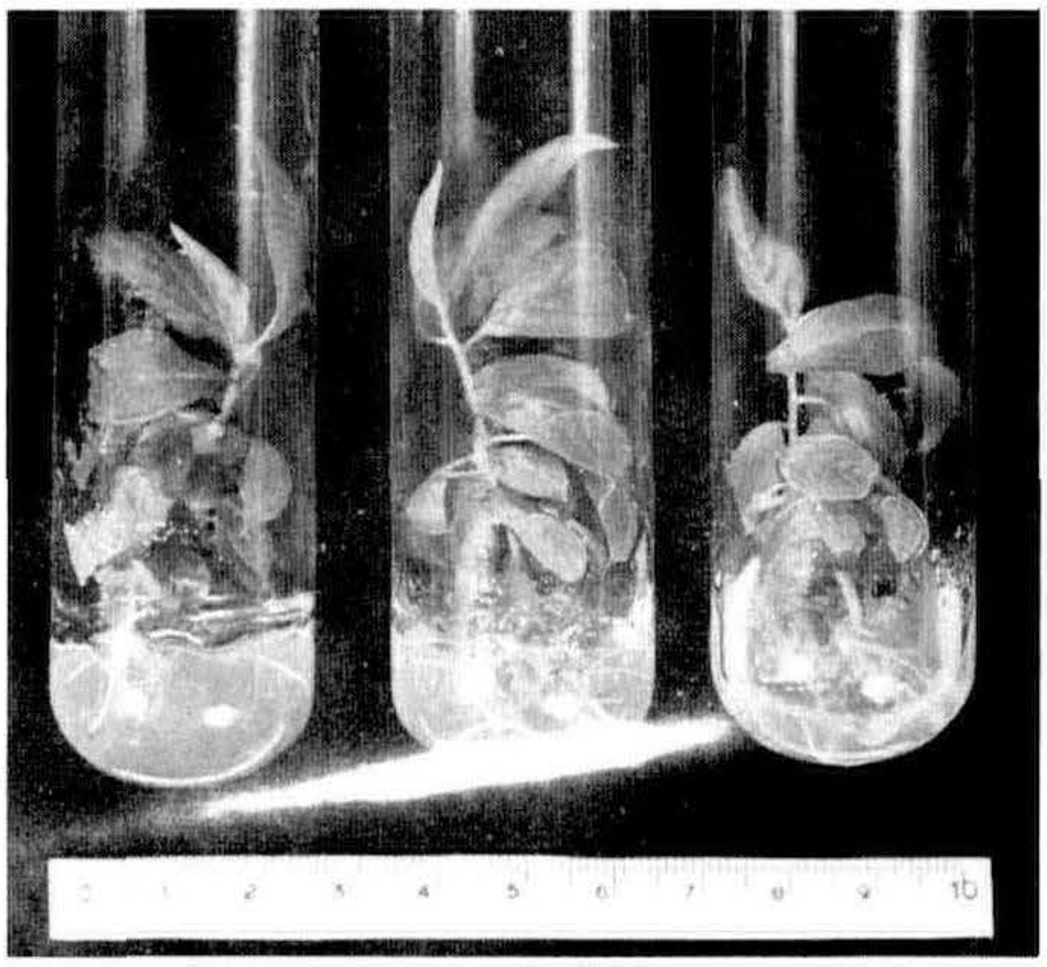

Figure 4. Rooted shoots of 'Mr. S. 2/5' plum rootstock.

Rooting percentage and the length of the rooting period were affected by the components of the elongation media. Thus, the medium without growth regulators and with nutrients reduced to ½ enhanced the rooting effects of IBA and gave more satisfactory results.

The negative response in rooting observed with the shoots coming from substrate B could be related to a residual effect of BAP which was present in the previous elongation medium. Also, in other trials, this growth regulator showed a residual effect wich reduced the rooting capacity of apple shoots (3).

More studies are needed to elucidate the causes of abnormal morphology of new shoots.

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PREPARATION OF PLANTS FOR MICROPROPAGATION

STEVEN M. McCULLOCH and BRUCE A. BRIGGS

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Several researchers have experienced the frustration in trying to obtain viable, sterile explants. This step, frequently referred to as stage 1 (17), is initially the most important area with which researchers should be concerned. Simply stated, a plant cannot be multiplied effectively if a plant part cannot be properly sterilized. It is the purpose of this paper to reexamine this area and offer possible solutions to these problems.

Whenever possible, the stock plant used for multiplication should be healthy, vigorous, and preferably virus-indexed. If the plant is indexed for certain viruses, care should be taken to prevent reinoculation of that plant. Screening methods have been developed to detect systemic contaminants (2,14).

As in conventional propagation, timing is very important. The physiological state of the plant part will partially determine whether or not the plant will grow, stay dormant, or die.

The environment in which the stock plant is grown is an important consideration. If possible, plants should be grown in a greenhouse. Water should be applied only to the soil so as not to wash contaminants into the axils of the leaves. Plant diseases should be controlled with appropriate fungicides, insecticides, and antibiotics. Systemic pesticides have proven effective. The plants should be grown in a loose, sterile soil mix. This is especially true if attempting to use underground structures as a tissue source. To reduce soil-borne contaminants, plants should be potted to expose those tissues needed for sterilization. When shipping or receiving plant material, it should be sent as quickly as possible and packed in a moist

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but not wet material. Care should be taken to prevent sweating in the container as contaminants spread quickly in this moist environment.

Frequently stock plants are available only in the field. If above-ground parts are used, they may be brought in before bud break to force growth, or dormant material may be used. It is often difficult to obtain clean explants after the spring or summer rains have started. This can be partially overcome by loosely covering the developing bud or shoot with a sterile bag (8).

The choice of the explant will determine the type of sterilization needed. Although meristems are relatively easy to sterilize, their survival rate is generally low. Meristems have been useful for virus eradication (16) and obtaining sterile explants from material difficult to sterilize. The removal of bud scales appears to satisfy the cold requirement of the plant.

Shoot tips are probably the most common explant. Stem tips with swollen buds, 2 to 6 cm. in length, appear more tolerant to culture environment and sterilization than shoot apices. Since there is more surface area, sterilization can be more rigorous and, therefore, contamination is more easily controlled.

Underground structures are difficult to sterilize. Tubers may have to be vigorously scrubbed with a brush to remove soil particles before sterilization can begin (7). Obtaining etiolated shoots from excised root pieces may be a way of obtaining clean material from underground structures (2).

Seeds and seedlings are a useful source of explants. Plants arising are juvenile and generally respond much faster to culture conditions. They are a useful tool for determining media and culture requirements of mature plants (1,4). Generally seeds are easy to sterilize. However, seeds with very permeable seed coats should be sterilized carefully in order to prevent damage to the embryo.

The terminology used to describe the actions of antimicrobial agents is confusing due to differing definitions from various sources (10,18). **Sterilization** is generally referred to as the destruction of all viable organisms. A **disinfectant** is a substance applied to inanimate objects that kills or removes infectous microorganisms. An **antiseptic** is an agent closely related to disinfectants, except being applied to living tissue. **Germicides** are agents that destroy microorganisms, which includes both antiseptics and disinfectants.

Freeing plant material of microorganisms is brought about by controlling three factors: concentration of the germicide, amount of tissue, and time the tissue is exposed to the germi-

cide. It would be helpful if researchers consider including average fresh weight of material used, besides germicide concentration and exposure time. We routinely use 400 ml of germicide with 250 to 500 g (fresh weight) of material for various times. The length of time the plant material is in the germicide is dependent upon several factors and should be experimentally determined by removing plant material from the germicide at different time intervals.

Vigorous agitation by shaking is a useful way of obtaining cleaner explants. Stirring may also be used but is not as effective. Use of an ultrasonic cleaner caused intracellular destruction and necrosis of the explants in our experiments.

At Briggs Nursery, we have conducted experiments to determine the efficiency of several germicides on shoots of *Rhododendron* 'Molly Ann'. These germicides and their descriptions are presented below:

ANTIBIOTICS

Antibiotics are not used by many researchers as a germicide. Antibiotics may only prove useful in freeing cultures contaminated with systemic or persistent bacteria. Generally these organic compounds break down under the high pressure and temperature of autoclaving and need to be filter sterilized to a previously autoclaved medium. Descriptions of antibiotics follow:

Ampicillin — is a penicillin-like compound commonly used in protoplast and suspension cultures to prevent bacterial contamination (19).

Chloramphenicol — has a fairly wide spectrum, effective against soil bacteria.

Gentimicin — is shown to inhibit cell division and decrease callus formation at high concentrations (50 μg/ml)(9); recommended concentration is 10 μg/ml, and it is autoclavable.

Incyte™ (Alcide Co., Westport CT.) — is a relatively new compound; preliminary results indicate some use in cleaning up contaminated cultures. One researcher notes it more bactericidal, but less fungicidal than sodium hypochlorite (12), and is autoclavable.

Novobiocin — is used to prevent growth of soil bacteria, has some fungicidal activity, and may be autoclaved. (20).

Tetracycline — inhibits soil bacteria, has a broad spectrum, is readily available, but with limited success in certain instances.

COMPLEX ORGANICS

Alcohols are weak germicides commonly used at concentrations from 70% to 95%. Alcohols are useful in removing surface waxes, allowing proper wetting of the surface for other germicides. Alcohols are bactericidal, but there are bacteria species that survive and can even grow in these chemicals. Ethanol is not sporicidal and therefore should not be used alone as a germicide (11). Isopropanol is slightly more germicidal and phytotoxic than ethanol. Generally germicidal activity of alcohols increases with increasing chain length. In other words, methanol is least active, followed by ethanol and propanol. Branching and additional hydroxyl groups lower potency (11), therefore isopropanol is less toxic than propanol.

Phenol and phenol-like compounds such as Lysol® (Sterling Drug, Inc. Montvale, N.J.) are effective germicides. Unfortunately, plant tissues appear sensitive to these compounds. After application, plant shoots become necrotic and stain the medium a dark brown.

Benzalkonium chloride (Zephiran) is used to control bacteria. Although this compound is somewhat effective, it is not sporicidal, relatively slow acting, and only moderately effective against fungi (11). This chemical is absorbed by porous material such as rubber gloves, cotton, and human skin (11). This absorption can reduce the effective concentration of the chemical and its germicidal activity. At Briggs Nursery benzalkonium chloride has never proved more effective than sodium hypochlorite.

DYES

Methylene blue is a weak germicide. Concentrations up to 0.1 ml of methylene blue per liter of water were used on explants for up to 32 minutes, but failed to obtain clean cultures.

Chlorophenol red has been added to media by one researcher to detect changes in pH caused by contaminants (21). Frequently, bacteria cause a pH change by fermentation. This indicator would turn yellow in a low pH solution.

HALOGENS

Chlorine is an effective germicide. Both chloride and hypochlorite ions possess antibacterial action. Harvey (11) states that in neutral or slightly acidic solutions, hypochlorous acid is highly bactericidal. In acidic solutions, the rate of deterioration and production of gaseous chlorine increases. In alkaline solutions, the bactericidal activity is greatly reduced.

After conducting a number of experiments, we have con-

cluded that in low pH sodium hypochlorite solutions, the bactericidal activity is increased but the fungicidal activity decreased compared to an alkaline solution. The germicidal activity of an acidic solution of hypochlorite was always lower than that of a nonacidified solution.

Organic matter appears to affect the activity of chlorine. Hypochlorite and chlorine are bound by organic matter (10). Solutions of hypochlorite tend to be relatively unstable. Tests at Briggs Nursery indicate that organic matter can bind chlorine from irrigation water, but not to a significant amount.

Hypochlorite is commonly available as two salts: sodium hypochlorite (laundry bleach) and calcium hypochlorite (chlorinated lime). Some researchers report that calcium hypochlorite produced less browning of tissue compared to that of the sodium salt (22). We have found little difference between the two salts and prefer to use the sodium salt due to the ease of preparation.

Some researchers have noticed, particularly with hypochlorite germicides, burning or browning of explants after application. Antioxidants, such as ascorbic acid or citric acid, have been used to counteract this effect (15). We found little benefit from using these chemicals.

At Briggs Nursery, we found combining molasses at 10 ml/l, when using high nitrogen fertilizer, could reduce burning of field plants. We examined the benefits of sucrose and molasses (a complex sugar) added to 0.5% sodium hypochlorite (NaOCl). After 30 minutes in these solutions, *Rhododendron* 'Molly Ann' shoots were not burned or showed only slight bud burning compared to NaOCl with no sugar or molasses. Sucrose at concentrations of 20 to 50 g/l or molasses at 10 to 50 ml/l added to NaOCl may be useful in preventing burning.

Iodine is a common but useful germicide. Elemental iodine is the most active germicide of the halogens. Most bacteria are killed within a few minutes at concentrations of 0.005%.

In tests using iodine tincture at a concentration of 0.005%, shoots were effectively sterilized after 15 to 20 minutes in this solution. Decolorized iodine tincture was used since it resulted in less staining.

Iodine is also available in an organic form as povidone-iodine. This is a complex of elemental iodine and polyvinylpyrrolidone (PVP). In experiments we have found it to be less effective than iodine tincture. Although povidone-iodine does cause less burning on human flesh, it did not prove any better than iodine tincture when browning of tissue was compared.

Bromine is a little used germicide. Methyl bromide is commonly used as a soil sterilant. Bromine in the form of bromine water may be used to sterilize plant tissue (5).

HEAVY METALS

Inorganic mercury compounds were used for many years as a disinfectant and antiseptic. It is still believed to be an effective germicide by some people. This is questionable since these compounds tend only to be highly bacteriostatic (11).

Mercuric chloride at 0.01% was once widely used as a surface disinfectant. Organic mercurials, such as mercurochrome, have been used to disinfect instruments and as antiseptics. These agents are primarily bacteriostatic and not sporicidal. Organic mercurials are not effective in sterilizing instruments (11).

OXIDANTS

Hydrogen peroxide is a feeble germicide. Explants placed in a 3% solution quickly became contaminated even after 32 minutes in this oxidant. Hydrogen peroxide may have some use in preparing explants covered with tomentose hairs or indumentum by cleansing the surface. Then a more powerful germicide may be used to penetrate these cracks and clean the explant.

Potassium permanganate is a more powerful oxidant than hydrogen peroxide. It has proven to be an effective antiseptic at a concentration of 0.01% from 4 to 32 minutes.

PRESERVATIVES

Preservatives, such as benzoic acid and propionic acid, have been used in food proparations to inhibit bacteria and fungi growth. Sodium benzoate used at 0.1% added to the stage 1 medium, did inhibit growth of bacteria and fungi. However, growth of the plant shoot was also inhibited and toxicity appeared at 0.1%. Propionic acid (calcium salt) was phytotoxic at 1% to 10% concentrations.

Woody plants are best started on a low salt medium. Cheng (6) reports that preconditioning plants on a low salt medium with no growth regulators gave more uniform growth when shoots were subcultured from these explants. A liquid medium causes faster bud break of cultured shoots, lower water stress, and generally lower contamination than a solidified medium. If shoots become contaminated in a liquid media the upper portion can be resterilized easier than when the shoots are lying on a solid medium. If a solidified medium is

used, a clear agar will allow easy visual detection of contaminants.

Plant material is never freed of contaminants and sometimes material is not available to be sterilized again. This is when and why plant material should be resterilized. We have found that using a different germicide on contaminated plant material is useful in removing bacteria contaminants. Sodium hypchlorite (0.5%) is useful as a fungicidal agent. Jones (13) resterilized *Malus* shoots for up to 40 minutes in 0.42% sodium hypochlorite. We resterilize shoots in 0.5% NaOCl for 5 to 20 minutes.

Several germicides are useful for preparing plant material for micropropagation. In our experiments we found iodine tincture, sodium hypochlorite, and potassium permanganate to be the most effective. Although there are many more germicides as yet untested, in the near future several more active chemicals will become available. Anderson (3) reports that one such chemical has shown promising results for sterilization of hard to clean material. We are confident that many more germicides and useful ways of handling them will be found.

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ASEXUAL PROPAGATION OF TROPICAL PLANTS USED IN THE LANDSCAPE

MAUREEN MURPHY

Poipu Kai Resort
Koloa, Kauai, Hawaii 96756

You can probably understand why Kauai's nickname of the "Garden Island" is so appropriate, for we have some of the most beautiful gardens in the United States right here. But these gardens did not happen naturally. It took a great deal of planning, preparing, and designing, or in other words, intentional landscaping to create the lush tropical feeling that is so prevalent here.

In most places, creating a garden involves getting plants from a nursery. Somewhere along the line those plants were carefully propagated by someone, and chances are, they made use of such supplies and equipment as rooting hormones, disinfectants, pots and rooting media, special timers, bottom heaters, mist beds, and temperature controlled greenhouses. Then

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after the new plants developed, they needed to be transplanted and acclimatized (in perhaps another greenhouse) before they could be put in the landscape. A fair amount of time, labor, and expenses goes into this process.

Here in Hawaii, it is a bit different. And that is what I would like to talk about today — how we can propagate plants as we install or improve on a landscape, and have a very high success rate.

The Hawaiian nursery industry (or commercial plant propagators) began with the backyard growers and involved very little sophisticated technique. They probably took a branch (any size) stuck it right side up in an old can, and left it under a tree until new leaves formed. Then it was given away or traded. Eventually, they graduated to air layering, and even some grafting and budding of special hybrids, but the basic care of the propagating material was the same — stick it under a tree and if for some reason the regular rains stop for a few days, sprinkle it with the hose.

Today, of course, we have many commercial nurseries which deal with propagation on a much larger scale and therefore, have gone to more modern methods. But the backyard growers, especially on Kauai, continue to be quite prevalent and are still achieving a high percentage of rooting with their basic operations.

If we landscapers are careful, and do a bit of extra planning, we can take advantage of these phenomenal growing conditions. We can install unrooted ground covers, shrubs, and even some large trees that will give us somewhat of an instant landscape effect, but in actual fact, they are nothing more than huge cuttings. Of course, one would not put in a complete landscape using only unrooted cuttings, especially on a commercial scale, but in many circumstances, this method can be incorporated into the project and reduce plant and planting costs considerably. Also, I might add that plant availability can be a real problem here on Kauai and the landscaper may not be able to find a plant with roots on it at the time he needs it.

This method of "in-house" propagation works especially well for someone in my position, where we are constantly expanding and improving an already established commercial landscape. We have about thirty acres of intensely planted grounds with a potential of 110 acres. The plants are already acclimatized to our particular conditions, which are somewhat less than ideal. They include very strong winds, heavily laden with salt, that blow almost constantly and a thin layer of soil over almost solid blue rock. Not all plants will tolerate these conditions, but those that do grow amazingly well, and even

here we have had quite a bit of success using propagating material during landscaping.

Starting with a few ground covers, *Rhoeo spathacea* (Syn.: *R. discolor*) cuttings will fill in within a few weeks. Then we can cut them back and propagate the trimmings. *Alternanthera ficoidea* 'Amoena' (Syn.: *A. amoena*) cuttings are placed with several together, giving finally a strong growing clump. This plant can also be divided very easily. *Ruellia makoyana* grows well from runners and fills out within a month, but none look as good right from the start as *Zebrina pendula* 'Discolor' which never even wilt.

Cordyline terminalis, or ti cuttings are great for giving instant heights to a landscape. They can also be air-layered if you have the time, in which case the end plant could be five feet tall. The dwarf *Schefflera arboricola* is another one tht air layers readily (in less than two weeks roots were showing) and the layers can be hidden from view so as not to detract from the existing landscape. *Hylocereus undatus* is rather slow growing but well worth the wait, especially during the summer and fall, when this night bloomer puts on its floral display. Even some of the small cuttings bloomed just a few months after planting.

Gingers, *Heliconias*, and bananas are quite easy to divide. The foliage of Kahili ginger *(Hedychium gardneranum)* was quite tall when planted. Banana "keikis," or suckers, make a great gift and are produced in abundance. *Alpinia purpurata*, or red ginger is quite interesting in that it undergoes vegetative apomixis as another means of reproduction. These can be used in the landscape, although the plants are much smaller than division would produce.

Giant spider lilies *(Crinum jagus* (Syn.: *C. giganteum))* are excellent for an instant landscape effect because of their size and fullness. Divisions four feet tall and six feet cross have been moved successfully with very little yellowing. But the trees are the greatest amazement to me. What do you do when your *Plumeria rubra* gets too big? Just simply cut off branches, any size, and let them dry out in the sun for one to four weeks. Then strip the bark off the lower four inches and plant about eight inches deep in a spot where a new tree is desired.

Pandanus odoratissimus is another tree that will tolerate a rootless condition for a long time. One particular tree blew down a few months ago and the roots were severed. Except for a few yellow leaves, the plant gave no outward signs of stress, and has begun to put out new growth.

So there you have just a few examples of how plants can be propagated while planting them directly into a commercial

landscape. For a private residence, where instant fullness is not so important, this technique is even more useful and cost efficient. A very common way of installing a *Hibiscus rosasinensis* hedge is to stick three foot branches into the ground in a criss-cross manner. Then water and wait. With a panax *(Polyscias guilfoylei)* hedge, you can use six-foot cuttings with or without leaves, placed vertically in a row. Some leaves will appear in a week or so.

As with many almost effortless endeavors, sometimes they backfire. In the old days, farmers used thick logs of the Hau tree *(Hibiscus tiliaceus)* as fencing material; not anymore, as the logs sprouted and engulfed a good portion of their land. A few years ago, I planted a vegetable garden and needed some poles for the climbing peas. There were some beautiful panax stakes near by that would be perfect. Being the "knowledgeable horticulturist" that I am, I put the stakes in the ground upside down so they would not grow but leaves still appeared. As the old saying goes, "in Hawaii, when you stick a plant in the ground, be prepared to jump back quickly." This may be a bit of an exaggeration, but as you have seen, we do make cuttings with chain saws!

DON DILLON: Jeanne, do the roots travel from one unit of the foam to the other throughout the strip? If so, does that cause any problem when they are separated?

JEANNIE JONES: In poinsettias there is a tendency for that to happen if the plants are kept on the bench too long. When the individual units are snapped apart the roots gently pull out from the foam because they left an impression as they are going in. So it tends not to cause a problem unless they are very, very over-rooted plants. But that means that they have been held too long.

VOICE: How cost-effective is the system and what percentage take do you get compared to conventional propagation materials?

JEANNIE JONES: Generally, it matches existing systems. At first we thought there might be a greater labor saving because we weren't preparing our own mix, but generally it has been a trade-off. What has occurred is that we have a higher uniformity of rooting and so there may be less than 1% shrink in the propagation. With those particular plants, we had above 90% take on that trial. But instead of having 10% shrink, as some people do in poinsettia propagation, we have been hitting under 1% consistently.

VOICE: We use a similar material in Australia called rock wool. Do you have any experience with this material?

JEANNIE JONES: I have seen the literature on it and I have seen the material. It does seem to be working quite well in Europe both for cuttings and seed germination. We do not have manufacturing capability as yet with any company that I know of in the United States. So it has to be shipped in, which is cost prohibitive. The Oasis material is used with constant liquid feeding. There is no cation exchange capacity in the material, so you must recognize that you have to fertilize the cuttings. As soon as the roots show, the fertilizer must go on.

VOICE: Have you done any work with this material on growing the plants, instead of just rooting them? That is, using it for a longer period of time.

JEANNIE JONES: Initial work is being done right now. Instead of the foam material being in solid form, it is being shredded and put in plastic bags. If you are familiar with the W.R. Grace bagged material, which is out right now, there is a similar sausage bag, called a Grow Bag under testing with this foam material. It is being used in Canada, and I have some trials to be set up in November near Dallas with tomatoes, cucumbers, and such types of plants. So we will begin to get some more information with it. It is light weight, it is easy to use, and workers seem to like setting it up. Production is being matched with existing systems in Canada right now but I don't have any first-hand experiences.

VOICE: That would be just in the shredded form, but what if you made it into the form, say, of a 4-inch pot?

JEANNIE JONES: It seems to be too costly. The individual cube units are about 1½¢ up to 3¾¢, depending upon size. So when you cut that much mass in a straight 6-inch pot, the plant that you are growing in it isn't going to sell for enough money to recoup the cost of the material. You have to get into a high cash crop like vegetables.

HUDSON HARTMANN: Curtis, would it help if you nailed the scions of your grafts into place, using flat-headed wire nails?

CURTIS ALLEY: We don't have to with the tape we use. It holds it very well except along the bottom where it tends to open up. If you put a nail down there it would hold it, but the grafters are under pressure. How many can I do a day? They don't want to take the time to nail the grafts.

MARGARET SCOTT: When you are cutting off the vine for grafting, do you leave one or two of the original shoots?

CURTIS ALLEY: No we don't; in other words, the head of the vine is up where the cordon is, and we go down about 14 inches below the head for grafting. There is nothing above; it is all cut off.

BRUCE BRIGGS: Is there any reason for not cutting off the base and then putting dirt around the base to cover it up completely. Some have done that. Why did you go away from that type of grafting?

CURTIS ALLEY: The question is why don't I go down to the base of the vine and do my grafting down there at ground level? But we have a nice trunk, it might be anywhere from three to eight years old, and with it we can get in with a French plow, or use herbicides, because with the thick bark we will not injure the trunk. If we start at the base and bring up a whole new trunk, we cannot French plow and we cannot use herbicides due to the tender new stem.

HUDSON HARTMANN: Filiberto, where in Italy is the location of the laboratories doing the micropropagation which you mentioned?

FILIBERTO LORETI: They are all in the center of Italy, the Cizana area, the most important areas for peach and apple fruit growing.

VOICE: Do you have any problem with the tissue-cultured plants not growing away well without having a cold period?

F. LORETI: For fruit plants we collect the shoots during the late fall, and put them in cold storage for a certain period. After the cold storage we put them in a growth chamber with high temperatures to promote bud burst and shoot elongation.

VOICE: So they are having a cold period before you use them?

F. LORETI: That's right.

VOICE: For sanitation in tissue culture, why do you not want to have any water go on the top of the plant?

BRUCE BRIGGS: We should wet the plant from the base. When a leaf comes out on a plant with a rain taking dirt out of the air, the dirt seems to get into the body of the plant. For example, if you want to ship some plants to a person who wants to start tissue culture on the plants, you might go out and gather the cuttings for shipping. If the foliage is wet you cut them off, put them in a poly bag and put them in the mail; the percentage of success in getting them started by tissue culture is very, very low. They are dirty. But if you go out on a hot, dry day, pick off those cuttings and put them in a poly bag — but don't close the bag so the cuttings can breathe — ship them so they get there almost wilty and dry, the percentage of success is much, much better.

When you sweat the bag, with all the moisture in there, you immediately start reactions with all the bacteria growing.

VOICE: Bruce, you kept saying sterilization in your discussion; don't you really mean disinfection?

BRUCE BRIGGS: Yes, this is correct, it is actually disinfection.

CURTIS ALLEY: Bruce, have you tried a bacteriacide called Chinosol? It is one of the most widely used bacteriacides in Europe on grape cuttings. It disinfects them and is particularly good in controlling *Botrytis*. The active ingredient is 8-hydroxy quinone.

BRUCE BRIGGS: No, we have not. Has anyone in the room used this in tissue culture? This is the thing we need to do, to get such materials out so we can try them.

VOICE: In rooting Plumaria cuttings, does it help to dry them out?

MAUREEN MURPHY: Absolutely necessary. Otherwise they tend to rot in the ground. Also stripping off the bark from the bottom four inches is an old Philippino technique some of my gardeners taught me. In some cases they know best.

RICHARD ZIMMERMAN: This is in regard to citrus grafting. The reason for the micrografting of citrus is because they cannot root shoots in tissue culture. They are interested in obtaining virus-free plants and multiplying them. They were not able to get multiplication or to get them in culture from shoot tips. So they used very small seedlings — cut off the top and do the micrografting on the seedlings. They were able to establish their culture this way. Several references to this are in the Journal of the American Society for Horticultural Science, back in the seventies.

KHENG CHEAH NG: I would like to add the reason for micrografting avocado. When they first started to get mature avocado material in culture it would not root. So, in vitro micrografting was done. The shoots were found to be able to root much better than that. They were trying to develop mass propagation methods for avocado clones.

BRUCE BRIGGS: Dr. Loreti, our guest from Italy, do you have anything to add to your paper in the way that you are working on tissue culture in Italy?

FILIBERTO LORETI: May I tell you about micrografting in citrus? We have been doing this for three or four years in Sicily where citrus culture is very important. We do micrografting to use certain rootstocks in order to avoid some diseases. We prefer to micrograft over conventional grafting because it is easy to graft very fast. We cannot grow certain orange or other species on their own roots because of diseases which attack the root system.

DEVELOPMENT OF A TISSUE CULTURE LABORATORY IN NEW ZEALAND[1]

BARRIE L. McKENZIE

Topline Nurseries Limited,
P.O. Box 20-165, Glen Eden,
Auckland, New Zealand

Topline Laboratories, Limited, was established in early 1981 after 6 months of research and construction. At the beginning it was decided that a new building would be erected, but due to local laws, delays were experienced, and the laboratory was, therefore, established within one of the present buildings sited on the premises of Topline Nurseries Limited.

The decision to move into this field was brought about after having attended one of the first tissue culture workshops held in New Zealand. Since this occasion, considerable interest has been shown in this field. A lot of plant breeding and research currently being undertaken in New Zealand has been a result of a horticultural boom. The establishment of a Laboratory Company within the nursery confines appeared most attractive.

The interest of a staff member, Lynsay Averill, who had been with the Company for 5 years, with a good horticultural background and basic plant propagation knowledge, also aided the decision to proceed with this new venture.

As Topline Nurseries Limited is part of the Hortex Group of Companies in New Zealand, being a major exporter to many countries, the possibility of rapid propagation of selected crops, and the placing of these on overseas markets, appeared attractive, and it was for this reason the Company was established as a separate identity so that it could contract itself to outside plant producers or operate within the four nursery operations currently running.

The decision to proceed was highlighted by the fact that the managers of the nurseries were invited to become shareholders and directors, and today Topline Laboratories Ltd is a private company with a shareholding split amongst five directors, the manager, Lynsay Averill, being a shareholder and director.

Over the past five years, tissue culture, or micropropagation, in New Zealand has developed considerably; this has been highlighted by the demand for orchids, which has caused an upsurge in the interest of tissue culture. Coupled with this, New Zealand, with its primary produce and the popularity of the New Zealand kiwifruit, has recently gone through a horti-

[1] Paper presented at the meeting by Terry Hatch.

cultural boom, ranging from many fruiting crops through to cut flowers. With the demands being placed upon the industry, there was an opportunity for a laboratory to develop and carry on the work currently undertaken by Government Departments and Universities. It is, therefore, the policy of the Company to only carry out the research that is necessary and, where applicable, contract out to Government Departments and Universities.

It was necessary for Topline Laboratories to establish itself with the necessary equipment to carry out media preparation. At the inception of the Company, it was intended that the Laboratory include a small transfer room which contained one laminar flow hood and all the relevant requirements for media making; that is, water still, autoclave, balance, pH meter, etc. The culture room had shelving added as required.

This was well underway when the first crop of tamarillos was in propagation, but a decision was made to travel to Australia and look at tissue culture laboratories in Sydney; this was undertaken by two of our directors. The purpose of this trip was to ascertain if our thinking was correct, and to gain any available practical knowledge. We were both encouraged by our reception at the Australian laboratories and by the assistance given. To this day a close liaison is maintained with several of these Companies.

It became obvious that the field of work we were undertaking was going to change rapidly, and it would be necessary to make modifications and adjustments within the Laboratory if we were to keep up with the changing theories being applied throughout the world. It is for this reason that as a Company, althugh in depth research is not carried out at present, managers and directors should, when possible, attend research meetings. This year both the writer and manager attended the World Tissue Culture Congress in Japan; it is felt that such meetings as these assist in many of the long term plans for the future.

In the early stages of 1981 the work carried out was the propagation of one crop only, that being tamarillos, and this quickly proceeded through the Laboratory and into the nursery operation, ending up as container stock available to the industry within New Zealand.

With this one simple crop nearly behind us, one of the most obvious problems that appeared in the Laboratory was the need for media preparation. An association with a laboratory offering their services to make media for us was finalized, and a decision to move to glass or plastic containers was necessary. In New Zealand, where we have a small population,

many products are high priced, and glassware is a very expensive item; therefore it was decided to proceed with disposable containers if at all possible.

Fastfood containers, proved to be an ideal unit for our cultures, while the use of petri dishes for the first stages of in vitro culture was successful.

Today all our media is prepared on a pre-order basis at least 2 to 3 weeks in advance by the Laboratory responsible for media making. It is delivered to us sterilized, in plastic sleeves, after being held for approximately 2 weeks on their premises to ensure against contamination. This eliminated the use of labour for media making on our premises and allowed staff to apply their time where best suited, that is, at the laminar flow hood.

Today we still maintain media making facilities within our Laboratory and this is used for small runs where necessary, but all volume crops are produced in plastic containers with commercially made media.

After approximately 6 months of operation, the first contract to be undertaken by our Laboratory with an outside Company was signed, and this brought home the need for planning for at least the next 15 months.

The production of zantedeshias on a commercial scale in vitro had not been undertaken previously in New Zealand, and it was only recently that research work had been undertaken by Government Departments. Through a close liaison with these people, it was possible to establish clones of these cultures quickly and within a short period of time, our Laboratory was developing the flow line of sub-cultures.

Included in this contract was the transfer of the plant from in vitro to nursery facilities as the plant was required to be offered for sale as a dried rhizome or a green plant in a small propagation tube.

During the period of this contract, other crops were brought into production — many of them being what I would describe as short term lines, such as Nephrolepsis and Rex begonias. These were introduced for the purpose of quick cash flow, and secondly, taking out some quiet periods when proliferation was slow.

With the increase in volume, the staff slowly increased from one full-time and one part-time, to three people and, at this point, a second laminar flow hood was introduced. It was found that the capacity of our culture room was greater than what one laminar flow hood could offer.

Since the introduction of these crops in the Laboratory, a

program based on between 5,000 and 6,000 transfers per week per hood has been established, and it is from this basic figure that our budgets for the next 12 months have been based. This allows for approximately 40,000 plants to be produced per month from the Laboratory.

The Laboratory now works with a series of staff members who are trained to work with laminar flow hoods, consisting of women who are available for approximately 4 hours per day. From the outset, 4 hours of concentrated work at a laminar flow hood was considered sufficient for one person per day, and it was for this reason that alternating staff are used from the nursery.

With media preparation being made off the premises by a separate Company, it is necessary to have an understanding of each other's operations. There must be a certain amount of trust, as formulations are made available to the Company concerned, and the order is placed for the forthcoming month's requirements.

Topline Laboratories have always made their premises available for viewing to a restricted number of people, as we believe in sharing the information we have. Although some people believe that it is necessary to have secrets, it is basically my opinion that the formulations and facts are available to most commercial producers today and it is, therefore, the applications of this information that makes success or failure. We see our Laboratory as an operation carrying on the work from where research organizations leave off. The expression of a "bread and butter" operation may not appear particularly complimentary, but it has meant that we commercialize and bring into production crops that are required within the industry, and it is through the use of micropropagation that plant numbers can be increased rapidly and brought onto a market place much more quickly than through other conventional propagation methods.

There is no doubt that research is one of the most important areas of the whole horticultural industry and I believe, as a New Zealand horticulturist, we are very fortunate to have facilities available to us within Government Departments and Universities. Although research must be paid for by such Companies as ourselves when undertaken, the cost of applying this within their own Laboratory would be somewhat daunting, and it is our wish that these services available to us will continue in the future. Likewise, it is the wish of Topline Laboratories to assist with University training, and we are pleased to be able to offer students training for practical horticulture as well as degree courses. The opportunity to work

during their holiday periods in the Laboratory gives them understanding of the practical aspects of this exciting area.

We are now approaching the end of a second year since we established the Laboratory, and it is with some excitement that we look to the future as we foresee the development of many new crops along with the increase in the numbers of many basic crops currently in production.

Plans are already underway for the development of a new Laboratory in association with a new nursery. This will include 5 work stations and 3 culture rooms. It would also include a basic laboratory area as well as facilities for media preparation, as we must be aware of the possibility, due to changes of ownership, for failure of other companies to meet our needs. Should media preparation be necessary within our own Company for commercial use, we must safeguard ourselves. This would not mean the expense of all the equipment, but at least the basic space.

Tissue culture, or micropropagation, is presently the most exciting, challenging, and demanding aspect of horticulture and, putting aside all of this, it is one of the most demanding on the dollar. Anyone who is involved in it will surely agree that the money spent in what is a small square footage area, along with the cost of running such an operation, is sizeable.

Nevertheless, it is possible to make a profit, but it is necessary that crop planning and projections be carefully estimated. Records as to actual performances must be kept so that a case history of crops can be developed and, therefore, a plan for future production can be applied. Tissue culture can be fun, fascinating, and frustrating but, what's more, it can be financially disastrous without careful planning.

AN OVERVIEW OF A COMMERCIAL PLANT TISSUE CULTURE LABORATORY IN HAWAII

KALFRED K. YEE

Exotics Hawaii, Ltd.

1344 Hoakoa Place

Honolulu, Hawaii 96821

We are a specialized laboratory with over 90% of our work dealing with the mericloning of orchids. The other 10% entails the mericloning of other ornamentals, such as *Anthurium andraeanum*, *Cordyline*, *Dieffenbachia*, Spathiphylum, and bromeliads.

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In sharing my experiences with you I will cover:

(1) Planning and building the laboratory

(2) Culture and management

(3) Production and marketing

(4) Personnel

As I have just returned from a visit to various tissue culture laboratories in the Philippines, Thailand, and Singapore, I will also touch upon the facilities and problems I saw in the Southeast Asian laboratories.

First of all, about planning and building the laboratory. When we started in 1977, we had very little information on hand to guide us. If we had had ample funds, we could have hired a professional consultant, engaged a private contractor, and thus perhaps lessened our problems. But we accepted the challenge of starting something new and did most of the work ourselves. To begin with, we visited a number of commercial laboratories in the U.S. and also some University research facilities. We wanted to get some first-hand observation and knowledge of as many facets of these operations as possible. One thing we were particularly interested in was the type of equipment being used by the various laboratories.

In planning, we had to clarify in our minds what the functions of our laboratory would be, keeping in mind expansion possibilities. Our basic function remained, of course, to produce large quantities of economically feasible, clonable ornamental plants. After exploring dozens of plant genera, we finally settled on orchids, *Anthurium*, *Cordyline*, *Dieffenbachia*, and *Spathiphyllum* as the main plants we would focus on. Of these, we are now cloning mostly orchids. The other four plant types were cloned for mother block purposes only.

Once we pinned down the function of our laboratory, we set to work building the facility. This involved planning for size and location of various work areas, preparing for positive aseptic conditions, allocating space for culture shelves, (allowing for shelf height and size) lighting, air conditioning, shakers, laminar flow hoods, traffic flow patterns, etc. . . . All of these and more had to be worked out in detail.

Today our facility occupies 1,800 square feet of working laboratory space. Our transflasking room is approximately 300 square feet, with five laminar flow hoods, two 18,000-BTU air conditioners, and UV lights on the ceilings. We also made provision for installing a suction fan with absolute HEPA filters to bring in outside air, and an exhaust fan to interchange the inside air in the laboratory in order to clear up any build-up of alcohol in the room.

Within the inner laboratory, our explanting room of 72 square feet contains our dissecting microscope. There is also a sink for the sterilization of explants. In addition, we have an interior office and library with two four-tiered lighted shelves. Here we place some of our PLB's mother flasks for evaluation, and here we do our research. This room is 12 × 12 feet.

Our largest room is the culture room. This is 20 × 36 feet. It houses the following:

- Three units of a four-wheeled roll-a-drum rotating shaker, with a capacity of revolving 3,000 test tubes when filled;
- Two units of gyratory shakers, one holding 50-ml flasks and the other designed for 250-ml flasks; and
- Units of single roll-a-drums for research purposes.

The remaining space in our culture rooms holds six sets of 54-in × 8-ft shelves with six tiers of shelving. These are all lighted with four sets of Cool White or Gro-Lux lamps per shelf. The lights are timed to be on for 12 hours only. Our total lighted shelf space has a capacity of holding 13,000 500-ml flasks — more if we interspersed these flasks with our 250-ml mother flasks. (In contrast, the Bangkok Orchid Centre in Thailand, which has a laboratory three times larger than ours in square footage, has a culture room holding 20,000 bottles at a time. The tissue culture laboratory of Multicos Orchids in Singapore was acceptalbe but the one at the University of Philippines at Los Banos was unacceptable, in my opinion.)

Our glassware room of 120 square feet has enough shelving to hold 5,000 flasks, together with our chemicals and other laboratory supplies. We use around 25,000 or more flasks in our operation at a cost of $2.00 per flask. (In contrast, the Bangkok laboratory accommodates around 50,000 bottles at a cost of only 10¢ each. That is a real plus in savings in glassware alone.)

For preparation and sterilization of glassware, for media preparation, and for storage cabinets, we have allocated a room of 400 square feet. This room also houses our autoclave, distiller and de-ionizer, pH meter, electronic balance, microwave oven, blender, propane stove, refrigerator, chemicals, and additional glassware.

Our energy bill averages about $1,200 a month. On the whole, I feel we have a fairly efficient laboratory complex, with our procedures well optimized and our operations properly maximized.

Let me now turn to some problems in culture and management . . .

One of the interesting things about learning is discovering what questions to ask. We've identified some questions of importance to us regarding procedures and techniques of in-vitro propagation. For instance:

- What part of the plant should we try to excise in order to get the proper explant tissue to start with? Or . . .
- How do we get the tissues to produce shoots or other structures that will ultimately grow into a viable plant?
- Among the multitude of factors involved in micropropagation, what are important to measure and balance? . . .

These are factors such as:

— Cytokinins and auxins
— Strength of various chemicals, whether liquid or solid
— pH of media
— Speed of rotation of shakers
— Light intensities
— Temperatures . . . etc. . . .

The key factor in all of this is when to begin and when to stop the various stages of culture. All of these questions require some research on the part of the laboratory, in order to arrive at satisfactory procedures. For instance . . . with our Vacin and Went media, we have 11 different variations being used, just for orchid culture.

The many problems associated with commercial tissue culture operations often can be alleviated by careful planning. Standard operating procedures have to be developed; specific goals have to be set regarding the final form of the product that is to be marketed.

In our case, because we have 8 acres of land for growing and a retail outlet in the heart of Waikiki, we are hopeful that we can sell all of our products — the orchids, the anthuriums, and the bromeliads — in an integrated way. We are at present planning the grow-out and retail operations. We plan to surround our retail outlet with a ¼-acre exotic garden consisting of orchids, bromeliads, and other landscape plants. Our products will be in test tubes, baby food jars; they will be in flasks, community pots; they will also be individual 2-inch cell paks and 4-inch nearly blooming plants, to full flowering plants, ending up with the cut flower stages. What I am saying is that we hope to be one of the few commercial laboratories in our field that will be dealing with the full circle of plant propagation — cloning the plants and growing them to different stages and finally retailing the various products in Waikiki — where more than 3 million tourists visit annually. Our packaging concept is such that we will have products for both

the domestic and the foreign tourist. The U.S. tourist will be able to buy certified, nursery-grown plants; the foreign tourist will be able to purchase test-tube plants that will clear their plant quarantine restrictions.

In operating any tissue culture laboratory, a careful study of the potential market for any of the lab's products must be made before any significant production is initiated. In short, markets determine the best possible program for the laboratory; markets dictate the proper operating procedures to use. In addition, a monitoring program must be installed to insure that the planned procedures are being followed for a consistently high-quality product.

If planning is done well, redundant as well as extra work can be eliminated. This will result in increased efficiency — that is, more actual work results for the same amount or even less effort. This leads to more plants being produced, a larger share of the market, and a resultant higher profit margin. Because of the "newness" of the plant cloning technology as applied to commercial enterprises, studies are needed to determine "fitting" the lab's products into existing practices. In other words, a concerted effort must be made to study the potential market for this new technology. Due to the variations found in each potential crop, specific questions must be answered before the production of any crop is initiated. Questions include the following:

(1) Where is the market for the plant? In our case, as mentioned earlier, because we are not only a commercial micro-propagator but also a grower with good acreage, and a retailer with an ideal location, we can afford to produce plants which are uneconomical for wholesaling, but which can be very profitable for retailing. For example, our *Anthurium andraeanum* plants in baby food jars prepared for retailing to the foreign tourists.

(2) What parts of the market can be integrated with the products of the laboratory? Our operation integrates the culture and the marketing of a full gamut of products — from test-tube plantlets to blooming plants and cut flowers.

(The Bangkok Orchid Growers Cooperative, which is owned by 500 orchid growers farming 6,000 acres, grosses well over 30 million dollars annually. Their tissue culture facilities are the largest that I have seen. They are using eight laminar flow hoods, have seven standing types of autoclaves, they employ 25 workers and have a culture room capacity of 20,000 bottles on triangle-arranged, three-tiered racks. The main function of these facilities is to mericlone and to propagate by seed their various orchid genera for the growers. A few years back, they were selling only the larger cut flower sprays. Today, over 60% of their export cut flower sales are geared to supermarkets in Denmark and Germany. By mixing five sprays of *Dendrobium* and *Arachnis* or *Arandas*, and then adding sword fern stems,

they have created an arrangement packaged for this European market. This is a small example of integration with fabulous economic results.)

(3) Is the plant to be cloned conducive to this kind of technology? And when processing is completed, is the plant still a commercially viable product? Our answer to this question is the key reason we are cloning either award orchids or cut flower cultivars.

(4) What advantages does propagating a certain plant in-vitro have over the standard methods? Will cloning help remove viruses or other plant pathogens? We concentrate on specific orchids in large part because of our high rate of success in explanting and the short period needed for PLB's proliferation. In dendrobium mericloning, we get close to an 80% "take," which is just as good as the world's largest orchid laboratory in Bangkok. Also, we have been successful in culturing out the *cymbidium* mosaic and *odontoglossum* ringspot viruses.

(5) What is the complete cost of production to deliver the finished prouct? In dendrobium orchids, or in the rapid proliferation plants, such as the reed epi's and miniature oncidiums, we estimate our production costs to be approximately 10¢ per mericlone in 5,000 lots, and we are wholesaling them at 25¢ each. For cattleyas, the production cost is double and more, because our "catch" rate is only about 50%. This rate is better than for Bangkok orchids, as they are successful in only 30% of their cattleya explants. I believe their low rate is a matter of techniques or procedures.

(6) What is the future market potential of any cloned plant? And what are the parameters that can affect its future market? Say, in orchids, what will the consumer preferences be in style or in color five years from now? Will the demand continue to be for large flowers for corsages and the smaller flowers for blooming plants, as it is presently?

(7) Is there another crop that is more profitable to clone in the coming years? A crop with better potential than, say, orchids? A crop that can bring a higher unit of return for a longer period of time? We are already looking into the intergenerics, such as the warm climate odontocidiums, aspoglossums, vuylstekearas, maclellanaras, and miltocidiums, to name a few, and the miniature cattleyas, including their intergenerics. The main reason we are doing this is that the newness of these plants and the lack of competition in these genera makes exploration attractive. Also, the present trend in home ownership is in high-rise cubbyholes rather than single-family dwellings with lots of yard space, thus necessitating the growing of smaller plants.

All of these questions impinge upon planning the present and future operations of a commercial tissue culture operation. In addition, for our laboratory, the limited space found in the present facilities must be a consideration, as well as the limited capital available for research and/or improvements. Until such a time when expansion in both space and capital can occur, these limitations will assert considerable influence on our analysis of potential crops and potential growth.

To me, the greatest error any laboratory can make is to produce a crop uneconomically just for the sake of prestige. In the long run, prestige probably won't make money. On the other hand, research is a must. However, it cannot be achieved until there is sufficient capital or cash flow from the products generated by one's laboratory.

I firmly believe that at this developmental stage of commercial ornamental production via tissue culture, the bulk of research should be at the University level, with support from private industry. Research work such as anther culture, chromosome doubling, protoplast fusion, etc., would be of extreme importance to our field.

Earlier I talked about culture and management. That means that a commercial laboratory such as ours must be able to increase the propugule at least four- or five-fold within a year's span, and then have the work scheduled for output accordingly. We must also be successful in growing the plants out from an in-vitro condition into in-vivo nursery conditions, without any appreciable loss from plant mortality. I firmly believe that if the quality of production in the laboratory is good (this means good roots and shoots), then the acclimatization process after the plant leaves the laboratory will be easier and quicker under an increased humidity mist system. Our experience has been that dendrobium explants can be cultured into flowering orchids in less than 30 months.

All of the problems I have discussed and the questions I have cited, must be resolved and commercial procedures optimized before we can say definitely that the cloning of plants, whether orchids or any other genera, is economically viable. My wish is that more persons in the plant cloning field will publish their data oftener and share their knowledge more willingly. It is only through research and shared knowledge that this young industry can survive and thus contribute to a dramatic growth in commercial micropropagation of plants desirable to mankind.

Lastly, a brief word about personnel. It has struck me over and over again that micropropagation is — and will probably always be — a labor-intensive type of operation in a special

sense. That is to say, unless you have dedicated personnel who do not mind tedious, repetitious, daily work, most laboratories will have turn-over problems. I have found that if the owner knows micropropagation in theory and in actual practices, he will not necessarily find himself in a position of having to hire overqualified personnel. He is able to hire less qualified persons who can be trained, and thus he may be able to lessen turn-over problems. Also, once a laboratory is firmly established and can pay well, including provision of worker incentives, then everything that the laboratory does and seeks to do, including research can challenge the employees to good performance. Detail work, in the perspective of learning and achieving, can become an adventure.

In closing, I would like to say that with all of the trials and tribulations I have experienced in starting and operating a commercial tissue culture laboratory, I can testify to pleasures that are denied to those who are not willing to venture into a new enterprise. The pleasure of learning is, to me, undeniable — a very great personal value.

HOW CAN WE GET MICROCUTTINGS OUT OF THE LAB?

JEANNE BARNHILL JONES

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The current use of in vitro techniques for rapid clonal propagation is the most advanced area of plant tissue culture. According to Murashige, by 1978 there were at least 100 facilities engaged in commercially propagating a variety of plants through tissue culture. Nearly all of them arose within the previous 5 years, and several new ones continue to emerge each year (6). It is difficult to obtain accurate production numbers from these commercial micropropagation laboratories. Conservative annual United States estimates range from 14 million units (flower crops, ornamental foliage and ferns) to 55 million (all agronomic crops).

Commercial propagators using plant tissue culture techniques produce plants through adventitious shoots and/or enhanced axillary branching pathways. The in vitro propagation steps are as follows:

Step I. Establishment of an aseptic tissue culture of a plant.

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Step II. Rapid numerical increase of organs or other structures.

Step III. Preparation of propagule for successful transfer to soil, involving rooting of the shoot cuttings, hardening of plants, and initiating the change from the heterotrophic to the autotrophic state.

Step IV. Establishment in soil of a tissue culture derived plants, either after undergoing a Stage III pre-transplant treatment, or in certain species, after direct transfer of plants from Stage II into soil (5).

The tissue culture process is expensive and requires the right combination of facilities, materials, personnel, and plants. Labor has been shown to be the major cost factor in the production of tissue culture grown plants. Anderson and Meagher (1) in 1978 reported that labor, excluding supervisory salaries, was 30.8% of the cost of producing a crop of lilies and that Stage III labor use was 75% of the total labor cost. In 1977, Anderson, Meagher and Nelson (2) reported that wages, supervisory and administrative salaries amount to 65.9% of the total cost of producing a crop of *Brassica oleracea* L. Therefore changing the tissue culture steps to reduce labor is a direct way to reduce the cost of production.

Donnan (3) in 1978 suggested the elimination of a laboratory rooting phase to reduce production costs. He determined that it is possible to take Stage II-3 cultures of *Begonia* × *rex-cultorum* 'Merry Christmas' to the greenhouse, separate out at least 10 plants per culture and plant them. By eliminating Stage III a reduction of 56% in labor cost is realized. Similarly shoots of *Ficus* may be cut from cultures in the laboratory and stuck directly into the rooting medium in the greenhouse. Plants without roots that do not have to be removed from a rooting container and medium can be handled at a faster rate when compared to the conventional method. Additional savings would come from the elimination of Stage III media cost, media preparation labor cost, and the overhead cost per plant when grown in the culture room. Although the elimination of a laboratory rooting Stage III makes costs more reasonable, there remains a great need for determining the specific environmental requirements for successful re-establishment of propagules in the greenhouse.

It has been clearly established that tissue culture derived plants differ considerably from conventionally produced seedlings. Grout and Aston (4) reported that tissue culture produced cauliflower plants have a modified leaf anatomy, where the palisade mesophyll tissue is absent or minimal. In addition, poor vascular connections occur between the root and shoot in vitro and little epicuticular wax is present. Just as in Stage III, the successful re-establishment of unrooted shoots in

the greenhouse requires rooting shoots which have developed in Stage II, hardening the plants to moisture stress, and converting the plants to a more autotrophic form of growth. Detailed studies on the environmental conditions favorable to re-establishment of unrooted shoots in the greenhouse are few.

Donnan (3) reported on rooting uniform unrooted shoots of *Saintpaulia ionantha* 'Marshmallow', *Begonia* × *rex-cultorum* 'Merry Christmas', and *Nephrolepis exaltata* 'Bostoniensis' from Stage II tissue cultures. These shoots were planted into four greenhouse transplant media in seed trays. Some trays were covered with a clear plastic top and placed on a greenhouse bench while others were placed uncovered in a polyethylene covered tent. He indicated that conventional mist systems raise the relative humidity of the atmosphere surrounding a plant. In such situations the moisture content of the growing medium becomes excessive and the CO_2 and O_2 levels become abnormal with subsequent inhibition of root development. In contrast a tent-like structure can maintain high relative humidity without excessive overhead misting required. His results also showed the great variation in growth of unrooted tissue culture grown plants in the greenhouse environment due to rooting medium. A commercially prepared soiless mix, Redi-Earth, from W.R. Grace Co. was better than sand, peat plus styrofoam bead mix, and Plant-Gar plus peat plus styrofoam bead mix for *Saintpaulia* and *Begonia*, whereas *Nephrolepis* shoots did not adapt well to any of the treatments. Plants in tents did better than individually covered trays.

In 1981 a review of synthetic foam growing media from The Smithers Company was initiated by the author to determine whether existing foam products could satisfy both in vitro and in vivo rooting needs. Foam slabs could replace agar as the physical support system. Foam could be saturated with root inducing nutrient formulations, then flushed to remove the sugar containing medium before transferring rooted plants in foam slabs to the greenhouse. A systems approach to getting plants out of the laboratory could be envisioned that would allow for the efficient handling of plant materials as groups of plants instead of individuals. Rooting shoots from Stage II cultures directly in the greenhouse might be feasible for more difficult-to-root plants if a foam rooting medium had the proper balance of open and closed cells which governs saturation and drainage. This gives a proper moisture level for improved rooting.

Foam samples, ¾″ thick were cut from slabs of test materials listed in Table 1 to fit 1 qt Mason jars or Magenta AG7 containers. Distilled water was added to moisten the foam. Vessels containing the foam samples were autoclaved at 121°C,

15 p.s.i., for 15 minutes to determine physical changes. Results are reported in Table 1.

Table 1. Oasis® Grower Product Review.

Product name	Withstands autoclaving	Leaching required	Roots penetrate foam medium, emerge from foam
Rootcubes® Growing Medium	Yes	Yes	Yes
Horticubes® Growing Medium	Yes	No	Yes
Horti III		No	No
Mod. Rootcubes® Growing Medium	Yes	No	No

Products were evaluated for practical use in vitro. Oasis® Rootcubes® Growing Medium used for the rooting of poinsettia cuttings and other vegetatively propagated flowering plants is sterile, economical, and easy to handle in a greenhouse situation. However, the material must be leached by flushing with water to remove residual neutralizing salts from manufacturing. These can cause stem damage to sodium sensitive plants. Foam units could not be economically dried after the leaching step, which makes in vitro use impossible. Known nutrient medium composition could not be added to a wet foam medium. A no-leach phenolic foam was developed by The Smithers Company for actual rooting tests.

Stage II stock cultures of *Philodendron* × *wend-imbe*, an easy-to-root species, were obtained from Phyto-tech Lab. in Torrance, California. Preliminary screening of this no-leach foam against traditional Stage III agar rooting medium was done by placing ¾ in thick slabs of foam in 1 qt Mason jars with 100 ml of liquid rooting solution. Jars were covered with aluminum foil and sterilized by autoclaving at 121°C for 15 minutes. After cooling uniform ¾ in shoots were aseptically taken from Stage II stock cultures and inserted in the foam or agar medium, 24 shoots per jar. Planted jars were placed in the culture room environment of 27°C, 16 hour photoperiod and 3000 lux. Although shoots began to root into the foam slabs within 7 days, no roots emerged from the no-leach foam. Therefore transplanting to greenhouse was not possible.

Additional tests were run using 4 in × 4 in Flow Lab. PlantCon containers, but not under controlled aseptic conditions. Slabs of foam were cut to fit the vessel; distilled water or 50 ppm nitrogen solution (Peters 20-20-20) was added before inserting the *Philodendron* shoots. Shoots were removed from Stage II stock cultures and rinsed in distilled water to remove any agar medium. Each PlantCon contained 36 shoots. Four ⅛ in holes were made in the PlantCon lid to allow for air circu-

lation and to reduce the condensate which collected in the container while in the culture room environment. Again, while shoots began to root into the foam slabs, no roots emerged from the no-leach foam units.

Similarly, shoots placed in Horti III foam slabs in PlantCon containers with distilled water began to root into the foam but no roots emerged. Cubes were cut open to expose the roots which were brown and clubby. Foliage color became increasingly yellow in the distilled water treatments. Tests done on the water drained from the test foam indicated a drop in pH from 6.4 to 2.68. Dilute sodium hydroxide was added to the distilled water until the starting solution level was 10.12 but after a 15 hour soaking period the water drained from the foam was 3.2. No further tests were made.

The last foam growing medium to be reviewed was Oasis® Horticubes® Growing Medium. This product is used for vegetable seed germination, N.F.T. and/other hydroponic growing systems as well as rooting of foliage cuttings in commercial propagation greenhouses. Rooting tests were conducted with Stage II *Philodendron* shoots in PlantCon containers as described above. Shoots began to root into the foam within 7 days and were ready for transplanting after 14 days. Plants with fertilizer were greener and more vigorous at time of transplanting than those without nutrients. Additional rooting tests were performed in the laboratory with *Syngonium podophyllum* 'White Butterfly' and *Gerbera jamesonii* 'Apple Blossom' Stage II shoots with positive results. Consequently rooting tests were transferred from the laboratory and controlled culture room environment to actual greenhouse conditions for larger scale trials.

Horticubes® Growing Medium was cut into 10 in × 20 in sheets, ¾ in thick. Sheets were grooved to make 630 minicubes, ½ in square. These could be used in shallow trays at a spacing of 453 "cubes" per sq ft or separated into individual "cubes" and placed in commercially available plug trays, 288 wells per 11 in × 22 in tray, 171 units per sq ft. To date shoots from Stage II cultures of *Gerbera*, *Syngonium*, *Dieffenbachia*, *Spathiphyllum*, *Ficus*, *Philodendron*, and *Eucalyptus* have been successfully rooted in Horticubes® in the propagation greenhouse environment, thus eliminating the costly labor step of Stage III in vitro.

Additional testing through pilot programs with micropropagators is underway to further determine specific plant and greenhouse requirements for the foam system. Culture media formulation to enhance direct rooting of microcuttings is needed as well as determination of cultural practices (light intensi-

ty and duration, temperature, moisture, relative humidity) during acclimitization and rooting procedures.

The polyurethane foam medium can be autoclaved to meet in vitro needs as well as a combined Stage III+IV in vivo rooting process. The material is sterile through manufacturing procedures and has a 50% drainage factor. This high drainage reduces the likelihood of excessive moisture content, creating a more favorable rooting environment. The material will readily absorb nutrient solutions and can be flushed for quick changes in nutrient composition. Shoots rooted in "cubes" are easy to handle and lend themselves to handling through automation equipment already in use by bedding plant nurserymen today. The use of synthetic rigid foam systems may be the more cost efficient, labor saving way to get millions of microcuttings out of the laboratory.

Acknowledgements. The author wishes to thank The Smithers Company, Smithers-Oasis Division; Phyto-tech Lab. Inc.; Hartman's; Elsberry Greenhouses Inc.; Clonal Resources Inc.; and Greenwood Nursery for their cooperation in this project.

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CUTTING PROPAGATION OF *METASEQUOIA GLYPTOSTROBOIDES*

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In a world where it seems that every time we turn around we hear of another life form that is near extinction or has become extinct it is nice to read or talk about a life form that

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In a world where it seems that every time we turn around we hear of another life form that is near extinction or has become extinct it is nice to read or talk about a life form that

has been rediscovered after it was thought to have been extinct. Such is the case of the genus *Metasequoia* or Dawn Redwood. "Meta" means "akin to" and "sequoia" refers to relating to *Sequoia* and *Sequoiadendron*, all of which are related to the *Taxodium*. Fossil specimens of *Metasequoia* have been identified in Europe, Asia, and North America as old as 50 million years. However, in the mid 1940's, Mr. T. Wang of the Chinese Central Bureau of Forest Research discovered groves of trees of *Metasequoia* growing in central China. Upon hearing this news, the Arnold Arboretum in the United States financed an expedition to secure seed. In the late 1940's, the first seed was delivered to the Arnold Arboretum, which then shared seed with other botanical institutions throughout the world. It was also then that the trees were formally described and named *Metasequoia glyptostroboides*, the only known living species of the genus.[1] The last part of the name means "similar to *Glyptostrobus*", which is another genus of Chinese deciduous conifers.

Metasequoia glyptostroboides is a fast grower, putting on as much as five feet of growth in a season, and may reach a height of 150 feet. The tree has a tapering trunk, with its foliage being a soft green and feathery in appearance, turning a rusty red or pinkish color in the fall. In the United States, it has been hardy into New England. The tree seems to do best under moist soil conditions, but has tolerated mild droughts.

We at the Monrovia Nursery Company have been propagating *Metasequoia glyptostroboides* for many years. The following procedure works best for our propagation of the plant.

Dormant hardwood cuttings are collected off of our bank plantings of *Metasequoia* during late December or early January. The cuttings are cut to about four inches in length and are washed in chlorine water (15 ppm chlorine) followed by a wash in Consan disinfectant (200 ppm Consan). The cuttings are then placed into clear plastic bags containing about 2000 cuttings each. The bags of cuttings are put into cold storage at 45°F for 30 days. Occasional checking of the bags during the 30 day period for possible contamination is advisable. After the 30 days are up, the cuttings are removed from the bags and washed again in the 15 ppm chlorine water and 200 ppm Consan. They are now ready to stick into our propagation mix of 90% coarse perlite and 10% fine peat moss which is steam pasteurized in plastic flats before it is used. The *Metasequoia* cuttings receive a quick basal dip in 3000 ppm IBA (indole-3-

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[1] Bot. Ed. Note: The genus was named in 1941 by Miki in Jap. Journ. Bot. II:261. The species was named in 1948 by Hu & Cheng in Bull. Fan. Mem. Inst. Biol. N.S., I:154. Introduced by Arnold Arboretum in 1946.

butyric acid) and are placed into the propagation medium at the rate of 300 cuttings per flat. The flats of cuttings are then put into one of the outdoor rooting beds with intermittent mist. The rooting beds are made of concrete and supply bottom heat of about 72°F to the cutting flats through the use of copper tubing inside of the concrete which circulates hot water supplied by our boilers.

The *Metasequoia* cuttings will root in about four months at 90%. After rooting is complete, the cuttings are hardened-off and potted about two weeks later. The new plants root into the pot quickly and aready to sell in pots or be canned into larger containers 5½ months from the date that the cuttings were collected.

Our current propagation technique works well into our current set-up for the propagation of our conifers at Monrovia Nursery Company during the winter months. However, softwood cuttings root readily during the early summer months with the use of IBA rooting hormone.

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CUTTING PROPAGATION OF *ACTINIDIA CHINENSIS* (KIWIFRUIT)

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Kiwifruit is a relatively new product on our supermarket shelves, but kiwifruit plants have been around for centuries. Once again, we must go back to China where the kiwifruit, or Chinese gooseberry (*Actinidia chinensis*), is native. In the early 1900's, *Actinidia* was introduced into New Zealand. Eventually, it found its way to California where the production of major quantities did not get a foothold until the early 1970's. Presently, several thousand tons of kiwifruit are produced each year in California.

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Kiwifruit is about the size of an egg and gets its name from the kiwi bird of New Zealand whose body resembles the shape of the fruit. The fruit weighs about four ounces and has a high vitamin C content. It is best eaten raw, and its use with other foods is becoming more popular.

Actinidia chinensis is a deciduous vine that is dioecious (that is, a plant produces either all male or all female flowers). To obtain fruit development, male vines are needed to pollinate the female vines. The leaves are quite large and roundish in appearance.

The most common of the female cultivars in production are 'Abbott', 'Allison', 'Bruno', and 'Chico Hayward'. The most common of the male cultivars are 'Tomuri', 'California Male', and 'Matua'.

The Monrovia Nursery Company has been growing 'Chico Hayward' since about 1975. The most common form of propagation initially was grafting or budding, but this did not give us very good percentages. Cuttings did a little better, but needed much improvement. With the existing demand for plants, we continued experimenting with *Actinidia* to improve cutting propagation.

Another problem we ran into was the chilling requirement that the 'Chico Hayward' cultivar seems to need. In Southern California, the stock plants planted out at Monrovia Nursery are sometimes not ready to collect cuttings from until late June or early July. By the time they root and are potted, fall is already upon us and the root systems are not developed well enough to get them through the winter months and, in addition, many do not break dormancy either because of the chilling requirement or because of poor root systems. Also, the 'California Male' has been more difficult to root than the female cultivar.

With all of these problems, we set out to root the plant well and grow it on into a quality item which is the Monrovia Nursery tradition. The following is an update on the cutting propagation procedure for *Actinidia* 'Chico Hayward' at Monrovia Nursery, beginning with a discussion of the female cultivar.

We started out using single node cuttings, washing with chlorine water (15 ppm chlorine) followed by a wash in Consan disinfectant (200 ppm Consan). The large leaves were cut in half. The base of the cuttings received a quick dip in 3000 ppm IBA (indole-3-butyric acid). The cuttings were then put 120 to a plastic flat containing a propagation medium (90% coarse perlite and 10% peat moss), which had been pasteurized before use. The flats of cuttings were then put into heated

greenhouses under intermittent mist where the rooting took two to three months. The rooting was poor (under 35%), and the root systems that did develop were poor.

We then tried using higher concentrations of IBA at 6000 ppm and 8000 ppm, but with no major improvements. Finally, we decided that other types of hormones and/or combinations of hormones should be tried. NAA (naphthaleneacetic acid) was tried next at 1000 ppm and rooting improved to 70%. This was a major breakthrough for us, but again the roots that did form were not well developed. Since we felt that NAA was perhaps the right hormone to work with, we set up more experiments using NAA and IBA combinations, as well as with DMSO (dimethyl sulfoxide), as a carrier. We also kept records of the appearance of the root systems as the rooted cuttings were pulled; 400 cuttings each were tried with four different hormone concentrations, with 1000 ppm NAA being used as the control. The same cutting type, heated greenhouse, and propagation medium were used as previously described. The results are presented in Table 1.

The rooting time was about the same (two to three months), but the number rooted increased with the 3000 ppm IBA + 3000 ppm NAA treatment and the 3000 ppm IBA + DMSO treatment. Root proliferation had greatly improved with the 3000 ppm IBA + 3000 ppm NAA treatment, but was less with the 3000 ppm IBA + DMSO treatment. Therefore, after again repeating the experiment, we decided to use the 3000 ppm IBA + 3000 ppm NAA treatment as our standard treatment for *Actinidia chinensis* 'Chico Hayward'.

However, our problems were still not over, as the dormancy requirement was still to be contended with. We conducted a cold storage experiment on bare-rooted *Actinidia* cuttings to encourage bud break in the spring. We found that 500 hours of cold storage (three weeks) at 39°F gave us 51% of the plants on which the buds broke after they were potted, versus only 35% of the control (which were rooted cuttings stored outside in their propagation flats through the winter). We then decided to cold store bare-rooted *Actinidia* cuttings before spring potting.[1]

Table 1. Effects of selected hormone treatments on the rooting of *Actinidia chinensis* 'Chico Hayward'.

Hormone	Percent rooted
1000 ppm NAA	72.5%
1000 ppm IBA + 1000 ppm NAA	53.5
3000 ppm IBA + 3000 ppm NAA	72.2
3000 ppm IBA + DMSO	73.5
6000 ppm IBA + DMSO	58.5

[1] Ed. Note. Hayward kiwifruit plants require about 700 hrs. of chilling below 45°F.

The 'California Male' *Actinidia* was a slightly different story. The male *Actinidia* rooted best for us with the use of IBA + NAA combinations and IBA + DMSO as well. We also got better root systems as on the female cultivar. However, the overall rooting percentages were lower. Again, 1000 ppm NAA was used as the control, as well as the same type of cutting and conditions as used for the female cultivar's propagation. The results are presented in Table 2.

Table 2. Effects of selected hormone treatments on the rooting of *Actinidia chinensis* 'Chico Male'.

Hormone	Percent rooted
1000 ppm NAA	12.8%
3000 ppm IBA + 3000 ppm NAA	32.8
3000 ppm IBA + DMSO	37.5
6000 ppm IBA + DMSO	27.0

The cold storage experiment was also repeated, again with percentages of bud development being below that of the female cultivar; 46.5% of the potted *Actinidia* males broke dormancy after potting in early spring versus 40.1% for the control which were stored outside in their propagation flats.

For the present, we are going to utilize 3000 ppm IBA + 3000 ppm NAA as our standard hormone treatment, as well as the cold storage of rooted cuttings before potting in the spring. Please note that we did not want to use the 3000 ppm + DMSO as our standard treatment for either the female or male Actinidias, even though rooting percentages were higher. That decision was made because the root proliferation was not as great as with the 3000 ppm IBA + 3000 ppm NAA treatment, and saved us working with another chemical when mixing hormones.

We have also had success rooting hardwood cuttings, but will try this again next year to verify our first year's results. So far, it looks feasible.

Monrovia Nursery is also working with other *Actinidia* cultivars that may do better in Southern California as far as chilling requirements, fruit production, and propagation are concerned. Female cultivars which we are investigating are 'Vincent' and 'Bruno'. The 'Vincent' *Actinidia* is a 'Hayward' seedling developed in Southern California by Ray Vincent of the California Rare Fruit Growers. So far, propagation indicates that these two females are easier to root and grow on than 'Chico Hayward'.

Other male cultivars of *Actinidia* are 'Tomuri' and 'Matua'. We are currently propagating these, but it will be a while before we know how they perform. There is even a monoecious cultivar being tried called 'Blake'.

It seems that we are finally on the right track with the cutting propagation of *Actinidia*, and hopefully our future production will no longer be a problem.

Acknowledgements. I would like to thank Richard Wells and Rodger Duer, who work with me in Monrovia's Propagation Department, for their help and suggestions in the previously discussed experiments, and also Gene Blythe, Monrovia's Research Propagator, for carrying out the propagation experiments, preparing the hormones, and collecting and summarizing the results.

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MAILE SEED GERMINATION AS AFFECTED BY PREPLANT SOAKING IN WATER WITH AND WITHOUT AERATION AND BOTTOM HEAT

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Abstract. Removal of fleshy seed pulp accelerated germination of maile (*Alyxia olivaeformis*). Trendwise, presoaking in aerated water was the most effective treatment. Non-heated medium produced highest germination whereas 31°C severely inhibited germination.

REVIEW OF LITERATURE

Maile (*Alyxia olivaeformis*), a valuable foliage plant for making leis in the Hawaiian Islands, is propagated primarily by seeds. Tanabe (5) demonstrated that preconditioning with growth regulators increased the germination rate and percentage of depulped maile seeds. A 48 hr soak in 1000 ppm gibberellic acid (GA) resulted in 97% germination after 13 weeks. The control had only 3% germination for that same period. Although presoaking with growth regulators proved effective, these compounds are not readily available. GA is also expensive and requires a centigram weighing balance to weigh the small amounts of material required.

It has been documented that soaking seeds in water increases germination rate for several plant species (1,2). Kidd and West (3) found that germination rate could be increased for pea, dwarf bean, barley, and sunflower without injury. Chippendale (1) worked with cocksfood (*Dactylis glomerata* L.) and speculated that soaking seed increased water uptake through the palea, thereby accelerating germination.

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Bottom heat in conjunction with chemical soaking treatments has been employed as a means of increasing seed germination (4). Germination rate of presoaked Macarthur palm seeds was greatly increased with 27° ± 1°C medium temperature when compared to an unheated medium.

This study was conducted to evaluate the effectiveness of presoaking seeds in water, with and without aeration, in conjunction with bottom heat.

MATERIALS AND METHODS

Vine-ripened maile seeds were obtained from the 365 M elevation at Kalapana, Hawaii. Thirty seeds with intact pulp served as the control. The pulp was removed from the remaining seeds prior to treatment and placed in beakers containing 250 ml water. Aeration was provided by a Whisper model 700A air pump. The seeds were planted in flats containing No. 2 vermiculite and placed in a shade cloth covered greenhouse under 27 klx. Low watt propagation mats (model OP-175) were used as a source of bottom heat. Germination percentage was based on plumule emergence from the growing medium.

Each treatment consisted of 3 replications and 10 seeds per replication. The presoaking treatments included the following: 72, 96 and 120 hr soak in water with daily water change; 72, 96 and 120 hr soak in water with aeration and daily water change. The bottom heat treatments provided the following media temperatures: 26°C, 31°C, and 18° to 27°C.

RESULTS AND DISCUSSION

Depulping increased maile seed germination rates and percentages at all media temperatures (Tables 1, 2 and 3). Germination percentage at 10 weeks was 2½ to 5 times higher than the control, probably because the fleshy seed pulp inhibited seed germination. Very poor germination was observed at 31°C medium temperatures. The higher medium temperature probably reduced seed viability because no germination occurred after the bottom heat source was removed.

Germination was higher than the control for all no aeration presoaking treatments but was not different from the depulping treatments (Table 1, 2 and 3). This implies that germination inhibitors were probably not involved or that the inhibitors were not readily leached by presoaking treatments. There was also no difference between presoaking treatments at all media temperatures. The extended water soak apparently had no adverse affect on seed germination. The 31°C medium temperature delayed germination and greatly reduced germination percentage at 10 weeks.

Table 1. The effect of depulping and presoaking in water with and without aeration on the germination of maile seeds with 26°C medium temperature.

Treatment		Percent Germination			
		4 wk	6 wk	8 wk	10 wk
Control (seeds + pulp)		3 a[z]	3 c	3 c	10 b
Depulped		3 a	13 bc	27 bc	50 a
Presoaking Treatments					
No aeration,	72 hr	13 a	33 abc	40 ab	47 ab
	96 hr	3 a	37 ab	47 ab	57 a
	120 hr	3 a	20 abc	40 ab	53 a
With aeration,	72 hr	3 a	27 abc	43 ab	47 ab
	96 hr	13 a	47 a	63 a	67 a
	120 hr	7 a	23 abc	40 ab	30 ab

[z] Mean separation in columns by Duncan's multiple range test, 5% level.

Table 2. The effect of depulping and presoaking in water, with and without aeration, on the germination of maile seeds with 31°C medium temperature.

Treatment		Percent Germination			
		4 wk	6 wk	8 wk	10 wk
Control (seeds + pulp)		0 a[z]	0 a	0 a	0 c
Depulped		0 a	0 a	7 a	17 ab
Presoaking Treatments					
No aeration,	72 hr	0 a	7 a	10 a	17 ab
	96 hr	0 a	13 a	17 a	23 a
	120 hr	0 a	3 a	3 a	3 bc
With aeration,	72 hr	0 a	7 a	7 a	7 bc
	96 hr	0 a	3 a	13 a	13 bc
	120 hr	0 a	0 a	10 a	17 ab

[z] Mean separation in columns by Duncan's multiple range test, 5% level.

Table 3. The effect of depulping and presoaking in water with and without aeration on the germination of maile seeds with 18° to 27°C medium temperature.

Treatment		Percent Germination			
		4 wk	6 wk	8 wk	10 wk
Control (seeds + pulp)		0 f[z]	3 c	13 e	20 cde
Depulped		20 bcd	43 b	47 bc	53 ab
Presoaking Treatments					
No aeration,	72 hr	3 ef	35 bc	35 bcd	38 bcd
	96 hr	17 bcde	43 b	57 abc	60 ab
	120 hr	7 def	23 bc	40 bcd	50 abc
With aeration,	72 hr	23 bc	40 b	57 abc	67 ab
	96 hr	40 a	70 a	77 a	80 a
	120 hr	30 ab	40 b	43 bc	57 ab

[z] Mean separation in columns by Duncan's multiple range test, 5% level.

Presoaking aeration treatments produced a trendwise increase in germination rate and percentage especially at 18° to 27°C medium temperature (Table 3). Highest germination was

observed with the 96 hr aeration presoaking treatment. Total germination percentage at 10 weeks was 80% for 96 hr aeration presoak, 20% for control, 53% for depulping, and 60% for 96 hr no aeration treatments. The effect of high medium temperature was consistent with the other experiments. A 31°C medium temperature severely inhibited seed germination.

In summary, depulping greatly improved maile seed germination. Presoaking the depulped seeds in water with and without aeration produced similar germination trends to the depulping treatments. However, presoaking with aeration for 96 hr produced the highest seed germination with the unheated medium (18° to 27°C). Bottom heat is not necessary and 31°C medium temperature drastically reduced germination.

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COMPARISON OF ROOTING MATERIALS ON LEUCOSPERMUM CUTTINGS

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The development of proteas as an export cut flower crop for Hawaii is relatively recent. As a result of a research project in the University of Hawaii's Department of Horticulture, the first commercial protea farm was planted on a 6-acre tract of land adjacent to the Experiment Station in Kula, Maui in the fall of 1972. The second farm was planted in 1975, encompassing approximately 12 acres. Today, there are over 110 acres of proteas planted in Hawaii on the cool slopes of volcanoes on Maui and the Island of Hawaii.

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At first, plants from seed were considered to be the appropriate material to use. As the protea industry expands on an

international level, it has become increasingly evident that farms planted with vegetatively propagated selections of cultivars with superior colors, shipping qualities, and resistance to disease will have significant competitive advantage over farms with seedlings of variable quality.

In anticipation of the release of 3 clones of the sunburst protea, (Leucospermum) to the industry in the fall of 1982, a project to compare three commercial rooting materials was conducted at the Maui Agricultural Research Center in Kula. Two *Leucospermum* hybrids from South Africa were used: 'Firefly' (*L. tottum* × *L. cordifolium*), and 'Veldfire' (*L. conocarpodendron* × *L. glabrum*).

The three commercial rooting materials were two liquid formulations and one powder. The two liquids contained both IBA and NAA while the powder contained IBA only. Table 1 presents the concentration of auxins listed on the labels of the three materials used and Table 2 lists the various treatments.

Table 1. Auxin composition of the three materials tested.

	Composition	
Material	IBA	NAA
Dip 'n Grow (liquid)	1.0%	0.5%
Hormex #8 (powder)	0.8%	—
Wood's Rooting Compound (liquid)	1.03%	0.51%

Table 2. Treatments used in rooting *Leucospermum* cuttings.

Treatment No.	Material	Dilution
1	Dip 'n Grow	1:5
2	Dip 'n Grow	1:10
3	Dip 'n Grow	1:20
4	Wood's Rooting Compound	1:5
5	Wood's Rooting Compound	1:10
6	Wood's Rooting Compound	1:20
7	Hormex #8	Talc dip
8	Control	—

The basal portion of 4 in. terminal cuttings of recently matured wood were dipped for 5 seconds in the compound appropriate for each treatment. The cuttings were stuck in alternate squares of the Speedling tray with 0.4 cm. openings. A rooting medium of 50% coarse peat moss and 50% #2 grade perlite was used. Bottom heat at 21°C was maintained on the propagating benches and mist of 2.5 seconds duration was on every 5 minutes during daylight hours.

Cuttings were stuck June 15, 1982; 45 days later, August 1, cuttings with roots showing through the bottom opening in each square were potted. The project was concluded Septem-

ber 1, 75 days after sticking, when all remaining rooted cuttings were potted up.

Table 3 gives the results of the various treatments on rooting of the two Leucospermum cultivars.

Table 3. Effectof three materials on rooting of *Leucospermum* 'Firefly' and *L.* 'Veldfire' cuttings.[1]

		Percent of Cuttings Rooted and Potted		
Cultivar	Treatment No.	45 Days	75 Days	Total
'Firefly'	1	18	52	70
	2	53	41	94
	3	55	29	84
	4	53	23	76
	5	54	27	81
	6	42	28	70
	7	12	48	60
	8	16	30	46
'Veldfire'	1	44	50	94
	2	50	40	90
	3	30	30	60
	4	50	44	94
	5	30	40	70
	6	40	15	55
	7	56	19	75
	8	3	19	22

[1] 64 cuttings per treatment — 'Firefly'
20 cuttings per treatment — 'Veldfire'

The use of a commercial rooting material resulted in an increase in rooting percentage as compared to the untreated control, (Treatment No. 8).

After 45 days, better than 50% of the 'Firefly' cuttings had rooted with no appreciable difference between Dip 'n Grow at 1:10, 1:20 and Wood's Rooting Compound at 1:5 and 1:10. With 'Veldfire', 50% of the cuttings had rooted in the Dip 'n Grow 1:10 and Wood's 1:5 treatments; 56% of the cuttings had rooted in the Hormex #8 treatment after 45 days.

For total percent rooting after 75 days, for 'Firefly', the three best treatments were: Dip 'n Grow at 1:10 (95%), Dip 'n Grow at 1:20 (84%) and Wood's Rooting Compound at 1:10 (81%). For 'Veldfire', 94% rooting was achieved with either Dip 'n Grow or Wood's at 1:5. Dip 'n Grow at 1:10 produced 90% rooting.

BRANCHING OF *TUPIDANTHUS* AIR LAYERS AFTER TOPPING AND DEFOLIATION

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Abstract. Defoliation of topped *Tupidanthus* layers initially stimulated higher numbers of lateral breaks than decapitation alone. The subsequent elongation of the laterals, however, was greatest in the non-defoliated treatment.

Tupidanthus calyptratus Hook. f. & T. Thoms. is a tropical ornamental that is increasing in popularity. Although similar in habit to *Brassaia actinophylla* Endl. (1), *Tupidanthus* possesses a higher value in the wholesale foliage market. In Hawaii, air layers are used to increase field stock plantings of *Tupidanthus*; however, these air-layered shoots exhibit strong apical dominance with little branching occurring after transplanting into the field. The potential for obtaining additional layers from these shoots would be improved if greater branching was achieved. In this paper, we report the effect of topping and leaf removal on lateral shoot growth of air-layered *Tupidanthus*.

MATERIALS AND METHODS

Tupidanthus plants growing in Keaau, Hawaii were air-layered in August, 1981 by, making 3 spirally arranged slits 76 cm from the shoot apex. Thirteen weeks later, the layers were removed, treated, and planted into holes filled with 20 liters of sugarcane ash. The parent soil in the area was a histosol composed primarily of crushed Aa cinder and organic matter. Treatments were: 1) intact control; 2) decapitation + complete defoliation; 3) decapitation + defoliation with the 5 uppermost leaves intact; 4) decapitation + defoliation with the 5 lowermost leaves intact; and 5) decapitation without defoliation. Each treatment consisted of 10 replicate plants. All decapitations were performed at the internode above the latest fully expanded leaf. Observations of lateral shoot number and length were made at 6 and 29 weeks.

RESULTS AND DISCUSSION

At 6 weeks after treatment the greatest number of breaks was evident in the decapitated, fully defoliated plants (Table 1). Removal of the upper leaves was more effective in stimu-

lating lateral breaks than removal of lower leaves. These results indicate that leaves contribute to the inhibition of bud outgrowth and are consistent with the conclusions obtained by previous workers (4). The greater inhibition experienced in plants with the upper leaves intact is not surprising since leaves are known auxin sources (2), and auxin transported from apical tissues is involved in the inhibition of lateral bud growth (3,4).

Table 1. Lateral breaks in *Tupidanthus* air layers at 6 and 29 weeks after decapitation and defoliation

Treatment	Mean number of lateral breaks	
	6 weeks	29 weeks
Intact control	0	0.4
Decapitation + no defoliation	0.7	4.0
Decapitation + lower leaves removed	1.1	4.0
Decapitation + upper leaves removed	3.2	5.6
Decapitation + complete defoliation	12.5	Dead
LSD, 5%	1.8	2.6

The data in Table 1 also show that decapitated, non-defoliated plants initially exhibited a low number of lateral breaks, but no significant differences were evident in the surviving decapitation treatments at 29 weeks. Length of the laterals in the non-defoliated plants, however, was superior to those in the remaining treatments (Table 2). By 29 weeks none of the fully defoliated plants had survived the treatment.

Table 2. Length of lateral shoots in *Tupidanthus* air layers 29 weeks after treatment

Treatment	Mean length of lateral shoots (cm)
Decapitation + no defoliation	36.4
Decapitation + lower leaves removed	24.7
Decapitation + upper leaves removed	16.7
LSD, 5%	10.5

Thus, although lateral breaks in decapitated plants was encouraged by defoliation, it probably resulted in sufficient deprivation of photosynthates to limit the subsequent growth of the laterals. Our study provides practical information regarding *Tupidanthus* propagation and indicates that decapatition without defoliation is the preferred method to obtain material for additional layers.

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SEED PROPAGATION OF PALMS

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Abstract. Interest in the production of palms in Hawaii has accelerated in recent years. This has resulted from greater use of palms in the landscape and the potential production of palms for the export market for interior landscape use on the mainland.

With this increased production has come a great awareness of some of the production problems with this crop. During the past year we have initiated a research project to study the culture and nutrition of palms. One of the objectives of the project is to determine the factors that influence the rate of palm seed germination and establishment. Two preliminary trials are reported here.

REVIEW OF LITERATURE

There are several different methods that have been used to improve the germination of palm seeds. *Copernicia* palm seeds were found to begin germination within 5 to 21 days after the pericarp was removed and the seeds were soaked in tap water which was changed daily. Mechanical scarification and soaking in 10% sulfuric acid for 15 minutes further hastened germination (10). Scarification by filing the hilum until the embryo was visible accelerated seed germination of *Gastrococos crispa* (Syn.: *Acrocomia crispa)* and *Arenga engleri* (8). Supplemental bottom heat (75 to 80°F) has been found to accelerate germination in many palm species (16,19,20) and soaking areca palm seeds briefly in sulfuric acid has also been recommended (2,15).

Most researchers agree that palm seeds germinate best when fresh, ripe seeds are used. Many palms lose their viability within a month as they have almost no ability to withstand desiccation (6). The fruit pulp or pericarp is usually removed and the seeds sown in a sterile, well drained medium such as vermiculite, which has good porosity and a high water holding capacity (19). However, Bunker (4) reported a germination rate of 83% after 30 days for *Chrysalidocarpus lutescens* seeds with the fruit pulp still attached when treated with 75° to 85°F bottom heat.

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Nagao and Sakai in 1979 (13) demonstrated that presoaking Alexandra palm seeds *(Archontophoenix alexandrae)* in water for 24 to 72 hours enhanced germination and was further increased by soaking in 100 and 1,000 ppm GA. The following year, Nagao *et al* (14) found that scarification and presoaking with water or 1,000 ppm GA were the most effective methods of accelerating seed germination in Alexandra and Macarthur *(Ptychosperma macarthurii)* palms, and that the use of bottom heat (27°C) further reduced the germination time of Macarthur palm seeds.

Palm seeds are often planted in flats or beds and transplanted to container for growing on. Vegetable transplanting studies have found that yield, size, overall growth, and health are greatly influenced by the time of transplanting due to the physiological recovery of the young plants (1,11,21). The general rule is to transplant seedlings with the appearance of the first true leaves (3,17,18). Failure to remove plants from the flat at this stage can result in extensive root damage of the over-developed root system which results in slower establishment and poor growth (3). It is suggested that palm seedlings should be transplanted when one to two mature leaves have developed (5,9,12,19).

MATERIALS AND METHODS

Areca palm or golden-fruited palm *(Chrysalidocarpus lutescens* H. Wendl.), an important ornamental foliage plant from Madagascar, was used in these trials. Although their seeds germinate more readily than those of many other palm species, accelerating the germination rate and increasing total germination are still matters of concern to commercial nurseries.

Experiment I.

The purpose of this study was to determine if presoaking Areca palm seeds in water or aqueous solutions of gibberellic acid (GA) would shorten the time to, and increase the percentage of germination. Mature Areca palm seeds were obtained locally in January, 1982. After the exocarps were removed, the seeds were treated as follows: a) presoaked in distilled water for 24 to 72 hours; b) presoaked in aqueous solutions of GA at 10, 100 or 1,000 ppm for 72 hours; and c) untreated. The 6 treatments were replicated 6 times, with 150 seeds per treatment in a randomized block design.

The seeds were planted in No. 2 vermiculite and placed in a 73% shade Saran house, with a medium temperature range of 68 to 72°F. Germination was determined by shoot visibility 30, 40, 50 and 60 days after planting.

Experiment II

This study was initiated to determine the best stage and method for transplanting areca palm seedlings for optimum growth and development. It has also been observed that recently transplanted seedlings exhibit unexplained leaf spotting and plant losses. This study was also designed to evaluate the influence of handling during transplanting on seedling establishment and growth.

Emerging seedlings were taken from community seedling flats at three stages: (1) when the first leaf was elongated but not unfolded; (2) when the first leaf was fully matured; and (3) when the second leaf was fully unfolded. Seven treatments were installed in a completely randomized design with 8 replications for each of the three stages. The treatments consisted of: (1) seedlings carefully removed, leaving roots and the medium intact; (2) seedlings separated and planted immediately; (3) seedlings separated then allowed to sit on top of the flat exposed for 30 minutes then planted; (4) seedlings separated then planted but not watered until the next day; (5) seedlings separated then placed under intermittent mist for 30 minutes, then planted; (6) seedlings separated, planted, placed under inermittent mist for one day; and (7) seedlings separated then planted immediately and placed under 30% Saran shading.

Seedlings of all stages were planted into 10.2 cm black plastic pots with 5 uniform seedlings per pot. The medium consisted of a 1:1 (v:v) peat:perlite mix, with Micromax and dolomite lime added at the rate of 1.5 and 8 lbs per cu. yd., respectively. A soluble 20-20-20 fertilizer was applied every 10 days.

Treatments, with the exception of No. 7, were placed under 80% Saran shade at the Magoon Research Facility on the University of Hawaii at Manoa campus. Plants were watered immediately unless treatments dictated otherwise. Temperature in this area during the experiment ranged from 20° to 30°C.

Observations were made at 10-day intervals consisting of 1) increase in height and 2) seedling mortality. Measurements were concluded at the 50th day from the start of the transplanting. Analysis of variance and mean separation were conducted on the data.

RESULTS AND DISCUSSION

Experiment I

Seed germination was higher than the control for each treatment at the 40 day interval, with the highest germination

at 1,000 ppm GA (Table 1). At the 50 day interval, only GA at 100 and 1,000 ppm significantly enhanced the germination over the other treatment. However, the final germination percentage at 60 days after planting was not significantly influenced by any of the treatments. Thus, while the treatments did accelerate the germination rate, the final germination percentage was not significantly greater than the control. Future research should determine if presoaking seeds in GA shortens the time of germination to an amount significant to justify the additional material and labor expense.

Table 1. The effect of seed treatment on germination percentage of areca palm (*Chrysalidocarpus lutescens*) seeds.

		Days following treatment			
Treatment	Rate	30	40	50	60
Control	—	0	8.0[x]	52.0c	73.3ab
Water presoak	24 hrs	1.3	26.7b	51.3c	64.0b
Water presoak	72 hrs	0.7	27.3b	56.0bc	70.7ab
GA	10 ppm	0	35.3b	67.3ab	81.3a
GA	100 ppm	0.7	39.3b	71.3ab	78.7a
GA	1,000 ppm	2.7	66.0a	76.0a	82.0a

[x] Mean separation within columns by Duncan's multiple range test, 5% level.

The slow germination of palm seed has been attributed to the possibility of chemical inhibitors within the seed as well as the hard seed coat surrounding the endosperm (7,14). Nagao *et al.* believed the effectiveness of GA was related to its ability to penetrate the seed coat of the palms, since scarification and GA at 1,000 ppm increased the germination rate (14). While no chemical inhibitors have been found in palm seeds to date, they may contribute to their slow germination rate. Thus, it is possible that GA, as a germination promoter, might counteract *many of the inhibitory effects of these endogeneous substance.* This work demonstrates that presoaking in water and GA accelerate areca palm seed germination.

Experiment II

Areca palm seedlings transplanted at the spike leaf stage showed little growth reduction due to handling methods (Table 2). Exposing the seedling roots to the air for 30 minutes prior to planting resulted in a slight set-back in height 20 days after planting. However, after 30 days these plants had recovered and were comparable in size to the other treatments.

When the seedlings were transplanted after the first leaf was fully expanded (Table 3), those that had their roots exposed to the air for 30 minutes were permanently stunted, showing no indication of recovery 50 days after transplanting.

Again, the other treatments had no adverse effect on seedling growth.

Table 2. The effect of transplant treatment on growth[x] of areca palm (*Chrysalidocarpus lutescens*) seedlings transplanted at "spike leaf" stage.

Treatment	Days After Transplanting				
	10	20	30	40	50
1. Minimum disturbance	1.2a[y]	5.0ab	6.2a	8.6ab	9.4a
2. Normally planted	1.1a	4.1bc	6.2a	8.8ab	9.7a
3. Seedlings exposed to air	1.4a	3.7c	6.5a	8.4ab	9.9a
4. Planted; water withheld	1.2a	4.1bc	6.2a	7.3b	9.6a
5. Seedlings exposed to mist	1.4a	4.8ab	6.4a	8.2ab	9.9a
6. Planted; exposed to mist	1.4a	4.9ab	6.9a	9.0	10.4a
7. Planted; 30% shade	1.5a	5.4a	6.0a	8.4ab	9.2a

[x] Average growth increase after transplanting (cm).
[y] Means followed by the same letter are not significant at the 0.05 level.

Table 3. The effect of transplant treatment on growth[x] of areca palm (*Chrysalidocarpus lutescens*) seedlings transplanted at first stage.

Treatment	Days After Transplanting				
	10	20	30	40	50
1. Minimum disturbance	2.2a[y]	4.3a	6.5a	7.8a	8.5a
2. Normally planted	1.5ab	3.4ab	5.8a	7.6ab	8.4a
3. Seedlings exposed to air	0.9b	1.5b	2.3b	3.7b	5.3b
4. Planted; water withheld	1.7ab	3.6a	5.8a	7.5a	8.7a
5. Seedlings exposed to mist	1.5ab	3.5a	5.8a	7.4ab	7.9a
6. Planted; exposed to mist	1.6ab	3.1a	5.3a	7.0a	7.9a
7. Planted; 30% shade	1.4ab	2.9ab	5.7a	6.8a	8.1a

[x] Average growth increase after transplanting (cm).
[y] Means followed by the same letter are not significant at the 0.5 level.

Transplanting at the two-leaf stage resulted in greater growth reduction on seedlings with their roots exposed for 30 minutes (Table 4). These plants were 64% shorter than seedlings that were bare-rooted but planted immediately, when measured 50 days after transplanting. This compares to a 37% growth reduction for seedlings transplanted at the one-leaf stage. Also, seedlings transplanted at this stage and placed under mist for 24 hrs following potting were significantly reduced in growth for the first month, but appear to recover as indicated by the measurements 50 days after transplanting.

The number of seedlings which died were again highest where the seedling roots were left exposed for 30 minutes prior to potting (Table 5). The mortality increased as the age of the seedling increased with losses of 63 percent for seedling transplanted at the 2-leaf stage compared to only 8 percent when transplanted at the spike stage.

The results of this trial would suggest that areca palm seedlings can be successfully transplanted from the communi-

ty seedling flat when reasonable care is exercised but plant losses can result if the seedling roots are allowed to dry. Best results were obtained when the roots received minimum disturbance or were removed from the germination medium, potted, and water immediately. It is also suggested that plant losses can be minimized by transplanting at an early stage, at the spike leaf or 1st leaf stages.

Table 4. The effect of transplant treatment on growth[x] of areca palm (*Chrysalidocarpus lutescens*) seedlings transplanted at two-leaf stage.

	Days After Transplanting				
Treatment	10	20	30	40	50
1. Minimum disturbance	2.2a[y]	3.0a	3.6ab	7.1a	10.1a
2. Normally planted	1.6ab	2.9a	4.0a	6.5a	9.4a
3. Seedlings exposed to air	1.1b	1.4b	1.6c	2.4c	3.4b
4. Planted; water withheld	1.8ab	2.8a	4.1a	6.0ab	8.3a
5. Seedlings exposed to mist	1.4ab	2.9a	3.9a	5.8ab	8.6a
6. Planted; exposed to mist	0.9b	1.7b	2.5bc	4.7b	7.9a
7. Planted; 30% shade	1.9ab	3.1a	3.9a	5.9ab	9.2a

[x] Average growth increase after transplanting (cm).
[y] Means followed by the same letter are not significant at the 0.05 level.

Table 5. Mortality[x] of areca palm (*Chrysalidocarpus lutescens*) seedlings due to treatment.

	Development Stage of Palm Seedlings		
Treatment	Spike leaf	1 leaf	2nd leaf
1. Minimum disturbance	0%	0%	0%
2. Normally planted	0	0	0
3. Seedlings exposed to air	7.5	35.0	62.8
4. Planted; water withheld	0	7.5	7.5
5. Seedlings exposed to mist	0	2.5	5.7
6. Planted; exposed to mist	0	2.5	0
7. Planted; 30% shade	5	2.5	0
TOTAL	1.8	7.1	11.0

[x] Percent that died of all seedlings in treatment.

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ROOTING OF STEM CUTTINGS OF BREADFRUIT (*ARTOCARPUS ALTILIS* [PARKINS.] FOSB.) UNDER INTERMITTENT MIST

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Abstract. Mature, woody, leafless cuttings of 'Ma opu' and 'Maafala' breadfruit rooted with 95% success under intermittent mist in about 10 weeks after treatment with rooting hormones. Some cuttings rooted and/or sent out shoots more rapidly than others and additional time under mist might have produced stronger root systems. There is also a preliminary indication that leafless stem cuttings can be rooted in a shaded transparent plastic tent, used as a humidity chamber. This would be a particularly

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useful and practical method where mist propagation facilities are not available.

INTRODUCTION

The traditional method used for propagating seedless breadfruit in the islands of the Pacific where it is an important staple food is by root suckers or root cuttings (1,2,3,8). Root suckers are encouraged by severing a root an inch or more in diameter which is then uncovered, pulled up and tied to a stake or propped up a few inches above ground level. After a few months an adventitious shoot will emerge from the cut root. Eventually this new shoot with a section of the attached root can be dug up and transplanted. This method is slow, tedious, inefficient, and facilitates the spread of soil-borne pathogens. Root cuttings 2 to 3 cm in diameter and about 20 cm long planted diagonally in sand or sandy soil are sometimes used to propagate seedless breadfruit clones but have the same disadvantages as root suckers and often fail to grow and produce shoots or new roots. Root cuttings and root suckers are also slow to become established as plants and are not an efficient means of propagating large numbers of plants. A detailed account of the establishment and transplanting of plants from root cuttings and root suckers is given by Pope (5).

Breadfruit leaves are large, cumbersome, and so difficult to maintain upright that rooting of leafy cuttings is generally not considered feasible. Most rooting trials with stem cuttings have given negative results, probably because leafy cuttings were used, although some degree of success with stem cuttings has been reported (4,6,7). Because of the relative abundance of stem cutting material it was considered worthwhile to attempt to root stem cuttings using mist propagation facilities and root stimulating hormone mixtures.

MATERIALS AND METHODS

An experiment was set up at the University of Hawaii at Manoa in 1981 to test the rooting behavior of leafless breadfruit cuttings under intermittent mist. On May 18, 1981, 20 well-matured, 3 to 5 cm diameter leafless cuttings of the cultivar Ma opu were cut into 30 to 40 cm lengths. They were immersed in a Captan slurry for 5 minutes and the terminal end of each cutting was sealed by dipping in melted paraffin wax. Then the basal ends of the cuttings were dipped in a talc dust mixture containing 5 percent captan and 2500 ppm each of IBA and IAA. They were set upright in 10 cm peat pots in a sterile medium consisting of 1:1:1 sphagnum peat moss, medium grade vermiculite, and perlite on a greenhouse bench un-

der intermittent mist with an "on" frequency of 6 seconds every 2 minutes.

After 10 weeks all 20 cuttings had developed shoot growth as well as adventitious root growth from callus tissue which formed at the basal end of the cuttings (Table 1). The cuttings were then transplanted into 20 × 22 cm black plastic bags and placed in a shaded area for 4 months. A count of well-established surviving cuttings on July 20, 1981 showed 19 out of 20 original cuttings growing well enough for transplant to the field (Table 1).

In the 1982 experiment, cuttings of the Maafala cultivar were prepared and handled in the same way as in 1981 except that the rooting hormone mixture contained 4000 ppm IBA but no IAA. Nineteen out of 20 cuttings rooted after 10 weeks (75 days) under intermittent mist (Table 1).

Besides the mist test there were 4 extra cuttings which were treated with the talc/captan/IBA rooting mixture and planted in a 20 cm clay pot in the 1:1:1 peat moss, vermiculite, perlite medium. The entire pot and cuttings were covered with a light gauge plastic bag to make a closed humidity chamber. These cuttings rooted in 11 weeks in a shaded area of the greenhouse without further attention or additional watering and were successfully planted into plastic planting bags.

Table 1. Rooting of stem cuttings of 'Ma opu' and 'Maafala' breadfruit under intermittent mist and high humidity.

Cultivar	Starting Date	Rooting Data Taken	Total No. of Cuttings	No. Cuttings Rooted	Percent Rooting
Ma opu	5/19/81	7/30/81	20	19	95
Maafala	3/25/82	6/8/82	20	95	
Maafala*	3/25/82	6/18/82	4	4	100

* Rooted under plastic bag without mist.

DISCUSSION

This method of propagating seedless breadfruit appears to be more efficient, rapid, and economical than the traditional sucker or root cutting methods. It is apparent that selected leafless stem cuttings can be rooted fairly rapidly and easily under mist with the use of appropriate rooting hormone treatments.

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WESTERN REGION 1982 MERIT AWARD RECIPIENT*

PRESENTED BY STAN SORENSEN

The Western Region's 1982 Award of Merit is presented to the recipient to recognize his outstanding contribution to his community, the IPPS and the field of plant propagation.

He was a charter member of the Western Region of the International Plant Propagators' Society which held its first meeting in Asilomar, California, in 1960. He was elected to the Executive Committee of the Western Region in 1972. He became president of the Region in 1976-1977 and President of the International Board in 1981-1982.

In 1962 he was elected to the City Council of Fremont, California. He served as mayor for 5 of the 16 years he was on the City Council. During that time the new city grew from 25,000 to over 110,000 in population. He was a driving force in establishing a beautiful 400-acre park in the center of the community, complete with lake and swim lagoon. He worked to save three homes and gardens of historical consequence; namely, the Vallejo Adobe at the old California Nursery, the Joseph Shinn Home, and the Patterson Ranch home and gardens near Coyote Hills. He served on the Alameda Creek-Coyote Hills Joint Agency which guided the development of a 900-acre park on San Francisco Bay, and 14 miles of hiking and equestrian trails along the creeks.

During those 16 years he also served on the regional boards of the San Francisco bay area. He was president of the Association of Bay Area Governments (ABAG), and a member of the Metropolitan Transportation Commission, two planning agencies of the Bay Area.

Born in El Centro, California in 1921 he attended public schools in Piedmont, Sausalito, and Mill Valley, California, then moved to Milwaukee, Wisconsin, for high school. He attended Stanford University, graduating in political science in 1943.

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served during World War II for 15 months in the Atlantic and 15 months in the Pacific, aboard destroyer escorts. After WWII, he and his wife lived in Mill Valley, California, where he worked in San Francisco for a wholesale paper house. Five years and three children later he was recalled to the Navy during the Korean War. He completed 22 years of service in the naval reserve and retired with rank of Commander.

At the end of his Korean tour of duty he went to Piru, California, to assist in his father's beginning nursery business. In the early 1950's the dwarf citrus nursery moved to Mission San Jose, Alameda County, California to be free of the orange quick decline virus quarantine.

Their twig grafting system was developed at UCLA by Dr. F.F. Halma. The nursery was one of the early ones to employ the intermittent mist system of propagation and growing in containers. They propagate 30 citrus cultivars which are sold to retail nurseries throughout California and Hawaii, plus shipments in smaller quantities by air parcel post throughout the United States.

Although our recipient has had no formal training in horticulture he has constantly worked to improve propagating techniques and the quality of his plants. The development of citrus as a popular plant in the home gardens of Californians in the 1960's and 1970's was encouraged by his nursery. The "How to Grow" booklet they publish has won a national award from the American Association of Nurserymen. Garden talks, radio and T.V. shows, magazine articles, nursery tours by gardeners, students, and plant propagators all attest to his interest in educating both his customers and the general public.

Donald F. Dillon, a real propagator, is the proud father of three children, attentive uncle of seven nieces, and doting grandfather of six grandchildren!

It is indeed an honor and a privilege to present to such a man the Western Region's highest award: the Award of Merit.

PROPAGATION OF PERENNIAL PLANTS

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This paper will consider mainly the herbaceous types of perennials, i.e. those that die down each winter and grow again from ground level.

SEED PROPAGATION

We grow a number of species from seed. Some species reproduce true from seed so long as there is no opportunity for cross fertilisation, but selections with improved characteristics (cultivars) are numerous and must be increased by vegetative means. However, in some cases seedsmen have "fixed" a number of cultivars by line breeding and these breed true or nearly so. These include cultivars of *Aquilegia*, *Althaea rosea* (hollyhocks), *Geum*, and *Delphinium*. However, seed should not be used of heterozygous cultivars. To illustrate this point take a look at aquilegias. The McKenna Long Spurred Hybrids are a lovely mixture of bright colours with large flowers and long spurs. None of the individual colours would breed true. But there are several named cultivars which do — 'Crimson Star' (crimson and white) and 'Nora Barlow' (double pink and green). But for other colours, it is necessary to go back to the species, such as *Aquilegia caerulea*, a species I saw at Kew, 60 cm, with blue and white flowers and *A. longissima*, 70 cm, which has glaucous leaves and 15 cm spurs on the yellow flowers.

The single pyrethrum, *Chrysanthemum coccineum*, is another example. Seed strains of pink and red come sufficiently true to have superseded the old cultivars, 'E.M. Robinson' and 'Harold Robinson', but the named doubles — so scarce in New Zealand — must be grown from divisions. The latter, and cultivars of *Scabiosa caucasica*, should not be divided until growth has begun in spring. Division in autumn in the colder climates can be fatal.

DIVISION

There are a considerable number of cultivars of perennial plants which may be increased from division of the roots quite easily, such as *Aster novae-belgii*, *Helianthus*, *Helenium*, *Monarda*, and *Physostegia*, to suggest just a few. This is normally done in late winter to early spring by which time many of the new growths will have initiated a new root system so that they may be replanted outdoors or potted straight away. In all

cases, when more increase is required top cuttings may be taken when the shoots have reached 20 cm and such cuttings can be rooted under glass.

There are some vigorous perennials, such as *Hostas*, *Hemerocallis*, and *Astilbe*, which develop into large clumps requiring considerable physical effort to break them up. For maximum production it is better to divide and replant each spring but this is not always done so that one can be faced with a solid clump of interlocking roots, say 30 cm across. Two border forks driven back to back and close together into the clump often is the only way to separate them.

In the case of hostas and others it is necessary to use a strong knife, cutting the crown vertically to separate the growth buds, each with a share of the root system. Each strong bud will develop into a satisfactory plant the first season but the full beauty of foliage and flower will not appear until the second or third season.

Alstromeria, on the other hand should be divided and replanted or potted when the plants are dormant at the end of the summer. Even 'Walter Fleming' can be safely handled then and will make new growth before winter.

Paeonia officinalis, *P. lactiflora*, and *P. lobata*, which are hardy tough plants, should be divided in autumn by cutting the roots with a sharp knife to leave one, two, or three eyes on each plant. They may be replanted straight away or potted for sale later. Delay after this time means less growth and fewer, if any, flowers.

PROPAGATION BY CUTTINGS

Perennials which form woody roots are normally propagated by cuttings, first taken in spring from the first flush of growth and subsequently as further suitable growth develops. The cuttings are struck in sand or a peat-pumice mix under close conditions, with or without bottom heat, and after the application of a hormone powder suitable for softwood material. *Lythrum*, *Anthemis*, *Gaura*, *Scrophularia*, *Aster amellus*, and *Gypsophila* 'Rosy Veil' are examples, while the more popular *Gypsophila* 'Flamingo' and *G.* 'Bristol Fairy' need ideal conditions for rooting or else they must be grafted.

Named cultivars of *Lupinus polyphyllus* and *Delphinium elatum*, need special treatment. The roots should be lifted in early winter from open ground, then planted in a cold frame, or a sheltered outdoor site in warmer areas. When growth develops the cuttings are removed when 7 cm long and taken with a solid heel. Often a second and possibly third batch may be taken, after which the stock plants are discarded. Cuttings

of both these plants must be rooted in cool conditions with little or no artificial heat, but shaded if the sun is strong. Hormones will assist rooting.

Campanula persicifolia and some other campanulas make numerous small white shoots around the crowns of 1-year plants. Lift the plants about midwinter and use these small shoots, with or without green leaves, as cuttings made 1½ to 2½ cm long. Dibble them into sand boxes 2½ cm apart with the tips at ground level. Usually every one will root and, if planted out later in light soil, will make good clumps by autumn.

Pelargonium (Geranium?) regale stock plants should be cut back in late summer while the weather is warm and growth is active. The new growth will provide excellent cuttings for rooting in frames or a cool greenhouse and may be grown on for a good display by the following spring onwards.

Grafting Gypsophilas. The two aforementioned gypsophilas are often grafted to obtain a better "take" than when they are grown from cuttings. Sow seed of *Gypsophila paniculata* in early spring and plant out in early summer to produce a batch of rootstocks for grafting. These are lifted with the root systems complete in the winter and bedded outdoors if necessary. Roots of pencil thickness are cut up into lengths of 7 cm with the tops cut square, but giving the bases a sloping cut. When your stock plants of 'Bristol Fairy' and 'Flamingo' have begun growth the root sections are cleft in the centre and a wedge-shaped scion of the desired cultivar is inserted with the cambium layers lined up on one side. The scion may be held in position in any convenient way but I have seen good results with no binding at all. The grafted roots are dibbled into sand, either in boxes, tubes, or beds and kept in close conditions. The advantage of boxes or tubes is that the plants are more easily hardened off.

ROOT CUTTINGS

A number of kinds of perennials may be propagated by means of root cuttings, which is very convenient. The stock plants should be grown in the open ground rather than in planter bags because thick cuttings root and shoot much better than thin cuttings. Generally they need to be pencil thickness or thicker except in cases where plants normally have thin roots. The following plants are usually propagated by root cuttings: *Papaver orientale, Verbascum, Romneya coulteri, Anchusa italica* and *Catananche caerulea*. The following have thinner roots but the same principles apply: *Primula denticulata, Anemone japonica, Phlox paniculata*. Phlox plants produced in this way are often free of virus, which is a serious disease in some countries.

Some tuberous plants have numerous dormant eyes, such as tuberous iris, *Acorus calumnus, Zantedeschia*, and *Liatris spicata*. It is possible to propagate these by removing the eyes with part of the tuber, treating them with fungicide, and strik-

ing them in a sterilised medium. With *Zantedeschia* the fungicide treatment is especially important, as the corms decay easily if damaged. The tubers should be in a dormant state.

FOLIAGE CUTTINGS

Lachenalia aloides 'Pearsonii' may be increased by cutting the mature foliage horizontally into strips 8 cm wide, treating with hormones, and setting the sections into sand boxes, lower edge in the sand, in a cool greenhouse. Numerous small bulbs will form on this edge and, in due course, may be separately boxed.

Haemanthus katherinae may be propagated in this manner, inserting the leaf cuttings in mid-summer. I have propagated from a partly decayed corm of *H. natalensis* by sterilising with Benlate (benomyl) and placing in sand. Some 25 cormlets developed in 2 years and it is still producing. I would expect *H. mutliflorus* and *H. katherinae* to behave in the same way.

MIST PROPAGATION

Generally speaking only a few herbaceous perennials get any benefit from mist propagation and, in the cases of pelargoniums (all types) and silver-leaved plants, mist is positively harmful and leads to a lot of stem rot.

GERMINATING EUCALYPT SEEDS

LYNNE SCOTT

Plant Diseases Division, DSIR
Private Bag, Auckland

Abstract. The optimum germination temperatures were determined for *Eucalyptus* species which failed to germinate satisfactorily at 25°C, using a range of temperatures (15 to 35°C), and including pre-chilling for some species. A broad relationship was found to occur between the optimum temperature for germination and the climatic conditions in which a species occurs naturally.

INTRODUCTION

There are over 500 species of *Eucalyptus*; some are tall trees while others are shrubs. Most species are native to Australia but a few are also native to the Phillipines, New Guinea, and Timor. Two species, *E. deglupta* and *E. urophylla*, do not occur naturally in Australia. In New Zealand some species have naturalized, e.g. *E. tereticornis* (forest red gum); others are grown as ornamentals, e.g. *E. ficifolia* (red flowering gum), or for timber, e.g. *E. saligna* (Sydney blue gum).

The earliest mention of eucalypts naturalizing around Auckland, New Zealand (Karaka District) appears to be that of

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There are over 500 species of *Eucalyptus*; some are tall trees while others are shrubs. Most species are native to Australia but a few are also native to the Phillipines, New Guinea, and Timor. Two species, *E. deglupta* and *E. urophylla*, do not occur naturally in Australia. In New Zealand some species have naturalized, e.g. *E. tereticornis* (forest red gum); others are grown as ornamentals, e.g. *E. ficifolia* (red flowering gum), or for timber, e.g. *E. saligna* (Sydney blue gum).

The earliest mention of eucalypts naturalizing around Auckland, New Zealand (Karaka District) appears to be that of

Urquart in 1883 (12) who noted that *E. globulus* (Tasmanian blue gum) had spread the most freely. Simmonds in 1917 and 1925 (11) recommended species for shelter and timber and gave instructions on cultivation. Hall in 1935 (5) provided a key to 73 species growing in New Zealand. Palmer (7) lists 29 species, of which 21 are not listed by Hall.

Eucalypts belong to the Myrtaceae family which also includes pohutukawa, tea-tree, bottlebrush, and feijoa. The flowers of eucalypts never have typical petals and their colour is largely due to the stamens. They are bisexual and the ovary, which becomes the capsule, contains many ovules and sterile structures. Not all of the ovules become fertilized. The fertilized ovules have developed into seeds by the time the fruit (capsule) has become comparatively dry and woody. On extraction the capsule sheds, besides the seeds, the unfertilized ovules and sterile structures called "chaff". For some species the seed and chaff are indistinguishable. Even when they are different it is not easy to separate them (see Figure 1). Consequently, eucalypt seeds are normally sold and sown with the chaff. The amount needed to produce the required number of plants is calculated on the number of viable seeds per 10 grams (or per ounce) of seeds and chaff. This can vary from 450 for *E. ficifolia* to 3,500 for *E. cinerea* (Argyle apple, silver dollar).

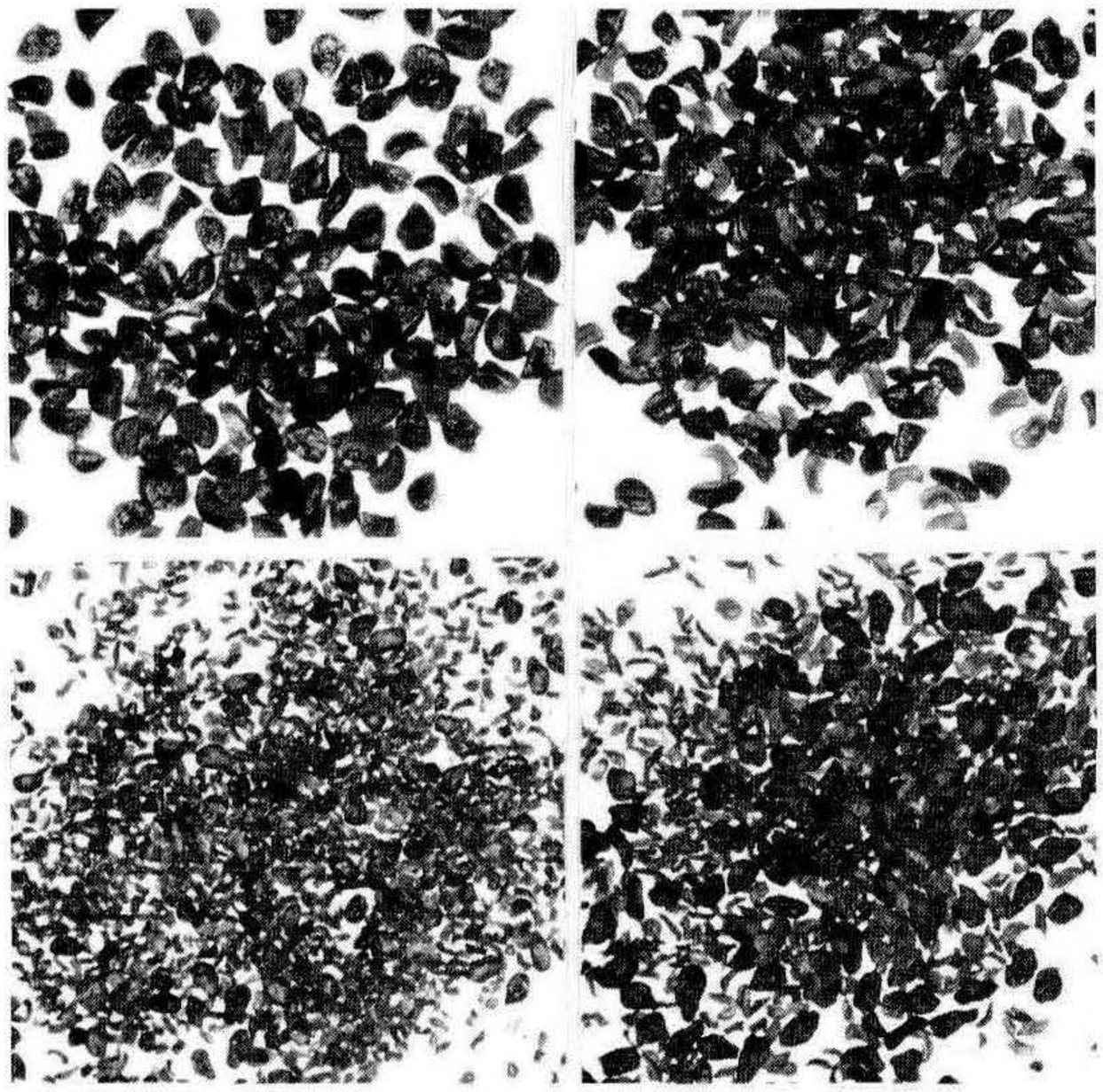

Figure 1. Showing seed and chaff of *Eucalyptus pauciflora* subsp. *niphophila*, upper left; *E. pauciflora* subsp. *pauciflora*, upper right; *E. nicholii*, lower left; and *E. perriniana*, lower right.

The Seed Section of the Forestry and Timber Bureau, Canberra, Australia had been collecting, testing and distributing seed for a number of years before I joined the staff in 1968. After collection, the capsules were spread out to dry and to allow the seed to be extracted. This also reduced the moisture content of the seeds. Extracted seeds were treated with a fumigant to kill insects before being stored in sealed jars at room temperature. Germination tests were made using a standard test at 25°C except for a few species which were pre-chilled. Some lots had very low germination or none at all. Larsen (6) presented a table giving the number of viable seeds per ounce, together with the method of testing, based on the lots in the seed store. He commented on the possibility of dormancy being present in lots with very low germination.

It was evident that for some lots not all the viable seeds had germinated, and the true viability of the lots was not being determined. My aim in the work reported here was to rectify this and to revise Larson's table, as well as to determine the optimum temperatures for germination.

THE VIABILITY TESTING TECHNIQUE

Tests are normally made on a weighed quantity of the seed lot rather than by seed number, because of the mixture of seed and chaff. The lots are well mixed and divided down to obtain the representative working sample. At the Forestry & Timber Bureau four replications of between 0.1 to 0.5 grams are used, allowing for approximately 50 viable seeds per replicate.

The sowing technique used by Larsen (6) was the one I adopted, i.e. the seeds were placed on damp filter paper over vermiculite saturated by tap water in a petri-dish.

All the seed lots in the store were re-tested at the temperature (25°C) used by Larsen, together with the lots collected since then. Germination counts were made twice a week. When little or no germination occurred for 2 weeks the remaining seeds were squashed. If the contents were white and firm it was deduced that the seeds were viable but that the optimum conditions for germination had not been met. The lots were then re-tested at 15°, 20°, 30° and 35°C. If none of these tests were satisfactory the lots were re-tested at 20°C after pre-chilling for periods of two, four and six weeks.

RESULTS

As the work progressed, a species name label was pinned to a map of Australia at the collection site of each seed lot.

The pins were colour-coded to denote the optimum germination temperature of each lot.

The first count of seedlings at the optimum temperature was made within one week and the final count usually within 2 to 3 weeks but for some species this was up to six weeks. Germination is epigeal and counts were made when the cotyledons were emerging from the seed coat and the radicle was 5 to 10 mm long. Abnormal seedlings were not included in the germination figure. Two tables were made, one giving details of the germination test and the other the estimated number of viable seeds per 10 grams (see Table 1). They covered over 350 species, based on tests on 2,250 seed lots. The first table appeared in a booklet by Scott (9) together with other observations made during the testing, while the second, as well as the results of more tests and an up-dated first table are included in the book by Boland *et al.* (3).

Table 1. Example of number of viable seeds and recommendations for sample weight, test temperatures, and test duration. (Data from Boland *et al.* (3).)

Species	Approx. no. viable seeds per 10 gr	Weight of replication (g)	Temperature (°C)	Time of first count (days)	Time of final count (days)
E. cinerea	3480	0.15	25	3	14
E. coccifera	1550	0.30	15	10	28
E. deglupta	40300	0.01	35	5	14
E. ficifolia	450	1.20	20	5	14
E. saligna	5380	0.10	25	5	14

An optimum germination temperature was found for all the species except four, each of which comprised only one or two seed lots. The viability of these was tested biochemically by the technique described in the International Rules for Seed Testing (1) as the "Topographical Tetrazolium Test". A state of dormancy probably existed which the germination conditions used did not break (dormancy sometimes is present in freshly collected seed, which may germinate after some months).

DISCUSSION

From the coloured pin-heads on the map it could be seen that optimum germination temperatures were related to the distribution of the species. *E. camaldulensis* (river red gum) which has a wide distribution across central, north, and north-western Australia and grows under a wide range of climatic conditions from tropical to temperate, germinated best at 30°C, although 25°C and 35°C were quite satisfactory also (Figure 2). *E. pauciflora* ssp. *niphophila* (alpine snow gum) which grows up to 6,500 feet in the Australian Alps required pre-chilling for four weeks. *E. ficifolia* (red-flowering gum) has a very restricted natural occurrence in a narrow coastal belt in the south of

Western Australia, where the climate is mild temperature; its optimum germination temperature is 20°C. *E. deglupta* from the tropics of New Guinea required a germination temperature of 35°C (Figure 2). *E. coccifera* (Tasmanian snow gum) grows at high altitudes on the central and southern mountains of Tasmania, where the climate is montane to sub-alpine; its optimum germination temperature is 15°C (Figure 2) although some lots require pre-chilling. *E. cinerea* (Argyle apple, silver dollar) with an optimum germination temperature of 25°C, occurs in the south of New South Wales in an area where the summers are warm to hot and the winters fairly mild. *E. robusta* (swamp mahogany) occurs in swamps and edges of salt-water estuaries in a coastal belt beginning in the south of Queensland and continuing to the south of New South Wales. This varies from subtropical to warm temperate. The seeds germinate satisfactorily at 15°, 20° and 25°C (Figure 2).

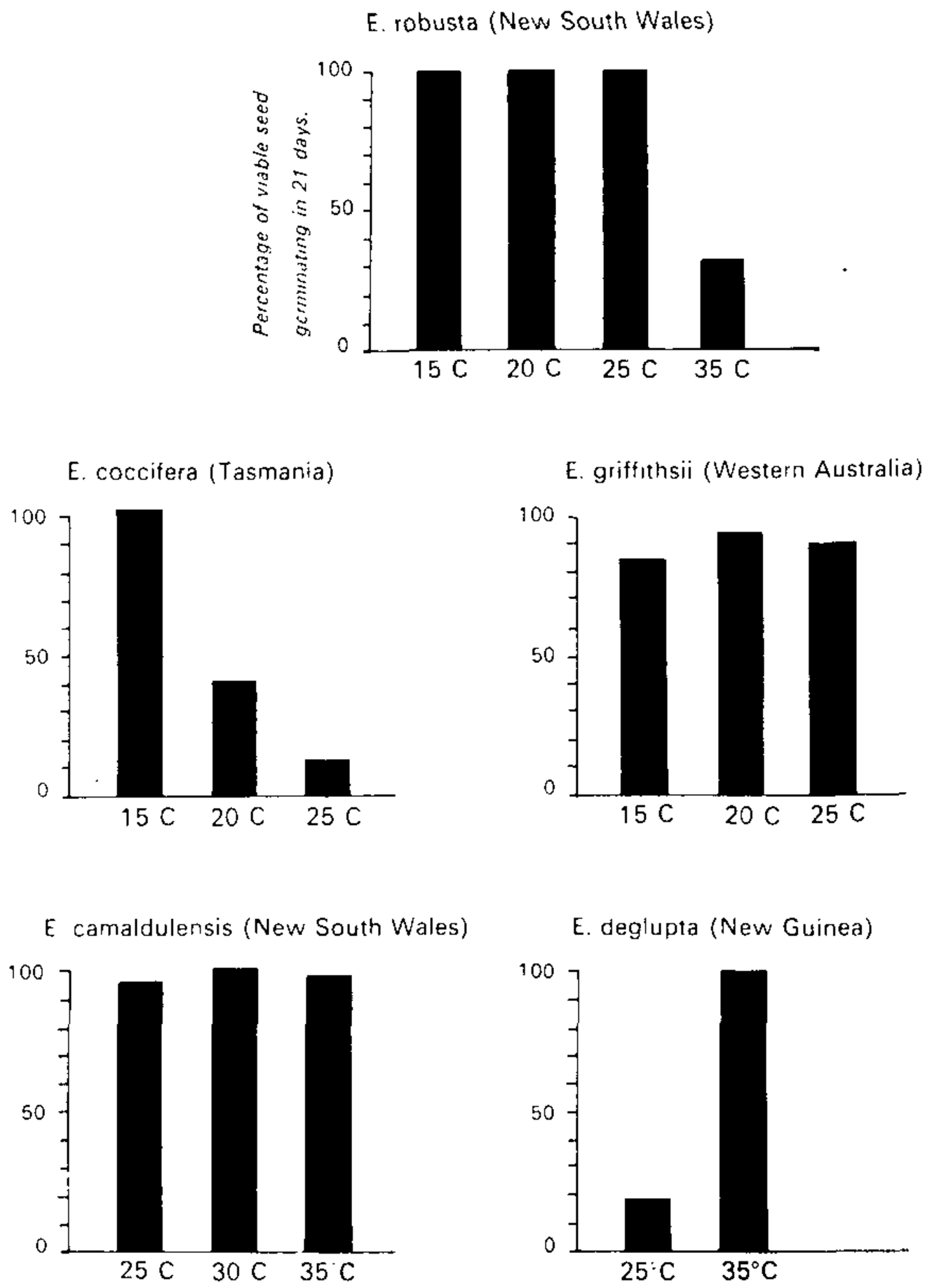

Figure 2. Examples of the germination of seed of eucalypts at various temperatures.

When a species does not germinate satisfactorily at 25°C, tracing its origins gives a clue to the likely optimum temperature. Hall *et al.* (5) and Blakely (2) provide information on distribution of species.

In re-testing all the lots in store it was found that those less than 10 years old had maintained their viability without special storage conditions. After ten years there was a gradual decline until by 20 to 30 years there was a complete loss of viability. Exceptions were *E. deglupta* and *E. microtheca* (Coolibah) which lose viability rapidly unless stored in sealed containers at a low temperature (5°C).

Details of nursery practice are described by Boland *et al.* (3) and Schopmeyer (8).

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CALADIUM — A CANDIDATE FOR MICROPROPAGATION?

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Members of the family Araceae have attracted considerable attention as subjects for micropropagation.

Seeds are used for propagation of some species (e.g. *Monstera deliciosa*, *Anthurium* spp.), but the progeny are variable. Other species are normally propagated by stem cuttings (e.g. *Philodendron scandens*, *Dieffenbachia maculata* (Syn.: *D. picta*), *Epipermnum aureum* (Syn.: *Scindapsis aureus*) and *Syngonium podophyllus*), but multiplication rates are not very high and large numbers of stock plants must be maintained. Propagation by crown, rhizome, or tuber division is also used with other species (e.g. *Anthurium* spp., *Caladium* × *hortulanum* and *Zantedeschia* spp.), but propagation by these means is even slower.

Faster rates of multiplication have been achieved by micropropagation than can be achieved by the traditional methods listed above. At the 1981 meeting, Cohen (1) reported that the proliferation rate for *Zantedeschia* in culture is approximately 5-fold/month (i.e. potentially 100,000 in 10 months), compared with approximately 10-20 fold/year by rhizome division. Multiplication rates for *Dieffenbachia* are considerably lower, 500-fold/year (8) compared with approximately 8-10 fold/year by cuttings. Pierek (13) recommended a callus phase for *Anthurium andreanum* which achieved rapid multiplication rates, but this method has lost favour because of undesirable variability in the progeny. Kunisaki (7) suggests a slower procedure involving proliferation of existing vegetative buds in order to maintain genetic uniformity.

Many aroids are susceptible to a number of systemic bacterial, fungal, and viral pathogens which are readily spread using conventional vegetative propagation techniques, resulting in inferior plants and loss of production.

In vitro methods are an established means for the elimination of pathogens and subsequent rapid multiplication of high-health plants. Knauss (5) developed a tissue cultured method to produce *Dieffenbachia* free of bacteria and fungi. Hartman (4) eliminated dasheen mosaic virus and other phytopathogens by shoot-tip culture of *Caladium* × *hortulanum*.

A survey of procedures recommended for araceous genera has been made (Table 1). The mineral salt formation of Murashinge and Skoog (12) and the vitamin supplements of either

Murashige and Skoog or Linsmaier & Skoog have been used by most workers.

Table 1. Hormone recommendations for the multiplication phase of various Araceous genera *in vitro*.

Species	Reference	Auxin	Cytokinin
Anthurium andreanum	(6,7)	—	0.2 mg/l BA
	(13,14,15,17)	—	1.0 mg/l PBA
A. scherzerianum	(16)	—	0.1 mg/l PBA
Caladium × *hortulanum*	(4)	15 mg/l TAA	1 mg/l K
Dieffenbachia maculata	(8)		2 mg/l BA
	(18)	2 mg/l IAA	16 mg/l IPA
Monstera deliciosa	(3)	2 mg/l IAA	10 mg/l PBA
Scindapsis aureus	(10)	—	10 mg/l IPA
Spathiphyllum clevelandii	(2)	—	2 mg/l PBA
Syngonium podophyllum	(10)	—	20 mg/l IPA
	(9)	3 mg/l IAA	20 mg/l IPA
Zantedeschia	(1)	—	3 mg/l BA

Abbreviations: BA — benzyladenine
IPA — isopentyladenine
K — kinetin
IAA — indoleacetic acid
PBA — Shell Development — SD 8399

The procedure for *Zantedeschia* hybrids recommended by Cohen (1) relied on the control of bud multiplication, elongation, and rooting by the alteration of a single medium component, the cytokinin benzyladenine (BA). Other workers often use BA to induce shoot multiplication, but a wide range of other cytokinins are also used. In some methods the auxin, indoleacetic acid (IAA), is added and it has been suggested by Kunisaki (6) that auxin is required when petiole or leaf blade explants are used, but not when entire leaves or buds are cultured. The addition of coconut water and adenine sulphate is sometimes recommended and some workers prefer to use liquid media rather than solidified media for some stages.

MICROPROPAGATION OF *CALADIUM* × *HORTULANUM*

There has recently been interest in caladiums as houseplants in New Zealand. Although they are easily produced by the importation of dormant rhizones from Florida, there are several situations in which micropropagation could be advantageous.

1) Exportation of *in vitro* material to Australia (or elsewhere), as their quarantine laws do not allow the importation of rhizomes.

2) Rapid multiplication of a new cultivar, which would be considerably faster than the conventional division of rhizomes (4).

3) Possibility of the development of a lower cost method of production.

We were interested in the micropropagation of *C.* × *hortulanum* for several reasons:

1) To determine whether the procedure developed for *Zantedeschia* would be suitable for other araceous plants.

2) To investigate whether plants remained true to type when produced from compressed bud tissue.

We have developed a method for the tissue culture of caladiums similar to that used for the *Zantedeschia*, but more economical in terms of vessels and media. There are two stages involved rather than three, and space saving, inexpensive petri dishes are used for all stages, rather than jars.

There are slight changes in the hormone levels used for initiation and multiplication, and no separate elongation medium.

CULTURE INITIATION

Pieces of rhizome (approximately 2×2×1 cm) with dormant buds were cut off plants growing in the lab, washed under running tap-water and dried out on the lab bench for about an hour. These were then dipped in 95% ethanol and flamed twice.

Using a stereomicroscope, buds approximately 1 to 2 mm long, with some basal rhizome tissue and several leaf primordia attached, were dissected out and placed base down on the multiplication medium. Contamination was less than 20%.

MEDIA AND CULTURE CONDITIONS

For initiation and multiplication, the medium used contained MS salts, LS vitamins, 3% sucrose, 0.6% agar and benzyladenine (BA) at 1 mg/l.

Cultures were grown at 26°C under continuous diffuse light of approximately 1000 lux.

MULTIPLICATION

In the initial establishment phase of 8 to 10 weeks, growth was fairly slow. Two types of tissue developed. The apical bud grew into a small shoot, and a clump of suppressed bud tissue formed at the base. When the shoot was cut off and subcultured, clumps of shoots were formed and, in the first month, the multiplication rate was approximately 2 to 3 fold, but this increased to approximately 6-fold/month thereafter. When clumps of suppressed bud tissue were subcultured, there was

an increase in size of about 4 to 5 fold and some small shoots formed on most pieces.

At a higher concentration of BA (3 mg/l) shoots and meristematic tissue were more suppressed, and less shoots were formed later on the elongation/rooting medium. The addition of the auxin naphthaleneacetic acid (NAA) at 1 or 3 mg/l reduced shoot multiplication considerably and stimulated the excessive formation of roots.

When the medium recommended by Hartman (4) containing 1 mg/l kinetin and 15 mg/l IAA was tested, multiplication rates were lower and the shoots were large with many roots, making the material much harder to handle during subculture. Suppressed bud tissue formed at the base of the shoots, which Hartman referred to as "callus".

SHOOT ELONGATION AND ROOTING

The BA concentration for this stage was lowered to 0.1 mg/l, but all other factors were the same as for the multiplication stage.

Single shoots or small clumps of shoots were transferred to petri dishes containing the elongation/rooting medium, and after 4 to 6 weeks they had elongated, formed roots, and were able to be transferred out of culture.

Small pieces of meristematic tissue were also subcultured onto the elongation medium, but these generally needed a second subculture before transfer. At the rate of ten pieces of meristematic tissue/plate, single plates yielded from 40 to 60 shoots in the first subculture.

TRANSFER TO POTTING MIX

Plantlets were washed under tap-water to remove agar, planted into a 50:50 fine pumice:peat mix, watered with Hoagland's complete nutrient solution. They were then placed under high humidity in the 26°C culture room with the light increased to 3000 lux.

Survival on transfer was 100% and subsequent growth has been excellent.

Several unrooted shoots transferred to potting mix have rooted. This was not achieved with unrooted *Zantedeschia* shoots. There is a possibility that rooting in culture will not be important and clumps of unrooted shoots could be transferred directly to potting mix. This is currently being tested.

DEVELOPMENT OF COLOUR AND VARIEGATION

The pink colour and variegation has developed in some of

the faster growing clones. We are continuing to observe colour development and, in particular, we are interested in whether variegation is increased by repeated subculture or the use of the compressed bud tissue.

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GRAFTING UNUSUAL BETULA CULTIVARS

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Although many thousands of birches are raised from seed in New Zealand each season, two factors have limited our propagation techniques to grafting.

1. Seedlings of birches are well-known for their variability. This is a result of the ease with which the various species hybridise once they are removed from the geographical barriers which separate them in the wild. Thus, the only reliable seed sources are collections from the wild state and, unfortunately, these are rare.
2. While propagation of birches by cuttings has been successful to a limited extent with some cultivars, it is very unreliable. Moreover, propagation material has been difficult to obtain — our first material came in small quantities from arboretums and from overseas. Grafting has proved to be the only means of bulking up and producing trees quickly.

PREPARATION, TEMPERATURE AND HUMIDITY CONTROLS

Seedlings of *Betula pendula* and *Betula papyrifera* are raised in trays, pricked out into tubes, and finally established in two-liter polythene bags during the growing season prior to grafting. At the end of the season they are approximately 60 cm tall and have pencil-thick trunks. At the end of winter (late July or early August), after the plants have been cleared of all dead leaves (to break the re-infection cycle of *Melampsoridium betulae* rust), they are placed in a polythene-covered tunnelhouse.

We do not need to heat the house until grafting begins, since trapped solar radiation is sufficient to force growth of the seedlings. After 10 to 14 days the buds have burst and the leaves expand, signalling that it is time to commence grafting.

The source of heat for our greenhouse is a wood-burning stove. It heats 450 litres (100 gallons) of water which is then pump-circulated through grid radiators. The warm air around the radiators is blown through the greenhouse by fans which, together with the circulation pump, are thermostatically controlled at 18°C. We endeavour to keep the greenhouse about 20°C but, in practice, we achieve a temperature of about 12°C above the outdoor temperature. On frosty nights the temperature may drop to around 10°C but this does not appear to

adversely affect the grafts. Excessively high temperatures (i.e. over 35°C) are unlikely in late winter so there is little danger of "cooking" the buds at this stage. When the sun becomes stronger in early spring we put a 50% shadecloth over the polythene-walled greenhouse to reduce the extremes of both temperature and light.

Because our tunnelhouse has an earth floor, it generates considerable natural humidity. As the season progresses we keep the floor damp in order to maintain moisture in the air. The plants themselves need very little water while the grafts are young and the foliage is sparse. Where watering is required we soak the pots in a water bath rather than risk the spread of disease by using a hose. Disease outbreaks are largely prevented by applications of fungicidal powder with a hand duster throughout the season.

THE GRAFTING OPERATION

Success in grafting is never a foregone conclusion but the chances of success are vastly improved if vigorous, healthy scions and understocks are used.

Scions — At grafting time we collect scionwood directly from stock plants maintained in the nursery. Where necessary, we store scionwood by wrapping it in damp newspaper or sphagnum moss and putting it in a plastic bag in the refrigerator. Immediately before grafting we cut it into two-bud lengths.

Understocks — Prior to grafting, all buds on the lowest 10 cm of each seedling are removed and the top is reduced to 30 cm to facilitate handling and tying.

Grafting — We use a side cleft graft for all *Betula* cultivars. The scions are cut with two slanting cuts (one slightly longer than the other) at the basal end, to form a gradually tapering wedge. Next, a single cut (slightly longer than the cut surface of the scion) is made at an angle of about 25° into the understock. The scion is inserted with the longer side of the wedge outermost, by bending the stock plant back slightly to open the cut. This longer side of the scion is carefully placed so that the cambium layer of the understock matches it both inside and outside the scion. It is then tied firmly in place with a stretched rubber band. We do not use a sealant, partly because some grafting pastes cause rubber ties to loosen and slip and also because the high humidity eliminates the need.

The initial signs of a successful graft are slight browning of the cut edges of the understock after about two weeks, followed by the appearance of callus on the unmatched side of the understock cut and, finally, the swelling of the scion bud.

When the majority of the plants have swollen buds we head back each understock to the union and move the young trees to a shadehouse so that they may leaf out under normal outdoor temperatures.

Aftercare — Growth is rapid after bud-break (Figure 1) and extreme care is necessary to avoid damaging the graft. We transfer the newly-grafted plants into their final pot size when they have made about 30 cm of new growth, removing rubber ties (if they haven't already dropped off), and staking at the same time. Any shoots from the understock are carefully broken or cut out until the shoots from the scion dominate completely.

Rapid growth continues throughout the summer and, by autumn, we have a young tree, often over two metres tall, ready for sale.

Figure 1. *Betula albo-sinensis* var *septentrionalis* six weeks after grafting.

PROBLEMS IN HANDLING FORESTRY AND SHELTER TREES THROUGH THE RETAIL NURSERY TRADE

J.J. HOSKING

Hoskings Nurseries Ltd.
R.D. 9, Whangarei

When considering nursery and establishment practice of forestry or other mass produced trees, it should be appreciated that outside the state or large forestry companies, large numbers of trees are handled by various types of nurseries. These range from growers who supply their customers direct, to retail garden centres who buy in all trees from a wholesale

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source. Many nurseries fall between these limits, doing some direct selling and some buying in for resale.

This paper looks at problems associated with packing, transport, storage, shelf life and ultimate survival. The species involved are used primarily for forestry, orchard and shelter establishment, or for some large scale amenity planting schemes.

Objective. The primary aim must be the high survival of wind firm trees of good genetic quality. Problems in meeting this objective are:

1. Insufficient seed supply from recognised sources, with no genetic selection in the field of shelter. Seed is, therefore, obtained where available. Many retailers are unaware of provenance differences. This is complicated by the fact that customers of a nursery may be planting on widely different climatic sites. For example, *Eucalyptus regnans* seedlings may be obtained at a Hamilton nursery for planting in coastal Bay of Plenty or in severe frost areas in the central plateau. It would be unrealistic to expect a retailer to have two provenances of *E. regnans* for these sites unless he had forward orders a year in advance.

2. Few retail garden centres have adequate facilities for handling and storing bare-root trees, or for storing large numbers of small containers like peat pots, tubes, or small planter bags. Bundles of bare-root trees are often kept unopened for many days after considerable transport time. Roots may be dry or overwet. Foliage may be heating and subject to mildew. Heeling-in beds may be old decaying sawdust or inadequately cultivated soil having poor drainage or poor irrigation. Space is often limited at the height of the season so that trees are packed in too close with insufficient light and air circulation. Containers are often not placed in frames on level ground, so they blow over and miss watering.

3. Orders are usually placed with growers many months ahead to be assured of supply, but delivery dates may not be specified. Trees tend to come early in winter in large batches for economy of transport, so time until sale could vary from hours to several months.

4. There is often insufficient communication between the garden centre and the customer. The customer usually does not appreciate the perishable nature of the goods and may delay collection.

5. Root pruning may be necessary after long storage. Customers need to be aware of the relationship between root-bound trees in planter bags and subsequent wind throw.

Good Practice: Ideally, bulk trees should be taken from the growers' nursery to the planting site with minimum delay. They should not be packed tightly for long periods and should be kept out of the sun and in cool conditions until planted. If these criteria are met they could eradicate much retail handling, result in higher survival, better early growth, and lower prices to the consumer.

It is not anticipated that this will occur except where customers are knowledgable and fussy and, indeed, as in most commodities, the chain of producer to retailer to customer will continue. If the following practices are carried out, then this system should still allow for delays but ensure that the trees grow well:

1. Bare root trees should, if possible, be sent directly from the grower to the customer.

The retailer can hold sample stock, but provide his labels and freighting information to the grower. The customer must be given an expected arrival date of trees. In this case the grower bills the retailer who adds a reduced mark-up to the customer. There needs to be trust between the grower and retailer so that the customer is unaware of the grower's participation.

2. Trees grown in peat pots would also be best handled directly to the customer, although retailers could hold these and other container trees if they are kept in frames on a flat to gently sloping area with metal spread on ground surface. For long storage, frames with netting bases clear of the ground are to be preferred as they prevent roots from penetrating the soil, with the resultant air wrenching hardening the tree for transplanting onto hard sites.

3. Packaging. Bare root trees need roots protected by moist hay, shavings, sphagnum moss, etc., wrapped in hessian or polythene with the top ⅓ or so of foliage open. Polythene bundles should be wrapped in paper or put in multiwall bags if they are likely to be subject to sunlight.

Cartons for container stock need to be strong enough to prevent collapse during many handlings. In the case of wet weather or with peat pot stock, a polythene liner may be necessary to prevent the carton from absorbing moisture.

4. Education of customers through the distribution of sound planting advice on the care of nursery stock in written form is desirable. Customers should be told of the advantages of good site preparation and the correct planting of small hardy trees.

5. Both the nurseryman and the customer should have

readily available information in what to look for in good trees and on good handling and establishment techniques. M.A.F. "Ag Links", N.Z.F.S. Extension Officers, Catchment Authorities, Farm Forestry Associations, and the N.Z. Nurserymen's Association should all have pamphlets giving this information.

6. The present nursery registration system should be scrapped in favour of a well informed group of advisors sponsored by M.A.F., N.Z.F.S., or N.Z.N.A. who can advise growers, retailers, and customers on the suggested techniques outlined above.

INFLUENCE OF SEVERAL PRE-SOWING TREATMENTS ON GERMINATION OF *CYCLAMEN PERSICUM* SEED

J.B. GILLESPIE[1] and MICHAEL B. THOMAS

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Abstract. Several pre-germination treatments were given to *Cyclamen persicum* Mill. seed with the objective of improving germination percentage, speed, and uniformity. Soaking seed in water and in gibberellic acid improved germination speed, but the latter reduced survival. Etridiozole, benomyl, thiram, and sodium hypochlorite treatments did not reduce or delay germination as has been reported elsewhere, but gave no consistent advantage.

INTRODUCTION

Improvements in germination of *C. persicum* seed have been achieved through sodium and calcium hypochlorite surface disinfection treatments (1,8) but optimum germination has not been attained on a routine basis (12). *C. persicum* seeds show variability in uniformity, speed, and germination percentage, and are highly sensitive to environmental and pathogenic factors.

In 1977, 1.13 to 2.75 cents (NZ) were paid per cyclamen seed. Low and irregular germination of this expensive seed contributes to already high production costs particularly with increasing use of the more highly priced F_1, hybrid seed.

Germination of freshly harvested cyclamen seed tends to be slow and irregular (6,9), therefore, the following series of experiments used aged seeds. Heydeker (4) states that the ideal assessment of germination is taken when a viable, self-supporting photosynthesising plant has been produced. To avoid discrepancies between results, seedlings must be grown

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sufficiently large that defects can be seen and borderline cases included (or excluded) consistently. The experiments reported here were designed to examine the influence of a range of pre-sowing treatments and chemicals on germination speed and percentage.

MATERIALS AND METHODS

Four experiments were carried out to study the influence of pre-sowing treatments on the germination of *Cyclamen persicum* seed.

Experiment A — Water soak treatments.

Cyclamen seed of the cultivars, 'Rose of Aalsmeer', 'Early Deep Scarlet', 'Fringed Mont Blanc', 'Mont Blanc' (plan white), and 'Perle of Zehlendorf' were given surface disinfection in 5% sodium hypochlorite solution for one minute. The seeds were rinsed and soaked in sterile distilled water for 0, 1, 12, or 48 hours. Forty seeds of each cultivar were blocked according to cultivar, each with five randomised blocks.

On 31 March, 1977, seed was sown into trays of Springhill sphagnum peat containing 37 g a.i.m.$^{-3}$ etradiazole fungicide (Terrazole 50% wettable powder). The trays were placed in a germination cabinet in the dark at 15°C, and watered as required. After one month, the trays were removed to a glass-house and the emerging seedlings watered fortnightly with a balanced liquid fertiliser. A drench of benomyl was applied at this stage.

Experiment B — Water soak and fungicide treatments.

Seeds in this and subsequent experiments had been stored for 18 months to eliminate the post-harvest delay. Massante (1963) has shown that cyclamen seed can be stored for long periods without loss of germination potential. Seed of 'Aalsmeer Giants' and 'Foremost Mixture' (Colegraves' Seeds, England), was pretreated or sown with a treatment solution or suspension as specified in Table 2. Seeds were sown on 3 November, 1978 in sterile petri dishes on germination paper which had been soaked in 10ml of sterile distilled water or a treatment solution/suspension. The dishes were placed in the dark at a mean temperature of 19.4°C with a maximum of 23°C and a minimum of 12°C. Distilled water was added in 5 ml aliquots as required.

Experiments C and D — Gibberellin, fungicide, and water treatments.

The effect of gibberellic acid (GA_3), thiram, benomyl, etradiazole, and hot water treatments on germination of *C. persicum* seed were studied.

Two experiments were intended to further investigate the preliminary results from Experiment B. Seed of cyclamen cultivars, 'Early Pink', 'Perle von Zehlendorf', 'Mont Blanc', (plain white), 'Rose von Aalsmeer', 'Early Pure White', 'Early Flowering Deep Scarlet' (Arthur Yates, NZ), were surface disinfected in sodium hypochlorite (see Expt. A) and, after treatment as detailed in Table 3 and 4, were germinated in conditions described for Experiment B. The experiment was, therefore, a randomised block experiment of six replicates.

ASSESSMENT AND ANALYSIS OF DATA

In Experiment A germination was recorded when the seedlings emerged from the medium. In Experiments B, C, and D, seedling emergence was recorded, but germination was not regarded as complete and successful until a clearly defined corm and root system had formed and the first leaf was extending. The variation in morphological development creates a major source of error in the timing of this stage. Uniformity of germination was measured as the days between germination of the first and last seeds. Duncan's new multiple range test was used to compare all treatments.

Fungal colonies from the seed plates were grown on potato destrose agar and exmined for pathogens.

RESULTS

Experiment A. Overall germination was poor and treatments showed no significant influence on percentage germination (Table 1). Speed of germination was improved according to the length of imbibition treatment. A 48 hour water soak reduced mean germination by 12 days.

Table 1. Experiment A: The effect of pre-sowing water imbibition treatments on germination of *C. persicum* seed.

Treatment	Mean percent germination	Mean days to emergency
Control	25 a	51 a
1 hour imbibition	23 a	49 b
12 hours imbibition	26 a	44 c
48 hours imbitition	29 a	39 d
CV percent	15.6	4.33

Any means not followed by the same letter are significantly different at the 5% level according to Duncan's new multiple range test.

Experiment B. Although a high degree of significance was not achieved in this preliminary trial the results (Table 2) suggested the following:

(i). Although a faster rate of germination occurred as a

result of higher levels of GA_3 treatments, such treatments tended to reduce germination percentage while occasionally influencing uniformity.

(ii). The fungicidal treatments improved germination percentage, but here etradiazole and thiram showed a slight tendency to slow germination.

(iii). Hot water reduced germination percentage.

Table 2. Experiment B: Influence of different treatments on germination of cyclamen seed.

Treatment	Mean percent germination		Means days to germinate		Mean uniformity (days)	
Untreated	52	abcd	40.3	b	38.5	abc
Water soak, 1 min	55	abcde	41.0	bc	46.0	bc
SD (Control)	41	abcd	47.0	de	44.6	abc
SD 2hr water soak	48	abcde	40.4	bc	27.5	abc
SD GA_3, 1 ppm[2]	30	a	40.4	b	12.0	a
SD 2hr soak, 1 ppm GA_3	40	abcd	46.9	de	33.0	abc
SD 2hr soak, 10 ppm GA_3	43	abcde	40.8	b	22.0	abc
SD 2hr soak, 50 ppm GA_3	31	ab	39.9	b	47.5	bc
SD 2hr soak, 100 ppm GA_3	32	abc	34.6	a	35.0	abc
Hot (60°C) water, 5 min soak	32	abc	41.6	bc	47.5	bc
0.01% a.i. benomyl pretreatment	52	abcde	43.8	bcde	33.5	abc
SD 0.01% a.i. benomyl pretreatment	58	de	43.4	bcde	38.0	abc
1.0% a.i. benomyl pretreatment	60	de	43.1	bcd	36.0	abc
SD 0.005% a.i. etradiazole[1]	61	de	41.4	bc	30.8	abc
0.005% a.i. etradizole[1]	44	abcde	40.4	b	17.0	ab
0.05% a.i. etradiazole[1]	57	bcde	45.4	bcde	46.9	bc
0.5% a.i. etradiazole[1]	56	bcde	48.0	e	41.0	abc
Benomyl and etradiazole[2]	60	de	40.6	b	40.5	abc
0.1% a.i. thiram pretreatment	59	de	41.6	bc	51.0	c
SD 0.1% a.i. thiram pretreatment	67	e	43.8	bcde	47.5	bc
0.5% a.i. thiram pretreatment	59	de	46.3	cde	35.5	abc
1.0% a.i. thiram pretreatment	58	de	44.3	bcde	35.0	abc
CV%	24.5				38.6	

[1] Supplied as suspension or solution in the water in which the germination pad was soaked.
[2] 0.1% Benlate pretreatment and 10 ppm 0.005% etradiazole[1].
SD = surface disinfected for one minute in 5% sodium hypochlorite solution.

Experiment C. Gibberellic acid treatments gave up to eight days' improvement in germination time (Table 3), but the levels which gave these improvements resulted in 15% reduction in germination. Pre-soak GA_3 treatments showed greater improvements in germination speed than where the solution was included in the germination solution. No significant changes in uniformity of germination occurred.

Table 3. Experiment C: The effect of gibberellic acid on germination of cyclamen seed.

Treatment	Mean percent germination	Means days to germinate	Mean uniformity (days)
Control	64.8 b	39.9 a	32.3 a
0.1 ppm GA_3[1]	76.7 a	39.1 a	27.2 a
1.0 ppm GA_3[1]	56.7 bc	39.0 a	25.7 a
10 ppm GA_3[1]	41.8 d	35.9 ab	28.2 a
1 ppm GA_3 pretreatment[2]	56.5 bc	33.7 b	13.2 a
10 ppm GA_3 pretreatment[2]	48.8 cd	27.9 c	36.3 a
100 ppm GA_3 pretreatment[2]	49.0 cd	32.2 b	21.5 a
CV%	15.4	10.2	61.7

[1] Supplied with the solution in which the germination pad was soaked (10ml).
[2] Pretreatment here means a two-hour soak.

Treatments not followed by a common letter are significantly different at the 5% level according to Duncan's new multiple range test.

Experiment D. Overall no significant differences occurred among treatments in germination percentage. Because the controls of two cultivars showed an average of 92.5% germination, they were excluded from a repeat analysis of variance which showed a significant germination improvement as a result of 0.05% a.i. etradiazole treatment and 0.1% a.i. benomyl pretreatment (Table 4).

A 1.0% a.i. benomyl pretreatment significantly improved speed of germination. No differences in uniformity were significant.

It was not possible to determine causes of failure. Identified fungi growing on the seeds and those isolated were all common saprophytes.

Table 4. Experiment D: Effects of various fungal protection treatments on germination of cyclamen seed.

Treatment	Mean percent Germination	Mean Germination[1]	Mean days to Germinate	Mean Uniformity (days)
Hot (60°C) water, 5 min soak	56.2 a	24 a	43.7 a	26.5 a
Control	57.3 a	40.7 b	40.5 ab	32.3 a
0.1% a.i. thiram pretreatment	68.0 a	44.3 bd	43.1 a	39.5 a
1.0% a.i. thiram pretreatment	66.7 a	48.7 bde	41.9 a	20.4 a
0.05% a.i. etradiazole[2]	79.0 a	63.3 e	40.2 ab	20.2 a
0.5% a.i. etradiazole[2]	70.8 a	41.7 b	37.0 b	27.3 a
0.1% a.i. benomyl pretreatment	75.3 a	57.3 de	37.9 b	15.8 a
1.0% a.i. benomyl pretreatment	71.3 a	45.7 bd	31.0 x	18.2 a
C.V.%	15.4	24.7	7.57	54.6

[1] Cultivars: Plain White, Early Flowering Deep Scarlet, and Plain Rose Vaalsmeer only. Those means not followed by a common letter are significantly different according to Duncan's new multiple range test at the 5% level.
[2] Supplied in the solution in which the germination pod was soaked. Pretreatment here means a 1 minute dip.

DISCUSSION

Imbibition treatments improved speed of germination without improving germination strike (Table 1). Anderson and Widmer (1) found that imbibition was complete within 12 hours but that, here also, germination improved further on soaking for longer than 12 hours. Anderson and Widmer (1) and Hakozaki (3) found improvements in germination percentage as well as speed as a result of water soak treatments, but their method of data collection at fixed dates could have resulted in misinterpretation of late germination as a failure. Because seed populations vary continuously, it is not possible to draw conclusions about a successful population from the size of the unsuccessful one (5). The high proportion of failures tends to indicate that the number of failures could have been higher.

Poor germination levels in Experiment A can be attributed to erratic temperature control by the germination cabinet. Germination of *C. persicum* seed is inhibited at temperatures over 20°C (5,7).

Although gibberellin treatments improved speed of germination in both Experiments B and C (Table 2 and 3), strike was reduced. Our results are similar to those reported by Anderson and Widmer (1). This treatment does not influence a known dormancy condition; the delay in germination of recently harvested seed reported by Sumitomo and Kosugi (9), and Katsuki and Okazaki (6) should not have influenced germination of these aged seed. It can be concluded therefore that the effect was a result of typical gibberellin cell division and elongation effects. See Wareing and Philips (11). Anderson and Widmer (1) found thiram, truban, captan and benomyl all tend to inhibit seed germination. Valaskova (10) found that cyclamen seed germination was sensitive to a wide range of soil disinfection treatments. Grundler (2) also found poor emergence following thiram treatment, but improvements with phenyl mercury acetate treatment.

It is notable that the strongest advantage in percent germination occurred at the lower concentrations of fungicides used in both Experiments B and D (Tables 2 and 4). This suggests that high levels of benomyl, thiram, and etradiazole may be phytotoxic and that the poor results of others may be due to

excessive concentration of fungicide. An apparent delay in germination as a result of etradiazole treatment observed in Experiment B (Table 2) was not confirmed by Experiment D (Table 4). The advantage conferred by fungicidal treatments will probably vary according to the microflora present.

Further work may be necessary to determine the most suitable levels of these fungicides, but it seems reasonable to recommend their continued use at low levels as a precautionary measure.

Hypochlorite surface disinfection was used as a general precautionary measure in Experiments A, C, and D. This practice has been recommended by Neuray (8) and Anderson and Widmer (1), but Experiment B (Table 2) suggests that a more detailed investigation might show significant reductions and delay in germination. Neuray (8) reported a delay in germination as a result of this treatment.

PRACTICAL CONSIDERATIONS

The germination experiments did not succeed in demonstrating a consistent means of gaining optimum cyclamen seed germination. Gibberellin treatments did increase speed of germination, but associated decreases in germination percentages make this treatment unacceptable. Soaking seed in still or flowing water for 48 hours prior to sowing improved germination speed without decreasing germination percentage.

Drenches of 10 ppm Terrazole (etradiazole, 50% a.i.) to the seed medium and/or seed dip in 1 g l^{-1} Benlate (benomyl 50% a.i.) is recommended as a precaution against pathogenesis.

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AIDS TO PRODUCTION AND MARKETING IN A SMALL NURSERY

COLIN D. HENDERSON

Jarrah Park Nurseries Ltd., Tauranga

As plant propagators we are all practising conservation. It is in our interests to see that the conservation effort extends to a better use of our capital and labour inputs. Many small nurseries, and indeed larger enterprises, struggle with a shortage or at least an imbalance of capital and labour and the results show up in a variety of ways such as poor production or marketing volumes, or poor plant quality. Conservation means using what resources we have wisely. We need to make our operations cost-effective. We need to practice economy. If our businesses are running well we will have better opportunity to develop our propagation skills.

Although I am intensely interested and involved in ornamental plant production generally, I came into nursery work from a background in business management, economics, and accountancy. I use my previous experience to make my small nursery successful and my work enjoyable. The total labour force is equivalent to two full time labour units. We produce container grown ornamentals with an Australian plant emphasis. These plants are retailed from the property.

Firstly, I wish to emphasise that one of the basic keys to a successful nursery operation is good layout. With only two people in my nursery, good visual control is important, and this is achieved by grouping the retail area, the potting shed, and house, etc. around a central carpark. This reduces unproductive time to a minimum.

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I now wish to briefly detail some major and minor nursery aids that make my nursery function well and, therefore, reduce costs. Of course these aids are not expected to be suitable for all nursery operations. For example, larger operations can obviously justify a larger range of equipment with specific capabilities.

NURSERY TRANSPORT

(a) **Tractor.** I need a versatile basic transport unit. Eight years ago I purchased a 14 hp "Power Pony" tractor with a hydraulic front end loader. This unit tows, mows, and, thanks to the loader, shifts potting mix ingredients, loads out retailed mulching bark, and does a variety of minor earthwork functions. This tractor has a low profile and narrow wheelbase which makes it very convenient working in confined spaces and in and out of sheds and shadehouses.

(b) **Pallet system and trailer.** In my nursery I am fortunate to have a large stock of 1 m square tanalised pallets due to a fortuitous purchase some years ago. These pallets and the pallet trailer which moves them is the method I use to transport my plants. This pallet system forms the biggest single time and energy saver in the nursery. Most plants are bagged twice before reaching a saleable grade. Each pallet holds up to 100 plants, depending on the bag size. Because of the large pallet stock, I retain all plants on pallets during the initial bag size. This enables me to shift these plants promptly from the potting shed to the shade house or to stand-out areas, and eventually back to the potting shed for re-bagging. Only when plants are in their finished bag size are they lined out in a conventional nursery row. The pallet system has other advantages such as the assembly of orders. In fact, I also keep all my retail sales stock on pallets for speed of preparation. The pallet system is justifiably used simply as a transport system with a smaller stock of pallets and, of course, many nurseries do use this system.

In my small nursery I could not justify a fork-lift vehicle or even rear mounted forks on a larger tractor. Nor would such equipment suit my row spacing and shade house and shed heights. The loaded pallets are too heavy for the "Power Pony's" hydraulic system and, in any case, I did not wish to interfere with the availability of the front end loader for other work. Consequently I designed a pallet-trailer which tows behind the "Power Pony" as the cheapest and best solution.

This trailer is backed into position and the lifting and lowering device is a hand-operated 1 to 6 boat winch. In designing a pallet trailer one needs to ensure that when loaded

the point of balance is slightly forward of the trailer wheels. My trailer works very well and, provided the tractor operator is skilled at backing, can be manoeuvred quickly into spaces with minimal clearances. Incidentally, my trailer can lift a pallet to a height of 800 mm which makes it convenient when loading a truck, or as a mobile workbench.

PREPARATION OF POTTING MIXES

For several years I relied primarily on purchasing prepared potting mixes. Although I was purchasing from reliable sources I was never convinced that this was the best arrangement. For the last year I have been preparing my own potting mixes using a concrete mixer and a simple trolley. The trolley is a set of four wheels and, by using a hand pulled rope, the mix is conveyed up a timber rail to the potting bench where the trolley tips forward, spilling its contents.

The preparation of my own potting mixes has proved very worthwhile for the following reasons:

1. After allowing for labour and overheads, mix costs have been reduced by 35%.
2. The mix is always fresh when used and the ingredients and fertilisers in it are known.
3. Special mixes such as an acid mix or an experimental mix are quickly prepared in any quantity.
4. Dry storage space and funds are not tied up in keeping several heaps of different prepared mixes.

COMPUTER LABELLING

A recent improvement has helped considerably in providing descriptive plant labels. I have a 16K Commodore PET microcomputer and printer. Using a label programme at present loaded on cassette tape I am able to quickly provide descriptive labels in any quantity and need only hold a stock of blank computer tags. Hand writing labels is a tedious and costly job and pre-printed labels have many disadvantages relating to minimum quantities, space taking, etc. The computer prepared labels can also be priced or unpriced.

At present I have the minimum computer equipment to do the labelling job. This gives me a memory storage of 60 different descriptive labels and the facility to prepare any other label. When I can afford a disc drive input I will be able to vastly increase the number of different plant descriptions held in the library for immediate availability. The availability of a microcomputer will also give me the opportunity to perform other accountancy and record keeping functions. As an indica-

tion of possibilities read the article in the AMERICAN NURSERYMAN, 15 February 1982, by Robert West, entitled "How I Trained a Nursery Computer".

OTHER NURSERY AIDS

Some other efficiency aids in my nursery are:

Intercommunication system between potting shed and house.
Bicycle for quick check up jobs, or maybe quick getaways!
"Richdel" automatic watering system.
Blackboard by the telephone.
Winstone 100 litre spray trailer.
Pre-emergent weed control in containers using "Ronstar", at half the suggested rate, at time of potting up.
Dumping area for waste in a convenient location.

CONCLUSION

There are many ways in which New Zealand nurseries can be made more efficient. I have detailed some aids to production and marketing that have helped me. I hope to encourage others to observe more closely their own organisations and make improvements. Improvements need not involve large cash outlays and, in fact, by definition they should bring early cash benefits.

INFLUENCE OF NITROGEN, PHOSPHORUS, POTASSIUM, AND LIME ON GROWTH AND FLOWERING OF POTTED CYCLAMEN

JOHN B. GILLESPIE and MICHAEL B. THOMAS

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Abstract: The effects of five levels of nitrogen (N), phosphorus (P), potassium (K), and lime on potted cyclamen (*Cyclamen persicum*) grown in peat/sand, 1:1 v/v were studied. Nitrogen strongly influenced most aspects of growth and flowering; it was supplied by Osmocote (26% N). Strongest corm and foliage growth occurred at 450 to 600g N m^{-3}, while early flowering and flowers per plant were promoted at these levels, as long as added P was low. Low to medium levels of P and K appeared primarily to be required for flower quality, such as size. The plants appeared very tolerant of liming and a rate as high as 24 kg m^{-3} was optimal for flower size (dry weight) and stalk length, when combined with very high N rates.

INTRODUCTION

Previous studies on the nutrition of cyclamen considered (a): simple proprietary mixed or slow release fertilisers, as used by Burghardt (2), Soupcoup and Matous (8) and others or,

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INTRODUCTION

Previous studies on the nutrition of cyclamen considered (a): simple proprietary mixed or slow release fertilisers, as used by Burghardt (2), Soupcoup and Matous (8) and others or,

(b) the effects of single nutrients (6). Rarely were fertilisers quantified in terms of available nutrients, nor were interactions among nutrients investigated.

The objectives of the two experiments reported here were to examine the influence of N, P, and K fertilisation, and of liming, and to study their interactive effects within a single experiment. An additional experiment was carried out after the first experiment to study the effect of unusually high levels of N, P, K, and lime.

MATERIALS AND METHODS

Experimental Design. A four factor response surface Box-Hunter design, of Cochran and Cox (3), of the central composite second order type with incomplete blocks was used. It involved N, P, K and lime combined in 30 treatments arranged in 10 and 7 blocks for Experiments A and B, respectively. The blocks were divided into three sub-blocks. The treatment nutrient levels were given in Table 1. The same experimental design was used by Thomas (9) for container-grown nursery stock.

Table 1. The levels of N, P, K, and lime applied in Experiments A and B in g of N, P, K, and Kg of lime per m^3 of potting medium.

Nutrient	N ($g\ m^{-3}$)		P ($g\ m^{-3}$)		K ($g\ m^{-3}$)		Lime ($kg\ m^{-3}$)	
Experiment	A	B	A	B	A	B	A	B
	0	0	0	0	0	0	0	0
	150	300	100	200	83	166	3	6
	300	600	200	400	166	332	6	12
	450	900	300	600	250	498	9	18
	600	1200	400	800	332	664	12	24

Fertilisers. The fertilisers were the same as, or similar to, those in common New Zealand nursery use. Nitrogen was supplied from Osmocote (25% N) applied equally as a basal dressing and a side dressing after three months. All other nutrients were included in the medium at laying-down. Phosphorus and K were supplied from superphosphate (8% P) and potassium sulphate (39% K), respectively. The lime was a mixture of agricultural ($CaCO_3$) and dolomitic lime (3:1, by weight). The following ingredients at fixed levels were common to all treatments: 75 g m^{-3} sequestrene iron chelate (Na EDTA Fe 12% Fe), 150 g m^{-3} Sporumix (1.14% B, 5.46% Mn, 0.06% Mo., 0.05% Co, 9.78% Mg, 0.62% Zn, 1.27% Cu).

Plant Material and Potting Medium. Three month old seedings of *Cyclamen persicum* Mill. 'Bonfire' for Experiment A and mixed cultivars for Experiment B were potted into a medium containing 50% sphagnum peat and 50% coarse manufactured sand, (v:v). Experiment A was potted January 9,

1977, using 1.81 Planterbags and Experiment B on April 8, 1978, into plastic 15 cm (1.41) pots.

Growing Conditions and Plant Protection. The plants were grown in heated, automatically ventilated, glasshouses with a minimum temperature of 15°C and a maximum of 5°C above the ambient outside temperature. At the end of November (early summer) the plants were moved to a Sarlon 50% shade-house where temperatures ranged between 5°C and 37°C. The plants were returned to the greenhouse in April (autumn). Watering was by hand as required.

The medium had been disinfected with methyl bromide. Etridiazole (35 g a.i. m^{-3}) was included in the medium as a precaution against *Nectria radicola*, *Botrytis cinerea*, and *Fusarium oxysporum* f. sp. *cyclaminis*. The medium for Experiment B contained Dieldrin (19.5 g a.i. m^{-3}) to combat black vine weevil. A regular spray programme of benomyl (75 g a.i. 1^{-1}) was alterated every seven to ten days with captain (125 g a.i. 1^{-1}) as a precaution against *Botrytis cinerea*. A general insecticide (Maldison) was included with these sprays.

Data Collection and Analysis. These were taken as the average of two perpendicular measurements. Flower height was the maximum height of flowers above the corm. In Experiment A, flower stalk length, flower diameter, and width (widest part) were the mean of five flowers randomly selected from each plant at harvest.

For convenience a number of data were measured using arbitrary ratings from one to five. These are on an increasing scale, for example, five being allotted to the largest flower when flower size was being rated.

RESULTS

Foliage Growth. Nitrogen fertilization had much the greatest influence on the foliage of fertilizers used, and all growth parameters measured showed significant N responses. In Experiment B (foliar dry weight) plant width at 81 days and number of leaves per plant, were all greatest at close to 600 g N m^{-3} (Figure 1). There was a linear increase in foliar N. The response in Experiment A was similar, but optimum levels were under 450 g N m^{-3} which probably indicates the lower rates used for all fertilisers, compared to Experiment B. Additions of P, K, and lime had only minor influences on foliage growth. Foliage colour (mostly green) was optimal at medium K levels while plants were most compact at medium and balanced levels of P, K and lime (data not shown). The plants were very tolerant of the extremely high lime rates (up to 24

kg m^{-3} – pH 6) used in Experiment B, and there was little influence on any aspects of vegetative growth.

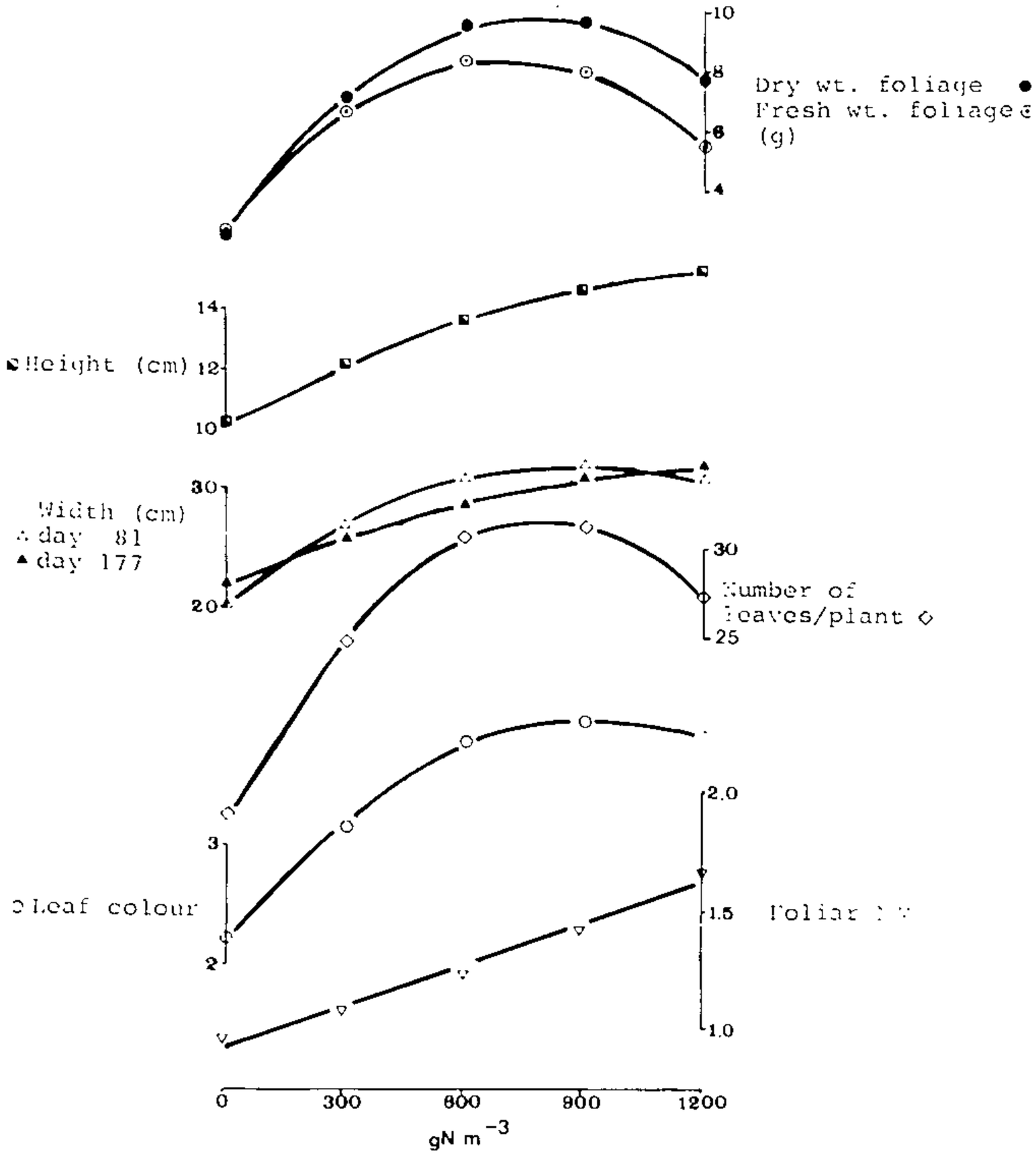

Figure 1. Influence of nitrogen fertilization on foliage growth (Exp. B).

Corm Growth. The results obtained from Experiment B indicated that corm dry weights were greatest at about 600 g N m^{-3} and were depressed, along with corm diameter, above this level (Figure 2). Phosphorus, K, and lime levels again had a moderate influence on growth and, in general, high levels of P or K depressed corm development. For example, high levels of P or K depressed corm diameter (data not shown).

Flowering. Nitrogen strongly influenced flowering while additions of P, K, and lime often interacted together to affect flower quality. In Experiment A flowering was 40 to 50 days earlier at the highest rate of N and nil P, than at low N and nil P (Figure 3). Figure 3 also indicates that P depressed flowering at high N rates. Nitrogen mildly promoted early flowering in Experiment B (Figure 2), while the number of flowers per plant was highest at medium to high N levels (Figure 2). Ratings of flower size indicated that quality was highest when

medium rates of P and K (200 g m^{-3}, 166 g K m^{-3}) were

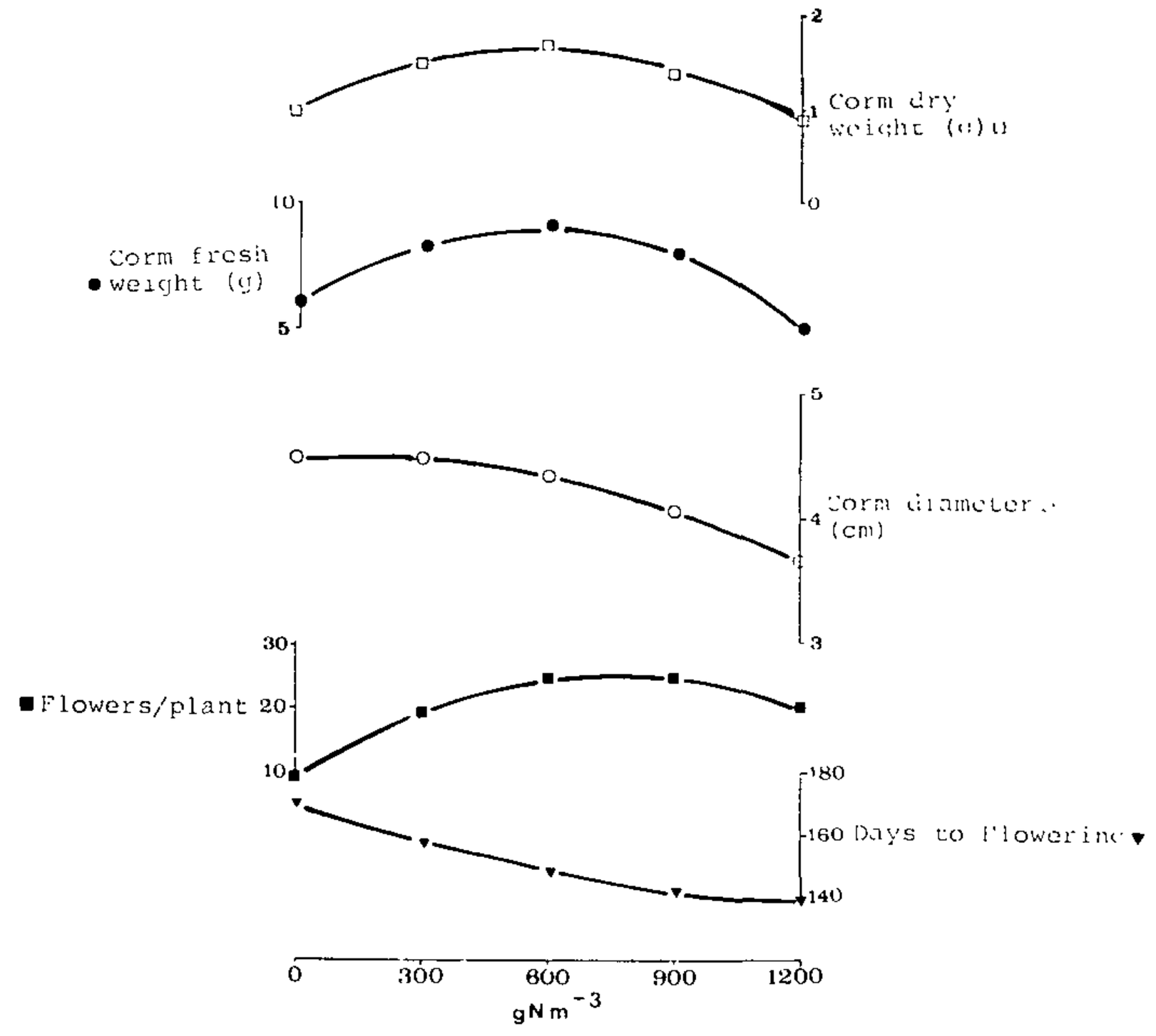

Figure 2. Influence of nitrogen fertilization on corm growth and flowering.

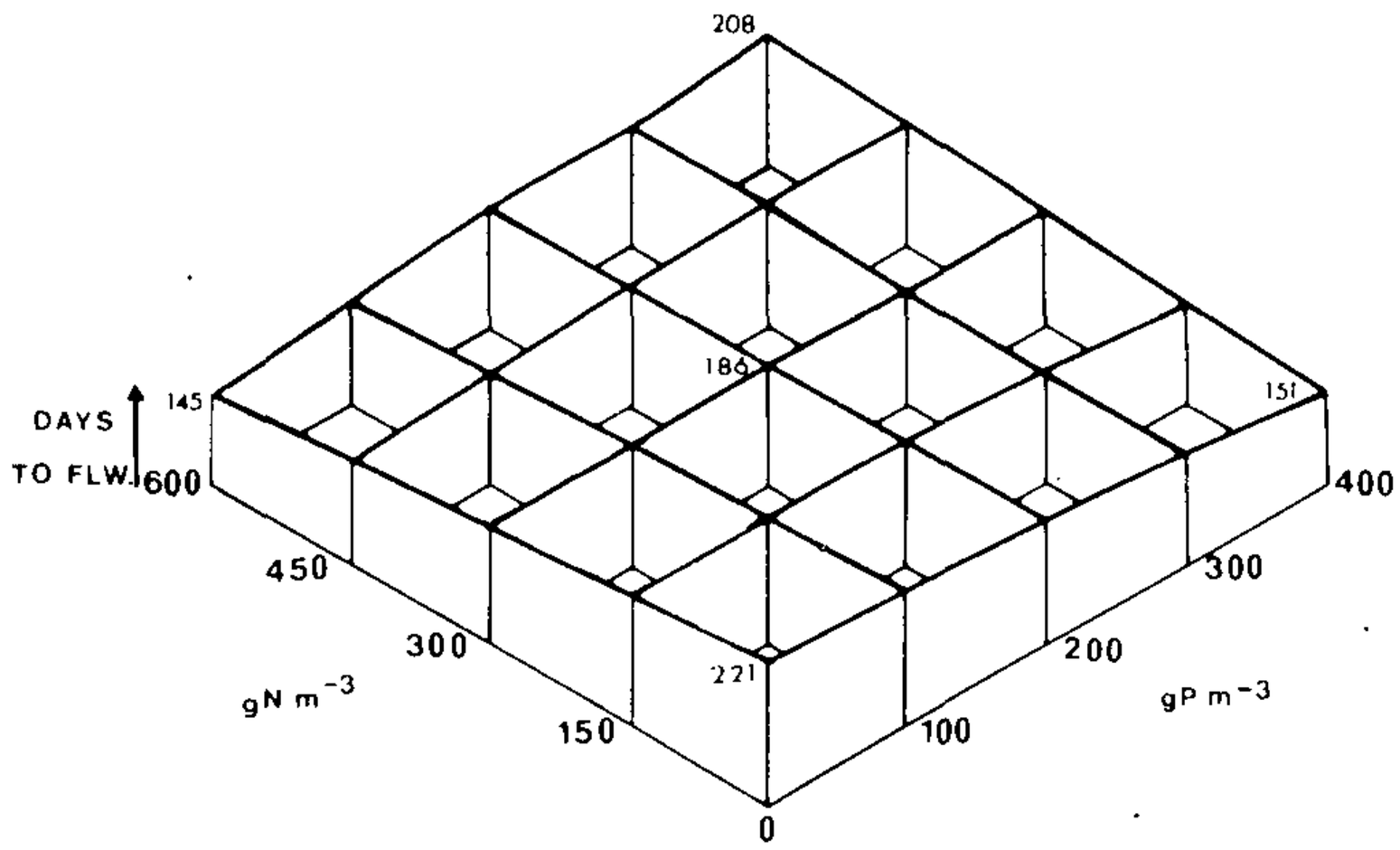

Figure 3. Interaction between nitrogen and phosphorus fertilisation on number of days to flowering (Exp. A).

combined (data not shown). The combined or interactive effects of N and lime levels had very similar influences on the dry weight per flower (Figure 4) and flower stalk length (data not shown). In both cases greatest responses were when the

highest N rate was supplemented with an extremely high lime rate (24 kg lime m^{-3} – pH 6 : nil lime – pH 4.8). High N rates with low or nil lime depressed the weight and stalk length of each flower. Tall flowers were also obtained when medium to high levels of P (300 to 400g m^{-3}) and K (166 to 332g m^{-3}) were combined with about 6 kg lime m^{-3} (pH 5.3 to 5.7).

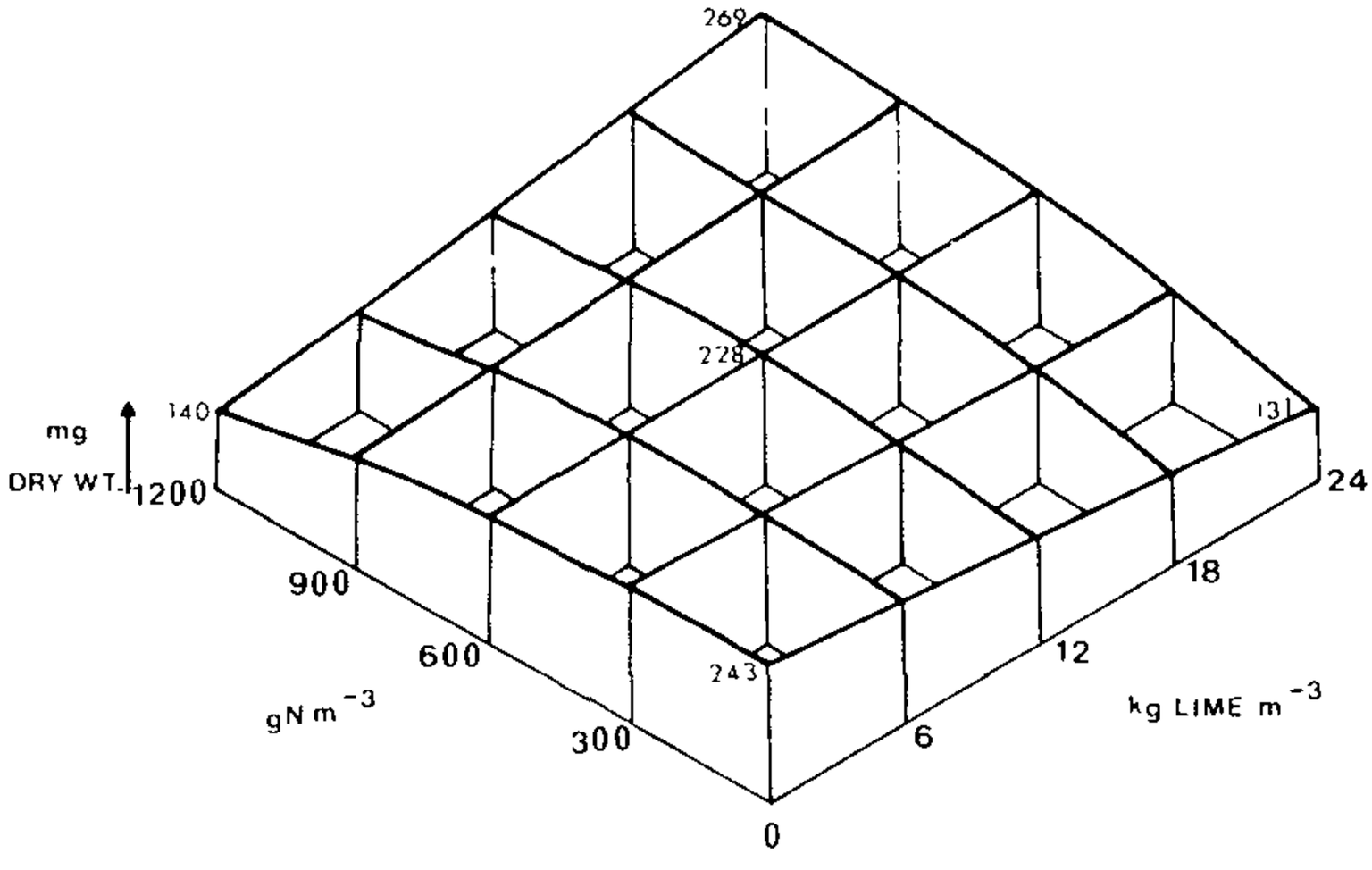

Figure 4. Interaction between nitrogen fertilisation and liming on dry weight per flower (Exp. B).

DISCUSSION

The maximum levels of nutrients supplied in Experiment A did not generally cause strong depression of flowering, nor were any other symptoms of toxicity present. The second experiment was carried out to investigate the influence of very high levels of fertilisation. Far from depressing growth or causing salinity problems, the high rates served to increase the response to N and a number of significant responses to other nutrients. Greater numbers of flowers, larger plants, and improved flower size were observed in Experiment B compared to A.

It can be concluded that cyclamen can tolerate unusually high nutrient levels and liming, providing adequate watering and growing conditions are provided.

Good responses to N have been recorded for most pot plants including cyclamen (6,7). Bunt (1) stated that they have very modest N requirements, but the work reported here indicates that under good growing conditions high N can give satisfactory flowering and growth if other nutrients and pH are adequate. Gugenhan (4) reported that P shortage delayed flowering while in the two experiments here, P appeared important to flower quality, but usually only at moderate levels

and when combined in interaction with other nutrients. Miura (6) reported that P had little influence on cyclamen shoot or root growth, and this was confirmed in the current results.

Cyclamen, in both experiments reported here, was very tolerant of very high lime rates. Hangitae (5) reported that although cyclamen does best under low pH conditions, it has a high calcium requirement. Miura (6,7) reported that excessive lime suppressed growth and caused leatheryness of cyclamen leaves, but nothing of this nature was noticed in the current work, possibly because the pH did not exceed six in the peat-based medium. Miura (6,7) reported that cyclamen will respond to high levels of K, but this also was not observed to any great extent, although high K was applied without detrimental effect.

Both experiments were carried out under warm growing conditions with high natural illumination and, under conditions conducive to rapid growth, the cyclamen responded strongly to high N and lime levels while P and K responses were quite minor.

Acknowledgements. We wish to thank M. Spurway and N. Ladd for technical assistance and Anderson's Nurseries for supplying cyclamen seedlings.

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PLANTS OF THE HIGHLAND TROPICAL REGIONS

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Exotic plants have been successfully established in New Zealand from the very earliest days of European settlement. Naturally these introductions come mainly from areas of similar latitude to New Zealand in either the northern or southern hemispheres. There is, of course, still considerable scope for further introductions from this source. However, I want to point out that there are other areas with a climate similar to that of New Zealand which offer even greater scope for plant introduction. One such region is the high altitude tropics.

High Altitude Tropics. We tend to consider that plants from areas near the equator are going to be unsuitable for New Zealand conditions. Sometimes we are aware of exceptions and wonder at the adaptibility of such plants. Mostly we do not realise the effect that altitude has on climate, or even that all areas within the tropics are not low lying and tropical in nature. If, however, we look at even a world scale relief map we see that there are large mountainous regions between the tropics of Cancer and Capricorn. Altitude has a major effect on climate, and even at the equator, climate changes rapidly with increase in altitude. Where the mountains are high enough there are regions of permanent snow right on the equator. In such places, between the extremes of tropical climate at sea level and permanent snow at very high altitude, there are gradations from subtropical to temperate climates. It is the zone of temperate climate that I wish to consider in further detail.

Temperate Climate Zone in the Tropics. As an example of the effect of altitude on climate we can consider the case of Ecuador in northwestern South America. As the name suggests Ecuador straddles the equator, but it is bisected by the massive Andes mountain chain with peaks up to 6,000 metres above sea level (m.a.s.l.), permanently capped with snow. Here the local definition of climate is in terms of altitudinal zones. From sea level to 1,000 m.a.s.l. is the "tierra caliente" (hot zone), from 1,000 to 2,000 m.a.s.l. the "tierra templada" (temperate zone), and from 2,000 to 3,000 m.a.s.l. the "tierra fria" (cold zone). The term "paramos" (bleak uplands) is used to describe the region from 3,000 m.a.s.l. up to the snow line. That this is a sensible and convenient division into climate

zones is shown by the mean annual temperatures at various altitudes listed in Table 1. This table is compiled from data derived from some 50 meteorological stations in Peru.

Table 1. Approximate mean annual temperature in relation to altitude[1] (Hurnard, N.Z. Met. Service, pers. comm.)

Altitude (m) above sea level	0	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500
Temperature °C	27	24	21	20	17	16	13	9	6	3

[1] Applicable to Ecuador and east and central Peru, excluding the coastal regions.

Given the latitude of New Zealand it is the "terra fria" or cold zone and the "paramos" that is of the most interest to us. The term cold zone is, in fact, not a good description of the climate of the 2,000 to 3,000 m.a.s.l. zone as its average annual temperature varies from 13° to 17°C, which is warmer than many temperate regions of the world. Better names for the various zones would be tropical, subtropical, temperate, and cold.

Comparison with New Zealand. As a comparison with New Zealand conditions the mean annual temperature of Kaitaia N.Z. is 15.5°C, that of Tauranga N.Z. 14.2°C, and for Invercargill, N.Z. 9.5°C. Other similarities in climate between high altitude areas of the tropics and New Zealand are the relatively small seasonal differences in temperature but considerable diurnal temperature changes and a long growing season. Annual hours of bright sunshine in the Ecuadorian highland basins are around 1,800 hrs which is similar to New Zealand locations where Auckland and Kaitaia enjoy 2,000 to 2,200 hrs, Tauranga 2,000 to 2,400 hrs, and Invercargill 1,600 to 1,800 hrs.

Increase in Latitude. With increase in latitude, the altitude at which a similar climate occurs decreases. The change is gradual and not very marked until about 17° to 20° south or north of the equator when seasonal and diurnal changes in temperature become more marked. Near the tropics of Capricorn and Cancer (23.5° latitude) areas at 1,000 m.a.s.l. have a similar climate to those of 2,000 m.a.s.l. near the equator or those at sea level at higher latitudes. For example, the city of Curitiba in the Province of Parana, Brazil, with an altitude of 950 m.a.s.l. and 25°S latitude has a climate very close to that of Kaitaia N.Z., at 80 m.a.s.l. and 35°S latitude.

Other High Altitude Areas of the Tropics. I have used South America as an example of high altitude climate in the tropics but I would like to emphasize that areas of similar climate occur in other mountainous regions within the tropics. This includes large areas of Southeast Asia, the Phillippines, Indonesia, Southern Indian, New Guinea, Central America, and parts of Africa. If one looks at a world climate map, where

New Zealand is wholly within the Maritime West Coast Cbf climate zone of the Koppen system, (a broad classification for cool moist climates) some of these areas have a large enough mountain mass for this climatic zone to be depicted. For example, there are parts of the mountains of New Guinea, Borneo, Ethiopia, Kenya, eastern South Africa, southeastern Brazil, and in the Andes from Venezuela to Bolivia. In addition to these areas, there are many individual peaks or smaller mountain masses of temperate climate that do not appear on a map of this scale. Taken together these high altitude areas of temperate climate add up to a large land mass. If one then considers that much of these areas is or has been forested and that there are many endemic plants, one can see that the highland tropics is a very interesting potential source of plants suitable for New Zealand's climate.

Subtropical Fruiting Plants. It is because of my work on subtropical fruit that I have become interested in plant introduction in general from the highland tropics. Several of the subtropical fruiting plants that are grown in northern coastal areas of New Zealand came originally from high altitude in Latin America. The tamarillo (*Cyphomandra betacea*) is native in the Andes mountains of northern South America at altitudes of 1,800 to 3,000 m.a.s.l., while the mountain papaya (*Carica pubescens*) is found at 2,400 to 2,700 m.a.s.l. in Colombia and Ecuador. The feijoa (*Feijoa sellowiana*) and purple passionfruit (*Passiflora edulis*) are from the mountains of Southern Brazil and two important races of avocado (*Persea americana*) are from the highlands of Mexico and Central America. Similarly, many important field crops came originally from these highland areas including the potato, tomato, and sweet potato, which are native in the Andes mountains of South America. These are examples of some of the successful plant introductions that we have from the highland tropics and they help to demonstrate that there is a real similarity in climate to parts of New Zealand. This has led me to become interested in what other plant material there is in the highland tropics of Latin America in particular.

Plant Collecting in Latin America. I am fortunate in having had two trips to this region, in 1973 to Central and South America, and in 1980 to South America. A number of fruiting plants were introduced from these visits, notable ones being the babaco (*Carica* × *heilbornii* Badillo nm. *pentagona* (Heilborn) Badillo), first introduced to New Zealand by me in 1973, the lucuma (*Lucumo obovata*), *Cyphomandra* species, as well as improved material of the pepino (*Solanum muricatum*), and the cherimoya (*Annona cherimola*). Each visit has confirmed that there still remains a considerably body of plant material,

in the wild and in peasant gardens, from which it would be possible to develop further commercial subtropical fruit crops. The Division of Horticulture and Processing of D.S.I.R. has an ongoing programme of plant collection in these areas in co-operation with equivalent organizations in the countries concerned.

Ornamentals from High Altitudes. We now have a reasonable programme of introduction of fruiting plants from high altitudes in South America but, as far as I know, there has been little introduction of ornamental plants to New Zealand from this area, whilst in America attention has focused mainly on the orchids and bromeliads. This is the field that I want to stress, as I am sure that there are very many interesting plants in the highlands of South America alone that could be valuable to New Zealand and of interest to plant lovers around the world.

Plant Associations at High Altitudes. My recent visit to South America in the winter of 1980 took me to highland areas of Colombia, Ecuador, and Peru. Many of these mountainous areas were once clothed in subtropical rainforest very like our own with many handsome trees, shrubs, creepers, and palms, some of which bear beautiful flowers. They are found in associations ranging from tall forest at the lower altitudes to low shrub forest of the paramos.

Very likely much can be learnt about what plants should be present from botanical literature, but there is often no thorough Flora of a particular area available. I can only speak about what I have seen at a particular time but it is enough to convince me that there are many plants that we should collect. Unfortunately this is an urgent matter as the forest in many of these mountainous areas is being destroyed at an ever-increasing rate. We saw vast areas of the mountains of the Central Cordillera of Colombia for instance that had been completely stripped of all vegetation. In fact the greatest difficulty we had in collecting plant material was to find out where forest still existed. This inevitably was in the most remote parts of countries and even here the forest destruction was going on apace. Often we were looking at tiny remnants of forest that would soon not exist. Land is cleared, farmed for a little while, then abandoned and people move on to destroy more. Practically the only trees planted are occasional eucalypts. There are very few forest reserves in these countries and the high altitude rainforest may become virtually extinct. It would be best if we could have some influence on conservation in these areas but at least we can help to save some species from extinction.

Some of the notable ornamentals of the area are the indig-

enous podocarps, *Podocarpus oleifolius* and *P. glomeratus*, *Cecropia* species, *Aralia* species, tree ferns, palms, a number of beautiful flowering melastomes, *Tibouchina lepidota*, *T. laxa*, *Meriania nobilis*, and *Blakea sanguinea*, as well as *Solanum lixiodes* and *Chionanthus pubescens*. We collected seed of a number of these plants and have a co-operative programme with the Nursery Research Centre at Massey to trial plants they have raised. Future DSIR plant collecting expeditions will collect further ornamentals but as a side line to other work, and I would like to see other people, such as members of the International Plant Propagators' Society collecting also.

Plant Collection. The simplest way of collecting plant material is as seed which also ensures a reasonably wide genetic base and minimises the danger of introduction of pests and diseases. Frequently clean seed only has to be declared for inspection on arrival in New Zealand. However, if you are planning to introduce any plant material it is wise to consult your nearest Horticultural Inspector of the Ministry of Agriculture and Fisheries in case a Plant Quarantine Permit is required.

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MAINTAINING TURGOR IN MACADAMIA SCIONS DURING GRAFTING

D.J. BOYES-BARNES

The Macadamia Centre, Kerikeri

One of the problems that we have encountered in the growing of grafted macadamia trees for commercial planting has been the development of techniques which will enable us to spread production over the whole year. The proper use of both facilities and people is tied to such an ability.

The central event that is required, is the ability to graft in summer or winter as well as in the more traditional spring and autumn periods. And the key to successful grafting is the ability to keep the scion alive and well until callusing has taken place and the rootstock can take over the job of supporting the graftlet.

Many methods are employed in New Zealand, Hawaii, Australia, California, and South Africa.

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The central event that is required, is the ability to graft in summer or winter as well as in the more traditional spring and autumn periods. And the key to successful grafting is the ability to keep the scion alive and well until callusing has taken place and the rootstock can take over the job of supporting the graftlet.

Many methods are employed in New Zealand, Hawaii, Australia, California, and South Africa.

Some of these methods are: scion painted with a bitumen emulsion or wax, scion wrapped in tape, whole plant bagged in a clear polythene bag, scion enclosed in a clear polythene bag, and the whole plant kept under mist.

All these methods work with varying degrees of success. However, in summer the scions cook under plastic or paint and in winter, fungi, particularly *Botrytis*, develop and become uncontrollable when the scion is enclosed.

A better method was sought for some time which would keep the scion turgid but not saturated and give full access to the whole plant. In the course of our search we came across a paper published in 1976 by Keith H. Kimball, New York State Agricultural Experiment Station, which dealt with "Converting Mature Vineyards to other Varieties." The method allowed side wedge grafting of existing vines without stumping and thus losing production. The key to the method lay in attaching to the top of the scion a water reservoir sufficient to keep turgor in the scion for some time. Success rates of 80 to 87% were reported using partially skilled people. The reservoir consisted of a piece of alkathene pipe with a cork in one end. A hole through the cork allowed the top of the scion to be pushed through it. Once the graft had been made, the pipe was filled with water and capped. The water level was checked periodically. Our first attempt to use the method failed utterly. A small piece of piping was attached to the top of the scion by moulding "Densotape" between the two to act as a seal. "Densotape" is a petroleum jelly impregnated bandage. It appears that any form of grease inhibits growth of macadamia. We have had little success with any of the grafting matrix that are sold. The next attempt used rubber finger stools, but these deteriorated quickly and failed to hold water.

In spite of these failures the method seemed promising. It has to be logical to provide a direct supply of water to the scion.

Finally, we came to use baby teats and these we still use. They seal well, stand up above the scion so that water is held and are not too heavy. Using these tests, success rates have gone from 42%, as the average of all other methods, to 82%.

The method is simply that a teat is pushed onto the top of the scion before the scion is shaped. The cleft graft is then made and wrapped. The plant is then set on the irrigation benches and the teat kept full until buds break. This usually takes some three weeks. All water used in the teats is chlorinated to inhibit mould growth. Teats are cut off with the tip of the scion when the shoots have expanded to at least two whorls.

The major disadvantage of the teats is that they cost some 25¢ each and, since they break down in light, are not re-useable. We are currently working on an injection moulded equivalent which should cost only a few cents each.

MYCORRHIZAL FUNGI — THEIR ROLE IN PLANT ESTABLISHMENT

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Abstract. Mycorrhizal fungi are beneficial soil fungi associated with the roots of plants. In forming a symbiotic association with the plant root, these fungi can: (a) increase nutrient uptake and improve plant growth in nursery and field soils, (b) reduce transplant injury, (c) assist rooting and survival of cuttings and (d), deter infection of roots by soil-borne fungal and nematode pathogens. Inoculation of horticultural plants with suitable mycorrhizal fungi in the nursery results in the beneficial mycorrhiza being carried with the roots when the plants are set out in the field, thereby improving plant establishment, survival, health, and growth.

INTRODUCTION

Horticulture is currently in the midst of a widespread boom. This is due partly to the introduction of new crops, but also to the adoption of new techniques in plant breeding, container production of plants, tissue culture methods for bulk propagation and pathogen elimination, and in the use of fertilisers, pesticides, herbicides, and soil fumigants. However, despite the obvious advantages associated with some of these progressive changes, problems still exist in growing horticultural plants. Plant pathogenic bacteria and fungi often cause concern and the control of some pathogens, particularly those below ground, is sometimes unsatisfactory or impossible by chemical means. Furthermore, the use of pesticides and herbicides, or soil sterilisation, can upset the delicate balance of micro-organisms present in the soil, often creating nutritional or pathogen imbalances and thereby adversely affecting plant growth. In the future, increasing costs and depleting energy resources could reduce fertiliser production, an industry essential to horticulture and agriculture.

Most soils contain a variety of fungi and other micro-organisms. Some of these are pathogens and are harmful to plant growth. However, there are others that are beneficial to plants. There is an increasing range of naturally-occurring soil bacteria and fungi which have found commercial use either as

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Most soils contain a variety of fungi and other micro-organisms. Some of these are pathogens and are harmful to plant growth. However, there are others that are beneficial to plants. There is an increasing range of naturally-occurring soil bacteria and fungi which have found commercial use either as

biological fertilisers or as agents for biological control of plant pathogens (1).

One such group of beneficial micro-organisms are the mycorrhizal fungi. The fungi involved form a symbiosis with the roots of plants. It is a beneficial association where both parties benefit: the host provides carbohydrates for the growth of the fungus and, in return, the fungus supplies nutrients to the host. Mycorrhizal fungi invade plant roots virtually forming an extension of the root system and thereby improving the uptake of nutrients by plants (14).

At present, four types of mycorrhizas are associated with different groups of horticultural crops (5). Ectomycorrhizas occur naturally on the fine feeder roots of many valuable trees — pine, spruce, beech, oak, pecan. Another group associates with plants of the heath family (Ericoid mycorrhizas). A third, very widespread group associates with a range of horticultural and ornamental plants, ranging from cereals to tomatoes to citrus and subtropical tree crops (Vesicular-arbuscular (VA) mycorrhizas). A fourth group associates only with orchids (Orchidaceous mycorrhizas).

The purpose of this article is to point out where mycorrhizal fungi (in particular the VA mycorrhizal group) can contribute to the establishment and production of horticultural plants.

Vesicular-arbuscular (VA) mycorrhizas: VA mycorrhizas are the most widespread of all the mycorrhizal associations. The fungi involved associate with a range of horticultural and ornamental plants, such as cereals and grain crops, tomatoes, legumes, citrus and subtropical tree crops, vegetable crops, and ornamentals. Roots become infected from very small spores (<1 mm diameter) which are present in the soil either singly or in groups. These fungi can benefit the establishment and growth of plants in several ways:

1) *Improve plant growth in nursery and field soils.* The most striking effect of VA mycorrhizas is their ability to improve the growth of plants, particularly in low or medium phosphate soils. The same effect could be achieved by adding quantities of phosphate fertilisers (Figure 1). However, it is possible to replace some of that fertiliser with mycorrhizal fungi and still produce the same increase in plant growth.

Phosphorus has consistently been shown to be involved in mycorrhizal-assisted nutrition. However, mycorrhizal fungi also increase the selective uptake of other minor elements, such as zinc, sulphur, potassium, and copper, and have been shown to relieve symptoms of zinc deficiency in peach, citrus, and apple (5).

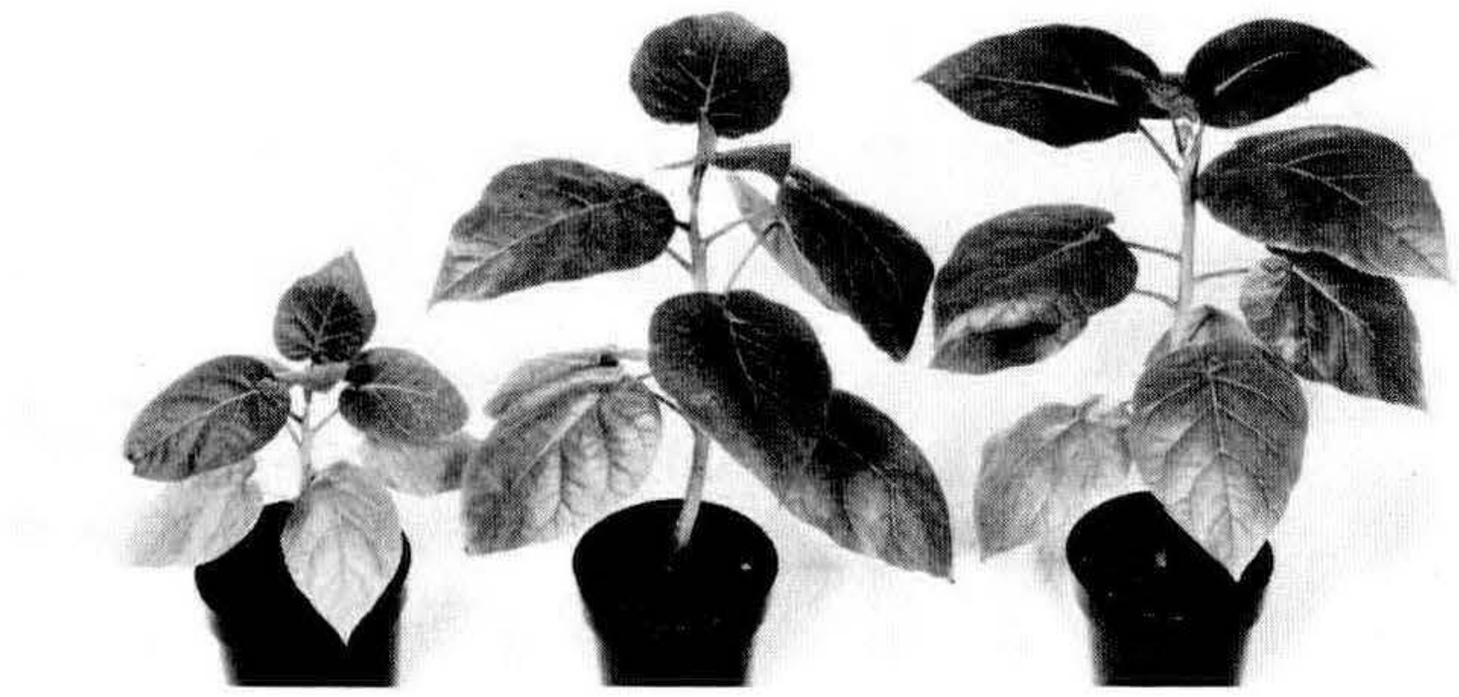

Figure 1. Effect of VA mycorrhizal fungi and added phosphate fertiliser on the growth of tamarillo *(Cyphomandra betacea)* plants in field soil. Growth in field soil is poor and indigenous fungi are slow to infect roots **(plant on left).** Plant growth is improved by the addition of mycorrhizal fungi **(middle plant)** or phosphate fertiliser (60 kg P/ha) **(plant on right).**

Although VA mycorrhizal fungi are present in most field soils, these naturally-occurring fungi are not necessarily the best at improving plant growth. Many of the field mycorrhizal fungi are slow to infect roots and are inefficient at improving the growth of transplanted stock (Figure 1.)

Figure 2. Avocado *(Persea americana)* plants infected with VA mycorrhizas (left) show greater resistance than uninfected plants (right) to wilting after transplanting.

Whereas most mycorrhizal fungi improve plant growth in low to moderate phosphate soils, some fungi are more effective than others. This effectiveness can vary depending on host and

soil type. For example, a fungus found to be particularly beneficial to the growth of tamarillo in one soil may not necessarily be the best fungus for either citrus or tamarillo in another soil. Furthermore, some fungi can depress the growth of one host but stimulate the growth of another. Before inoculating plants with mycorrhizal fungi it is, therefore, important to select the fungus, or fungi, most appropriate to a particular host and soil type.

At high levels of soil phosphate, some mycorrhizal fungi are either killed or simply do not function (5). However, it is possible to select fungi which will infect roots even in fertilized soils (2). These fungi will be particularly useful in horticultural soils and potting mixes, many of which have been heavily fertilised and have a high phosphorus level. It is also possible to produce mycorrhizal plants at an adequate growth rate by using slow release fertilisers (5).

2) *Reduce transplant shock.* Because mycorrhizal plants are more vigorous than uninfected plants they often recover more quickly when transplanted into the field. They are usually less susceptible to wilting and slowing of growth as a result of transplanting (7; Figure 2).

3) *Assist rooting and survival of cuttings.* Mycorrhizal fungi may be able to stimulate rooting of cuttings by speeding up root initiation and subsequent root development (Table 1). Mycorrhizal cuttings also show increased survival rates compared to non-mycorrhizal cuttings when transplanted into field soil (Table 1).

Table 1. VA mycorrhizas assist rooting and survival of tamarillo (*Cyphomandra betacea*) cuttings.

	Progress of rooting after 3 weeks			Percent survival after 6 months
	roots initiated	moderate root development	good development	
No mycorrhizas	+++	0	0	54
No mycorrhizas (+ hormone)	++	+++	+	76
+ mycorrhizas	0	+++	+++	98

\+ ≤ 10% of plants
++ 11 to 49% of plants
+++ ≥ 50% of plants

4) *Deter infection of roots by soil-borne nematode and fungal pathogens.* Recent work with mycorrhizal fungi has indicated that because of their ability to colonise both roots and soil, they may have a role in the biological control of soil-borne fungal and nematode root diseases (13). Inoculation of

plants with mycorrhizas can overcome the detrimental effects on plant growth caused by root-knot nematode (Figure 3), and can also reduce the number of nematodes able to penetrate into and develop within the root. This benefit is greater when the mycorrhizal symbiosis is well established before plants are placed in nematode-infested soils.

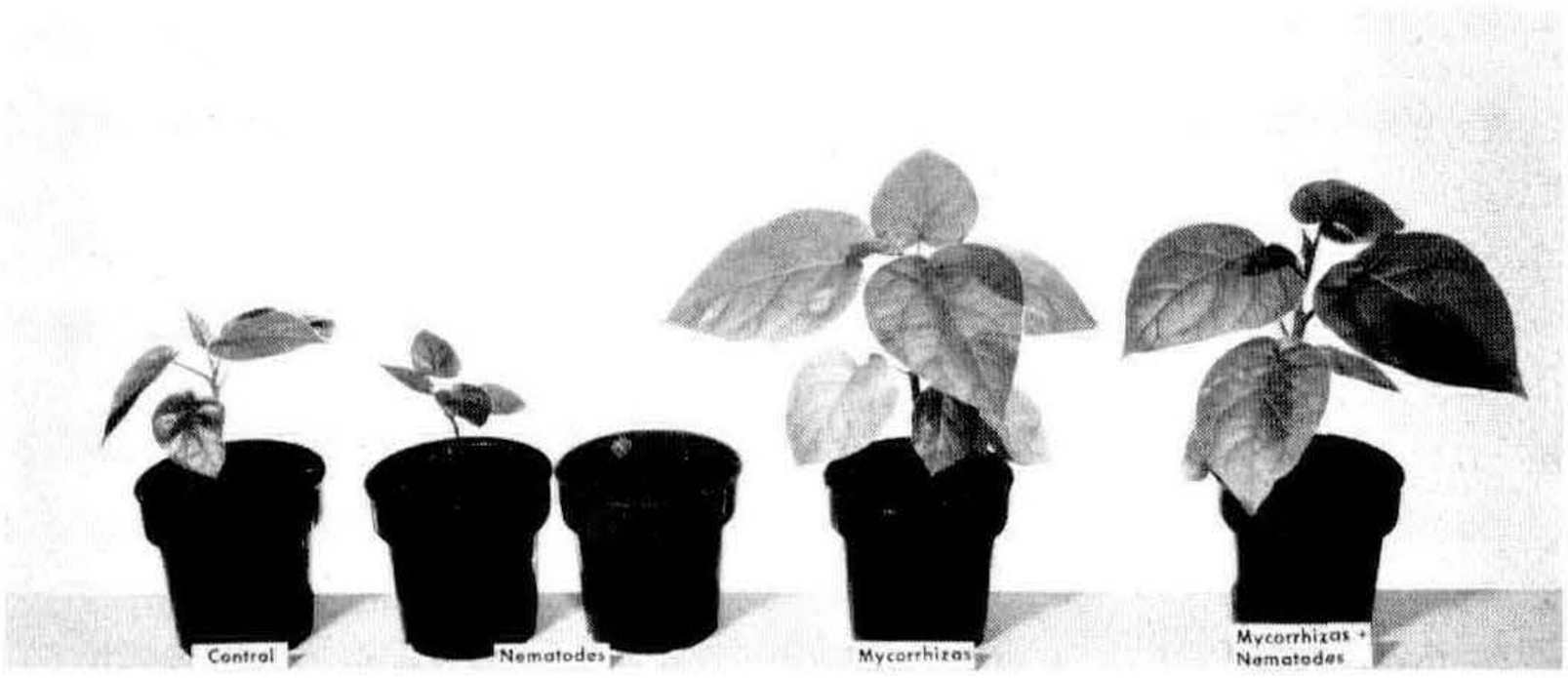

Figure 3. Inoculation of tamarillo (*Cyphomandra betacea*) plants with VA mycorrhizal fungi has overcome the detrimental effects on plant growth caused by root-knot nematode (*Meloidogyne incognita*) [data from (3)]. **Left to right:** Control, nematodes (2 plants), mycorrhizas, mycorrhizas + nematodes.

Ericoid Mycorrhizas. In natural ecosystems, plants belonging to the Ericaceae (such as *Erica*, *Vaccinium*, *Rhododendron*, and *Calluna*) are normally infected with the ericoid mycorrhizal fungus (12). These mycorrhizas influence plant growth by the absorption of nitrogren rather than phosphorus.

Ericoid mycorrhizal fungi could well have application in the improved production of ericaceous berry crops and in some ornamental nursery plants. Growth of *Rhododendron* plants in nursery soils has been improved by inoculation with ericoid mycorrhizas (19). In New Zealand ericoid mycorrhizas are becoming increasingly important with the introduction of blueberries as a significant horticultural crop. Natural mycorrhizal infection levels are very low in most of the mineral and peat soils where blueberries are now grown. This means that plants may remain non-mycorrhizal and poor croppers for several years before becoming infected. Inoculation of blueberry plants with ericoid mycorrhizal fungi has increased nitrogen uptake and has improved fruit yield in the first season by 11 to 92% (10,11).

Orchidaceous Mycorrhizas. In nature, most orchids require mycorrhizas at some stage in their life cycle and many require the association to facilitate seed germination. However, with modern sterile culture methods, orchid seed can readily be germinated on media containing inorganic salts and a carbon

source (e.g. sucrose). Many of these media are inhibitory to the growth of mycorrhizal fungi (16). Some fungal isolates can infect germinating orchid seeds and may establish a symbiotic phase. However, others, such as *Rhizoctonia solani*, which may be a vigorous pathogen of non-orchid hosts, can readily infect orchids but may lead to parasitism of the seedling protocorm (4). In a commercial enterprise, where orchid seed can readily be germinated artifically, and orchids can be propagated using tissue culture methods, it is doubtful if the orchid mycorrhizal symbiosis will ever be more than a curiosity.

Ectomycorrhizas: The ectomycorrhizal association can benefit its particular hosts in ways very similar to the VA mycorrhizal association. The fungi not only improve plant growth through increased nutrient uptake, but they can also infer some degree of resistance to soil-borne pathogens, relieve plant stress under adverse conditions of extremes of temperatures, soil acidity, moisture, and salinity, and produce hormones which can assist plant rooting and development (5).

Much of the practical application of this association has been in forestry, and artificial inoculation of tree seedlings with ectomycorrhizal fungi is now common practice in many countries (particularly USA, Canada, Europe). Mycorrhizal plants are used to advantage in the establishment of man-made forests and in afforestation of adverse sites such as coal spoils, scree slopes, and high altitude timberline sites (6,15). They may also have application in the establishment of shelter belts, in land reclamation or stabilisation, in the production of ornamental plants, and in the establishment of commercial nut crops such as hazelnut or pecan.

PRACTICAL CONSIDERATIONS

The normal horticultural practices of commercial enterprise can affect the beneficial mycorrhizal symbiosis. The use of phosphorus fertilisers can reduce the effectiveness of many mycorrhizal fungi. Similarly, certain fungicides or herbicides can be detrimental to mycorrhizal development, particularly during the early stages of fungal establishment (8). Therefore, if mycorrhizal fungi are to be used commercially, appropriate management procedures will need to be adopted to ensure continued survival of the fungus.

Soil sterilisation effectively kills mycorrhizal fungi and recolonisation of sterilised soil is slow by natural means. Inoculation of plants with mycorrhizal fungi has potential economic importance in all situations where soil is sterilised as part of routine horticultural practice (e.g. glasshouse crops,

horticultural nurseries, ornamental nurseries). Until recently, many nurseries raised their stock in field soils. Now, however, to avoid problems caused by infection with various pathogens, nurseries often raise their stock in fumigated soils or in some potting mix combination of bark, peat, sawdust, or sand. All of these mixes are usually devoid of mycorrhizal fungi. Stock from such soil-based or soil-less mixes is transplanted into the field without the benefit of a mycorrhizal association.

Commercial prospects for inoculation of plants with mycorrhizal fungi. Mycorrhizal fungi have been around a long time. People have long recognised advantages in transferring soil or humus from under a vigorous plant to developing seedlings or cuttings. This method usually does ensure mycorrhizal development, but it does create problems: the inoculum is bulky to handle and transport and there is a danger of introducing pathogens.

At present, there are three aims in infecting plants with mycorrhizal fungi:

a) to increase the plant's establishment and survival capabilities.

b) to improve plant health.

c) to increase plant growth and, if possible, production.

To achieve this, and to ensure a constant supply of pathogen-free inoculum, it is desirable to produce inoculum in culture of some kind.

Production of VA mycorrhizal inoculum is difficult. To date, the fungi involved in this symbiosis cannot be grown in pure culture — they must be raised in association with a host in sterilised soil, sand, or some suitable solid media, or in solution culture. Virtually all inoculum is currently produced from mycorrhizal-infected roots in a soil based mix. However, it is difficult to obtain sufficient quantities of pathogen-free mycorrhizal material. Production of various types of inocula is currently being investigated in several laboratories throughout the world. Unfortunately, commercial production still seems some time away, although small quantities of inoculum for citrus are currently being produced in commercial nurseries in southern California.

In contrast, the ericoid mycorrhizal fungi for blueberries and many ectomycorrhizal fungi for application in forestry and some ornamentals and nut crops can be grown very well in culture. Commercial preparations of ericoid mycorrhizal fungi suitable for inoculating blueberries are now available in New Zealand. Commercial preparations of some ectomycorrhizal fungi are currently available in the USA.

CONCLUSION

Horticultural plants are relatively easy to inoculate with mycorrhizal fungi. Mixing inoculum into sterile potting or nursery mixes, or incorporating it into nursery beds, allows the beneficial fungi to come into close contact with the roots of seedlings and cuttings. Inoculation of plants such as citrus, avocado, tamarillo, or blueberry in nursery beds or potting mixes with selected mycorrhizal fungi results in the beneficial mycorrhiza being carried with the roots when the plants are set out in the field, thereby improving plant establishment and early growth and reducing transplanting losses.

There are still many difficulties associated with the commercial production and application of mycorrhizal inoculum. Research on many aspects is still in its infancy and there is a distinct danger of rushing into commercial ventures before background information has been adequately researched.

Nevertheless, despite these difficulties and looking towards the future, it is desirable that:

1) Seedlings and cuttings should be inoculated with mycorrhizal fungi in the nursery prior to transplanting.
2) The most appropriate mycorrhizal fungus must be selected.
3) Nursery plants should be correctly managed using appropriate pesticides, herbicides, and fertilisers to ensure continued survival of the mycorrhizal inoculum in the soil.

There are tremendous potential advantages in manipulating mycorrhizas as a horticultural tool. However, it must be borne in mind that mycorrhizas are part of a complex biological system and may, therefore, be correspondingly difficult to manage successfully.

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PRODUCTION FORECASTING

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In the nursery business we do many types of forecasts, labor, expense, weather, sales, market, and production. The sales, marketing, and production forecasts have proven to be in the greatest need in the last two years.

Production forecasting can cover a wide range of areas. Some of these areas are scheduling supplies, labor needs, and equipment availability, but the most important area is in forecasts of product saleability. The forecasting of product maturity is important because if plants do not sell when predicted, warehousing becomes necessary and is very expensive.

Production forecasting is interrelated with and dependent upon accurate market and sales forecasts. Sales forecasts consist of sales by product line, territories, by month, week, or other time period, and by accounts. When making a sales forecast certain intangible factors must be estimated before measurable data is completed for the sales forecasts. These include long range trends of prosperity or depression, seasonal patterns of sales, and fluctuations of sales due to weather and other out-of-the-norm factors. It is the objective of the market and sales forecasts to determine what product and quantities will be needed for a given market. This information is necessary to set up the production schedules.

Production forecasting of plant material readiness becomes more difficult with relationship to age and size of desired finished product. Some bedding plant crops can be started and grown to maturity in only a few weeks while some specialty and landscape plants may take several years to reach the desired size.

It is very difficult to see market trends and react accurately because production cycles are so lengthy. At Wight Nurseries we have set up production schedules for all our crops. If we want to have a certain size plant in a certain size container within a certain span of time, we have a scheduled date by which the plant must be planted. Fifty percent of our sales occur in the months of February, March, April and May. Therefore, we schedule our production accordingly. This method is not 100% accurate, but it is very effective. The weather has always been a variable that affects the production schedules of any nursery. Temperature, rainfall amounts, and freak storms such as tornadoes, hailstorms, and hurricanes can

alter the production forecasts and plant saleability prediction.

At Wight Nurseries we also try to keep our production time span as short as possible. We try to shift the largest plant economically feasible to the next size to shorten the time it takes to make the plant saleable. Shortening this time span allows us more time to read the market and react accordingly. Shifting a large mature plant also improves crop uniformity as it eliminates some growing variables.

In today's economic situation production forecasts have been less beneficial than they should be. This is true because one can forecast with a fair degree of accuracy when a plant will be saleable, but many plants are being shipped well past their predicted availability dates. This is due to the soft retail market and the percent over-production dilemma in the industry.

Forecasts are based on past experience, present conditions, and future market outlook; they are an integral part of the planning process and must be based on carefully interpreted information, not guesswork.

PROPAGATION OF ORNAMENTAL GRASSES

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Abstract. From the world collection of 350 ornamental grasses, 15 were rated as superior performers in climatic zone 8A. Their propagation modes were studied simultaneously with evaluation as landscape plants. All annual grasses were propagated readily by seed with the exception of purple fountain grass, which is sterile. Many of the perennial grasses are sterile, necessitating vegetative propagation. Stem cuttings of four sterile perennials rooted readily.

Clump-forming ornamental grasses have been grown for centuries in Europe where they are used in informal designs, naturalistic settings, and as specimen plants. Only pampas grass, fountain grass, and blue sheep fescue have been used to an appreciable degree in this country. Since energy consciousness and limited landscape maintenance budgets in recent years are making low-maintenance plants more popular, ornamental grasses are receiving attention and acceptance from landscape architects and nurserymen. These grasses are ideal low-maintenance plants since they have low water and fertility requirements and are pest tolerant. In addition, most of them produce plumes that are ideal for dry flowers, making them dual purpose plants.

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MATERIALS AND METHODS

In 1969-1970 a collection of all ornamental grass germplasm from domestic and foreign sources was begun. During these years over 350 grasses were collected. Seeds of annuals were sown in greenhouse flats using artificial soil mixes and liquid fertilizers as is done in producing bedding plants by seeds. Perennial materials were usually received as divisions which were potted and grown for 4 to 6 weeks until vigorous root and top growth developed.

Transplants were established in field plots by early summer. Plants were irrigated when water stress occurred during the growing season. An application of 500 lb/A of 10-10-10 fertilizer was made in early summer and fall. Seeds of dubious germination capacity were harvested, cleaned, stored, and germinated according to recommended treatments for related grasses.

In 1981 and 1982 preliminary experiments were conducted to evaluate the effect of Hormodin No. 1 and Hormodin No. 3 on the rooting of stem cuttings of sterile grasses under intermittent mist. Tip and basal cuttings with 2 to 3 nodes from mature non-flowering stems were used.

RESULTS AND DISCUSSION

Table 1 provides a compilation of propagation modes for 15 superior-rated ornamental grasses. Annual grasses propagated readily from seeds with the exception of purple fountain grass (*Pennisetum macrostachyum*), which is a sterile annual. For the fertile annuals seed germination occurred in 2 to 3 weeks and gallon-sized plants were produced in 3 to 4 months. Reproduction of variegated grasses from seeds failed in all cases since seedlings reverted to normal green foliage.

Among the perennials, pampas grass (*Cortaderia selloana*) propagates readily by seed. However, the plants are dioecious and wind-pollinated, resulting in a high degree of seedling variability. Other perennials propagated by seed are ravenna grass (*Erianthus ravennae*), dwarf fountain grass (*Pennisetum alopecuroides*), feathertop (*Pennisetum villosum*), and the two species of *Uniola*.

Plant division is the usual technique for propagating sterile grasses. Since this is a slow process, a preliminary experiment was conducted to evaluate the effects of 2 concentrations of IBA on rooting of tip and basal stem cuttings of sterile grasses. Results are shown in Table 2. Basal cuttings of *Elymus* rooted readily while tip cuttings failed. Both tip and basal cuttings of *Pennisetum macrostachyum*, *Phalaris*, and *Uniola* rooted readily. IBA had no effect on the rooting response.

None of the *Miscanthus* cultivars rooted. Tissue culture may be a feasible alternative for propagation of sterile grasses whose stem cuttings do not root readily.

Table 1. Propagation modes of some superior ornamental grasses.

Species	Common name	Persistence	Propagation	
			Seed	Vegetative
Arundo donax versicolor	Variegated giant reed	Perennial		X
Cortaderia solloana	Pampas grass	Perennial	X	X
Elymus glaucus	Blue wild rye	Perennial		X
Erianthus ravennae	Ravenna grass	Perennial	X	X
Miscanthus sinensis	Eulalia	Perennial		X
Miscanthus sinensis 'Gracillimus'	Maiden grass	Perennial		X
Miscanthus sinensis 'Variegatus'	Variegated eulalia	Perennial		X
Miscanthus sinensis 'Zebrinus'	Zebra grass	Perennial		X
Pennisetum alopecuroides	Dwarf fountain grass	Perennial	X	
Pennisetum macrostachyum	Purple fountain grass	Annual		X
Pennisetum reppellianum	Fountain grass	Annual	X	
Pennisetum villosum	Feathertop grass	Perennial	X	
Phalaris arundianacea picta	Ribbon grass	Perennial		X
Uniola latifolia	Upland sea oats	Perennial	X	X
Uniola paniculata	Sea oats	Perennial	X	X

Table 2. Stem cutting rooting response of 9 ornamental grasses to 2 concentrations of Hormodin (IBA + talc).

Name	Type Cutting	Percent rooted cuttings*		
		Control	Hormodin No. 1	Hormodin No. 3
Cortaderia selloana	tip	0	0	0
(Pampas grass)	basal	0	0	0
Elymus glaucus	tip	0	0	0
(Blue wild rye)	basal	100	100	100
Miscanthus sinensis	tip	0	0	0
(Eulalia)	basal	0	0	0
Miscanthus sinensis 'Gracillimus'	tip	0	0	0
(Maiden grass)	basal	0	0	0
Miscanthus sinensis 'Zebrinus'	tip	0	0	0
(Zebra grass)	basal	0	0	0
Pennisetum macrostachys	tip	100	100	100
(Purple fountain grass)	basal	100	100	90
Phalaris arundinacea picta	tip	100	100	100
(Ribbon grass)	basal	100	100	100
Uniola paniculata	tip	100	90	100
(Sea oats)	basal	100	100	100

Mean of 30 cuttings

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LIN TABER: Can true sea oats be grown inland?

WILL CORLEY: We've had no problem in the Piedmont.

BRYSON JAMES: How does the time of cutting back affect winter hardiness?

WILL CORLEY: We cut back as soon as the plants are dormant and our survival rate is good.

TOM WALLACE: We have trouble ordering and then getting the correct cultivars. What do you suggest?

WILL CORLEY: There is much confusion in the nomenclature. Of course, it would be best to see the plants or their picture.

LEYLAND CYPRESS PROPAGATION

TED BILDERBACK

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Leyland cypress (× *Cupressocyparis leylandii*) is an intergeneric hybrid between *Cupressus macrocarpa* and *Chamaecyparis nootkatensis*. Several clones exist and the most common and available ones are listed in Table 1 (1,3,4,5,6,7,8). These clones may be the fastest growing conifers in the world (8). In full sun and well-drained soils, 3 to 5 ft. of growth per year is possible (1,5). The columnar form and rapid growth make it a good plant for hedges where fast screening is desired. Old Leyland cypress trees in Europe are 95 to 100 ft. tall but trees may reach only ½ to ⅔ that height in the Southeastern U.S. (3,6,8). It is reported to be hardy to zone 5 (9). Leyland cypress apparently has few insect or disease problems although bag worms have been observed on them; trees apparently do not grow well in the San Francisco Bay Area due to *Phomopsis* canker and a borer associated with the cankers.

Table 1. × *Cupressocyparis leylandii* (1888, 1911, 1940). (*Cupressus macrocarpa* × *Chamaecyparis nootkatensis*) clones.

'Haggerston Grey'	'Green Spire'
'Leighton Green'	'Stapehill'
'Naylor's Blue'	'Silver Dust'
'Castlewellan'	'Hyde Hall'
'Robinson's Gold'	

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PROPAGATION

Propagation of all clones is by cuttings, although they can be grafted to Monterey cypress (5). As Leyland cypress becomes better known in the U.S. by landscape architects and the general public, more nurseryman are becoming interested in propagating and growing it. However, some nurserymen have experienced difficulty in rooting cuttings. Propagation tips are listed in Appendix 1.

In Table 2 results of a rooting study are given. Cuttings were taken in January and placed in a medium of equal volumes of peat and perlite. Results were evaluated in May. Wounding the cuttings by removing the bark to the xylem 1 in. in length and ⅛ in. in width on opposite sides of the base of the stem improved rooting and root-zone diameter in comparison with nonwounded cuttings. Although the application of rooting hormones did not statistically improve rooting, rooting percentage and root-zone diameter tended to be greater with hormone treatments.

Table 2. Effect of rooting hormones on rooting percentage and root-zone diameter of × *Cupressocyparis leylandii*[z].

Treatment	Rooting percentage	Root-zone diameter (cm)
No wound; no hormone	67b[y]	2.3d
Wounded only	84ab	4.0c
Hormex 8 (0.8% IBA)	100a	5.4ab
Rootone 10 (0.4% NAA)	92a	4.2abc
2,4,5-TP (1.0%)	100a	5.6a
K-IBA (0.5%)	100a	4.2abc
Chloromone	92a	3.2cd

[z] Each value represents the mean of 12 cuttings.

[y] Mean separation within columns by Duncan's multiple range test; numbers with same letter are not significantly different at the 5% level

In various studies cuttings have been propagated in equal volumes of peat + perlite, peat + sand, pine bark + peat + sand, pine bark + hardwood bark, and in pine bark and in hardwood bark alone. A recently completed study on the effect of particle size on rooting response indicated no differences in media having from 11 to 43% air space.

From these results rooting response in nearly any commonly used rooting medium should provide adequate air space and moisture retention for successful rooting. Bottom heat of approximately 72°F and intermittent mist appear to be helpful in rooting cuttings; however, rooting may require up to 5 months to develop an adequate root system for transplanting.

Semi-hardwood to hardwood cuttings have been propagated in our studies in March, July, August, October, November,

and January, and cuttings can probably be rooted any month of the year. The one factor which appears to be most important in rooting Leyland cypress is to take large cuttings 8 to 12 inches or larger in length and to take at least 1 inch of dark red mature wood with the cutting.

Many times a great deal of callus tissue develops before root emergence occurs. From observations small cuttings often appear to form callus but are very slow to root or may not root at all.

TRANSPLANTING AND GROWING

A critical point in producing Leyland cypress trees occurs at transplanting. Few roots are formed per cutting and they must be carefully handled during transplanting. Cuttings are slow to become established in containers, therefore care must be taken after transplanting to reduce water loss. Shading or perhaps misting cuttings for approximately 2 weeks after transplanting seems to reduce cutting death. Laying cheese cloth over the transplanted cuttings would be beneficial if shading, wind breaks, or misting is not available.

In North Carolina State University media and nutritional studies, Leyland cypress has been grown in a variety of pine bark and hardwood bark media at several fertility levels (2). Media with a large percentage of fine particles, such as 3:1 (by vol) hardwood bark to sand, tend to reduce growth when compared to combinations of hardwood bark and pine bark, or pine bark alone. Best growth occurred in one study in a 2:2:1 (by vol) hardwood bark: pine bark: sand, when compared to 4:1 hardwood bark: sand, or 4:1 pine bark: sand. Growth has not been affected by pH between 5.2 to 7.0. High fertility levels produce greatest growth. Rooted cuttings were potted in 1, 2, and 3 gal. containers and fertilized with 200, 400, 600, and 800 ppm N supplied by NH_4NO_3 during two growing seasons. During the first season, 400 to 600 ppm N appeared optimum in all three container sizes and no difference in growth due to container size was observed. However, plants continued to grow during the winter and by the beginning of the second growing season container size had become a factor. The 3-gal. container at 600 to 800 ppm N produced the largest plants. The 2-gal plants were not significantly larger than 1-gal. container plants. These results indicate that for a 1 season production-market cycle, a 1-gal. container is adequate; however, a container no smaller than a 3-gal. container should be used to grow a 2-season plant.

CONCLUSIONS

Leyland cypress is a worthy plant to be considered for nursery production. In the landscape it may be the best plant available for creating a screen in open and well-drained areas. It apparently has few insect and disease problems. Selection of large cuttings with mature wood at the base and use of a rooting hormone has been successful for propagation. A cutting taken in November and potted into a 1-gal. container in April can attain an adequate size for sale by fall.

Appendix 1. Propagation Tips for Leyland cypress:

1. Use large cuttings with at least 1 in. of dark-red wood at base.
2. Wound cuttings.
3. Use a rooting hormone; 5000 ppm IBA is a good choice.
4. Use nearly any porous rooting medium — avoid a soggy medium.
5. Allow up to 5 months to root.
6. Bottom heat is helpful.
7. Use semi-hardwood or hardwood cuttings taken at any season.

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AIR ROOTING OF PEACH CUTTINGS

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Abstract. Semihardwood peach cuttings were successfully rooted by intermittently misting the bases and tops with water. Cultivar and cutting type (terminal or basal) did not affect rooting. Coverage with mist of the base and top of the cutting was essential for a high percentage of rooting.

REVIEW OF LITERATURE

Traditionally peaches (*Prunus persica* L. Batsch) are propagated as a two-part tree — rootstock and scion. Usually seeds are planted in the nursery row in fall. They are chilled during winter and germinate and grow the next spring. The scion cultivar is budded onto the seedling rootstock, the two unite, and the bud breaks and grows. The process requires much hand labor for the budding operation and for breaking off rootstock sprouts to assure adequate growth of the scion.

In recent years peach growers and researchers have sought methods to increase productivity of orchards. In many cases these attempts have involved planting more trees per unit of land (2, 4, 5, 6, 7). With these highly intensive production systems, the land area is covered with a tree canopy earlier in the orchard's life resulting in earlier economic fruit yields.

However, the relatively high cost of budded trees has made establishment costs for high-density orchards almost prohibitive. For example, standard peach orchards in the Southeastern U.S. are planted with approximately 250 trees per hectare (about 100 per acre) while the meadow orchard system being developed will require 5000 or more per hectare. Consequently, researchers have been developing methods to produce trees inexpensively. Most of these attempts have been aimed at providing own-rooted scions.

A number of successful attempts have been made at rooting hardwood peach cuttings (7, 8, 9, 10, 12). Where winter soil temperatures at a depth of 20 cm are 12°C or higher, hardwood cuttings may be rooted in the orchard site (7). However, in many areas soil temperatures are not suitable for this method. Another method that has been successfully used is rooting of semihardwood cuttings taken in early August, utilizing intermittent mist with vermiculite as the medium (3).

The research reported here involves attempts to root semihardwood peach cuttings without a rooting medium by misting

the tops and bases. Air rooting is not a new concept (1, 11, 12), but apparently has not been tried with peaches.

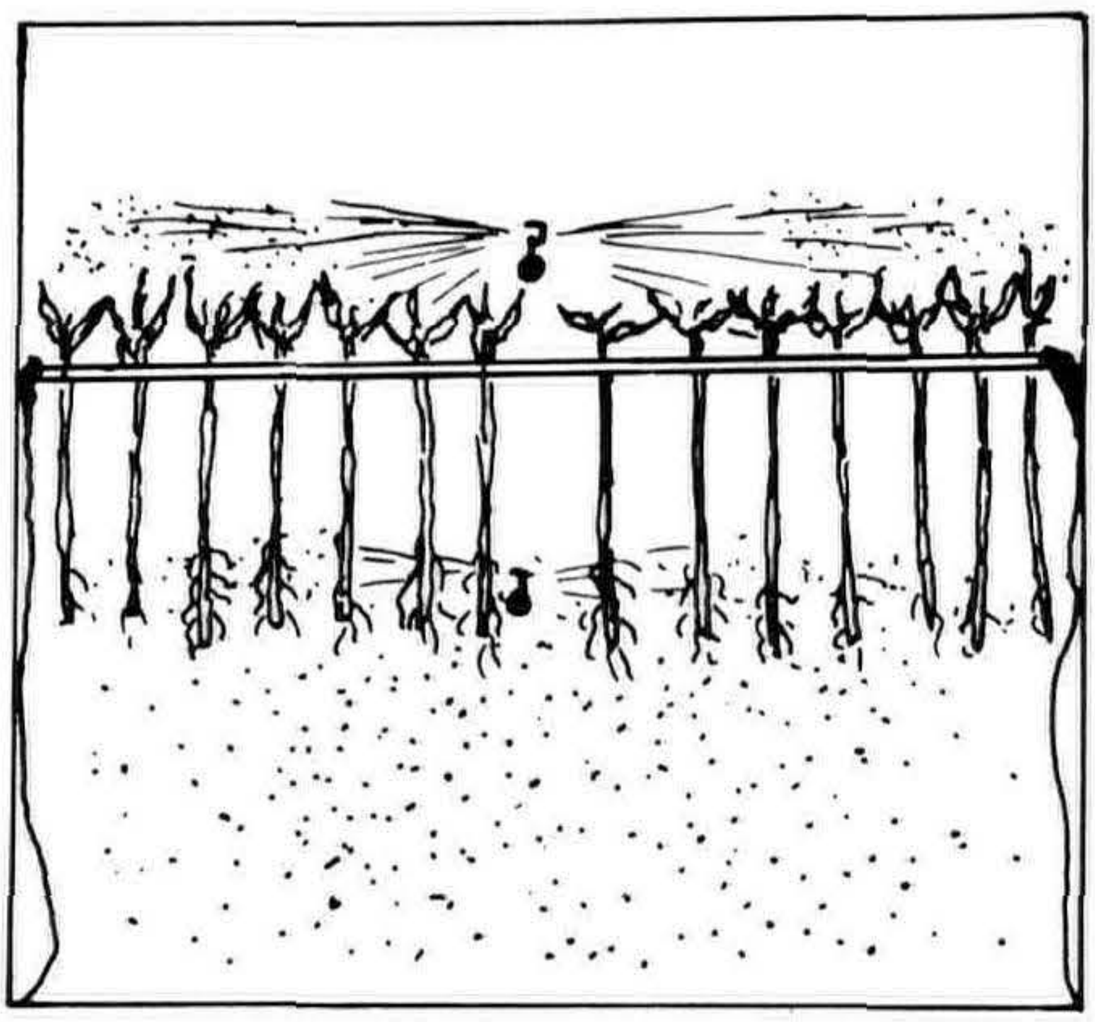

Figure 1. Diagram of the air rooting concept with mist on the bottom of the cuttings and over the cuttings.

MATERIALS AND METHODS

The first experiment used a 30.5 cm plexiglas cube painted black to exclude light. A deflective mist nozzle was mounted in the base of the cube and another above the cube. 'Redhaven' peach cuttings, approximately 25 cm long, taken in early August were wounded by removing bark on 2 sides from the lowest 4 to 5 cm. The bases of the wounded cuttings were dipped in 2500 ppm IBA in 50% ethanol for 5 sec. and inserted through holes drilled in the top of the box. Paper clips were placed 10 cm below the top of the cuttings to keep the bases suspended within the box. Mist was applied for 5 sec. each 2½ min. during daylight hours. Encouraging results from this initial test led to construction of a larger air rooting chamber.

A sheet of 2.5 cm thick styrofoam was suspended about 90 cm above the greenhouse floor. The top of the styrofoam was covered with aluminum foil to reduce light penetration. Black polyethylene was draped from the edges of the styrofoam to the floor to create a dark rooting chamber. A mist line with deflecting nozzles mounted 77 cm apart was placed 40 cm above the greenhouse floor and a second mist line was placed 30 cm above the styrofoam. Mist was applied through the two lines simultaneously for 5 seconds each 2½ minutes. Semi-hardwood cuttings of three cultivars — Redhaven, Springcrest, and Bicentennial — were taken in mid-September and treated as described previously. Cuttings were 35 to 50 cm long and were inserted through the styrofoam leaving 10 cm outside the chamber. Variables tested in this system were: position in the

box, type of cutting (basal or terminal), cultivar, and application of mist to the cutting base only.

RESULTS

With the plexiglas box in the initial test 73 of 75 'Redhaven' cuttings rooted within 3 weeks. Roots were evident on many of the cuttings within 7 days.

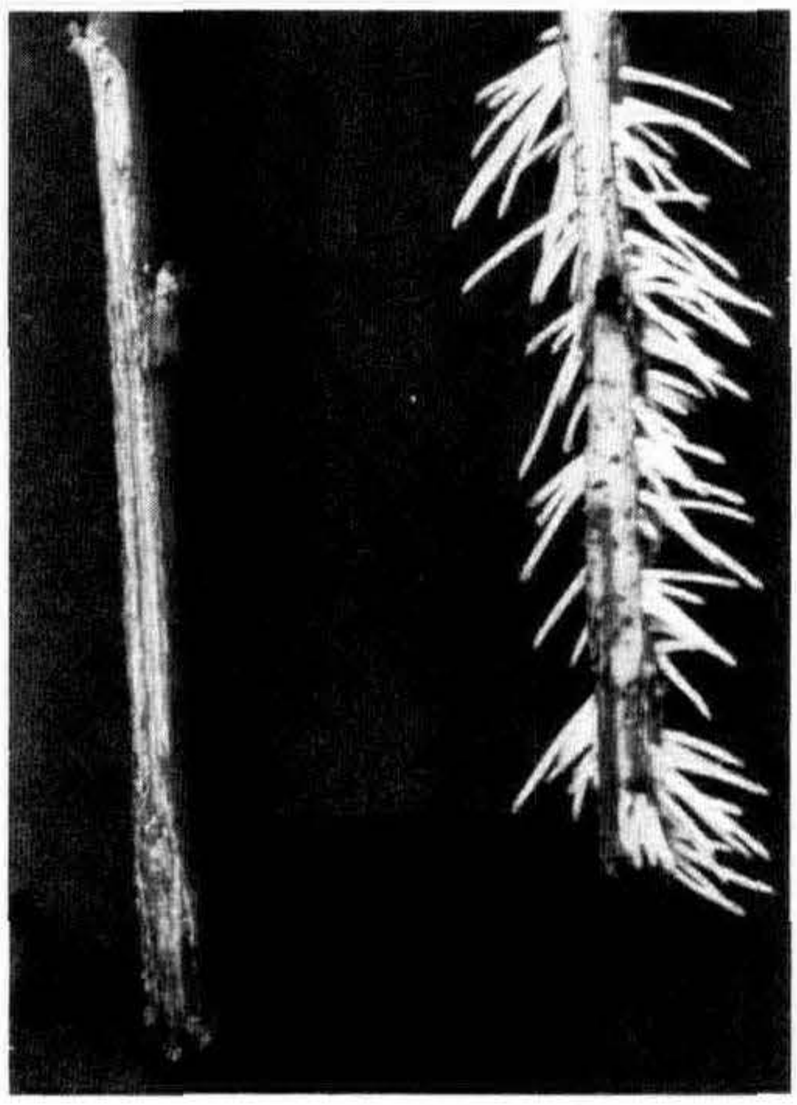

Figure 2. A 'Redhaven' peach cutting air-rooted (right) after 3 weeks in rooting chamber compared with a cutting (left) that only developed callus.

Cuttings were stuck in the styrofoam box September 18 to 22; callus was evident on cuttings in early October and roots were emerging by October 8. Rooting was evaluated in late October.

Cuttings near the center of the box (closer to the mist lines) rooted better than those near the edge (73% versus 48%). Of the edge cuttings which did not root, 40% callused.

The type of cutting (terminal or basal) had no effect on rooting. Also no differences were found in rooting among the 3 cultivars.

In another test 'Redhaven' cuttings that received bottom mist only did not root as well as cuttings receiving mist both above and beneath (27% vs. 65%).

DISCUSSION

Air rooting would provide an attractive system for propagating own-rooted peach trees without the expense of a rooting medium. The initial tests with the plexiglas box were quite

encouraging. However, the tests involving styrofoam demonstrated potential problems with the system. Time for taking cuttings in our area to obtain a high rooting percentage is late July through August (3 and Coston-unpublished data) when using vermiculite as a rooting medium. The results from the tests reported here suggest similar responses with air rooting.

Proper mist distribution is essential for good results. With the plexiglas box the tops and bases of the cuttings were well covered by mist. With the larger chamber the lack of adequate mist coverage at the outer edges greatly reduced rooting. Using a chamber that is narrower or using several mist lines to assure good coverage in all areas of the chamber should assure improved rooting. Also, the final test with 'Redhaven' cuttings demonstrated that for optimal results mist over the cuttings as well as beneath is essential.

Another essential ingredient to assure success is prompt removal of the rooted cuttings. Some of the cuttings in these tests were left in the chambers several weeks after rooting and *Fusarium* killed the roots.

Preliminary tests with several other plants (rabbiteye blueberry, hybrid rhododendron, wild deciduous azalea, crape myrtle, and juniper) indicate the potential for air rooting of cuttings taken in mid-September and processed similarly to the peach cuttings.

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LIN TABER: Are the rooted cuttings more susceptible to disease in the field than are the budded plants?

D. COSTON: We are only into our 4th year of growing rooted cuttings so we cannot be sure. However, 15-year-old plants in Georgia are doing well.

DON COVANT: How are plants irrigated in the field?

D. COSTON: We use drip irrigation.

SHIVU PATEL: Do the long roots create problems in transplanting and establishment?

D. COSTON: We have not encountered any.

JACK FINCH: The roots would seem to be fragile. How do you do the transplanting?

D.C. COSTON: We wrap them in damp paper and go right to the field. We have had no trouble.

PROPAGATION OF DECIDUOUS AZALEAS

DONALD MYLIN

Wells Nursery, Inc.
Penrose, North Carolina 28766

Our deciduous azalea propagation system has been developed over a 35 year period. We are currently producing about 60,000 plants yearly, which consist of several cultivars of the Exbury, Knapp Hill, and Ilam groups, as well as the Windsor hybrids.

Preparation of Stock Plants: Good healthy stock plants are essential for good cuttings. The majority of our cuttings come from our containerized stock that will be marketed at a future date. These plants are forced into growth in our standard overwintering houses. This commences sometime between February 15 and March 30. Proper maintenance of plants with regard to fertilizer levels and insect control is essential during this time.

Preparation of the Propagating Area: Preparation for a new crop begins by removing all old medium from the house

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Preparation of the Propagating Area: Preparation for a new crop begins by removing all old medium from the house

and washing down the benches. All repairs needed are made at this time. Since our benches are wooden, we treat them yearly with a copper naphthenate solution. The entire area is then sprayed with a formaldehyde solution and allowed to sit for approximately 72 hours. The house is then opened and allowed to air out for several days.

Fresh medium is prepared using a 1:1 ratio (by volume) of Canadian peat and horticultural perlite. This medium is placed into the benches at a depth of about 4½ in. and allowed to become thoroughly moist by using the mist lines.

Taking of Cuttings: We begin taking cuttings about the last week in April and try to finish by the third week in May. At this time the growth is very soft and growing vigorously. Cutting material is taken as early in the day as possible and maintained in a cool humid atmosphere until the cuttings are made. Only the quantity needed for the day is taken. Cutting length is 3 to 4 in. The terminal shoots are removed and the leaves are trimmed so as to retain 4 or 5 leaves, which are then reduced to about ¾ of their original size. Then the cutting is treated with the appropriate rooting hormone and placed under the mist.

Hormones: The use of hormones on this crop is essential for all cultivars. Over the years very specific concentrations and formulations have been devised for each cultivar. These, in turn, may vary somewhat according to the age of the wood. We utilize both liquid and powder formulations of IBA and NAA, as well as other materials such as boron and fungicides. Since there is so much variation, we custom mix our own hormones from commercially available powders and liquids.

Care in Bench: We follow normal production policy by trying to maintain a clean environment in the propagation house. Water comes uncontaminated from a deep well into a sealed pressurized system. The cuttings are given a fungicidal drench after insertion. Any dead material is removed by hand. Bottom heat of 70°F is supplied to the rooting zone.

Ventilation is supplied by a thermostatically operated fan. However, shading and mist are adjusted manually according to the current needs.

As soon as rooting begins a light feeding of 20-20-20 fertilizer is applied. The cuttings should be fully rooted and ready for transplanting within 8 to 10 weeks.

After care: Once the cuttings are rooted, we transplant them either into deep flats or quart pots. Mist is continued after potting for 10 to 14 days. To facilitate rapid top growth, a regular feeding schedule is commenced and artificial night lighting is begun as soon as the material is canned. This light-

ing regime consists of 5 minutes on and 5 minutes off from 9 pm to 4 pm. Pinching of plants is accomplished when the new growth is about 2 in. long. If the plant is to be marketed as a quart liner it may be pinched 2 to 3 times.

When the desired level of growth is achieved, the lighting is terminated and night temperatures are allowed to drop so as to encourage hardening-off. Our goal for the season is to grow a branched liner 8 to 10 in. high in approximately 5 months.

PROPAGATION OF RARELY CULTIVATED PLANTS AND NEW INTRODUCTIONS

ROBERT B. McCARTNEY

Woodlanders, Inc.
1128 Colleton Ave.
Aiken, South Carolina 29801

Few temperate regions of the world are blessed with so varied and diverse a flora as the southern United States. Nurseries in this region, which many of you here represent, produce millions of ornamental plants. However, surprisingly few of our native species are in the trade. Most of the plants you grow are of eastern Asiatic origin, but again they are only a small percentage of the possible choices from that area. Potentially useful plants from other regions of the world are hardly known.

Woodlanders, Inc. is perhaps unique in that we almost totally disregard the kinds of plants other nurseries grow. Instead we concentrate on a very broad range of native and exotic material, which is otherwise unavailable or difficult to find. Our plants are sold throughout the United States and abroad via mail order. Many of the plants we grow are hardy in cold areas, but we specialize in plants for milder climates. This affords a wider range of options horticulturally and serves a part of the country where specialist nurseries have been rare.

We are a very small nursery by most standards. We are located in Aiken, South Carolina, in the same hardiness zone (8) as Norfolk, Virginia. We are in the Sandhill Region and may have a somewhat drier climate than Norfolk, which is much moderated and influenced by the sea. This year Woodlanders, Inc. listed over 75 native tree species, over 130 native shrubs, more than 15 native vines, and over 75 native perennials. Over 100 exotic plants in similar categories and many new introductions are also listed. A number of the plants we grow are very rare and some are endangered species. We are

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not what is generally termed a "wildflower nursery". We do not sell collected plants and are generally opposed to that practice because it can definitely be a threat to the survival of some rare plants. On a regional basis the loss of critical habitat is perhaps the much greater threat to rare species.

We are able to buy a few of our plants from other nurseries but most of them we propagate from seeds, cuttings, root cuttings, or by other suitable methods. There is no other source for much of the material we grow. I will not discuss propagation procedures for specific plants as much of our propagation is still experimental. A slow and sometimes complex learning process is involved in growing new plants and often there are few guidelines. We do not have highly sophisticated facilities. Although we propagate over 400 kinds of plants, we do not produce any of them in great quantities. Sufficient numbers of plants for our purposes may result with propagation percentages unacceptably low for most commercial nurseries. Restraint must often be exercised to avoid overproduction and it is best to discard any excess material early-on. Demand for rare plants is, however, very changeable. A single article in a widely-read popular publication can stimulate instant demand for large numbers of a plant that was previously hard to give away.

Seed Propagation: We propagate many plants from seed. Seed of many native species is collected from wild populations throughout the Southeast. Some come from plants cultivated in our own garden or elsewhere. To collect seed of some plants we must visit the right spot at the right time. This may involve considerable travel, search, and research. Some years there is no seed produced, or we miss the critical timing. We maintain contacts with seedsmen, plantsmen, arboreta, and botanical gardens throughout the world; these are our primary sources for seed of new introductions.

Each kind of seed must be treated on an individual basis from collection, cleaning, storing, stratifying, media selection, sowing and growing. Some are planted in greenhouse flats or individual pots. Some are planted in outdoor seed beds. Germination of some seed is very quick, but other kinds may take up to two years. Some seedlings must be transplanted several times while a few can be sold directly from the seed beds.

Cutting Propagation: A wide range of plants is propagated by cuttings. We pursue this somewhat opportunistically and often experimentally. To date we have not used an automated mist system. Most cuttings are rooted in flats in the greenhouse. Some are rooted in sweat boxes but most are placed on the open bench where they are watered or misted manually.

We use various rooting hormones relying chiefly on past experience and intuition. Media is chosen in the same way and usually consists of sand, or combinations of sand, peat, sawdust, and perlite. Bottom heat is used on some cuttings during cool seasons. Quite a few plants we grow are xerophytes from our own desert-like sandhills or from arid regions. In rooting and growing these plants excess water must be avoided. These are rooted in a very porous medium with good light and good air circulation.

Other Methods of Propagation: A few plants have not reproduced readily from seed or from stem cuttings so other methods have been used. Root cuttings, taken during winter, work well for some. In some cases the sprouts which arise from root pieces are removed and treated as ordinary cuttings with good success. Layering is used occasionally but more often it is used in order to get a start of something than to produce it in quantity. Thus far the same has been true of grafting and budding. Many perennials are routinely increased by division.

Growing-On: Once started or divided, plants are grown in containers or in ground beds. Saleable plants are normally 1-gal container size or smaller. Shipping larger material is cumbersome and expensive. Beds and container mix are fumigated with methyl bromide. Potting mix varies but usually consists of three parts pine bark, one part sand, and one part ground, composted leaves. Composted leaves are available at our landfill. Fertilizer is mixed and/or added as a slow-release top dressing. Some native plants do not tolerate high levels of fertilizer and some grow too big too fast if fed at the rates practiced in many nurseries.

CONCLUSION

In summary, our products, techniques, facilities, and markets are still very much in evolution. In some respects we are doing everything the opposite of standard nursery practices in our region. While we are as yet unsure of many things, we do know that it is possible to grow a much greater diversity of interesting and attractive plant material than is currently available. This is especially true in the southeastern U.S. and we are encouraged that our efforts are being well-received by serious gardeners.

RAPID GROWTH OF TREE SEEDLINGS IN BOTTOMLESS *CONTAINERS UNDER CONTINUOUS LIGHT*

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G. SHANNON SMITH

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Since the discovery of photoperiod effects on plant growth and flowering in 1920 by Garner and Allard (1) it has been known in general that long days extend the vegetative growth phase of many woody plants, and conversely that short days are generally associated with the cessation of growth and the onset of dormancy in the fall (4). Exceptions to these generalizations were documented by USDA researchers in 1956, and the following year Nitsch (5) used 4 categories to classify woody plants according to photoperiodic response as follows:

A. Long days promote continuous growth while short days induce dormancy, as in *Weigela florida*.

B. Long days stimulate repeated periodic growth while short days will induce dormancy, as in *Quercus rubra*.

C. Long days promote continuous growth, but short days will not cause dormancy, as in *Juniperus horizontalis*.

D. Long days prolong the growing period, but plants eventually go dormant regardless of daylength, as in *Syringa vulgaris*.

It appears that the growth-promoting effect of long photoperiods may be especially effective on promoting growth when plants are in the seedling, or juvenile growth phase. Hanover and others (3) in Michigan have worked with this concept to speed growth of conifer, birch, and other seedlings with considerable success. They developed the accelerated optimal growth system, which uses long daylengths combined with optimum temperature, watering, fertilization, and even CO_2 enrichment of the greenhouse atmosphere to promote rapid seedling growth. Some commercially available pine seedlings are presently being produced using this system or something similar.

Also, in the last decade, there was considerable interest in various container systems other than the typical round pot, especially in sizes suitable for seedlings (6,7). These vary in configuration from the various plugs and "bullets", to "book" systems that open up to expose the elongated cells, to the inverted pyramid of the Speedling system, to various types of cell-pak trays, to the bottomless square milk cartons used by Gibson and Whitcomb (2). The complaint against the conven-

tional round nursery container, of course, was that in species with a dominant tap root or strongly growing branch roots a malformed, crooked, coiled, or distorted root system was often produced. This could cause slower growth of the plant and possibly premature death in cases where root strangulation is severe. Gibson and Whitcomb (2) showed that by growing trees in square bottomless containers on a raised bench so as to obtain air pruning of root tips protruding out the bottom, a more fibrous root system was obtained due to the branching of the air-pruned roots.

The work we did at Tennessee was an effort to combine the growth-promoting effects of long days on tree seedlings with the improved root system resulting from air pruning in bottomless square containers. We carried these 6 species through the experimental setup: sweet gum, pin oak, golden rain tree, white birch, saucer magnolia, and Carolina cherry laurel. The first 4 were from seed obtained from a commercial source while the latter [illegible] were from locally collected seed that had been sown in an outdoor bed the previous fall. Seed was stratified as needed in damp sand in a cooler held at 33 to 38°F, then sown March 25 directly into the containers used. They were thinned later to one seedling per container. The containers were one quart paper milk cartons with a thin plastic skin. They were cut down to 5½ in. tall and divided into one group with the bottom cut out and another group with the bottoms left in but with drainage holes cut in the corners.

The soil mix was 3:1:1 pine bark:sand:peat. Amendments per cu. yd. were 15 lb 18-5-11 Osmocote; 4 lb Perk; 4 lb 0-20-0; and 8 lb dolomitic limestone. To hold the containers up off the existing greenhouse benches, we set up frames of 2- × 4-ft lumber and nailed hardware cloth as taut as possible over the frame. To keep the soil mix from sifting out of the bottomless containers, we set them up on top of a single layer of newspaper as they were being filled and placed on the mesh frame. Six of the 12 benches had continuous light furnished by fluorescent fixtures 18 in. above the container. Fixtures were raised as the plants grew. At night these lights gave 300 to 500 foot candles at the top of the plant. During the day they actually shaded the plants somewhat but the amount was not considered significant. Control benches were curtained off from the lights with black sateen cloth at night and thus were exposed to natural daylengths. Pad and fan cooling was used to help control temperatures. The recorded temperatures were from the mid-70's to mid-80's with an occasional high of 95 F°.

Each plant species was grown in the greenhouse until enough top growth and root development had occurred in

most of the treatments to warrant planting out in the field or to 3-gal nursery containers. Actual time in the greenhouse was 84 days for the magnolia and cherry laurel seedlings, 105 days for birch, 112 days for golden rain tree, 116 for sweetgum, and 126 days for pin oak. Thus, field planting was in late July to early August in the summer of 1980, which was one of the hottest and driest summers experienced in Tennessee for decades. At the end of the growing season evaluations were recorded of height, caliper, straightness rating, fresh weight of top growth, and root quality rating. Responses to the photoperiod and bottomless container treatments will be discussed separately for each species.

(1) *Koelreuteria paniculata* — golden rain tree

Seedlings of *K. paniculata* respond to continuous light by increased height growth over seedlings under natural photoperiod treatments. The most height growth occurred in the bottomless container, continuous light combination.

Bottomless container culture influenced root production and fresh weight of top growth. Seedlings started in bottomless containers had higher root quality ratings and were also heavier than seedlings started in containers with bottoms.

Every treatment produced good one-year seedlings. The best seedlings, however, consistently came from the 24-hour photoperiod and bottomless container combination.

(2) *Magnolia* × *soulangiana* — saucer magnolia

Magnolia × *soulangiana* seedlings from 24-hour photoperiod and bottomless containers were superior to seedlings in other treatments in height, amount of height growth after planting, and fresh weight of top growth. Plants started in bottomless containers had greater caliper than plants started in containers with bottoms. Also, seedlings started in bottomless containers had better root quality ratings at both growing locations.

Plants from natural photoperiod treatments were straighter than plants from continuous treatments.

It seems that propagation in bottomless containers is an effective method for *Magnolia* × *soulangiana* seedling production.

(3) *Betula pendula* — European white birch

B. pendula started in bottomless containers were taller, straighter, and had greater caliper, fresh weight of top growth, and better root quality ratings than those started in containers with bottoms.

Photoperiod treatments had no effect on height growth, contrary to expectations.

Field production of *B. pendula* produced better seedlings than 3-gal container production. Field plants had greater caliper and fresh weight than container plants.

Results would suggest that square, bottomless containers be used during the propagation period with resulting seedlings planted in field culture.

(4) *Liquidambar styraciflua* — sweet gum

L. styraciflua was the most unresponsive species tested as no significant effect in height, caliper, fresh weight, or straightness ratings from treatments occurred. Seedlings grew approximately the same in all treatment combinations at both growing locations.

L. styraciflua is easily propagated and grown by commercial nursery methods, thus there is no advantage in growing it by the methods tested.

(5) *Quercus palustris* — pin oak

Seedlings from 24-hour photoperiod treatments were taller (60.5 cm) than seedlings from natural photoperiod treatment (38.2 cm). The fresh weight and root quality ratings also suggested a positive response to continuous light.

Container type, either bottomless or with bottom, had no influence on height, caliper, fresh weight, or straightness rating of *Q. palustris*. The root quality rating of seedlings from bottomless containers was better than those from container with bottoms.

Continuous light is effective in stimulating increased growth of *Q. palustris* seedlings.

(6) *Prunus caroliniana* — Carolina laurel cherry

P. caroliniana responded to continuous light by increased height (39.1 cm to 34.0 cm) over seedlings from natural photoperiod treatments. Bottomless container culture affected no growth parameter other than root quality ratings.

The production of *P. caroliniana* seedlings under continuous light may be feasible although seedlings from all treatments made comparatively little height growth.

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USING A MICROCOMPUTER IN THE NURSERY BUSINESS

FRANK F. WILLINGHAM, JR.
Research Farms, 7517 Alabonson
Houston, Texas 77088

My microcomputer was purchased to serve as a tool for learning about computers in general. Our company had reached a size and complexity level that made consideration of our own computer system necessary, but I really had no good basis for comparing the various features available. The $2500 spent on a micro seemed small compared to the $15,000 to $50,000 at stake for a complete business system.

Computer basics. A microcomputer is considered to be a desk top machine, as opposed to mini and main-frame computers, which require much more space and are many times more costly. The so-called "personal" computers are microcomputers. All computers, micros included, have certain features in common: a CPU, an I/O, a clock, and a memory. The CPU (central processing unit) does the work or calculations of the computer. The I/O (input/output) gets data to and from CPU. The clock times the various operations and makes sure the computer doesn't try to do two things at once. The memory stores information. Memory is of two types: ROM (read only memory) resides permanently in the computer and contains instructions and codes that cause the computer to operate in a certain way. RAM memory (random access memory) is temporary, and everything is lost when the power is turned off. RAM memory holds the programs and data being used at the moment. Microcomputers are often compared by the size of the RAM memory. My Apple II is a 48K, meaning it has 48,000 bytes of RAM storage capacity. Although these numbers really have little definitive meaning to the user, it is often implied that the bigger the RAM, the better the machine. RAM size becomes important when it limits the size of programs that can be run or data that can be handled. The 48K RAM is the

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most popular for beginning users, and options are now available for up to 256K RAM. The above components together form the hardware of the computer. The usable system requires the addition of a video (TV), data storage device (tape or disc), and possibly a printer. With these added pieces of hardware the computed results can be viewed (video), saved permanently (disc reader or tape machine), and a hard copy printed (printer).

Computer software, or programs, must be written in the same language as is located in the ROM. In the case of my Apple II, this is called Applesoft. It is a version of a more universal computer language known as BASIC. This language uses understandable words and phrases for its commands as opposed to the more symbolic languages of Fortran and Cobol, which are used for programming the larger mini and main frame computers. The microcomputer languages are easier to learn, but programs do not run as fast or efficiently.

Useful applications. Computers are at their best when set up to handle simple, but repetitive tasks, such as keeping track of large blocks of data. It would seem obvious, then, that bookkeeping would be the first application one would think of assigning to a computer. In our case, the micro system could not handle the volume of data associated with the various accounting procedures. We required that order entry, invoicing, accounts receivable, and general ledger all be interactive, and that several terminals be in use simultaneously. This was too much, and our decision was to go with on-line terminals tied to one of the major computer firms in our area. In deciding whether to use a microcomputer for bookkeeping work, look at the number of transactions or entries you will need to process. Consider also how you will back up your data, who will do the data processing, what would happen if you had a power loss or fire. Compare several systems and bookkeeping alternatives. If you do decide to use an in-house micro system, there are several good software packages on the market. Try them out before you buy.

Probably no other single piece of software is so versatile or has become so popular as VisiCalc, the electronic spread sheet. When added to a microcomputer of 48K RAM or more, the result is a powerful management tool. Financial models of budgets, crop production, inventory control, and endless other situations can be created and manipulated. I have found no better way of understanding the dynamics of my business than by using the VisiCalc program to change then recalculate the numbers in my budget. It soon becomes apparent which factors influence profit significantly, and which can be altered to accommodate a changing economic situation. For the new user

of this software, there are now newsletters and complete books on the subject of using VisiCalc.

There are a number of data base management programs that can be purchased right off the shelf. Their usefulness often lies in how well the instructions, or documentation, is prepared. This quality is known as "user friendliness". Most of them function as electronic card files and permit the information catalogued to be retrieved by any number of codes, such as by date, or subject matter, or salesman. We use such a program to keep track of incoming shipments. Other growers I know use these programs to catalogue pesticide usage and set up growing schedules. Again, this is software adaptable to so many nursery situations imagination is the only limitation.

The third kind of packaged software I find useful is word processing. I am just beginning to utilize it fully, but have now eliminated the typewriter that used to be in my office in favor of the microcomputer and its printer.

We occasionally like to look at our financial data in graph form and bought a plotting program to draw the graphs. I have found this to be interesting, but not nearly as useful as the others. I would probably not purchase this software again.

Programming your own. Those who buy a microcomputer and believe they will be able to write their own programs, as its sometimes implied in the advertisements, are in for a shock. It is extremely time consuming, frustrating, and not at all cost effective for the non-professional. Consider the example below, which illustrates a very simple payroll system. The components required include:

Files

1. Payroll master file
2. Payroll transaction

Programs

1. Add/change/delete master file
2. Program to create transaction file
3. Payroll program
4. Utility program to print master file

This simple payroll system was used by permission of Professor Michael Moore, Business Data Processing, University of Houston — Downtown, 1 Main Street, Houston, Texas 77002.

In the even simpler case of writing a program to calculate parts per million given the fertilizer application rate, we are still dealing with about 300 separate statements. I'm told that programmers consider it a good work day if they can design, write, and debug 10 statements. You quickly find out that if you are a busy manager, you just don't have the time to write your own software. The exception is that you do it because

the computer becomes your hobby, but I personally have not had the time for it.

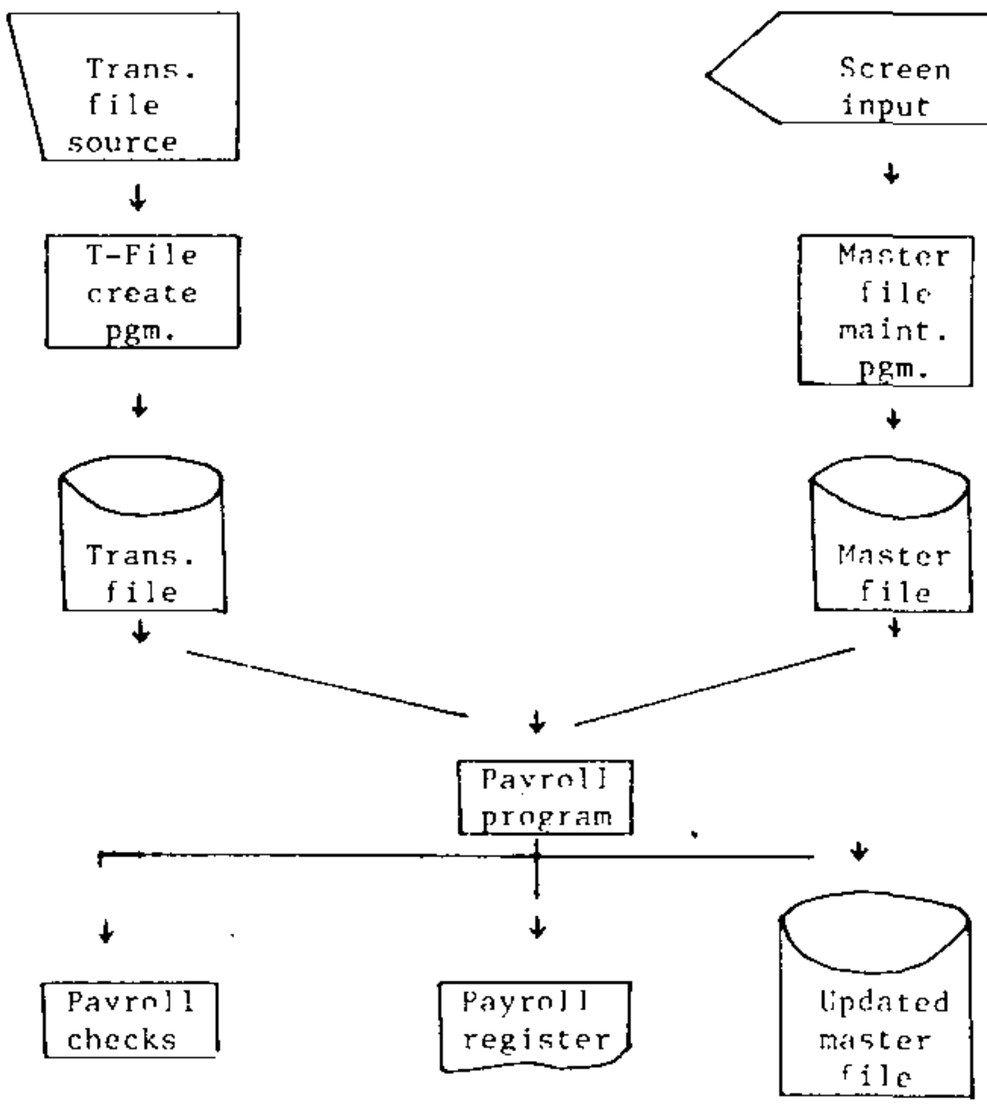

Figure 1. Systems flowchart for a simple payroll system.

Table 1. Estimated time and cost for preparation of each program.

Program #	Design	Programming	Testing	Total
1.	2	3	2	7
2.	1	2	2	5
3.	3	4	4	11
4.	1	1	1	3
TOTAL	7	10	9	26
Total Estimated Hours:		26		
25% Cushion/Overhead:		6.5		
Projected Total		32.5	@ $35 = $1137.50 @ $50 = $1625.00	

Table 2. Cost of in-house programming vs package programming based on cost/benefit analysis

In-House Cost:	$1137.00 – $1625.00
BPI* Payroll System:	$ 400.00

* Registered trademark

SUMMARY

My experience with microcomputers leads me to offer the following advice to the nurseryman:

1. Consider the purchase of a small computer as a management tool, rather than an accounting aid, unless you are convinced it can accommodate your present needs and future growth.

2. Buy your software. Unless you are a programming whiz, you won't be able to produce programs as good or as cheap as what is already on the shelf.
3. Visit your computer store often. New software is constantly appearing, especially for the more popular computers.
4. Decide what role the computer is going to play in your life. If it is to be used as a tool, don't over-complicate things by setting up computer files for things that are best done manually.
5. Select a computer brand that will not become obsolete. The field is progressing very rapidly, but the better companies will continue to support users of their older models.
6. Select a computer that can be serviced locally.

NEW MOUNTAIN LAUREL SELECTIONS AND THEIR PROPAGATION

RICHARD A. JAYNES

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Mountain laurel (*Kalmia latifolia* L.) is coming of age. Beautiful selections have been available since the 1800's, but because of propagation difficulties these and newer selections have been largely ignored until recently. Selection efforts by C.O. Dexter, Sandwich, Massachusetts, in the 1930's, followed shortly by selection and breeding by the Mezitts, Weston Nurseries, Hopkinton, Massachusetts, began to focus attention on this species in the U.S. A.G. Soames simultaneously selected pinks at Sheffield Park, Sussex, England. He presumably also used material originating with C.O. Dexter but obtained through the Arnold Arboretum, as well as with material from the Knap Hill Nursery. Research begun at the Connecticut Station in 1961 on *Kalmia* has not only demonstrated a wide range of desirable horticultural traits in mountain laurel but has also shown that many of these characteristics are simply inherited, and thus can be readily manipulated by the breeder (2,4). New cultivars have recently been named and released and new selections are anticipated, including five that are described here for the first time. More efficient means of vegetatively propagating them are evolving.

Seed propagation. Seed propagation is slow, but tried and true, and may still be the best means for multiplying the normal or wild-type as well as some selected forms that breed true-to-type. Self-pollination is not recommended because of

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Mountain laurel (*Kalmia latifolia* L.) is coming of age. Beautiful selections have been available since the 1800's, but because of propagation difficulties these and newer selections have been largely ignored until recently. Selection efforts by C.O. Dexter, Sandwich, Massachusetts, in the 1930's, followed shortly by selection and breeding by the Mezitts, Weston Nurseries, Hopkinton, Massachusetts, began to focus attention on this species in the U.S. A.G. Soames simultaneously selected pinks at Sheffield Park, Sussex, England. He presumably also used material originating with C.O. Dexter but obtained through the Arnold Arboretum, as well as with material from the Knap Hill Nursery. Research begun at the Connecticut Station in 1961 on *Kalmia* has not only demonstrated a wide range of desirable horticultural traits in mountain laurel but has also shown that many of these characteristics are simply inherited, and thus can be readily manipulated by the breeder (2,4). New cultivars have recently been named and released and new selections are anticipated, including five that are described here for the first time. More efficient means of vegetatively propagating them are evolving.

Seed propagation. Seed propagation is slow, but tried and true, and may still be the best means for multiplying the normal or wild-type as well as some selected forms that breed true-to-type. Self-pollination is not recommended because of

poor seed set and inbreeding depression. Controlled crosses between different selections of each of the following kinds should yield seedlings that are true for the same trait (4):

K. l. f. *myrtifolia* — miniature
K. l. f. *angustata* — willow-leaved
K. l. f. *polypetala* — feather petal
Cut corolla of 'Shooting Star' type
Reduced corolla of 'Bettina' type
Red — e.g. 'Ostbo Red' × 'Nipmuck'
Deep pink — e.g. 'Pink Charm' × 'Sarah'
White — e.g. 'Stillwood' × near white

In addition, open-pollinated seed of the various banded (*K. l.* f. *fuscata*) types, including 'Bullseye', 'Carousel', 'Fresca', 'Freckles', and 'Goodrich', should produce banded types among at least 50% of the offspring.

A method to mass produce hybrid *Kalmia* seed without making controlled crosses has been demonstrated (2). The desired parent plants (different *K. l.* f. *myrtifolia* seedlings, for example) are planted together in a block. Just before the flowers open the plants are enclosed with insect-proof screening. When the flowers open, a bumblebee introduced into the cage will cross-pollinate the flowers over the bloom period of about two weeks. If the bee should die, a second is used.

Although small in size, mountain laurel seed is long-lived. Kept dry and refrigerated it will remain viable for up to 20 years (5).

Cuttings. Mountain laurel has been successfully propagated by softwood cuttings taken at the end of the flowering period, by greenwood cuttings in mid-summer, by fall cuttings from September through November, and by early winter cuttings taken about January 1. More consistent success in rooting has been obtained with fall cuttings but, because of inadequate chilling, they often fail to break dormancy the following spring, resulting in little growth the first year. An advantage to summer cuttings is that after rooting in the fall, they can be chilled the following winter and then flush normally in the spring. Conversely, January cuttings have already had adequate chilling so that they break dormancy in the spring about the time or shortly after rooting.

Williams and Bilderbach (8), under their conditions, found no significant difference in the rooting of cuttings stuck in humidity cases vs. open mist benches, although the misted cuttings were "harder" looking. My experience and that of several other growers is that humidity chambers are superior to mist for rooting mountain laurel.

Auxin treatments such as 4.5% IBA in talc, 2,500 to 5,000

ppm liquid dip of IBA and NAA, and 1,000 ppm 2,4,5-TP in talc reportedly aid in the rooting of cuttings (1,7). However, my experience with these materials on numerous clones has not confirmed an overall positive effect. On the other hand, there clearly is a notable difference among clones in ease of rooting. 'Pink Surprise', 'Pink Charm', 'Nipmuck', and 'Quinnipiac' are relatively easy-to-root (70 to 95%), whereas 'Ostbo Red', 'Goodrich', and 'Stillwood' are difficult-to-root (<50%) (3).

Tissue Culture. Micropropagation of mountain laurel in sterile culture was described by G. Lloyd and B. McCown in 1980 IPPS Proceedings (6). At least three commercial nurseries have been successful in producing plants in sterile culture (Briggs Nursery, Olympia, Washington; Knight Hollow Nursery, Madison, Wisconsin; and Weston Nurseries, Hopkinton, Massachusetts). Tissue culture will likely become a more reliable, speedier, and perhaps economical means to mass produce selections in the future. It should also expedite the multiplication and testing of new selections.

New Cultivars. A register of all *Kalmia* cultivars is being prepared and should be available from the author by the end of 1983. Presently, there are about 25 named cultivars of *Kalmia latifolia*. There are also 5 unique new selections from the breeding program at the Connecticut station. They include the first named miniature (*K.l.*f. *myrtifolia*) mountain laurel, 3 distinct selections of banded (*K.l.*f. *fuscata*) forms and a red-budded selection that opens a deep pink to near red color.

'Elf' — Selection from a cross of miniature plants (*K.l.*f. *myrtifolia*) made in 1976. The foliage and habit is characteristically ⅓ to ½ normal size with the flowers somewhat less reduced. The light pink flower buds open near white. Cuttings root more readily than those of most selections.

'Bullseye' — The open flowers have a broad, purplish-cinnamon band of pigmentation on the inside of the corolla with a white center and white edge. It is a type of banded laurel, *K.l.*f. *fuscata*. This plant was selected from a cross made in 1972 between the Bristol Nursery banded plant and a red-budded seedling selection.

'Carousel' — The open flowers have an intricate pattern of bright purplish-cinnamon pigmentation on the inside of the corolla. It is a banded (*K.l.*f. *fuscata*) form selected from a cross made in 1972 of a banded plant similar to 'Goodrich' and a red-budded seedling selection.

'Freckles' — The open flowers have ten distinct pigment marks, purplish-cinnamon in color, on the inside of the corolla at the level of the anther pockets. It is a banded (*K.l.*f. *fuscata*) form selected from an F_2 population of a banded plant with a red-budded selection. The crosses were made in 1963 and 1969, respectively.

'Sarah' — The flowers are brilliant red in bud, similar to 'Ostbo Red', but pink-red when open. The flower color is eye catching in bud and open. It was selected from a 1974 cross of two intensely colored plants; the male parent was 'Pink Charm'.

Contact the author for availability of cutting material and sources of plants. Although they have not been tested over a wide geographical range, it is quite likely that some will be adaptable to the more southern areas.

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MYCORRHIZAE IN CONTAINER PLANT PRODUCTION

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Mycorrhizae refers to a symbiotic association between a nonpathogenic or weakly pathogenic fungus and living cells of plant roots. Most all plants of the world are mycorrhizal, although wetland rice, cypress, and many plants in the Chenopodiaceae and Cruciferae are not mycorrhizal (1,2,6).

Mycorrhizae are categorized into three major groupings: ectomycorrhizae, endomycorrhizae, and ectendomycorrhizae. Ectomycorrhizae are predominantly found in association with coniferous trees, and the fungi that form them have aboveground mushroom fruiting bodies. These disseminate small air-borne spores. They form a thick covering on roots called a mantle, which is essentially an accumulation of mycelium. The most common form of endomycorrhizae are vesicular-arbuscular (VA) mycorrhizae, which form on a majority of the

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Mycorrhizae are categorized into three major groupings: ectomycorrhizae, endomycorrhizae, and ectendomycorrhizae. Ectomycorrhizae are predominantly found in association with coniferous trees, and the fungi that form them have aboveground mushroom fruiting bodies. These disseminate small air-borne spores. They form a thick covering on roots called a mantle, which is essentially an accumulation of mycelium. The most common form of endomycorrhizae are vesicular-arbuscular (VA) mycorrhizae, which form on a majority of the

angiosperms of the world. In comparison to the ectos, the spores of VA mycorrhizal fungi are large (size of a pin head) and are disseminated by water or mechanical means. Both types of mycorrhizal fungi penetrate into outer regions of roots (cortical cells), but only the endomycorrhizal fungi enters the cells. Neither penetrates the endodermis of roots and, therefore, neither enters the vascular system of plants. Ectendomycorrhizae possess characteristics of both types are are commonly found on the Ericaceae (3).

Cultural practices in container production of ornamentals eliminate or significantly reduce populations of these beneficial organisms. Media components such as pine bark, vermiculite, perlite, builder's sand, and most peatmosses are usually devoid of mycorrhizal fungi. Many nurserymen steam, pasteurize, or chemically treat media to eradicate harmful pathogens. These procedures also eliminate beneficial organisms such as mycorrhizal fungi. Nurserymen compensate for absence of mycorrhizae by applying luxury amounts of fertilizer and water in order to achieve desired growth. High levels of nutrition and irrigation will not always be feasible because of petroleum shortages used in manufacture of inorganic fertilizers and rigid restrictions on water utilization. In addition runoff water is being carefully monitored by environmental regulatory groups for the presence of nutrients and pesticides.

Inoculation of container-grown plants with mycorrhizal fungi provides a possible means of reducing the need for current high levels of irrigation, fertilizers, and pesticides. A research program was established at University of Florida to determine potential benefits of mycorrhizae in container production and landscape establishment.

MATERIALS AND METHODS

Experiment I. VA mycorrhizae benefit growth of numerous agricultural plant species (1,6), but research on container-grown woody ornamentals is limited.

Rooted stem cuttings of *Viburnum suspensum*, *Podocarpus macrophyllus*, and *Pittosporum tobira* were transplanted into 3 liter pots containing a methyl bromide-treated 1 peatmoss: 1 sand (by volume) mixture. The growing medium was amended with 4.2 kg (9.2 lb) dolomite lime, 1.0 kg (2.2 lb) superphosphate, and 0.9 kg Perk (2.0 lb) per m^3 (1.3 yd^3).

Rooted cuttings were inoculated with a 10 g mixture of *Glomus fasciculatum* or *G. mosseae* spores (200 spores/gm), hyphae and infected roots of bahia grass at time of transplanting. We have found that a living root must be present for establishment to occur. An inoculum filtrate was applied to

roots of nonmycorrhizal plants. Plants were grown under 25% shade and fertilized every other week with 224 kg N,K/ha.yr^{-1} (200 lb/acre yr^{-1}). Mycorrhizae require good aeration, so it is important to avoid overwatering. Measurements of plant height, stem caliper, and dry weight of shoots and roots were recorded after 6 months. Root segments from all plants were cleared, stained, and percent infection determined according to procedures of Phillips and Haymen (8) at the experiment termination.

Experiment II. High levels of P have been shown to reduce mycorrhizae ,and subsequent plant growth benefit (5,7). However, effects of N and K on mycorrhizal benefit to woody plants have received less attention. This experiment was established to determine if N and K at various levels would negate benefits of mycorrhizal inoculation.

Rooted cuttings of *Pittosporum tobira* and *Podocarpus macrophyllus* were transplanted into 3 liter pots containing a methyl bromide-treated 1 peat: 1 sand (by volume) medium. The growing medium was amended with 4.2 kg (9.2 lb) dolomite lime, 1.0 kg (2.2 lb) superphosphate and 0.9 kg (2.0 lb) Perk per m^3 (1.3 yd^3). Half the plants were inoculated with *Glomus spp.* (*G. mosseae* and *G. fasciculatum*) according to procedures described in Experiment I. Factorial combinations of fertilizer solutions were applied monthly to provide 250, 750 and 1500 kg/ha.yr^{-1} (223, 670, 1340 lb/ac.yr^{-1}) N and K from NH_4NO_3 and KNO_3.

Plants were grown in an unshaded fiberglass greenhouse for 9 months. Shoot and root weights were determined at experiment termination and root segments from all plants were cleared, stained and percent root infection determined according to procedures described in Experiment 1.

RESULTS AND DISCUSSION

Experiment I. *Glomus fasciculatum* and *G. mosseae* infection resulted in a 2- to 3-fold increase in growth of the 3 woody plant species (Table 1). The percent root infection was high for the 3 plant species and was similar for both mycorrhizal fungi. This research indicated that production of high quality woody ornamentals is possible with mycorrhizal inoculation and low fertilizer levels.

Experiment II. Percent infection was reduced with increased N rates for inoculated plants (Table 2). Potassium, on the other hand had little influence on the amount of infection. Other researchers (5,7) have found similar reduction of infection in response to high P, but influence of N and K on infection has received less attention.

Table 1. Growth of 3 woody ornamentals grown for 6 months with or without VA mycorrhizae.

Species	Inoculum Source	Plant ht[x] (cm)	Stem Caliper[y] (cm)	Shoot fresh wt (g)	Root fresh wt (g)	Root infection (%)
V. suspensum	Control	18.2a[z]	4.3 a	33.9 a	17.7 a	0
	G. fasciculatum	39.9b	5.2 b	62.1 b	37.3 b	69
	G. mosseae	39.6b	5.2 b	63.0 b	38.2 b	77
P. macrophyllus	Control	14.1a	3.4 a	19.2 a	9.4 a	0
	G. fasciculatum	36.3b	4.3 b	52.1 b	33.7 b	73
	G. mosseae	34.3b	4.3 b	53.3 b	32.3 b	71
P. tobira	Control	12.3a	3.3 a	17.9 a	8.4 a	0
	G. fasciculatum	29.2b	4.7 b	30.1 b	16.1 b	67
	G. mosseae	31.2b	5.0 b	34.7 c	18.1 b	79

[x] Measured from pot rim to terminal of tallest stem.
[y] Measured 1 cm above media surface.
[z] Mean separation, within column, for each plant species by Duncan's multiple range test, 1% level.

Table 2. Effect of N and K on root infection of two woody ornamentals inoculated with VA mycorrhizae (*Glomus fasciculatum* and *G. mosseae*).

Inoculation treatment	Fertilizer rate (kg/ha.yr^{-1})	Roots infected (percent)	
		P. macrophyllus	*P. tobira*
Noninoculated control		0[y]	0
Inoculated *Glomus* spp.	N-250[z]	58	54
	750	50	46
	1250	44	45
Linear		*	*
Glomus	K-250[z]	51	49
	750	50	48
	1250	50	48
Linear		NS	NS

[y] Mean of 6 plants.
[z] 223, 670, 1340 lb. N or K/ac.yr^{-1}.
* N significant at 5% (*) or not significant (NS).

Shoot growth of noninoculated *P. macrophyllus* was increased with high rates of N, but *P. tobira* response with increased N was small and inconsistent (Figure 1). Increased levels of K showed only small growth increase of shoots for both plant species. Root development of *P. macrophyllus* was improved with high K, but other treatments showed no consistent response. Highest shoot fresh weight of inoculated *P. macrophyllus* and *P. tobira* was at the middle rates of N and K. Inoculation at all N fertilization rates improved root fresh weight, but only the K treatments for *P. macrophyllus* showed mycorrhizal response.

Container production of woody ornamental plants lends itself to use of VA mycorrhizal fungi even at high rates of N

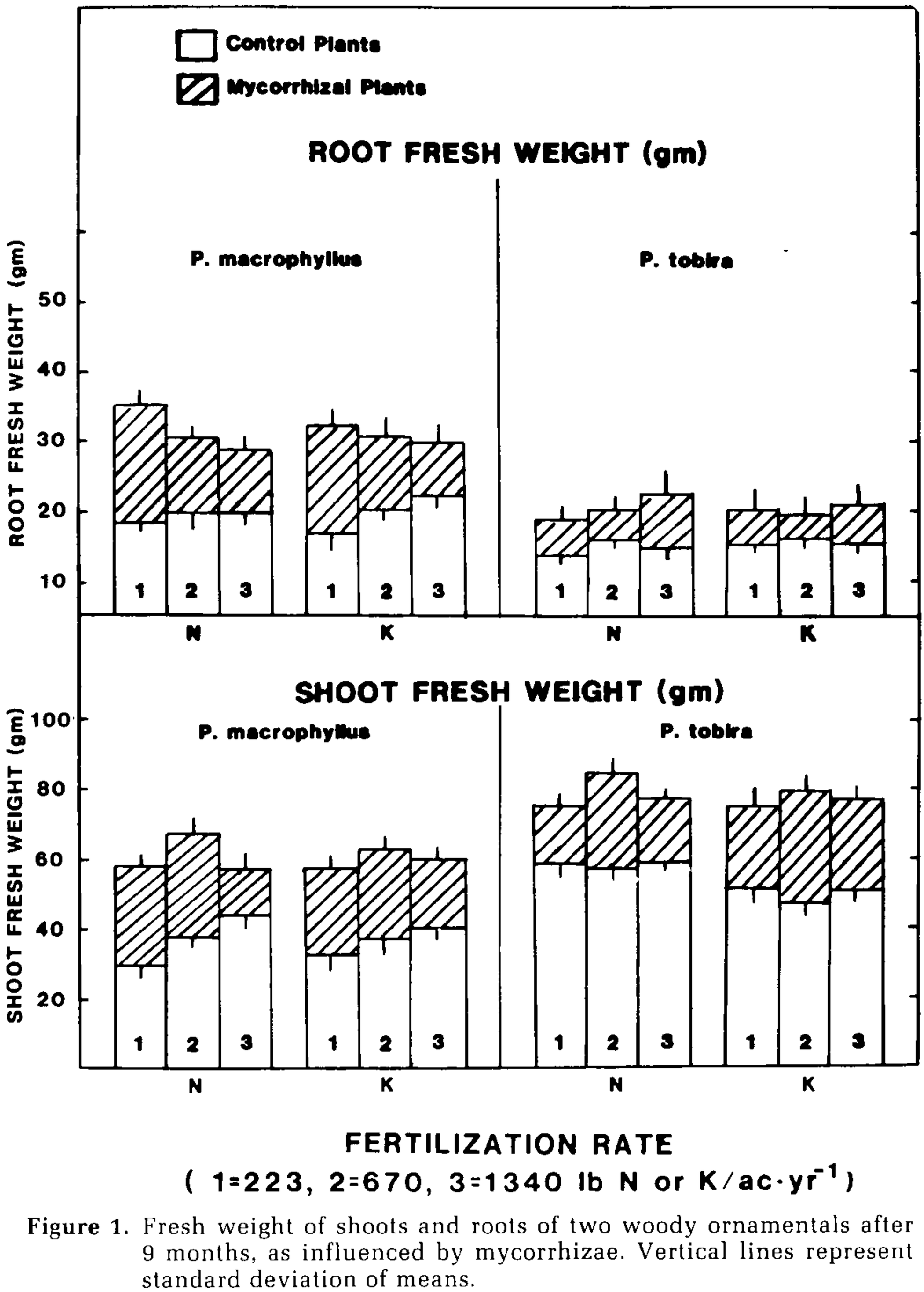

Figure 1. Fresh weight of shoots and roots of two woody ornamentals after 9 months, as influenced by mycorrhizae. Vertical lines represent standard deviation of means.

and K fertilization. The greatest plant growth and potentially economic benefit from using mycorrhizae would be realized at low to medium fertilization rates. However, this research indicates that VA mycorrhizal fungi could be used over a wide range of nursery fertilizer regimes.

Potential Economic Benefits: Because VA mycorrhizal fungi occur on a wide variety of woody plant species and also

because they improve growth, the potential of these fungi as commercial "biotic fertilizers" is great.

Fertilization currently constitutes 3 to 4% of current nursery production expenses (9), but will become a much greater portion of the nursery budget in the future. Data from our research on woody plants indicates P fertilizers could be reduced by approximately 70%. Current levels of N, K and micronutrient fertilizers could be reduced by 30 to 40%. This potentially could reduce fertilizer expenditures by 25% for a savings of approximately $12.13 per 1000 gallon containers annually for woody plants grown under a typical fertilization program (Table 3).

Table 3. Estimated fertilizer costs[x] for woody landscape plants grown in gallon containers with and without VA mycorrhizae.

Fertilizer		Annual fertilization cost for 1,000 gallon containers		
Material	Rate[y,z]	Without VA mycorrhizae	With VA mycorrhizae	Potential Savings
Micronutrients	31.2 g/ft 3 (1.1 oz/ft^3)	8.97	5.38	3.59
Superphosphate	2.2 kg/yd^3 (5 lb/yd^3)	3.72	1.11	2.61
25-0-25	Avg. 130 ppm N	35.90	21.54	14.36
VA mycorrhizal inoculum	2 gm/container		8.43	-8.43
		$48.59	$36.46	$12.13

[x] Based on December, 1982, price estimates.
[y] Fertilization rates based on commercial woody nursery operations using overhead fertigation system.
[z] Phosphorus levels could be reduced by approximately 70% and N, K and micronutrients by 30 to 40% using VA mycorrhizal fungi.

Preliminary research has indicated that an additional benefit is in improved establishment and survival of mycorrhizal plants in landscape soils (4). Improved plant survival and reduced costs for water and fertilizer should create consumer demand for mycorrhizal plants in the landscape.

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IMPROVED PRODUCTION OF NURSERY CROPS WITH MYCORRHIZAL FUNGI

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Mycorrhizae are the symbiotic (beneficial) association of helpful fungi with the fine roots of plants. All horticultural crops form associations with mycorrhizal fungi. What we need to do is learn how to manipulate mycorrhizal associations to reduce nursery production costs and increase profits (2).

Some of the problems confronting the nursery industry are increased production costs and greater governmental regulations, which may curtail water usage of water runoff containing undesirable levels of salt fertilizers, fungicides, pesticides, etc. We also need to produce and market more stress-efficient native ornamental plants that utilize lower levels of water and fertilization. The California industry is currently facing strict water runoff regulations and water salinity problems. The Texas nursery industry stands to benefit from more efficient production systems utilizing mycorrhizal fungi that enable production of nursery crops under reduced watering and fertility regimes. Nurseries throughout the Southeast can benefit from knowledge of mycorrhizal associations for the same and other reasons.

The association with mycorrhizal fungi makes plants more efficient in absorbing nutrients and water from the soil. Other benefits are increased pathogen resistance, adventitious root formation, enhanced seedling growth and plant establishment in the landscape. It has been documented that mycorrhizal nursery crops, which are more efficient and stress resistant, may consequently command a premium price on the market place.

Clearly there is a need for more research to be done with nursery crops looking at mycorrhizal benefits and potential

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Clearly there is a need for more research to be done with nursery crops looking at mycorrhizal benefits and potential

ways for incorporation of mycorrhizal fungi into production schemes. Likewise, there is a need for industry to support general research towards developing more efficient production systems.

An important point to remember is that by researching with mycorrhizae we are learning to manipulate *natural systems* to produce better nursery crops. Some California citrus nurseries are currently using mycorrhizae. Likewise, the forestry industry has been using commercial batches of mycorrhizae to increase tree seedling growth and production.

There are two basic types of mycorrhizae: the ectomycorrhizae and endomycorrhizae. A third lesser-known type is called endo-ectomycorrhizae, but it is not well understood. The ectomycorrhizae from associations with 5% of all higher plants such as pines, oaks, and other hardwoods. Ectomycorrhizae form fruiting bodies like puffballs and mushroom. Their mycelium strands colonize the fine roots of plants and form fungal mantles and hartig nets. An advantage of ectomycorrhizae is they can artificially be synthesized (grown) on a modified Melin-Norkrans medium and then be transferred to a canning medium and incorporated with the nursery crop (1).

Endomycorrhizae form associations with 90% of all higher plants and also colonize the fine roots of plants. They form vesicles and arbuscules inside the root, which are used for food storage and the transfer of nutrients and water from the fungi to the nursery plant and carbohydrates (sugars) from the nursery plant to the fungi. Inoculum of endomycorrhizae are increased by growing spores and mycelium on live roots of sudan grass, sorghum, or strawberries. Later a mixture of roots and soil containing the endomycorrhizae can be incorporated into the canning mix of a nursery crop (1).

We have been testing Texas native ornamental plants such as *Sophora secundiflora* (Mountain laurel or muscal bean), which has potential in the nursery trade. Sophora is an attractive evergreen shrub and is very stress resistent. Our research has shown that under natural conditions sophora forms both endo- and ectomycorrhizal associations and develops root nodules. The mycorrhizae enable this plant to pick up water and nutrients more efficiently. The development of nodules means sophora can capture and convert nitrogen into a utilizable form; i.e., the plant makes its own nitrogen fertilizer. We have obtained increased seedling growth and phosphorus uptake by incorporating endomycorrhizae into the potting mix.

Research recently completed by Michael Sweatt, an M.S. graduate student, showed that geraniums could be successfully grown under lower water regimes when mycorrhizal fungi

were incorporated. In comparison with control plants, mycorrhizal geraniums had greater plant growth, flower development, and increased internal nitrogen levels. Mycorrhizal geraniums also recovered from water stress more rapidly, which is an important factor in the diverse and often stressful climates of Texas.

Current research is designed to investigate the potential of utilizing mycorrhizae in the production systems of field roses, oaks, pines, and other Texas nursery crops.

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RHODODENDRON PROPAGATION — NO MIST WITH BOTTOM HEAT

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Since 1975, when Roadview Farm Nursery was established, rhododendron propagation has normally started in September. At this time the summer growth on the container-grown plants has matured sufficiently so that cuttings may be taken. The cuttings are stripped of the lower leaves, trimmed to a uniform length and double wounded. Leaf surface area is not reduced. Cuttings are then soaked in a Captan-Benlate solution. They are stuck in trays to give 1½-in. spacing. In the early years of the nursery the cuttings were stuck in 6-in. deep peat and perlite beds raised 3 ft. off the ground. The beds were in double poly propagation houses. Warm air from counter-flow oil-fired furnaces was blown under the benches, which were enclosed with plastic to contain the heat. Mist regulated by time clocks was applied to the cuttings until rooting was well developed. We found that the hot air furnaces were running constantly on cold nights and, with rising fuel oil costs, a more efficient system had to be installed.

In 1979, in an attempt to reduce heating costs, we switched from hot air furnances to hot water boilers to heat two of our three propagation houses. After considerable discussion it was decided to run 1-in. plastic pipe in loops in the ground to heat the cuttings. To increase the efficiency of the

were incorporated. In comparison with control plants, mycorrhizal geraniums had greater plant growth, flower development, and increased internal nitrogen levels. Mycorrhizal geraniums also recovered from water stress more rapidly, which is an important factor in the diverse and often stressful climates of Texas.

Current research is designed to investigate the potential of utilizing mycorrhizae in the production systems of field roses, oaks, pines, and other Texas nursery crops.

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RHODODENDRON PROPAGATION — NO MIST WITH BOTTOM HEAT

JAMES O. PELTON

Roadview Farm Nursery
Gloucester, Virginia 23061

Since 1975, when Roadview Farm Nursery was established, rhododendron propagation has normally started in September. At this time the summer growth on the container-grown plants has matured sufficiently so that cuttings may be taken. The cuttings are stripped of the lower leaves, trimmed to a uniform length and double wounded. Leaf surface area is not reduced. Cuttings are then soaked in a Captan-Benlate solution. They are stuck in trays to give 1½-in. spacing. In the early years of the nursery the cuttings were stuck in 6-in. deep peat and perlite beds raised 3 ft. off the ground. The beds were in double poly propagation houses. Warm air from counter-flow oil-fired furnaces was blown under the benches, which were enclosed with plastic to contain the heat. Mist regulated by time clocks was applied to the cuttings until rooting was well developed. We found that the hot air furnaces were running constantly on cold nights and, with rising fuel oil costs, a more efficient system had to be installed.

In 1979, in an attempt to reduce heating costs, we switched from hot air furnances to hot water boilers to heat two of our three propagation houses. After considerable discussion it was decided to run 1-in. plastic pipe in loops in the ground to heat the cuttings. To increase the efficiency of the

system we first laid 1-in. thick styrofoam boards beneath the hot water pipes to prevent the loss of heat to the ground. Next we placed 3 in. of crush-and-run gravel over the hot water pipes. The plastic pipe was spaced 6 in. apart and tied to a wire screen to keep the flexible plastic pipe stationary. The gravel was used to transfer the heat evenly to the propagation media and also to act as storage of the heat released from the hot water pipes. The cuttings were then stuck in trays containing 60% peat and 40% perlite and placed on top of the gravel. Thermostats placed in the trays keep the media at a temperature from 60° to 72°F. We estimated that fuel costs were reduced 50% by switching to hot water to heat the propagation beds. We have had no trouble with the durability of the plastic pipe.

In December, 1979, we decided to try placing a sheet of clear plastic over the propagation beds to confine the heat to the beds to save further on heating costs. Using the pipe frames that originally held the hot-air benches, we constructed frames of 1-in. conduit over which we could drape 4 mil clear plastic. The plastic was stapled to the outside edge of the bed. The inside edge of the plastic was left loose so that it could be raised to release excess heat on warm days. This also allowed for the application of fungicides to the cuttings. Condensation quickly formed on the inside of the tents covering the beds, evidence that the humidity was sufficient to allow us to turn off the mist system.

With this system we have been able to maintain a 70°F soil temperature with a minimum of heat even on the coldest nights. At 7 a.m. on December 22, 1980, the outside air temperature was 11°F. Within the propagation house the air temperature was 30°F, and frost had formed on the inside of the double layer of 6-mil plastic. Within the tents the air temperature was 48°F and the soil temperature was kept at 70°F.

We now are sticking cuttings beginning in July. We then remove rooted ones and refill the benches. We may continue to stick cuttings until January. We have normally taken our cuttings in the fall so we are not as experienced with judging maturity of the wood in the summer. It is changing rapidly at that time, making it more difficult to select cuttings that are in the proper stage of growth.

In conclusion, by using hot water to heat the propagation media, and by storing the heat in a gravel bed enclosed by plastic, we have been able to reduce heating sharply. With the tents in place humidity is increased and the loss of plant nutrients by leaching action of mist is reduced. Finally, we

believe that rooting percentages have increased and a better rooted cutting has been produced.

PROPAGATION UNDER POLY FILM — NO MIST

ROBERT F. BOCK

Lancaster Farms, Inc.
Suffolk, Virginia 23435

I had the pleasure of going to England, Belgium, and Holland on the 1980 IPPS tour. One of the most impressive things I saw was the way they propagated with poly lying on the cutitngs in the frames and benches. I asked why they had no mist, and the reply was, "What we do works."

Sealed or closed propagating structures are not new to IPPS members. The Nearing frame has been mentioned a number of times in the Proceedings. It was noted for use in rooting difficult-to-root material. It emphasized the use of cool north light and a good moisture reserve built in. The air space around the cutting was small and sealed. I felt that the conditions were similar to what the Dutch were doing. I made up my mind then that when I got home I would try their system. The simplicity of the idea seemed so appealing that I ordered a capillary mat and installed it on the floor of a heated house. The floor has porous concrete with hot water pipes below the surface, which produce good steady bottom heat. It was January when we made a crop of broad-leaved cuttings. We made an assortment of *Ilex crenata*, *I. cornuta* and others in flats and arranged them on the mat. They were watered well and then covered with a thin poly cover lying directly on the cuttings. Prior to sticking the cuttings they were treated with 0.25% IBA in alcohol. We used the quick-dip method, and bottom heat was adjusted to about 74°F.

I have never seen quicker or better roots form on these species. On most of the *Ilex crenata* cuttings roots were becoming well formed in two weeks. They continued to develop and even grew out the bottom of the flats. I became very enthusiastic and removed the plastic cover as soon as the roots had gotten a good start. A problem did develop at this point which turned up when checking the cuttings. I found some browning in the *I. crenata* 'Helleri' flats caused by a soft root rot identified as *Pythium*. A drench program using Subdue (metalaxyl-CIBA-GEIGY) seemed to do a good job in controlling this fungus. The disease had spread with an incline in the floor and the capillary mat apeared to be a good conveyer. The excellent roots on the 'Helleri' cuttings had grown out of the

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flats and picked up the *Pythium*. The flats of rooted cuttings were removed to another house; when we transplanted the damaged cuttings that were not killed, we found new roots forming. I have not used a capillary mat since that time.

At Lancaster Farms we have never developed a consistent system for rooting junipers. We have only gotten into considerable production of them since the big freeze in 1977, but since then they have become a good part of our plant income.

I have had high hopes that the Dutch system might be the answer to our juniper propagation problems. I have tried them under a number of conditions. In a cool unheated house we had conventional mist on cuttings stuck directly in small pots. We covered some of these direct sticks with a film of poly. In the house with bottom heat we have tried mist, poly-covered flats, and even Dr. Whitcomb's cloth tent with water moving through the cloth but with no water reaching the cuttings.

Our results were varying. After we had finished transplanting our juniper crop the next spring, we felt that the best results came from the pots and flats that had been covered with poly film. All of these checks were done in the fall of 1981.

Dr. Tom Banko, with the Virginia Truck and Ornamental Research Station, has tested juniper propagation every month in the year, and he feels that September and October, April and May are the optimum times for rooting junipers. With this in mind and feeling some enthusiasm for poly-covered cuttings, we filled a house full of juniper cuttings this September. The house is unheated and covered with white poly and shade cloth. We were concerned with the heat in September. Apparently our fears were well-founded and the results were rapid. Soft rot formed on some of the stems and foliage. Some root primordia developed rather quickly, but the overall picture was very poor. Our medium was peat, perlite, and some fine pine bark. We felt that this held too much moisture, and we re-did most of the house with a new mix and new cuttings. We are hoping for better results from this new crop.

In early October we started a number of juniper cuttings in the house with the bottom heat. These flats were sealed with a thin clear poly film and covered with a tent of white poly to keep it cool on the surface of the cuttings. It is still too early to form an opinion on this group. We would like to try cuttings in March, but unfortunately this is a very busy time for us.

We will continue to try different media and different hormones and hope to develop a better sanitation program. In the future perhaps we can work on a good fungicide program on

stock plants as well as a good cutting drench for prevention of rots and molds. We will continue to try to perfect this system as we have seen enough good results to encourage us even though there are many problems yet to overcome.

MY EXPERIENCE WITH HIGH HUMIDITY PROPAGATION

BUTCH GADDY

Colesville Nursery, Inc.
Charles City, Virginia 23030

Colesville Nursery is a wholesaler container nursery located in Charles City, Virginia. Since 1975 we have produced about 100 different cultivars of woody ornamental landscape plants. Currently, 7 acres are in container production and 10 acres are in field production. When we first began nursery production 100% of our liners were purchased from other nurseries; today, we are propagating 95% of our own material.

Since commencing our operations, we have employed a wide variety of propagation techniques. Initially we experimented with small propagation tents, but those turned out to be inefficient. We next set up a greenhouse using intermittent mist. But we soon discovered that our water source — a nearby pond — contained trash particles that clogged up the mist nozzles even when a filter was used. We then tried brass spinners, but found that method unsatisfactory because of low water pressure and uneven soil saturation.

In 1980, on the advice of Dr. Daniel Milbocker of the Virginia Truck and Ornamentals Research Station in Virginia Beach, we began using the high humidity propagation system. Dr. Milbocker presented a paper on the high humidity propagation system to the Southern Region of the IPPS in Huntsville, Alabama (2).

We began using the system to maintain the highest possible humidity in our propagation houses during daylight hours at a temperature conducive to root initiation without saturating the soil around the cuttings. We use an Agritech high humidity unit which is built in Raleigh, North Carolina. The humidifier has 4 centrifugal nozzles that produce droplet sizes ranging from 10 to 50 microns with a water output of up to 50 gph. A fan mounted behind these revolving nozzles suspends the droplets in 4000 cubic feet of air per minute, traveling at 30 mph. This unit is suspended by an oscillator that directs the air flow horizontally in an adjustable arc of approximately 90° (2). This unit is designed to humidify 1000 ft^2, but we have found through experimentation that 600 to 800 ft^2 is more realistic in our long and narrow greenhouses.

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As the amount of water put out by the humidity unit ranges from 0 to 50 gph, we are able to adjust the volume of water according to the weather. On very cloudy and cool days the unit is rarely turned on. On clear, hot days (80°F and up), the unit is set between 40 and 50 gph. We have found that maintaining a greenhouse temperature below 100°F produces the most successful rooting.

In each of our houses, which are 20 × 96 ft. and 20 × 80 ft., one unit is placed at an air intake with an exhaust fan at the opposite end of the house. A second unit is placed midway on the same side of the house. While we are still adapting the system to take into account dry spots, we have found that placing the easier-to-root plants in those areas reduces loss of total propagation area.

Our summer propagation of broad-leaved evergreens begins by mid-June. The soil mix contains equal parts of pine bark, perlite, and peat moss, plus limestone, superphosphate, Banrot-Topsin M (thiophanate-methyl) + Truban (Koban, Terrazole, Ethazol), and trace elements added. We are direct sticking cuttings into 2½-in. and 3-in. plastic pots or cavity trays. We omit a rooting hormone for easier-to-root plants (cotoneaster, forsythia, some azaleas, viburnum, and euonymus) because we have found no measurable difference when we administer the rooting hormone. When we do use a rooting hormone, it is Hormodin #2 (0.3% indole-3-butyric acid).

We purposely root the cuttings as quickly as possible and move them to a liner house to make room for the next crop. The high humidity propagation system allows us to plant 2 to 2½ crops, where before we were able to propagate one crop in the same period of time. We have found the average time in the propagation house for the many cultivars we grow is about 8 weeks. Timing seems to be the key to rooting with the high humidity unit; if the cuttings are taken too late they will either root slowly or not at all. However, because this system does not saturate the soil with water, a slow-to-root cutting will take root in the spring when the weather begins to warm up.

Winter propagation of conifers usually begins in mid-December. The propagation houses are maintained at about 40°F to prevent freezing. Again, as in the summer propagation, we are direct sticking the cuttings into 2-in. cell trays, with the same soil mix and hormone. We usually finish taking the cuttings by mid-February. The easier-to-root conifers such as *Juniperus horizontalis* 'Wiltonii' and *Juniperus horizontalis* 'Plumosa Compacta Youngstown' will begin to root around March 1, with the best rooting as the weather warms up. We

usually have 85 to 95% rooting of our conifers. Again, we have found that high humidity units enhance root progression by keeping the cuttings in good shape until temperatures rise. With the addition of bottom heat, we believe rooting would take place even faster.

Throughout the summer and winter propagation seasons, we have had few problems with disease, applying fungicides only as needed.

Despite our success rate we are not completely satisfied with the two units we have now. Since certain cultivars have different rooting responses, the location of the different plants around the unit is important. As an example, one row of flats with × *Cupressocyparis leylandi* cuttings began 3 ft. from the unit and ended 20 ft. from the unit. Within the first 10 ft. we had 90% take on the cuttings, but from there until the end of the row the percentage gradually dropped to a 30 to 40% take. The manufacturer is correcting this problem by pressurizing the hub that the nozzles are attached to and creating a more even mist with smaller droplets.

Overall we believe the high humidity propagation system has aided the success of our operations. The system has allowed us to become more self-sufficient in the propagation phase of our business.

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1. Milbocker, D.C. 1979. Ventilated high humidity propagation guide. Virginia Tech. Orn. Res. Sta., Virginia Beach.
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HIGH HUMIDITY PROPAGATION

CARROLL G. HALL

Carroll's Plant Center
Route 1, Box 359
Benson, North Carolina 27504

At Carroll's Plant Center we are using high humidity for cutting propagation. Three Agritech mist blowers can maintain 100% humidity in our 22 × 98 ft greenhouse. During most of the rooting season (June-October) we keep the humidity from 90% to 100%, adjusting the amount of water, registered in gallons per hour (gph), according to time of day and weather conditions. The mist blowers are set on 24-hour time clocks, which will automatically turn the blowers on and off, but the gph adjustment is made manually throughout the day. The

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amount varies from 20 gph during the July to mid-September period to a low of 8 gph midday in the winter.

We have one greenhouse for mist propagation and two greenhouses for hardening-off the rooted cuttings. When necessary the greenhouse can be cleared of some humidity by an exhaust fan. The temperature control is set on 95°F during the summer and 85°F during the fall. Cuttings are placed on raised benches made of treated lumber and expanded metal. This helps provide adequate air circulation. We use a rooting medium of 40% fine pine bark, 50% coarse perlite, and 10% sphagnum peat. The medium is placed in a TLC Polyform Pro-Tray[1], which fits into a flat. The medium is first wet, then drenched with a standard dilution of Banrot[2]. The cuttings are taken in early morning, placed in plastic containers and kept shaded and moist until stuck in the rooting flats. After bottom leaves are stripped, cuttings are soaked in a Chloromone solution. The dilution rate depends on the cultivar, with the majority soaked in a 5:1 solution. The solution also contain Benlate (benomyl-duPont) at the recommended rate. The flats of cuttings are then placed in the propagating house. We find that using the TLC inserts works well with the humidifiers. The inserts hold 72 cuttings, each cutting having its separate cell of rooting medium. This gives a plant spacing that allows proper air circulation. The combination of porous rooting medium and individual cells allows for good drainage. The humidifiers help maintain a proper rooting environment by keeping the humidity high without excessively wetting the cuttings or the rooting medium. These are shifted to 3-inch plastic cell paks as soon as rooted.

We propagate dwarf youpon (*Ilex vomitoria* 'Nana') in 10 weeks without hormone and get 95% or above rooting. This rooting percentage is about average for most of our cultivars. The dwarf youpon cuttings were rooted in 96 cell-paks, 2 cuttings per cell. The time for cuttings to root varies from 3 weeks for gardenias (*Gardenia jasminoides*), to 10 weeks for sasanquas (*Camellia sasanqua*); photinia (*Photinia* × *fraseri*) takes from 4 to 5 weeks. We have found that cuttings taken from plants that are slow grown root better under this system than cuttings taken from plants that are grown fast with new growth that is very succulent. *Ilex* × 'Nellie R. Stevens,' roots are formed in 6 weeks. Hino-crimson azaleas (*Rhododendron* 'Hino-crimson') also root in 6 weeks. Weeping fig (*Ficus benja-*

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[1] TLC Polyform, Inc., 4906 West 35th Street, Minneapolis, MN 55416.

[2] Banrot-Topsin M (thiophanate-methyl) + Truban (Koban, Terrazol, Ethazol), Mallinckrodt.

mina) roots in 8 weeks. We stick 2 cuttings directly into a 4-inch pot.

We also root non-woody plants under the humidifiers. Joseph's coat (*Alternanthera bettzickiana*) roots in 3 weeks. After they grow large enough, we can sell these plants in the same cell packs they were rooted in. Dwarf scheffleras (*Schefflera arboricola*) are rooted in 3-inch pots and can be shifted into 6-inch pots within 12 weeks.

After the cuttings have rooted well enough, we shift them into another greenhouse. They are misted by hand 8 to 10 times a day for the first 3 days, 4 to 5 times a day for the next 3 days, then twice a day for a week. They are misted with a coarse spray Fogg-It nozzle. After that they are watered once a day by hand. The liners remain in the greenhouse during the winter. Starting in April the liners are shifted into 2-, 3-, and 5-gal containers. We may also have 1-, 2-, and 3-quart liners, which we plant in July and August. They are protected with plastic-covered greenhouses beginning in mid-November. Many of these will go into 5- and 7-gal containers in the spring. Some of the 1-gal liners of hardier species will be left outside and protected only with shade cloth during the winter. Our wholesale growing area is 10 acres in size; 2½ acres are taken up by our water reservoir; 5 acres are in the container area; and the rest is used for greenhouses, potting area, bark pile, and grinding and soil mixing facilities. We grind and screen the bark on site in order to get the fine grade needed for propagation and liner mixes. We use a Bouldin-Lawson Tumble Mixer with a 2 yd^3 mixing capacity for mixing all of our different types of rooting media.

ROOTING CUTTINGS UNDER A WET TENT[1]

CARL E. WHITCOMB

Department of Horticulture
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Stillwater, Oklahoma 74078

Abstract. A wet tent that maintains high humidity yet allows sufficient light penetration to support photosynthesis in leaves of cuttings has been devised. The system may be used alone or in conjunction with reduced conventional mist. With little or no mist, leaching of metabolites from leaves and overwatering of the media is reduced or eliminated. With less water in the mix, bottom heat is more effective and aeration is increased, thus stimulating more rapid root development and subsequent growth. Rooting of cuttings in the wet tent has been excellent in fall and winter. Summer softwood cuttings have required some mist since the fabrics tested have not allowed sufficient air exchange for cooling and humidification.

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[1] Journal Series #4258 of the Oklahoma Agricultural Experiment Station.

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One of the major advances in plant propagation made in recent years was intermittent mist. However, excess water from misting cycles that are either too frequent or too long leaches an assortment of nutrients and metabolites from the leaves (2,4) and may overwater the rooting medium, reducing oxygen and suffocating new roots as they are being formed (5).

Prior to intermittent mist, many cuttings were rooted without mist or under polyethylene covered structures (3). Relatively few plants root well without mist due to desiccation of the foliage, thus the practice of cutting off part of the leaf. However, this causes more harm by reducing carbohydrates than it helps in reducing water loss. Rooting under polyethylene tents increases humidity part of the time. However, when exposed to direct sunlight, even for short periods, the temperature increases and humidity decreases very rapidly, frequently damaging the cuttings.

An ideal alternative would be a structure that provides very high humidity, even with fluctuating temperature, and then to limit misting of the cuttings. This would reduce or eliminate leaching and maintain a good moisture-air balance in the rooting medium. Disease problems could also be expected to be minimal. If such a system is incorporated into a propagation structure with constant bottom heat, further improved rooting of cuttings and/or plant growth may be achieved.

During September, 1980, while in Europe, I met Andre Franclet, an imaginative researcher with a private forestry research company in France. He was successfully rooting Scotch pine (*Pinus sylvestris*); Austrian pine (*Pinus nigra*), and Douglas fir (*Pseudotsuga menziesii*) under a wet fabric with bottom heat (1). The fabric was supported by a wire frame over the cuttings and wetted by troughs of water on each side of the bench. The primary problem with this system was getting sufficient light to the cuttings.

After returning to Oklahoma we tried several fabrics in a similar apparatus. We could not get the water to "wick" on the fabric more than 16-20 inches without using a fabric so heavy that very little light penetrated. After much trial and error, during September-October, 1980 a system was devised that works well in the fall and winter. This system is described here.

METHODS AND MATERIALS

The system consists of 2-inch PVC pipe (schedule 40) cut on one side the entire length using a jig saw with a thin, fine-toothed blade. The center fold of a fabric of desired size and density is inserted into the slit along with 6- to 8-inch wide filler or wick fabric (Figure 1). The first fabric tested was 100%

polyester, which provided about 40% shade. The filler or wick fabric used to fill the slit in the pipe was a heavy wool fabric. The ends of the pipe were fitted with a bell reducer and standard waterhose fitting and cap. The PVC pipe and fabric tent, with the slit down, was then suspended over the desired area. Triangular end frames covered with clear polyethylene were put in place. The hose was adjusted to allow a small but continuous quantity of water to the pipe and tent, using a flow-control valve. Only enough water is used to keep the fabric wet.

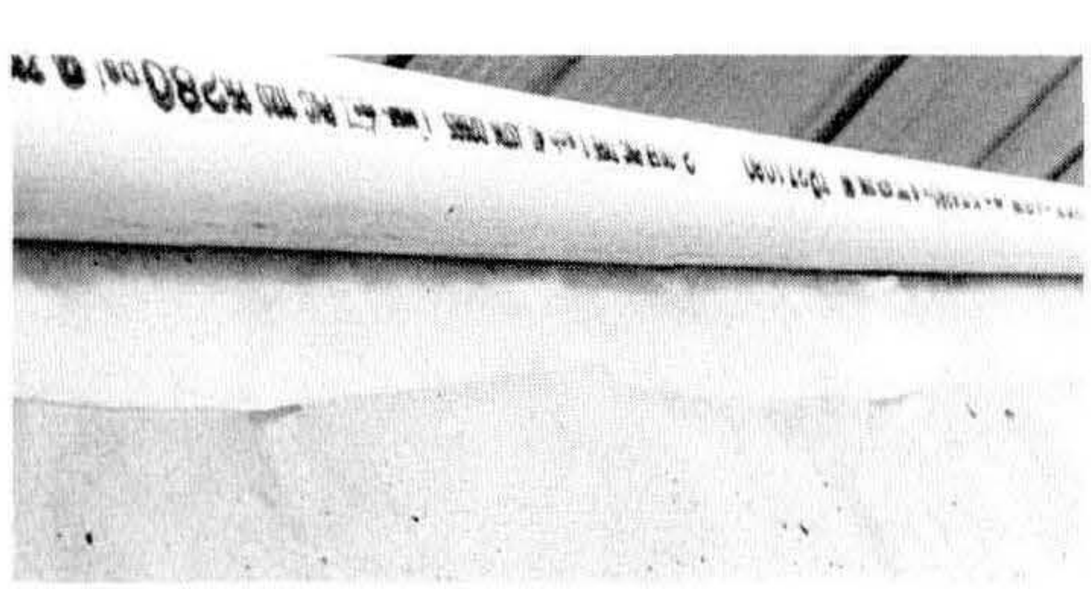

Figure 1. Wick fabric and filler fabric are inserted into the slit, cut the length of the pipe.

As the temperature in the greenhouse increases, additional water evaporates from the fabric, increasing the humidity inside the wet tent and moderating the temperature increase. As the temperature inside the tent decreases in the evening, some moisture condenses on the foliage of the cuttings and/or the surface of the rooting medium. This action stabilizes the moisture level of the rooting medium while avoiding the common waterlogged condition. The wet tent was first set up in a double-layer poly greenhouse with a solar-heated floor maintained at approximately 75°F.

During the late October and early November, 1980, cuttings of several species were stuck in 2×2×3 in deep containers in a rooting medium of 1:1 peat and perlite. Identical blocks of cuttings were handled similarly and placed under conventional intermittent mist.

RESULTS AND DISCUSSION

Cuttings of most species rooted similarly under intermittent mist and the wet tent. Three exceptions were noted, however;

(1) *Ilex vomitoria* 'Nana', dwarf yaupon holly, rooted 100% under both conditions, but cuttings dropped 94% of the original leaves under mist, whereas no leaves were lost under the tent. As a result the dwarf yaupon liners from the tent were much larger with more roots at transplant time.

(2) *Rhododendron* 'Fashion', rooted 42% under mist and 96% under the tent.

(3) *Cedrus atlantica* 'Glauca' did not root under mist but rooted 66% under the tent.

During the fall, winter and spring of 1981-82 the tent continued to work reasonably well. However, as with any new technique, some complications remained. With the original 100% polyester fabric over a conventional mist system, and the mist cycle reduced to 4 seconds every 30 minutes, the system worked well (Figure 2). However, if we did not use the mist, on some bright sunny days, even during fall and winter, the humidity in the tent would drop below the desired 98-100% level as a result of heat build-up in the tent.

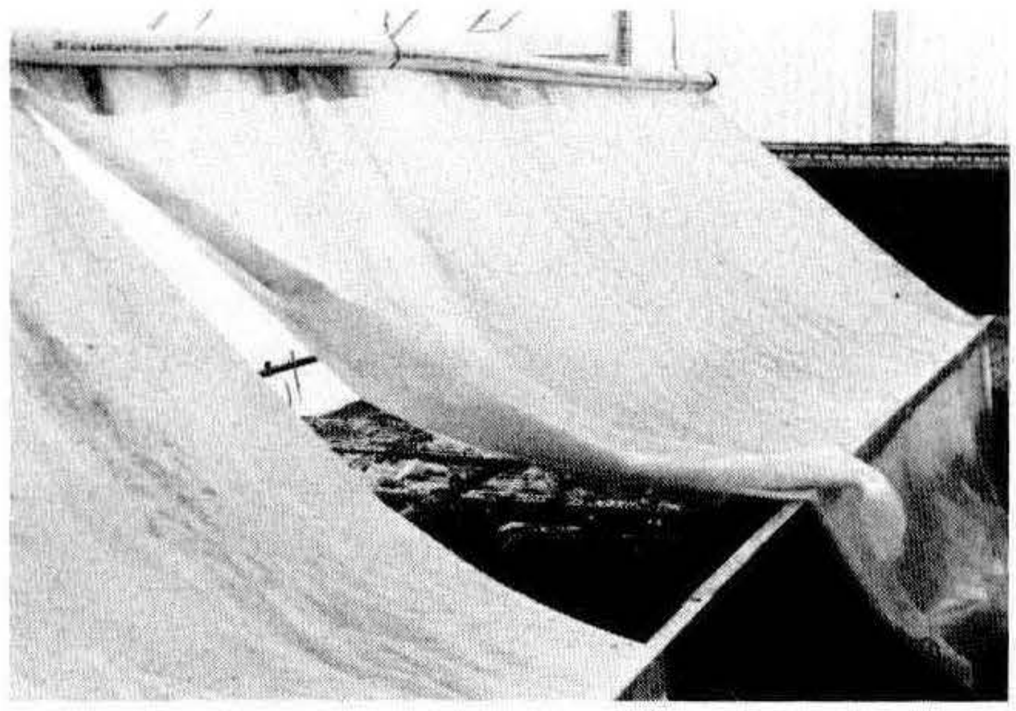

Figure 2. A wet tent over a conventional mist propagation system. The tent allows the mist cycle to be reduced substantially without creating moisture stress on the cuttings.

Even though the fabric was porous when dry, it functioned as a solid sheet when wet and prevented any air movement into or out of the tent. The next approach was to try a more porous fabric, and during the summer of 1982, a small thermostatically controlled exhaust fan was added (Figure 3).

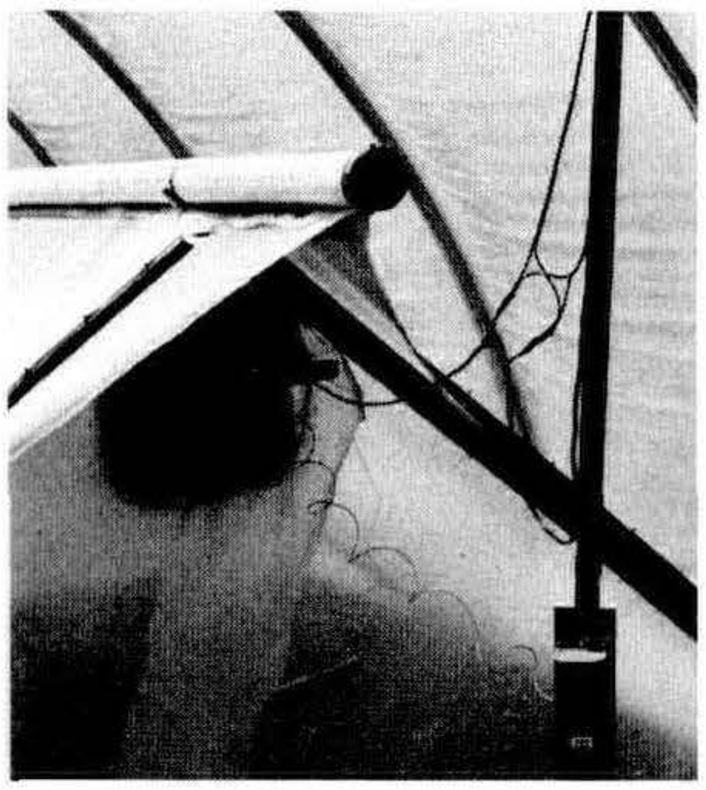

Figure 3. Location of a small "squirrel cage" fan inside the tent increased air flow into the tent and provided substantial moisture coating during warm, sunny days. The thermostat, with sensor inside the tent, was set at 70°F.

A knit polyester fabric was found (Figure 4) that allowed air movement through the tent even when wet. Some natural convection air currents could be observed as the warm air rose in the tent, exited the top, and cooler air moved in. The exhaust fan drew more air through the fabric and created an evaporative cooling effect. The fabric in Figure 4 has rows of large and small holes. The small holes are approaching the ideal size. The large holes allow some air into the tent without ample humidification. On the other hand, if the openings in the fabric are too small, the holes will be sealed off as a film of water forms around each thread. We have not yet found the "ideal" fabric. However, we feel it should have the following characteristics: (1) have holes or pores large enough to remain open when wet, yet small enough to provide a large combined surface area around each hole for evaporation and humidification of the air; (2) be of polyester or other non-organic material that does not support algae growth readily; (3) have sufficient strength and flexibility to allow for easy movement and handling; (4) be sufficiently thin to provide no more than 30 to 40% shade. White fabric appears to be most effective in transmitting light as opposed to other light colors.

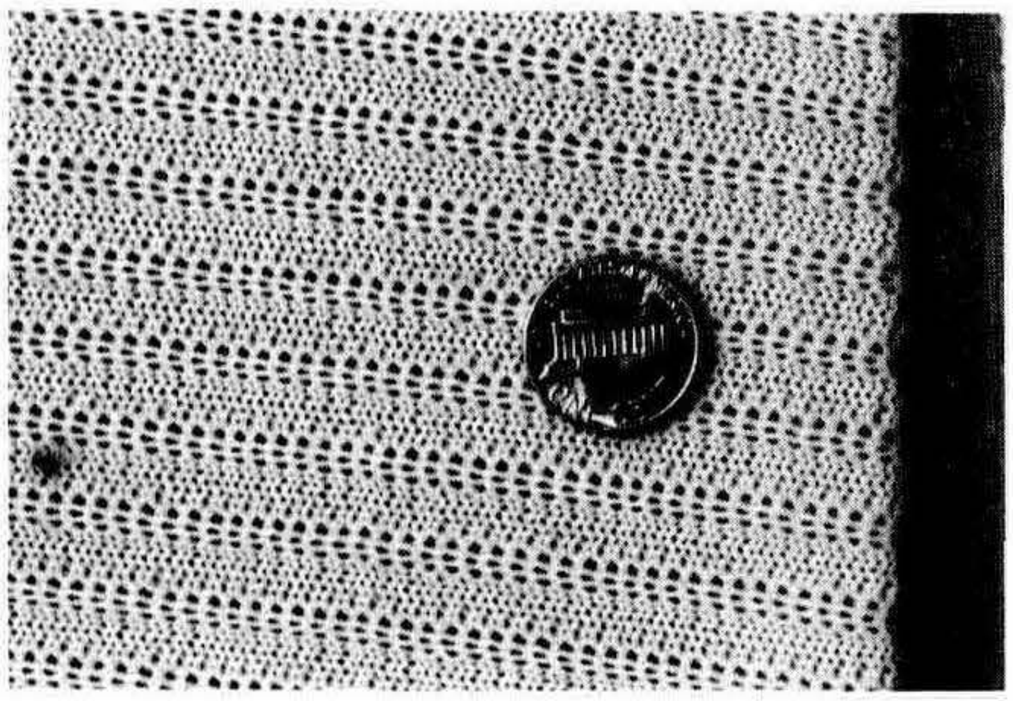

Figure 4. This polyester knit was one of the most promising fabrics tested. However, the large holes were probably too large, thus allowing some air to enter without sufficient humidification. The strips with the smaller holes appear near ideal, and holes are not filled when water is moving down the side of the tent.

The wet tent system should not be viewed as a cure-all for propagating difficult-to-root plants. However, it does provide an inexpensive method for reducing moisture stress of cuttings and improving control of water and air in the rooting medium with little or no mist required. With this amount of light transmission through the tent, supplemental light would not be needed.

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Nursery Organization Panel

MODERATOR BYERS: Nurseries are a complicated, complex, and difficult form of agricultural production. Our efforts are greatly affected by factors outside our control — the weather, the economy, and the labor supply. In Huntsville Alabama, we have an average of 151 winter days between first and last frost. Of these 45 are weekends and holidays and about 40 are bad weather. Thus, we have 66 working days. Divide this figure into sales volume, and it's obvious that efficient management is critical for survival and success. That we are almost a cottage industry means we have no price or production controls. Also many nurseries are undercapitalized. We have on our panel three nurserymen to discuss the systems they use for efficient management.

GENERAL ORGANIZATION OF GREENLEAF NURSERY

AUSTIN F. KENYON
Greenleaf Nursery Company, Inc.
Route 1, Box 98
Park Hill, Oklahoma 74451

Greenleaf Nursery Co., Inc. is a wholesale nursery specializing in production of container-grown ornamental plant material. Our offices are located in northeastern Oklahoma on the banks of beautiful Tenkiller Lake, which also is our source of irrigation water. In addition, we have a branch operation located 4 miles south of El Campo, Texas, which is 31 miles from the Gulf of Mexico.

The Oklahoma operation, which receives low temperatures each year of at least 0°F., primarily grows junipers, deciduous trees, and deciduous shrubs. The Texas operation, with the more gentle Gulf Coast climate, specializes in broadleaved evergreen plant material, such as, azaleas, hollies, euonymus, pyracantha, pittosporum, etc.

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GREENLEAF NURSERY CHAIN OF COMMAND

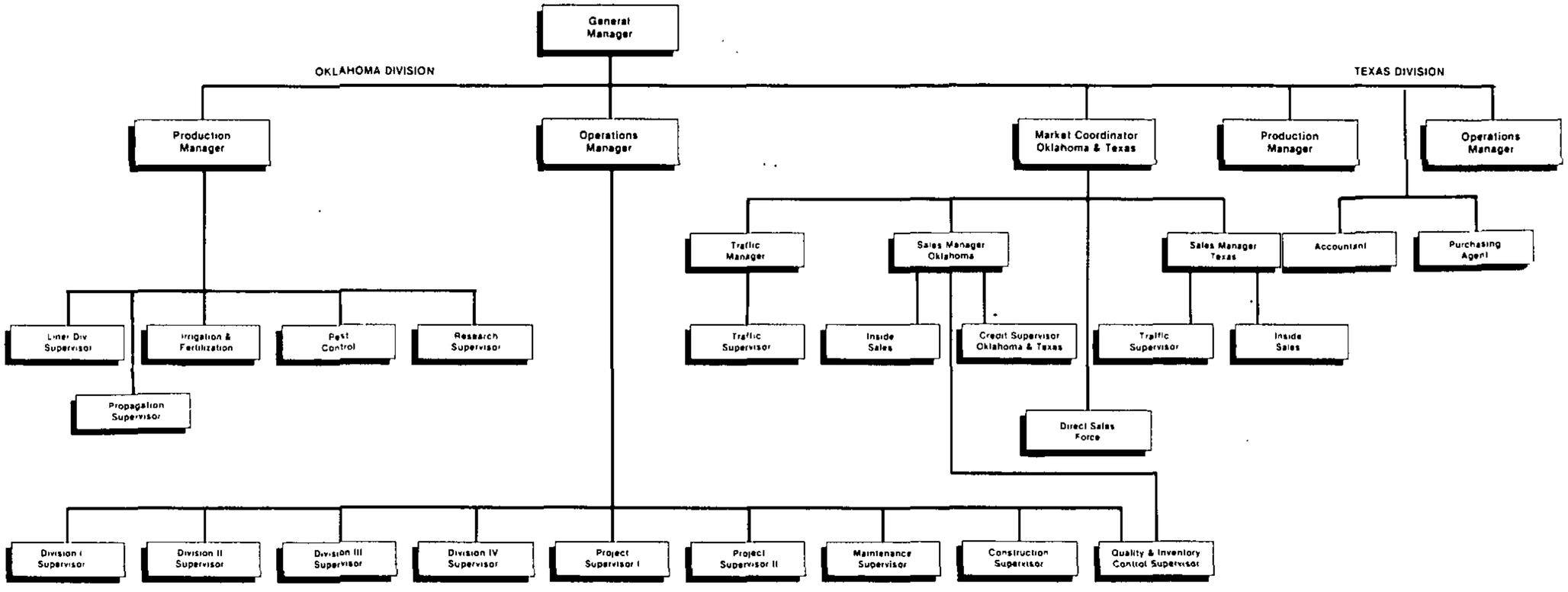

Figure 1. Greenleaf nursery chain of command

This is a dicussion of the organizational structure of Greenleaf Nursery. Figure 1 shows the chain of command outlining the structure of responsibility for all key personnel in the company.

The General Manager has a total of 7 people at the two operations who answer directly to him. All other personnel work for one of these 7 individuals. Two of these people are the accountant and purchasing agent, who handle totally administrative functions for both the Oklahoma and Texas divisions.

The Sales and Marketing Director has the overall responsibility for the sales and shipment of all products grown at both divisions. This would cover the areas of sales, advertisement, shipment, collections, training of personnel in all areas of customer relations, and product acceptability. He coordinates the efforts of the following people:

Sales Managers at both Oklahoma and Texas divisions are responsible for all areas of sales at their divisions. They handle day-to-day flow of information to outside sales force and maintain general responsibility for quality of material shipped. They control paper flow as to bookings and handle customer relation questions on credits and problems. Our sales managers plan for the trade shows, compile material list selections for the shows and set up coordination with the traffic department.

Traffic Manager and **Traffic Supervisor** (Oklahoma and Texas) set up all aspects of shipping, direct efforts of the assistant traffic manager as to the customer staging of loads. They work as backup salesmen for overflow sales calls, and do all the paper work for shows and special events such as sales meetings, and nursery tours.

Credit Supervisor (Oklahoma and Texas) oversees all aspects of credit, which include clearing, collecting, and handling special problems. He also backs up inside sales on overflow calls.

Our **Direct Outside Sales Force** sells all they can, to whom they can, for what we say they can, as fast as they can. They work closely with the sales manager on a day-to-day basis. They must handle their market areas in a productive, professional manner.

For the sake of simplicity, I will describe the organizational structure of Plant Production at the Oklahoma nursery, since the Texas and Oklahoma divisions are basically the same. We have divided the production work into two separate divisions. The **Production Manager** handles the supervision of

personnel involved in the more technical aspects of growing as follows:

Propagation Division:

Propagation Supervisor

Propagation by rooting of cuttings
Mist control and maintenance
Media preparation for cuttings -
Pest control of cuttings
Greenhouse and Quonset covering
Heater installation
Maintenance of related equipment and buildings

Liner Division Supervisor

Maintenance and growth of liners
Overhead Irrigation
Fertility control
Pest control of liners
Shearing of liners
Seedling production
Grafting
Potting
Planting

Plant Culture Division:

Irrigation and Fertilization Supervisor

Overhead watering in container areas
Directing division probers (personnel checking daily water needs)
Fertility in container areas
Hand feeding
Soil mix area
Maintenance of related equipment and buildings

Pest Control Supervisor

Preventative spray schedules
Follow-up of all inspection reports
Weed control
Insect control
Disease control
Chemical testing and evaluation
Maintenance and care of related equipment and buildings

Research and Development Supervisor

Researching improved propagation and growing techniques
Testing and evaluating new plant cultivars
Diagnosing problem areas
Testing and evaluating new products

The **Operations Manager** is responsible for supervising the activities of the personnel involved in the following areas:

Division Supervisors. Their primary responsibility is plant care and includes water control, disease and insect inspections, minor odd jobs in their divisions and keeping the operations manager notified about any major projects that need to be done in their divisions.

Project Supervisors. Their primary responsibility is people and the efficient work of the larger crews on the nursery. One project supervisor handles shipping, can filling, some of the shearing, and portions of overwintering. The other project supervisor handles all of the planting, bunching, spreading, some of the shearing, and portions of overwintering. At times they will have up to 100 people under them, but with several foremen dividing the responsiblity.

Maintenance Supervisors. They are responsible for the maintenance of all stationary and rolling equipment, as

well as the construction of new pieces of non-commercially available equipment in our welding shop.

Construction Supervisor. He is responsible for the construction and maintenance of all improvements on the property. He builds new propagation structures, shade areas, new growing blocks, and all other improvements other than major buildings.

Quality Control/Inventory Control Supervisor. He functions as liason person between production and sales. He inspects all loads that leave the nursery and sees that the loads are assembled as required. He supervises the grading of all plants for shipment and handles all field counts, inventory adjustments and planting reports in order to maintain an accurate, up-to-date perpetual inventory system.

NURSERY ORGANIZATION

CARL FLETCHER FLEMER, III
Ingleside Plantation Nurseries, Inc.
Oak Grove, Virginia 22443

Nursery organization is a broad and very encompassing subject. Nursery owners, managers, and propagators have to be organized in order to be successful. Nurseries which produce and grow plant materials are complex, complicated operations because of the hundreds of details which must be constantly monitored and managed.

How we organize on a daily basis may be completely different from your operations since organization is determined by goals, business philosophy, size, location, product mix, and personnel.

How is our nursery organized? My father started our nursery operation in 1948 and since then our business philosophy has been the same. Ingleside Plantation Nurseries, Inc. is a general line nursery. We produce and grow vines, broad-leaved evergreens, conifers, and shade trees in containers, B&B, or bare-rooted for sale to garden centers, landscape contractors, and governmental agencies.

In Oak Grove, Virginia, we have 4 distinct seasons of the year — spring, summer, fall, and winter. Plant growth and development are determined by these seasons. You cannot run a successful nursery operation and fool with Mother Nature. Nurserymen have to let the seasons of the year dictate what

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they are going to do and when. Each season of the year influences plant development in such a way that there are specific functions that have to be done during specific times or they might as well not be done at all. By specific functions I mean budding; grafting; propagating; trimming; and applying fertilizer, herbicides and insecticides, just to name a few.

I have made a chart to help illustrate this concept (Table 1). As this chart shows, nurserymen and plant propagators have little control over the seasonal organization of their work schedules. Almost everything which influences plant development is constant from year to year. Our one big variable is labor! Our success as nurserymen is determined by how well we can manage and organize our personnel on a daily and seasonal basis.

Table 1. Seasonal organization of nursery work schedules.

CALENDAR YEAR	SEASONS OF THE YEAR	NURSERY SEASONS	PLANT OPERATIONS	PERSONNEL (LABOR)
March April May	SPRING	Harvest and Production	Digging Shipping Planting Propagation Sales	Spring Fever Fishing
June July August	SUMMER	Maintenance and Production	Cultivation Irrigation Trimming Staking Fertilizing Insecticides Herbicides Propagation Sales	Trade Shows Vacations
September October November	FALL	Harvest and Production	Digging Shipping Planting Propagation Sales	Thanksgiving Hunting Season
December January February	WINTER	Maintenance	Planting Trimming Pruning Sales	Christmas and New Year's vacations, Trade Shows
Constant every year	Constant	Constant with seasons	Constant with seasons	Variable

This concept should be used in establishing a Master Production List for every nursery operation. A Master Production List is essential for nursery organization and planning. Prior planning is necessary for successful nursery organization.

However, this success is never complete until nursery managers see that seasonal tasks are performed in an efficient, timely manner.

I find it is easy to develop an annual Master Production Plan but that organizing the actual daily and weekly tasks for employees can be a problem. You know the old saying — if we did not have people problems we would not have any problems at all! This is certainly true in our labor-intensive industry.

A Master Production List should give you an overall look at your entire nursery production. You can then use this plan to organize on a seasonal, monthly, weekly, and daily basis. The Ingleside Plantation Nurseries' Master Production List is shown in Figure 1.

TOTAL QTY	VARIETY	SEEDLING PRODUCTION	CONTAINER PRODUCTION						FIELD PRODUCTION FOR						RECEIVED	CULLS	SOLD
			For [illegible] SALES		Grow for Field or Specimen Production		Move up from Smaller Cont		Container or Basket SALES		Field Grown from 5'-6' Rows		SALES 10' Rows				
			QTY	Cont Size	QTY	Cont Size	QTY	Cont Size	QTY	Cont Size	QTY	Style	QTY	Size			

Figure 1. Master production list used at Ingleside Plantation Nurseries, Inc.

GENERAL ORGANIZATION OF NURSERIES

R. OWEN BLACKWELL, III

Blackwell Nurseries, Inc.
Semmes, Alabama 36575

Blackwell Nurseries was started in August, 1938, by my father, Owen Blackwell, Jr., after gaining experience at other nurseries in the area. The nursery was originally in general ornamentals with azaleas and camellias as the lead crops. This evolved into lining-out stock, especially magnolias, and then into container production. The azalea, always a mainstay of our production program, is now our sole crop. These plants are grown in various-sized pots for the florist and nursery trade as either growing-on or budded plants. The majority of our sales are to other growers, and all plants are graded according to head size, not pot size.

PRODUCTION AND PROPAGATION

The production organization is built on the idea of responsibility for each area, though one person may have to cover

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PRODUCTION AND PROPAGATION

The production organization is built on the idea of responsibility for each area, though one person may have to cover

more than one slot. This is a simple necessity in a family-owned and operated business. The production starts with cuttings taken from current production, not from stock plants. The cuttings are not stripped, except for the lower leaves, and are not pinched as in the past. This appears to shorten the rooting time, generate more breaks when pinched after rooting and, of course, eliminates the necessity of a stripping crew.

The cuttings are taken from the on-going production area and stuck in 96, and some 72, cell pak trays containing a medium of peat, perlite, and vermiculite. The propagation crew is separated into a sub-crew for taking and sticking cuttings, and a sub-crew for growing the cell paks. This crew also moves the rooted cuttings so there is room for new cuttings. They also pot all finished cuttings into 4-inch pots. The responsibility of the propagation crew ends with this potting.

The 4-inch potted cuttings go into the liner area to be used for 4-inch sales in the spring, or into the other production sections where they will be grown for potting into 5-, 6-, or 7½-inch pots.

The azalea production is geared for two markets; growing on plants for sale in May and June, and budded plants for October shipment. There are actually three basic crews that grow these plants past propagation, with each group providing more than one function. The separation of responsibility is determined by whether the plants are for growing-on or for budded sales, and division is according to species and cultivar. The idea is to divide the growing so all plants are cared for and to minimize any overlapping of work. By consistently growing certain groups of cultivars, in a particular sized pot, for one or more precise markets, a crew knows their responsibility without having to guess.

The assignments must necessarily change with the changes in production techniques and markets; but if you have a record of being consistent in the past, you can reassign and go forward with no problems.

SALES

The marketing function is considered a continuation of production since, generally, the same crews are responsible for grading the crops they grow. As stated earlier, all the azaleas, growing-on and budded, are graded according to head size, not pot size. This sometimes creates a situation where you may have a similar grade coming from two different sized pots, but this way the customer knows what he is getting each year. Our business is built on repeat orders and a consistent grade, year to year, seems to be the better way to maintain this

position. The trucking is done by individual carriers experienced in horticultural products or by the customer's picking up their orders. A few smaller orders are sent by UPS, bus, or air freight.

MAINTENANCE AND CLERICAL

The maintenance group is small and provides basic services for the other crews. This involves one man for installing water lines, basic carpentry, and covering the polyhouses. Another maintenace man takes care of the service to tractors and equipment. The maintenance crew also loads trucks and provides general weed control through herbicide application or mowing.

The office staff is composed of one full time employee for processing orders and handling inventory, bookkeeping, and correspondence. During busy seasons, we will hire part-time help here as well as in the maintenance or production areas. The company we hire for part-time help provides their employees' workmen's compensation coverage so that we have no problem with our unemployment tax rate when they leave.

Before being hired, all employees are required to fill out and sign an application that includes a 90-day probation period.

PESTICIDE SAFETY

BRYSON L. JAMES
P. O. Box 13
McMinnville, Tennessee 37110

CAUTION is the signal word on the label of the least toxic pesticides. *When used according to label directions, there is no danger* to the applicator nor to the environment *from any pesticide*, even the most highly toxic ones. No pesticide is safe when used haphazardly.

TOXICITY AND HAZARD NOT SYNONYMOUS

Toxicity value is not the *only* factor to consider regarding the potential danger or hazard of a chemical to human or other animal life. Users of pesticides should be concerned with the hazard of exposure to the chemical and not just the toxicity of the material itself. Hazard and toxicity are *not* synonymous. *Toxicity* is the inherent capacity of a substance to produce injury or death.

Hazard is a function of toxicity and exposure and is the potential threat that injury will result from the use of a given formulation or quantity of chemical.

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Before being hired, all employees are required to fill out and sign an application that includes a 90-day probation period.

PESTICIDE SAFETY

BRYSON L. JAMES
P. O. Box 13
McMinnville, Tennessee 37110

CAUTION is the signal word on the label of the least toxic pesticides. *When used according to label directions, there is no danger* to the applicator nor to the environment *from any pesticide*, even the most highly toxic ones. No pesticide is safe when used haphazardly.

TOXICITY AND HAZARD NOT SYNONYMOUS

Toxicity value is not the *only* factor to consider regarding the potential danger or hazard of a chemical to human or other animal life. Users of pesticides should be concerned with the hazard of exposure to the chemical and not just the toxicity of the material itself. Hazard and toxicity are *not* synonymous. *Toxicity* is the inherent capacity of a substance to produce injury or death.

Hazard is a function of toxicity and exposure and is the potential threat that injury will result from the use of a given formulation or quantity of chemical.

A pesticide may be extremely toxic but present little hazard to the applicator or others when used:

— in a very dilute formulation,
— in a formulation that is not readily absorbed through the skin or readily inhaled,
— occasionally and under conditions to which humans are not exposed,
— only by experienced applicators who are properly equipped to handle the chemical safely.

On the other hand, a chemical may exhibit a relatively low mammalian toxicity but present a hazard because it is normally used in a concentrated form that may be readily absorbed or inhaled.

THE PESTICIDE LABEL

Labeling regulations require all manufacturers of pesticides to indicate clearly relative hazards in using the contents of each container and to give instructions for its safe use. This includes protective clothing and container disposal information as well as environmental hazards.

Signal words used to indicate relative hazard are DANGER, WARNING, and CAUTION. Products bearing the word DANGER must also bear the word POISON printed in red and are about 10 times more hazardous than products bearing the word WARNING. Products that bear the word CAUTION are 10 times less hazardous than products identified by the word WARNING.

RECOMMENDED PROTECTIVE CLOTHING

Most injuries resulting from the use of pesticides have occurred because applicators ignored label directions to use protective clothing and devices during mixing and application. There are only two reasons for *not* wearing protection; ignorance and stupidity.

Everyone who handles and/or applies pesticides should use neoprene gloves, goggles or face shield, respirator or gas mask, long-sleeved shirt, full-length trousers, neoprene boots and a wide-brimmed hat or waterproof head covering of some type. With products bearing the signal word CAUTION goggles and respirator may not be required by law (label directions), but we use and recommend their use with *all* pesticides.

GENERAL SAFETY PRECAUTIONS

When more than one product will effectively control the target pest, choose the pesticide with the least potential hazard

to you, the environment, and your plants. This does not always mean the product with the lowest mammalian toxicity. Consider rates and frequency of use required for each product.

Pesticides by their very nature are poisonous to man, other animals, and sometimes plants. They become dangerous when improperly or carelessly used. When the following steps are observed, misuse will seldom, if ever, occur:

1. Properly identify the pest problem and determine what pesticide to use. Seek an expert's advice if in doubt.
2. Apply according to label instructions. Read the manufacturer's label carefully and completely, paying particular attention to the precautions and antidotes.
3. Wear clean protective clothing and use clean equipment.
4. Remove clothes after using poisonous chemicals and bathe with soap and water. Wash clothes before reusing.
5. Store pesticides in their original labeled containers in a locked storage area out of the reach of children, pets, and livestock. Never guess as to what is in a pesticide container. If you are unsure, discard the entire container with its contents.
6. Dispose of empty containers and/or old chemicals properly, safely, and according to the law.
7. Never use sprayers with leaking hoses or connections. Clean equipment immediately after each use and store it where children and livestock cannot get to it.

MISUSE IS DANGEROUS

Good coverage is not possible with poor equipment. Poor coverage is wasteful and potentially dangerous because repeated applications will be required. Also, poor coverage, resulting in ineffective control, usually encourages applicators to use stronger pesticides than should be necessary to control the target pest. Any form of misuse is dangerous.

There is not a single documented case of anyone's being killed or even injured by any pesticide, worldwide, when the product was used according to label directions. Also, no environmental problems have resulted from labeled use of pesticides. Misuse or accidents are responsible for all documented problems caused by pesticides.

Pseudo-scientific propaganda and the tireless drumbeat of misguided environmentalists has resulted in the banning of some of our safest, cheapest, and most effective pesticides. The only evidence they can cite of injury has been from misuses. Actually it seems that misuse of a pesticide is more hazardous to the survival of the pesticide than of mankind. The U.S.

Environmental Protection Agency banned DDT on what it later conceded to be political, not scientific, grounds. Few pesticides on the market today are less hazardous than DDT. Let's not lose more good chemicals by misusing them.

SUMMARY

Follow label directions. Remember that CAUTION is the signal word on the label of even the least toxic pesticide. When used according to label directions, there is no danger from any pesticide, even the most toxic ones. No pesticide is safe when used haphazardly.

WATERING CONTAINER-GROWN PLANTS

GERALD E. SMITH

Horticulture Extension, The University of Georgia
Athens, Georgia 30602

Twenty-six years of working with Georgia nurserymen has acquainted me with a wide range of problems that can affect the production of shrubs in the artificial environment of containers. By far the most common problems that I have encountered are related to watering practices and/or soil aeration of potting mixes.

The single most important practice in container production is water application. If the grower is sensitive to the effects of water on container plant growth, then he is in a position to refine other practices, including fertilization and pest control.

Here are some observations that I would like to share with you concerning water application:

There is often inadequate communication by nurserymen to their employees who actually make the day-to-day water management decisions. The ultimate quality of the crop depends, to a great extent, upon the quality of decisions made by the individual in charge of watering. Nurserymen often do not take the time to train their employees to identify the variables that can affect decisions of how often and how much water to apply.

The term "overwatering" is a poor choice of words due to the variety of meanings that it imparts. Actually the term is used to refer to two distinct situations: (1) too frequent applications of water, and (2) too much water in a single application. Irrigating too often is the cause of most water-related problems that I encounter. The result is that the potting mix is at or near field capacity for too much of the time. Applying an excessive amount of water in individual applications is a rare

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cause of root problems in southern nurseries in my estimation. Watering too frequently adversely affects the roots of plants in a number of ways. It reduces the soil oxygen supply, thus affecting root initiation and growth. It also increases the soil's content of gases such as CO_2 that can be toxic to the roots. It also results in an environment ideal for massive multiplication of destructive soil-borned disease organisms such as *Pythium* and *Phytophthora*.

There is a direct relationship between root-rot disease problems and watering practices. Most growers "water" their plants into an eventual root-rot situation. Four to 6 weeks of frequent rains can result in a noticeable decline in the condition of roots of container plants during the growing season. Likewise, watering a saturated mix repeatedly for a period of 4 to 6 weeks can result in massive root deterioration. Decisions not to water are refinements in production practice that lead to high quality container plants. These decisions are always present when accelerated plant growth is obtained.

Root-rot disease organisms are not always the cause of root deterioration. Microscopic examination of affected roots by plant pathologists does not always reveal the presence of disease organisms. This suggests that low soil oxygen or the presence of toxic gases in the soil is the cause of the problem. In most nursery situations, however, all three factors would contribute to the root decline.

Other than for roots, the space between soil particles must always be occupied by either air or water. There is no way to increase soil water content without a corresponding reduction in air content. Nurserymen should have a clear concept of irrigation water forcing a portion of the air out of the pore spaces every time that they apply water.

Some growers "build in" long term problems when they install their irrigation system. Designing irrigation systems for container plants requires that an equal amount of water be applied to a multitude of individual plants. Many frustrating problems result when improperly designed systems are installed. Consulting with individuals knowledgeable in nursery irrigation system design is highly recommended.

Irrigating for short periods can result in dry spots in the mix that will affect plant growth. Other than syringing the foliage, there is no way to water "lightly." An attempt to do this usually results in uneven applications and dry areas in the mix. Water saturates an area of the mix until no more can be held (reaches field capacity), then the excess water moves on to saturate an adjacent area to field capacity.

If a grower is not careful, perhaps 20 to 25% of the soil

volume can be extremely dry immediately after irrigating. These same dry pockets are likely to remain dry for long periods of time with no live roots remaining in them. Dry areas in the mix are more likely to begin when the mix is allowed to become extremely dry before re-watering. If this occurs, it may be necessary to water two or three times longer to saturate uniformly the potting mix. The problem is more common on older plants, which have large roots in contact with the sides of the container. These roots act as channels to move water down and out at a rapid rate before a uniform penetration inside can occur.

Proper bed construction is critical for uniform growth. Failure to crown beds or failure to provide a level surface for plastic-covered beds results in unnecessary water problems. The portion of the plants in containers "sitting" in water receives water from both the top and bottom and are thus more susceptible to root deterioration.

Arrangement of plants in groupings with similar water requirements is the most difficult, yet critical, decision made by the nursery manager. A successful manager becomes very skilled in arranging plants and predicting future space needs. It is obvious that a great deal more time should be allocated to planning in this area.

Instrumentation has not been developed that will accurately measure water levels in light-weight mixes. Tensiometers are being used effectively to measure water needs in heavier potting mixes such as those used in Southern California. Tensiometers do not perform accurately, however, in the porous bark mixes used in southern nurseries. Knocking plants out or using a soil probe are the only practical means of determining if water is needed.

Uniformity is the key to plant quality. Only when there is uniformity of plants in a block can all of the plants be irrigated at the optimum time. Varying size plants have different transpiration rates and thus remove the water from the mix at varying speeds.

Striving for uniformity of cuttings that root at the same time and produce identical-size liners should be a standard objective in a nursery. Instigating a grading system to discard nonuniform cuttings and liners will aid greatly in reducing problems related to watering practices.

The installation of cutoff valves on the risers is the most practical approach to providing positive control over water applications. Only in very large nurseries can identical plants be grown under a single irrigation line so as to provide optimum water. In my estimation, the installation and use of cutoff

valves in an average nursery can do more than any other single innovation to improve quality and reduce problems in growing plants in containers.

I have observed that there are stages in the production cycle when there are variations in water needs or stages when growers tend to misjudge water requirements. These are as follows:

1. *Immediately after sticking cuttings* — Excessive misting does not appear to be a major problem at this early stage in propagation. Adequate mist, on the other hand, is critical for survival of the cutting at this stage.
2. *After roots have formed on the cuttings* — Failure to gradually reduce the mist applied at this stage is a major cause of root deterioration.
3. *During over-wintering of liners in plastic structures* — Reduced air movement, lower temperatures, low light, and high humidity greatly reduce both leaf transpiration and evaporation of water from the soil in enclosed structures. Frequent water applications under these conditions can cause a disastrous decline in the root system.
4. *Immediately after canning* — Many plants are stressed due to canning into dry mixes that are extremely difficult to rewet. Other problems have been observed when liners growing in a dry mix are canned into a moist mix. Failure of the water to penetrate into the liner mix at the first watering is a common occurrence in this situation. There is also a tendency to keep recently-canned liners too wet for the first 6 to 8 weeks. This reduces the soil oxygen levels and retards root growth and also predisposes the roots to heavy infestations from soil disease organisms. On the other hand, care is necessary to water when needed since the roots are occupying a small soil volume with a limited water reserve at this stage.
5. *Stage approaching maturity* — At this stage it is much more difficult to create problems during the growing season by too frequent water applications since leaf transpiration is removing the soil water at a rapid rate. Excessive drying at this stage creates stress conditions that often result in an end to accelerated top growth. Also at this stage, a high percentage of the pore spaces are now occupied by roots, thus reducing the water-holding capacity of the mix.

QUESTION BOX

The Question Box was moderated by Carl Whitcomb, Oklahoma State University, Stillwater, Oklahoma.

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QUESTION BOX

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TED RICHARDSON: Carl, I would like to know more about the pot you developed that has slits in the sides.

CARL WHITCOMB: The roots are air-pruned when they reach the slits, which leads to the branching. In fact, we believe this container may even encourage top branching in some plants. We have no explanation, but the container is the only different factor used in production of the plants that were better branched. They have been costly to manufacture, but we are now working with Lerio and believe they have a method that will make it possible to manufacture the pot economically.

JOSE GARCIA: Does anyone have a method for effective mole control?

BRYSON JAMES: If you eliminate grubs, the moles will likely disappear.

GERALD VERKADE: Can *Acer grisseum* be propagated from cuttings?

MRS. BEN PERRY: I have propagated it using a peat:sand medium. I took the cuttings in May.

CARL WHITCOMB: It roots reasonably well using softwood cuttings under mist; 8000 ppm IBA in talc helps. They do not do much growing until the second year.

BILL BEATY: Would the rooting chamber used in air rooting need to be dark:

CARL WHITCOMB: There are reports in the literature that light inhibits rooting. However, cuttings of some plants root in a clear glass of water.

BRYSON JAMES: Why not root peaches right in the ground? It can be done rather easily.

CARL WHITCOMB: The main advantage to air rooting is improved oxygen availability.

BILL BEATY: What is your recommendation for converting propagation to the wet tent method?

CARL WHITCOMB: It is not the answer to all propagation problems but may be very helpful on real toughies. Bob Hartline suggested using a mist nozzle to keep the fabric wet and I have been told Hercules makes a fabric called Herculon that might be good. Jim Berry, Mobile, Alabama, pointed out that a different climatic environment could greatly affect success. Bryson James mentioned the importance of water quality to avoid salts build up that would affect wicking.

CARL WHITCOMB: Bon Hartline, Ana, Illinois, has brought specimens of *Ilex decidua* cultivars that would be

good plants for the U.S. Southern Region. Bon will tell us something about them.

BON HARTLINE: The common name of *Ilex decidua* is possum haw. There is also a deciduous holly, *I. longipes*, that has stalked berries. I've heard these hold the berries well. Joe McDaniel, Urbana, Illinois, and I have selected and named several from the deciduous species. Byers Nursery has a golden form, but it is difficult to propagate. Bob Simpson, Vincennes, Indiana, has also introduced several hybrids. These deciduous hollies are hardy to zone 5. They are not pH sensitive and can survive flooding. Mature *I. decidua* plants are about 20 ft tall; *I. verticillata* plants are 6 to 7 ft. There is some tendency towards altnerate bearing, but it is not a serious problem.

JIM BERRY: They can be found clear to the Gulf. I've seen pink, orange and red forms. Berries persist on some trees until March, then the birds may clean the trees in one day. Would you tell us more about propagation?

BON HARTLINE: At first we used the same procedure we do with *I. opaca*, which we propagate from July to March. The cuttings looked good but did not root. We now take cuttings as soon as frost hits in the fall.

CHARLIE PARKERSON: I'd like to discuss winter protection. We are using a system that seems to work and it may be of interest to others. We lay opaque copolymer plastic on the plants, then cover with Saran so that we have about 78% shade. The plants haven't been crushed nor have we had a significant heat build-up. We have not even laid the plants down. We formerly waited until after a rain and then punched small holes in any low spots so that the water could drain through. We now drill small holes in the roll of plastic before laying it, which is much less time consuming. We do not have black plastic under the containers, so drainage has not been a problem. What we are trying to do is avoid the expense of building frames. Labor costs are also reduced.

FLETCHER FLEMER: What is the best source for a seed cleaner?

DAVID BYERS: We use Bouldin-Lawson equipment. We buy seed and prefer to buy from local collectors who know the area. We like to have it gathered just as the pulp begins to soften. We believe we get better germination when the pulp is removed although Bill Dutcher has said he found little differences.

BILL DUTCHER: I'll like more information on callusing. Why do we get excessive callusing?

BRYSON JAMES: It is associated with poor aeration.

CARL WHITCOMB: Too high auxin concentration can cause callusing also. The season in which the cutting is taken also affects the formation of callus. Also, response may be different from one year to the next. There are reports that increased auxin may help one year but not the next on rhododendrons. Callus is formed in a different area than are the new roots.

DOUCHER: Does callus take up moisture?

CARL WHITCOMB: I have no direct evidence but believe that it does.

JIM BERRY: I have found on *Photinia* that with inadequate levels of auxin we get callus formation. I believe the plants are under stress and that fertilizing helps.

TED BECKETT: Decreasing the water is critical. We treat a callused cutting just as if it were rooted.

SHIVU PATEL: I believe there is a difference in *Photinia* rooting between the red new growth and mature green-leaved material.

CARROLL HALL: We get 95% rooting using high-humidity propagation, which, of course, helps reduce soil water content.

GERALD SMITH: Some of the speakers have indicated they rinse cuttings with Benlate[1]. Does it inhibit rooting?

ROBERT LAMBE: John McGuire[2] found better rooting when he used Benlate. Truban[3], however, may inhibit rooting, but using a drench with the 5G formulation improved rooting.

DAVID MORGAN: We have just finished a study of the effect of 22 different fungicides on rooting. We found no inhibition from either the drench or soil incorporation with most of the materials. However, Lesan[4] used as a soak did lead to a slight decrease. Each plant would need to be tested separately.

CARROLL HALL: We soak cuttings 5 to 10 minutes in Benlate at the concentration recommended for spray and have observed no inhibition.

BILL DAUGHTRY: Related to the use of fungicides is the importance of using clean water. We inject chlorine using equipment manufactured by Pennwalt, 25 Main Street, Belleville, NJ. We have found their series B 500 remote vacuum chlorinator to be our best choice. It is, we think, the safest.

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1 Benlate — benomyl, duPont

2 Dr. John J. McGuire, Department of Plant and Soil Science, University of Rhode Island, Kingston, Rhode Island 02881.

3 Truban — Ethazol, Mallinckrodt

4 Lesan — Dexon, fenaminosulf

The chlorine is injected between the water reservoir and the pump with the result that we are actually chlorinating a small volume of water in the reservoir right at the pump intake. The fertilizers injected at the pump tend to inactivate the chlorine so there is little pathogen exposure time to the treatment. We lengthen that time by injecting the chlorine as long as possible before the water reaches the pump. We try to maintain a concentration of 0.3 ppm Cl as measured with swimming pool equipment. Dry material costs $1/lb and is only 65% Cl while the cylinders of gas costs $0.23/lb and are 100% Cl. We use about 400 lb of the gas per pump annually as 90% of our water drains back into the pond, and we do recirculate it. We felt treatment was essential, but treating the entire pond is cost prohibitive. Subdue* will suppress but not kill the water mold fungi. Robert Lambe points out that we don't know about development of resistence to Subdue and says chlorine is probably the best control. However, chlorine affects fungi with mobile spores and does little to control others. It is important to test continuously and keep up the sanitation program.

TED RICHARDSON: At the Research Station in Boskoop, The Netherlands, the water goes into the canal with *Phytophthora* but comes out without it.

CARL WHITCOMB: The same thing is true in Australia. Actually, research indicates that if other growing conditions are optimum and plants are healthy, we can have high levels of fungi in the water without damage. It is also true that water will often clear up, probably due to aeration and to the action of other microorganisms.

ED KINSEY: We find methyl bromide is cost effective for use on pots.

ROBERT LAMBE: It does not have the penetrating action on pots that it does on soil, and it is difficult to get good control. I would recommend washing with a chlorine solution instead.

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* Subdue — Metalaxyl (CIBA-GEIGY)

TECHNICAL SESSIONS
Tuesday Morning, December 14, 1982

The thirty-second annual meeting of the Eastern Region of the International Plant Propagators' Society convened at 8:15 a.m. in the Ambassador Ballroom East of the Amway Grand Plaza Hotel, Grand Rapids, Michigan.

PRESIDENT SPARMANN: Welcome to the thirty-second annual meeting of the Eastern Region of the International Plant Propagators' Society. The local site committee under the leadership of Dick Brolick has done everything to make your arrival and stay a very enjoyable one. At this time I would like to recognize the members of the Internation Board present: Ralph Shugert, Historian; and John Wott, Vice-President-Elect. We have several members here from other Regions. I would like to recognize from the Western Region, Bruce Briggs, Ray Maleike, Steve McCulloch, and Robert Tichnor. From the Southern Region, Stanley Foster and Ted Richardson. A special welcome to you this morning. I will now turn the meeting over to our program chairman, Don Shadow, who has put together an excellent program.

Jim Cross served as moderator for the morning session.

STEWARTIA — PROPAGATIONAL DATA FOR TEN TAXA

ALFRED J. FORDHAM
Weston Nurseries, Inc.
Hopkinton, Massachusetts 01748

Some of the most interesting and unusual small trees and shrubs for use in ornamental planting are the deciduous taxa of the genus *Stewartia*, which is a member of Theaceae, the tea family (1). Plants grown in the area of Boston, Massachusetts, start flowering in late June and continue to flower into July, a time when the flowering of most woody ornamentals has passed. Figure 1, photographed on May 1st, shows the presence of flower buds and partly expanded leaves. Buds present at this early date remain inactive and blossoms do not appear until late June. Flowering characteristics of most taxa are basically alike, comprising single white flowers, with bright yellow stamens, borne in the axils of the leaves. Exceptions are *S. malacodendron* with purple stamens and *S. ovata f. grandiflora*, where flowers with yellow stamens and flowers with purple stamens may be found on the same plant.

Members of the genus *Stewartia* are found only in eastern North America and eastern Asia. Those found in the Orient can attain heights of 80 feet while the two found in America are shrubby and rarely grow to 16 feet.

Figure 1. *Stewartia* shoot photographed on May 1st showing the presence of flower buds together with partly expanded leaves. Buds present at this early date remain inactive and blossoms do not appear until late June. Photo by Alfred J. Fordham.

The bark of the two American species is somewhat nondescript, while the bark of some oriental species is truly spectacular. As the trunks and branches increase in size, the deciduous outer bark peels away revealing underlying bark which is bright cinnamon in color. When laid bare to the weather, the newly exposed bark undergoes gradual color change. Therefore, a beautiful color pattern, varied in hue, is created by the length of time each section has been exposed to weathering.

Stewartia pseudocamellia 'Korean Splendor' (Figure 2) has an especially long flowering season that starts in late June and continues into early August. Despite the fact that the flowering period lasts for about 5 weeks, individual flowers persist on the plants for only about 24 hours after opening. Open flowers and unopened buds are found together on the plant throughout the long flowering period. After a blossoming period of about 24 hours, the petals (with the stamens still attached) fall from the plant and literally carpet the ground. The ovary and style remain attached to the tree. Meanwhile, new flowers open each day from the vast number of reserve buds which continuously develop. Two species of honey bees and one species of bumble bee have been observed visiting the flowers of *Stewartia*.

PROPAGATION OF *STEWARTIA* BY SEED

Stewartia seeds are produced within five-chambered woody capsules and each chamber, depending upon the species, contains 2 to 4 seeds. In some instances fewer seeds are produced in each chamber due to the abortion of one or more of the ovules. Abortion results because the egg within the

Figure 2. *Stewartia pseudocamellia* 'Korean Splendor.' Open flowers, unopened buds, and partly developed seed capsules are found together on the plant owing to its long flowering period. Photo from Arnold Arboretum.

ovule either was not fertilized, or the egg failed to develop after fertilization. Natural dispersal of the winged seeds of most species is by wind, and in the latitude of Boston, Massachusetts, the capsules open and the seeds are dispersed during late September and early October.

A careful watch must be maintained if one intends to collect seeds since tightly closed capsules may open in a few days, and the seeds will be lost to natural dispersal. Maturity of the seeds can be determined by a color change of the capsules. About mid-September they start turning from green to brown and, at this stage, the seeds are fully developed and the capsules can be collected.

Separation of the seeds from the capsules is a simple matter. When the fruits are placed in a container (such as a paper bag) that is then put in a dry location, the closed capsules will open in a few days. When the container is shaken the seeds will fall out. Separation of the seeds from the capsules can then be accomplished by emptying the contents into a screen of suitable mesh size to retain the capsules but allow the passage and final collection of the seeds. Difficulty in the separation of seeds from capsules may be experienced only with fruits of *Stewartia malacodendron*. The angular seeds are often held tightly within the chambers and their removal may require forceable opening of the capsules.

When kept in dry storage, *Stewartia* seeds lose their viability quickly. As a result they should be sown or placed in pretreatment without delay. All the species tested at the Arnold Arboretum produced seeds that were doubly dormant. In their natural habitats the seeds would require two years to germinate. Seeds dispersed in October, 1982 would be physiologically prepared to germinate by natural seasonal changes in spring of 1984. However, by placing the seeds in a stratifying medium and providing artificial seasons, the seeds can be induced to germinate in about 7 months.

This pretreatment is done in two stages. The container for the seeds and stratifying medium should be a polyethylene plastic bag. Polyethylene plastic has the property of being air permeable yet vapor proof. Twisting the top of the bag and binding it with a rubber band makes the unit vapor-proof for the entire treatment period, and it does not need to be opened until both steps have been accomplished.

At the Arnold Arboretum we used a stratifying medium composed of equal parts sand and peatmoss. The mixture is dampened (moist but not wet) and in proportion the medium should be 2 or 3 times the volume of the seeds. This factor is important since at sowing time the entire contents of the bag are sown. A large volume of medium could lead to some seeds lying at unsuitable depths.

Using seeds of taxa tested at the Arboretum, it was determined that a period of 4 months warm stratification followed by cold stratification for 3 months satisfied the requirements for germination. Seeds placed in warm stratification in early October are transferred to cold treatment in early February and are ready for sowing in early May. This timing is excellent since the seedlings will develop and grow during the lengthening days of spring.

Warm stratification is accomplished by placing the sealed bags in a location where the temperature is subject to normal day and night fluctuations. Our bags were placed in bins on a greenhouse bench where the temperature ranged between 60° and 100°F. Any location where the day and night temperatures vary would be satisfactory. Full sun, however, should be avoided since it might lead to high temperatures within the bags that could be detrimental to the seeds. When the period of warm stratification has been completed, the bag is transferred to a refrigerator to satisfy the cold requirement. At the Arboretum, cold pretreatment was accomplished at about 40°F. However, this temperature is arbitrary and the temperature maintained in the storage area of any refrigerator will suffice for the cold period. Keeping track of the time to move the seeds from one treatment to another is easily done by marking

dates on a calendar or by keeping a card file arranged in chronological order.

The following is a list of *Stewartia* taxa seeds that were germinated by following the procedure outlined above: *S. ovata f. grandiflora, S. malacodendron, S. serrata, S. rostrata, S. sinesis, S. monadelpha, S. pseudocamellia, and S. pseudocamelia* 'Korean Splendor'

It should be noted that *Stewartia* hybrids are beginning to appear among seedlings grown from seeds gathered in botanical garden and arboretum collections. Therefore, it is only safe to propagate seeds taken from isolated individual specimens.

PROPAGATION OF *STEWARTIA* BY CUTTINGS

At the Arnold Arboretum, cuttings of *Stewartia* have been taken as early as June 23rd and as late as August 20th. Although rooting has been partially successful in all attempts over this time period, the greatest number of cuttings have rooted when the cuttings were processed between June 23rd and mid-July.

Although a wide variety of root-inducing materials have been used with good success on *Stewartia* cuttings, indolebutyric acid (IBA) has proven satisfactory. The cuttings are treated with an 0.8% formulation of IBA in talc, with Thiram added at the rate of 15%. High percentages of rooting have also occurred employing quick-dip treatments using a combination of IBA plus naphthaleneacetic acid (NAA) at 2500 parts per million of each. Quick-dip treatment involved immersing the bases of prepared cuttings in the liquid preparation for five seconds..

Rooted cuttings of *Stewartia*, particularly those made late in the growing season, have presented a survival problem during the subsequent winter. When potted or flatted after rooting, the plants have gone into a dormancy from which they never recovered. This loss can be averted, however, if the cuttings are not disturbed after they have rooted. The procedure used is to fill plastic flats with a rooting medium of half sand and half perlite by volume. The cuttings are made, treated, and inserted in the flats which are then placed under intermittent mist. When rooting has occurred, the cuttings are left in the flats and hardened off. In November they are transferred to cold storage where the temperature is maintained at approximately 34°F. In February or March, depending on the work load, the flats are returned to a warm greenhouse and when new growth begins to appear they are transferred to containers. When handled in this manner, the rooted cuttings can be expected to survive and grow. The following is a list of

Stewartia taxa that have been propagated by the procedures described above: *S. ovata*, *S. ovata f. grandiflora*, *S. malacodendron*, *S. rostrata*, *S. henryae*, *S. sinensis*, *S. monadelpha*, *S. pseudocamellia*, *S. pseudocamellia* 'Korean Splendor'

JUVENILE SHOOTS FROM ROOT PIECES

To test if shoots would develop from root pieces, roots of 6 taxa plants were dug in December and cut into 5-in. pieces. These were buried horizontally 1-in. deep in flats of sandy soil. Shoots that arise from roots are physiologically juvenile and often will root quickly. However, no shoot development took place.

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DON SHADOW: Do you know if there were *Stewartia* seeds brought in from China a few years ago?

AL FORDHAM: Yes, there were.

WILLIAM VANDERKRUK: Did you notice any difference in hardiness between rooted cuttings and seedlings?

AL FORDHAM: I have never noticed any difference. Of course, with seedlings you get genetic variation and with cuttings you get the same hardiness as the parent plant.

TOM McCLOUD: You mentioned cold storage. Would a cold greenhouse be satisfactory? Is light a factor?

AL FORDHAM: Any place that can be kept between freezing and 40°F is satisfactory. Light is not a factor.

RALPH SHUGERT: What is the hardiness of the genus in Michigan?

AL FORDHAM: *Stewartia pseudocamellia* would be hardy there. *Stewartia serrata* is the only one that is not hardy with us at the Arboretum — in Zone 5.

PROPAGATION OF *CORNUS FLORIDA* FORMA RUBRA BY SEED — THE PROCESS AND POTENTIAL[1]

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Abstract. Plants of *Cornus florida* forma *rubra* are currently propagated by budding or by softwood cuttings. Seed propagation of *rubra* plants would be of interest for economic reasons. Crosses of *rubra* x *rubra* yielded all *rubra* seedlings whereas progenies of *rubra* x a *rubra*/white heterozygote showed 1:1 segregation for pink or red and white-bracted plants. These data are consistent with the hypothesis that the *rubra* characteristic is conditioned by a single recessive gene. Thus, it would be possible to produce pink- and/or red-bracted plants from seed by growing *rubra* plants of diverse origin in an isolated seed block. However, anthocyanin pigmentation of the foliage and bracts of *rubra* seedlings is highly variable; also, undesirable floral "doubles" occur with high frequency in some progenies. The production of pink- and/or red-bracted plants from seed provides the potential for selecting new and superior plants that can be propagated asexually.

Plants of *Cornus florida* forma *rubra* (Weston) Palmer and Steyerm, in cultivation since 1731 (6), have long been prized for the floral contrast they provide in mixed plantings with white-bracted plants typical of the species, *C. florida*. As used in the nursery trade, *rubra* includes both pink- and red-bracted plants. Historically, *rubra* plants have been propagated by budding, a relatively expensive form of propagation. In recent years, some growers (2,3,4,7) have reported success in propagating this plant material more economically from stem cuttings under intermittent mist, but there is still controversy among propagators as to whether or not plants of *C. florida* f. *rubra* propagated from stem cuttings are less winter-hardy the first few years than are plants of the same clones grafted onto the typical white-bracted seedling understock. Some nurserymen, largely for economic reasons, are showing increasing interest in producing pink- and/or red bracted plants of *Cornus florida* from seed. This paper discusses techniques and problems associated with producing such plant material from seed.

INITIATION OF BREEDING PROGRAM

In 1965, bare-root plants of most of the cultivars of *C. florida, C. kousa,* and *C. Nuttallii* available in the trade were assembled in performance trials at the New Jersey Agricultural Experiment Station, Cook College, Rutgers University, as the first step in initiating a breeding program devoted to the devel-

[1] New Jersey Agricultural Experiment Station, Publication No. E-12006-01-83, supported by State funds.

opment of new and superior cultivars of the flowering dogwoods through intra- and inter-specific hybridization. One of the objectives of this program was, and remains, the development of superior cultivars with pink and/or red bracts. Over the years, nurserymen specializing in *C. florida* have had the opportunity to observe and evaluate millions of white-bracted dogwood seedlings. As a result, numerous excellent cultivars of the species type were available in the trade when the current hybridization work was initiated. In contrast, the cultivars of *C. f.* forma *rubra* were limited in number and traced directly to plants found in the wild or selected from relatively small seedling populations. Therefore, it seemed reasonable to attempt to develop improved cultivars with pink and/or red bracts from more diverse germplasm through intraspecific hybridization.

ORIGIN OF CULTIVARS UTILIZED

Initially, the available cultivars of *C. f.* forma *rubra* included 'Prosser Red' (D48), 'Cherokee Chief' (D7), 'Sweetwater' (D18), 'Spring Song' (D55), 'Welch's Jr. Miss' (D75), and an unnamed clone (D3) obtained from Princeton Nurseries:

1. 'Prosser Red' (dark red bracts) — traces to a plant discovered in a wooded area on the Prosser Estate in Knoxville, Tennessee (8).
2. 'Cherokee Chief' (medium dark red bracts) — traces to an open-pollinated seedling of 'Prosser Red' found by Mr. Bruce Howell in a nursery row on his farm in Sweetwater, Tennessee (8).
3. 'Sweetwater' (red bracts) — a sibling or half-sibling of 'Cherokee Chief,' tracing to the same planting of open-pollinated seed from 'Prosser Red' (8).
4. 'Spring Song' (red bracts) — this cultivar was introduced to the trade by the Wayside Gardens Company, the plants having been produced from propagation wood taken from a tree growing in a large planting of dogwoods on an estate in the East.
5. 'Welch's Jr. Miss' (dark red bracts) — originating in the deep South, this cultivar traces to a plant found by Mr. Clarence Welch, Welch Brothers Nursery, in the wild in Alabama (8).
6. D3 (red bracts) — The clone designated D3 in the pedigree records of our *Cornus* breeding program at Rutgers is produced by Princeton Nurseries, Princeton, New Jersey. This clone traces to a plant found by a farmer in a pasture near Chester, Pa., and was placed into commercial production by a Mr. Achelis who was a Pennsylvania fruit grower (5).

RESULTS AND DISCUSSION

As any dogwood grower who has ever attempted to produce pink- or red-bracted plants of *C. florida* from seed undoubtedly knows, plants of this species are highly self-sterile. However, plants of different cultivars hybridize readily except, of course, in those not too rare instances where plants of the same clone have been introduced to the trade under two or

more names. As indicated by the data shown in Table 1, all plants resulting from crosses of *rubra* x *rubra* exhibit anthocyanin pigmentation in the floral bracts. However, the level of pigmentation in the progenies of the first 3 crosses listed in Table 1 is extremely variable. In the last 2 crosses shown, extensive winter injury to the trees and flower buds resulted in the development of flower heads with two small, distorted bracts, the outer bracts of each flower bud remaining undeveloped. Under such conditions, the pigmentation of the stunted bracts appears to be intensified. The variability in the expression of the pigmentation of the normal bracts in *rubra* seedlings is not unexpected. Being self-sterile, plants of *C. florida* are obligately cross-pollinated in nature and would be expected to be heterozygous for many genes, some of which could modify the expression of a major gene conditioning anthocyanin pigmentation in the plant.

Table 1. Subjective visual ratings of anthocyanin pigmentation of the floral bracts of seedlings resulting from crosses among 5 selected clones of *Cornus florida* forma *rubra*.

	Number and percent of progeny							
	Pigmentation of floral bracts							
Cross	non-fl.	lt. pink	pink	pinkish-red	red	dark red	total	floral doubles*
D3xD7	4 (4.8%)	6 7.2%)	13 (15.7%)	17 (20.5%)	32 (38.6%)	11 (13.2%)	83 (100%)	12 (14.5%)
D3xD18	5 (4.6%)	7 (6.5%)	14 (13.1%)	20 (18.7%)	35 (32.7%)	26 (24.3%)	107 (100%)	7 (6.5%)
D7xD55	1 (1.5%)	1 (1.5%)	8 (11.6%)	12 (17.4%)	35 (50.7%)	12 (17.4%)	69 (100%)	20 (29.0%)
D55xD18					6 (60%)	4 (40%)	10 (100%)	1 (10%)
D75xD7					6 (33.3%)	12 (66.6%)	18+ (100%)	— —
D75xD18	2 (3.1%)		2 (3.1%)	1 (1.6%)	25 (39.1%)	34 (53.1%)	64+ (100%)	— —

* Flower heads exhibit extra bracts (small and undeveloped) and few true flowers.

+ Bract color intensified due to two-bracted condition resulting from winter injury.

Additional information on the mode of inheritance of the *rubra* characteristic was obtained by crossing the unnamed clone (D3), 'Prosser Red' (D48), and 'Spring Song' (D55) with plants of 'Apple Blossom' (D77) (Table 2). Introduced by the Wayside Gardens Company, 'Apple Blossom' traces to a tree on the same estate where 'Spring Song' was selected. The name was chosen as being descriptive of the pigmentation of

the floral bracts of the plants during some seasons. However, the intensity of the anthocyanin pigmentation of the bracts in this cultivar is extremely variable from year to year and was observed to be essentially the same as that observed with seedlings resulting from controlled crosses of *rubra* x white, the bracts being nearly pure white during most years.

Table 2. Subjective visual ratings of anthocyanin pigmentation of the floral bracts of progenies resulting from crosses between three clones of *Cornus florida* forma *rubra* and 'Apple Blossom' (D77).

	Number and percent of progeny *pigmentation of floral bracts*					
Cross	white	white with tinge of pink	pinkish-red	red	dark red	total
D77xD3		10	5		1	16
D77xD55	3	3	2	5	2	15
D48xD77		10	2	6	4	22
all crosses	3	23	9	11	7	53 (100%)
white vs. *rubra*		26 (49.1%)		27 (50.9%)		

The simplest hypothesis regarding the mode of inheritance of the *rubra* characteristic in *C. florida* is that it is conditioned by a single recessive gene. The data in Tables 1 and 2 are consistent with this hypothesis. The 1:1 segregation for *rubra* versus white bract color in the progeny of the 3 crosses involving 'Apple Blossom' (Table 2) is clearly consistent with the hypothesis that plants of this cultivar are heterozygous for a single pair of genes conditioning bract color.

It should be noted that 5 of the 7 crosses listed in Table 1 yielded a substantial number of plants exhibiting flower heads classified as "doubles." Most of the "doubles" were vastly inferior to the flower heads of the white-bracted cultivar known in the trade as 'Flora Plena,' as the majority of the extra bracts were small and distorted and the trait was variably expressed throughout the tree and varied in degree of expression from year to year. Thus, the expressivity of the "doubles" character appears to be markedly influenced developmentally either by internal factors or by environmental factors. The limited data that are available merely allow one to say that this character appears to be related to the gene conditioning the *rubra* characteristic as "doubles" have rarely been observed in seedling populations resulting from crosses between white-bracted plants. Progency of the crosses involving 'Welch's Jr. Miss' (Table 1) were not scored as including "doubles" but the pres-

ence of this trait may have been masked by the severe winter injury which is inflicted annually on flower heads of seedlings from this southern cultivar.

Having established that crosses of selected plants of *C. f.* forma *rubra* yield all *rubra* seedlings, crosses were initiated with select *rubra* seedlings from crosses involving the winter-hardy clone (D3) from Princeton Nurseries. The results of one such cross are presented in Table 3.

Table 3. Subjective visual rating of anthocyanin pigmentation of the floral bracts of seedling *Cornus florida* f. *rubra*.

	Number and percent of progeny							
		Pigmentation of floral bracts						
Cross	non-fl.	lt. pink	pink	pinkish-red	red	dark red	total	floral doubles
D3x (D3xD18)	5 (5.2%)	3 (3.2%)	24 (25.3%)	21 (22.1%)	27 (28.4%)	15 (15.8%)	95 (100%)	1 (1.1%)

The progeny of this cross illustrate further the variability encountered in the expression of the anthocyanin pigmentation of the floral bracts in a seedling population of *rubra* plants. Apparently, one backcross generation had little effect in reducing this variability. One floral "double" was observed among the seedlings.

With reference to the variability in bract color exhibited by the progenies listed in Tables 1, 2, and 3, it should be mentioned that the intensity of the pigmentation of the bracts is usually indicative of the intensity of the anthocyanin pigmentation of the foliage. Furthermore, in the experience of this researcher, the intensity of the expression of the anthocyanin pigmentation in the foliage appears to be inversely related to the vigor of the plant, possibly because the anthocyanin pigmentation may reduce photosynthetic activity in the leaves. At any rate, the point to be made is that any search for a parental combination yielding progeny exhibiting uniformity in the intensity of the bract color should be directed away from the dark red phenotypes. Plants exhibiting intense anthocyanin pigmentation of the foliage do not invariably possess dark red bracts. However, it would probably be difficult to find a parental combination that yields progeny with lightly pigmented foliage and uniformly dark red bracts.

EXPRESSION OF THE *RUBRA* CHARACTERISTIC IN DEVELOPING SEEDLINGS

Based on the findings reported above, it would be relatively simple to produce plants of *C. florida* forma *rubra* from seed

if one were to grow *rubra* plants of diverse origin in an isolated stock block.

Another aspect of the problem is that it would be 5 to 6 years under field conditions in New Jersey before the majority of the plants would flower so that one could assess the level of pigmentation in the bracts. However, *rubra* seedlings can be detected a few days following germination as the underside of the cotyledons develop anthocyanin pigmentation. Also, the expression of anthocyanin pigmentation is quite marked in the first true leaves. Thus, it would be possible to rogue contaminant seedlings very early on the basis of their green cotyledons or at later stages of growth on the basis of their green foliage. Possibly, one could eliminate most of the plants that would ultimately produce light pink bracts by rogueing all seedlings that show only light anthocyanin pigmentation on the underside of the cotyledons or in the first true leaves, but this would be a tedious operation. Unfortunately, one would still have to accept a degree of variability in the intensity of bract pigmentation when the *rubra* seedlings flower as the intensity of pigmentation in the cotyledons or in the foliage is not always directly related to the intensity of pigmentation in the bracts. An obvious approach would be to resort to sib matings of select seedlings or to backcrossing select progeny to a parental cultivar in an attempt to produce a line homozygous for the *rubra* characteristic but exhibiting less variability in the intensity of the anthocyanin pigmentation. Furthermore, the parental combination should yield progeny free of the undesirable floral "doubles." At this point, one should be cautioned to be very alert to the possibility of encountering inbreeding depression. Plants of *C. florida* are highly self-sterile but progeny resulting from self-pollination have been obtained in the work at Rutgers University. Those plants have been abnormal in habit and low in vigor. If this low vigor is, in fact, a result of inbreeding, progeny resulting from sib matings or from backcross matings would be expected to exhibit inbreeding depression to a lesser degree.

When one considers the "dogwood decline" that has been occurring in New Jersey and other areas in the eastern U.S. in recent years, it seems clear that *C. florida* is a species in which the best genetic material is none too good. Superimposed on this is the fact that plants of *C. florida* forma *rubra* are not as vigorous or winter-hardy as the species type (1). Thus, not even low levels of inbreeding depression could be tolerated.

POTENTIAL FOR DEVELOPING SUPERIOR CLONES OF *CORNUS FLORIDA* FORMA *RUBRA*

The production of plants of *Cornus* forma *rubra* from

seed offers the potential of reduced costs of production. However, considering the variability in vigor as well as in bract color that must be tolerated in the end product, should one expect to gain commercially, or economically? This variability probably would be of no consequence in highway plantings. However, from the perspective of the plant breeder, plants of a tree species that might be expected to remain in a residential or business landscape for a period of 25 to 30 years should be the best genetic material that is available. At present, that is not pink- or red-bracted dogwood grown from seed.

The most promising aspect of generating plants of *C. f.* forma *rubra* from seed is the potential for selecting one or more superior plants that can be reproduced asexually. In the breeding program at Rutgers University, this aspect of the work will receive high priority.

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HARRISON FLINT: You mentioned a cultivar that is not hardy in the north. What was it?

ELWIN ORTON: 'Welch's Jr. Miss.'

DON SHADOW: Have you tried to incorporate the red-bracted form into other forms, such as the dwarf and weeping forms?

ELWIN ORTON: Yes. We have put effort into developing dwarf, red-bracted forms. The weeping form I have never been impressed with and have not tried.

RUTH KVAALEN: Is there a red-bracted *C. nuttallii*?

ELWIN ORTON: I am not aware of any and the people on the West Coast tell me no.

VOICE: Have you considered similar studies with *C. kousa*?

ELWIN ORTON: Yes, we have. However, there are no pink or red forms of *C. kousa*. We did interspecific crosses between *C. florida* and *C. kousa* at the suggestion of Hans Hess with the idea of producing a pink *C. kousa*. We have also incorporated *C. nuttallii*. The major thrust of our work now is interspecific hybridization. I have imported supposedly pink forms of *C. kousa* from Japan but they have all produced only white flowers. I have chased down many claims of pink flowered *C. kousa* dogwoods. Every year I get calls from people who have pink-flowered *C. kousa* and they are right. If you look at them during a 24-48 hour period when the flowers are senescing they will have a pink color. In some cases I have seen the color last for 7 days.

AL FORDHAM: If the flowers abort, you will also get pink bracts.

PROPAGATION OF TRIFOLIATE MAPLES BY SEED

DENNIS P. STIMART

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In the section *Trifoliata* of the genus *Acer* are 4 species: *A. griseum*, *A. mandshuricum*, *A. maximowiczianum* (*A. nikoense*) and *A. triflorum* (10). The species are characterized by short tree stature at maturity and autumn foliage of red, scarlet, or orange. A cinnamon-brown or yellow-brown flaking bark of *A. griseum* and *A. triflorum*, respectively, further enhance the horticultural qualities of these maples, making them excellent ornamentals.

Schizocarps of *A. griseum*, *A. maximowiczianum* and *A. triflorum* have a ligneous pericarp which delays germination for several years (3,6). Two to 5 years can elapse between good fruiting, with most fruits producing few seeds exhibiting double dormancy (6,15). Trifoliate maples are not easily rooted by cuttings but can be grafted; however, they need a rootstock of a similar species. Thus, trifoliate maples are rarely seen in cultivation.

Dormant seeds of *Acer* have germinated following gibberellin or kinetin treatments (12,13). Radicle elongation of *Acer pseudoplatanus* was promoted by kinetin while gibberellin treatment promoted cotyledon unrolling and growth (9). This paper reports results from experiments conducted to deter-

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mine the role of growth regulators, the seed coat, and light on germination of trifoliate maple seeds.

MATERIALS AND METHODS

Fruits of *Acer griseum* and *A. maximowiczianum* were collected during October, 1979, from trees in the U.S. National Arboretum, Washington, D.C. *Acer mandshuricum* and *A. triflorum* fruits were supplied by the Arnold Arboretum, Jamaica Plain, Massachusetts. Samaras were stored in paper bags at 10°C in the dark.

Seeds were extracted from schizocarps by breaking the hard pericap with pruning shears and a budding knife. Softening the seed coat in water at 25°C for 30 to 40 min facilitated embryo removal under a dissecting microscope. Seeds or embryos received treatments while being incubated on wick cultures which consisted of a folded 12.5 cm Whatman No. 2 filter paper inserted into a 25 x 150 mm glass tube. The seeds or embryos were placed into an upper fold of the filter paper with the embryonic radicle pointing down.

Control and growth regulator solutions of auxins, cytokinins, or gibberellic acid were prepared by adding 5 drops of 1N KOH to the crystals and diluting to volume with deionized water. Ten ml of solution were added to each culture before the tubes were capped. Cultures were incubated at 25°C for 21 days. Each treatment consisted of 10 replications. Germination was defined as expansion of the embryonic radicle, cotyledons, and plumules.

Experiment 1. Naked embryos excised from seeds of *A. maximowiczianum* were treated with solutions of IAA, NAA, BA, kinetin, or GA_3, at 0, 10, or 100 mg/liter. Treatments were placed in 8 hr of darkness with irradiation from Cool White fluorescent lights (160 $\mu Em^{-2}s^{-1}$) for 16 hr on a 24 hr cycle. The purpose of this experiment was to determine if auxins, cytokinins, or GA_3 at different concentrations could stimulate germination.

Experiment 2. Germination is promoted in some kinds of seed by light. To establish the role of light in germination, seeds and naked embryos of *A. maximowiczianum* were treated with solutions of 0 or 10 mg/liter GA_3 and incubated in either darkness or in the lighted environment previously described.

Experiment 3. Dormancy is caused in many kinds of seed by water soluble inhibitors present within seed coats. Seed coats of *A. maximowiczianum* were therefore assayed for nonspecific water soluble inhibitors. Air-dried seed coats (250 mg) were finely ground and extracted with 5 ml of deionized water

for 24 hr at 25°C. The leachate was filtered and a 4 ml aliquot placed on filter paper in a 90 mm Petri plate. One hundred seeds of *Lactuca sativa* L. cv. Grand Rapids were then sown on the filter paper and percent germination determined after 48 hr at 25° in the lighted environment.

Experiment 4. Seed coats can prevent imbibition and prolong seed dormancy. To study this, seed coats of *A. maximowiczianum* were lacerated on one side and the cut surface was placed in contact with filter paper moistened by solutions of 0 or 10 mg/liter GA_3. Germination results were collected after 21 days of incubation in the lighted environment.

Experiment 5. The influence of GA_3 on overcoming embryo dormancy of other trifoliate maples was investigated. Since limited seeds were available of *A. griseum*, *A. mandshuricum*, and *A. triflorum*, only treatments of 0 or 10 mg/liter GA_3 were given to naked embryos. Incubation was in the previously described lighted environment for 21 days.

RESULTS

Experiment 1. Germination of *A. maximowiczianum* naked embryos occurred when incubated in all solutions of kinetin or GA_3 and BA at the lowest dilutions (Table 1). Most significant increases in root length occurred on embryos on wick cultures wetted with solutions of BA (10 mg/liter) or kinetin (100 mg/liter). Cotyledon and epicotyl growth were greatest on embryos cultured in solutions of GA_3 (10 mg/liter). Excised embryos remained tightly coiled and dormant when incubated in water, dilutions of IAA or NAA, or solutions of GA_3 or BA at 100 mg/liter.

Table 1. Lengths of radicles, cotyledons, and epicotyls of *Acer maximowiczianum* embryos incubated in solutions of GA_3, kinetin, BA, IAA, or NAA after 21 days.

		Length (mm)		
Growth regulator	Concn (mg/liter)	Radicle	Cotyledons	Epicotyl
Control	0	5.4a[z]	14.6ab	0 a
GA_3	10	13.4c	27.3e	4.8d
	100	5.5a	16.9c	0 a
Kinetin	10	9.9b	16.0bc	1.9c
	100	23.6e	19.6d	3.7c
BA	10	20.0d	17.2c	2.7b
	100	5.4a	13.3a	0 a
IAA	10	5.2a	117.0c	0 a
	100	5.4a	14.6ab	0 a
NAA	10	5.5a	17.0c	0 a
	100	5.3a	13.3a	0 a

[z] Mean separation within colums by Student-Newman-Keuls Test, 5% level.

Experiment 2. Excised embryos of *A. maximowiczianum* were induced to germinate in the lighted environment when incubated in the GA_3 solution. Seeds in the same solution or seeds and naked embryos incubated in water remained dormant. No growth was detected on treated seeds and extracted embryos when placed in continuous darkness.

Experiment 3. Based on the bioassay, there were no apparent inhibitory substances in the seed coats of *A. maximowiczianum* preventing lettuce seed germination. Ninety percent germination occurred in both treatments.

Experiment 4. Laceration of *A. maximowiczianum* seed coats failed to initiate embryo germination. Solutions of 0 or 10 mg/liter GA_3 were ineffective in promoting the unfolding of embryonic radicles or cotyledons of lacerated seeds.

Experiment 5. *Acer griseum* and *A. triflorum* embryos excised and treated with 10 mg/liter GA_3 germinated within 21 days. The non-treated control embryos did not germinate since they failed to unfold their cotyledons or radicles. Treatments of *A. mandshuricum* naked embryos with either 0 or 10 mg/liter GA_3 resulted in germination. However, embryos treated with GA_3 germinated in 7 days while non-treated controls required 14 days.

DISCUSSION

Treating *A. maximowiczianum* embryos with GA_3 promoted cotyledon expansion, cytokinins promoted longest root growth, and auxin treated embryos remained dormant. Thus, in some species of *Acer* it appears that termination of seed dormancy, cotyledon unfolding and expansion are promoted by gibberellins, root development is enhanced by cytokinins, and auxins are ineffective in promoting germination.

Gibberellins can stimulate seed germination in a large number of plant species (11), inducing germination of many light-requiring seeds and substituting for the effect of light. Results from the current experiments demonstrate that both light and GA_3 were required for germination of *A. griseum*, *A. maximowiczianum* and *A. triflorum* seeds, but not for *A. mandshuricum*. Thus, light cannot substitute for GA_3 during germination of the first three maples. However, the promotion of *A. mandschuricum* seed germination in the light without GA_3 demonstrates that basic physiological differences exist among these species.

Seed coats can prevent germination by restricting water flow (4,13), reducing oxygen uptake (1), preventing embryo enlargement (2,5,14), or by chemical inhibition (7,8). The current experiments showed that seed coat laceration of *A. max-*

imowiczianum seeds and treatment with GA_3 were insufficient to promote germination and that application of seed coat leachate to lettuce seeds did not suppress their germination. This suggests oxygen, water deficiency, or mechanical restriction to embryo expansion by the seed coat are probably of minor importance in the regulation of embryo dormancy; however, the seed coat appears to have an active role in preventing germination, Thus it appears that 3 sites of dormancy delay seed germination of *A. maximowiczianum*: 1) the ligneous pericarp surrounding the seed probably enforces mechanical restriction to embryo growth; 2) the seed coat; and 3) a physiologically dormant embryo.

Acknowledgement. This research was partially supported by the Horticultural Research Institute, Washington, D.C.

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RALPH SHUGERT: Have you tissue-cultured *A. griseum* and *A. maximowiczianum*.

DENNIS STIMART: We have tried them; however, both have a bacterial contaminant in the conducting vessels.

ESTABLISHING AND MAINTAINING A SEED ORCHARD

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The primary purpose for establishing seed orchards is the genetic improvement of plants that are usually propagated by seed. In addition to improved quality and quantities, seed produced in orchards greatly reduces the cost of collection and insures a more dependable, consistant source with known parentage.

Site selection. Northeast Missouri offers a favorable climate for a wide range of deciduous species. Although temperature extremes can range from a high of 115°F to a low of −22°F, the climate is favorable for plant growth, flowering and fruiting. I selected a site that was elevated above surrounding terrain because it offered good air drainage. This is desirable to reduce the danger of late frost damage to flowers and fruits. A deep, well-drained soil is preferred to produce healthy, vigorous growth which favors heavier seed production. Rolling terrain with strips of native tree growth can offer protection from strong winds and also serve as a barrier to eliminate unwanted cross pollination between closely related species.

Site preparation. An established bluegrass sod meadow, that had been improved by the addition of limestone and commerical fertilizer for a period of years, resulting in high organic build up, served as a planting site. Bluegrass is preferred above other grasses because it is easy to maintain and less competitive. This is particularly important in dry summers when it becomes dormant, thus increasing moisture available for the orchard plantings.

Plant selection. Plant selection is by far the most important aspect of seed orchard establishment. Many species take from a few years to as many as 20 years to produce seed so care must be exercised to make sure only true-to-name, top quality, disease-free, vigorous plants are used. Careful selection of the more vigorous individuals can result in marked genetic improvement of their progeny. Interplanting individuals of the same species from a different seed source with the same selection criteria is beneficial, and results in hybrid vigor and more pronounced genetic improvements.

Late flowering and heavy fruiting characteristics are important considerations when selecting planting stock. Care must be exercised to make sure species planted will produce viable seed in the selected location.

Planting. Actual planting is done primarily in the early spring, usually March and early April. Results have shown early planting improves survival and first year growth. To insure the earliest possible planting, preparation starts in the fall. A 3 foot wide band, the seed row, is treated with Paraquat in the fall, usually mid to late October. After sufficient kill is observed, the planting holes are marked. Holes are augered with a conventional tractor post hole auger, 18″ in diameter. Holes are dug in both fall and spring depending on soil conditions and general work load.

The distance between rows and plants was designed to provide a uniform system for ease of maintenance and efficiency while achieving maximum production. Maximum efficiency and production is realized by having a hedge row at fruiting age. Most flowering shrubs and small trees are planted 6 to 8 ft apart and larger growing trees are spaced 12 to 18 ft in the row. The distance between hedge rows varies from 18 to 24 ft depending on the species and the orchard maintenance plan.

Maintenance. Maintaining a seed orchard is costly but a must if it is to return its full potential. Weed control is accomplished by repeated sprayings of Paraquat, using a small off-set nozzle, to maintain the 3 foot planting band until such time that the hedge develops and dominates most of the weed competition. Mowing between rows is done as required to minimize competition and stress. A standard bushhog is used.

Roguing is important to remove undesirable or off type plants and to remove stray woody plants that invade exisiting hedge rows.

Pruning is an important management practice in a seed orchard. Old wood that loses seed-producing potential should be removed. Pruning care also facilitates seed collection by maintaining individual plants and hedge rows in a form and at a height that permits easy fruit harvest.

Fertilization of the seed orchard is practiced with two programs: For new plantings not yet producing fruit, a program designed for rapid vegetation growth is followed. Five hundred pounds of 24-12-12 per acre is broadcast over the entire area in winter followed by an individual application of ½ lbs of 24-12-12 per plant around the base of each plant in early summer. Fruiting plants receive the same number of pounds at the same time; however, the analysis is changed to 12-24-24 to promote fruiting instead of vegetative growth. Other maintenance demands, such as insect and disease control, and wild life damage, must be recognized and handled on a continuing basis.

A seed production program can have an important impact on a propagation program. Having known seed sources that will remain consistant from year to year is extremely important to a production program. Like any other production system, seed production must be treated as an important part of a total nursery growing program.

RALPH SHUGERT: Have you tried pruning 6 to 8 year old viburnums to the ground instead of your normal method of pruning about 50%?

ROBERT LOVELACE: I have not tried that because I felt I would get a quicker return to production my way.

RALPH SHUGERT: I would suggest that you take a few plants of *V. prunifolium* or *V. lantana* and make a comparison.

PROPAGATION AND GROWING OF THE CHINESE PISTACHE[1]

JOHN C. PAIR AND HOUCHANG KHATAMIAN[2]

Kansas State University
Horticulture Research Center
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Abstract. Germination percentages of Chinese pistache (*Pistacia chinensis* Bunge) seed ranged from 63 to 92 percent after 60 days stratification at 40°F (4°C) compared to 0 to 24 percent when sown directly without chilling. T-budding performed in August was more successful than in May. Softwood cuttings taken from juvenile shoots of seedlings and treated with 0, 5,000, 10,000 and 20,000 ppm IBA rooted at all hormone concentrations, but cuttings from older trees were unsuccessful.

REVIEW OF LITERATURE

The Chinese pistache (*Pistacia chinensis* Bunge) is an ornamental member of the Cashew family, Anacardiaceae (7). The name, pistachio, is generally reserved for the edible species, *P. vera*, which is not as hardy and is occasionally budded on rootstock of *P. chinensis* in California (1,8), but, more often, on *P. atlantica* or *P. terebinthus* (6). The Chinese species also has excellent heat and drought tolerance (2) and thrives in regions of long, hot summers but needs moderately cold winters to satisfy its chilling requirement (7). Chinese pistache is widely grown in California and has been suggested as a tree for desert and seaside plantings in the southwest and Gulf coast areas (1). It has proven hardy throughout Texas, Oklaho-

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[1] Contribution No 82-685-J, Kansas Agricultural Experiment Station, Kansas State University, Manhattan, 66506

[2] Research Horticulturist, Horticulture Research Center, Wichita, and Associate Professor, Department of Horticulture, Manhattan, respectively.

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ma, and into southern Kansas (zone 6 — USDA). Several trees occur on the Kansas State University campus in Manhattan (zone 5).

This highly ornamental tree is valued for its showy, autumn coloration of deep burgandy, red and eventually bright orange hues, particularly on drought-stressed, sandy sites. In addition to autumn colors, female trees exhibit attractive, multi-colored red, green and blue fruit. Fruitless, male trees are prized as street trees in the southwest because of their dense canopy. It is used extensively for residential, street and park planting (5). The cultivar 'Keith Davey' is reported to be excellent (1). Mature trees may reach a height of 20 meters in their native range in China but usually only 10 to 15 meters in Kansas.

Seed propagation is the most common method of growing this species in commercial nursery production. Fruit is harvested in late September or October. Red fruits are immature and only seed from purplish or bluish-green fruit will germinate (3). Seeds from superior trees are used by the Modesto, California, Park and Recreation Department in their selection of trees for improved type and vigor (5). Superior forms with outstanding fall color have been observed by the Wichita, Kansas, Park Department and attempts to propagate them vegetatively are currently underway.

Vegetative propagation is quite difficult and may explain why few cultivars are available in the trade. Several authors have noted difficulty with budding (3,5,6). Budding is best done in August with poorer results obtained during March and April, especially if the weather is cool and rainy (3). Hall (6) also reported difficulty in budding pistachio. However, Long (5) reported 96% success with shield budding, using buds that were not enlarged but with wood mature enough to be firm. Some California growers report better success when wood is removed from the bud (3).

Rooted cuttings would appear to be the easiest and most rapid propagation method for superior clones. Joley (3) reported only 5% rooting of cuttings under mist, but Lee and others (4) increased rooting of semi-hardwood cuttings from 28 to 70% using a pretreatment of 2N H_2SO_4 for 15 seconds, followed by a 20 second dip in 3,000 ppm IBA. This acid treatment was thought to stimulate rooting in the way that auxins affect cell wall loosening through enhanced acidity.

MATERIALS AND METHODS

Seed propagation. The mature, resinous fruit was collected as soon as ripe in October, removed from the loose panicles

and soaked for 2 or 3 days to allow the pulp to lightly ferment so it slipped free from the seed. Fruit were then macerated in a blender at a slow speed for a few seconds to separate pulp from seed. Heavier seed settled to the bottom and light seed and pulp were strained off and discarded.

In 1980 seed was obtained from several locations to test hardiness in zones 5 and 6. Sources included seed from Lubbock, Texas, and various locations in Kansas, including a tree in Manhattan. Some of the seed, obtained earlier, was stratified in November, some not until January, and germination of both was compared with seed sown directly in March without chilling. All seed was sown in trays in a commercial peat and vermiculite mix then placed in a cooler at 4°C until spring, when unchilled seed stored dry through the winter were also planted. All seeded flats were placed over bottom heat at approximately 27°C.

Vegetative propagation. Since fruiting might be a desirable characteristic of trees in a park or wildlife area, but less desirable in downtown street plantings or near patios, the ability to propagate male and female clones would be advantageous. Trees of superior form and outstanding fall color have been observed among both male and female trees in the Wichita area. Scionwood from two such trees was collected and budded on August 21, 1981 on seedling understock using standard T-budding techniques. Spring budding had been unsatisfactory in previous years. A few rootstocks were also budded in 1982 using a chip budding technique in an attempt to improve percent bud take.

Hardwood cuttings, approximately 10 to 12 cm long, from previous season's growth were taken in January of 1981 and 1982, treated with 0, 5,000, 10,000 and 20,000 ppm indolebutyric acid (IBA) and placed in a peat:perlite (30:70 v/v) medium with bottom heat. Cuttings were also wounded on both sides before dipping in IBA in 1982.

Softwood cuttings, approximately 10 to 15 cm long, were taken from tips of young, one-year-old seedlings because of the abundance of juvenile wood available and previous difficulty in rooting more mature cuttings. These tip cuttings were given a 10-sec dip in 0, 5,000, 10,000 or 20,000 ppm IBA dissolved in ethanol and water (50:50 v/v), stuck in coarse sand, and misted intermittently for 10 seconds every 6 minutes in an outdoor mist bed. Cuttings were taken on May 4 and June 15, 1981 and repeated on June 8, 1982. Since percent rooting did not increase above 10,000 ppm, the 20,000 ppm treatment was omitted in 1982 when cuttings were again taken from young, juvenile seedlings as well as a branched, two-year-old budded clone.

RESULTS AND DISCUSSION

Germination improved dramatically when seed was stratified (Table 1). From 63 to 92% of stratified seed germination compared with 0 to 24% for untreated seed. Joley (3), however, had reported that no pretreatment was necessary other than soaking for 2 to 3 hours prior to sowing, especially if spring-planted. We experienced some germination without stratification when using one-year-old seed in a separate study, but generally achieved more rapid and complete germination with stratified seed, usually within 15 days if given 6 weeks of chilling.

Table 1. Germination of *Pistacia chinensis* seed as affected by stratification.

Seed source	*Seed treatment	Date planted	Stratification time	**Date of emergence	Percent germination
Manhattan, Kansas	Stratified	11/26/79	110 days	3/31/80	82%
	Non-stratified	3/18/80	None	4/20/80	20
Waterloo, Kansas	Stratified	11/26/79	110 days	3/31/80	63
	Non-stratified	3/18/80	None	—	0
Wichita, Kansas	Stratified	1/17/80	60 days	3/31/80	92
	Non-stratified	3/18/80	None	4/25/80	1
Lubbock, Texas	Stratified	1/17/80	60 days	3/31/80	94
	Non-stratified	3/18/80	None	4/20/80	24

* Non-stratified seed stored dry at 40°F until planted.
** Stratified seed brought out of cooler on 3/18/80 and all seed given 50°F night and 80°F daytime temperature.

No appreciable differences were apparent among seed sources nor were there detectable differences in hardiness when seedlings were later grown at various locations in the state. Although considerable dieback occurred following −30°C on February 6, 1982, most seedlings recovered. It was formerly thought that the Manhattan, Kansas trees originated from a different part of China, but apparently they are not of a hardier strain.

Vegetative propagation has been quite difficult. T-budding in August was more successful than in May, which agrees with Joley (3), but even then, no more than 40% success was achieved in budding a superior male selection. Other clones and methods, including chip budding, were even less successful.

Softwood cuttings from seedlings appear quite promising as a means of asexually producing superior clones. As high as 92% rooting occurred using 5,000 ppm IBA, but considerable variability occurred among treatments and dates on which cuttings were taken (Table 2). Although percentage of cuttings

rooted did not increase appreciably above 5,000 ppm, root development appeared better at the higher IBA levels (Fig. 1). Although 56% of the juvenile cuttings rooted at 10,000 ppm, none of the cuttings from the two-year-old clone rooted sufficiently to survive transplanting. It appears that juvenility is very much a factor in the rooting of this species as, reported by Joley (3) and Lee (4).

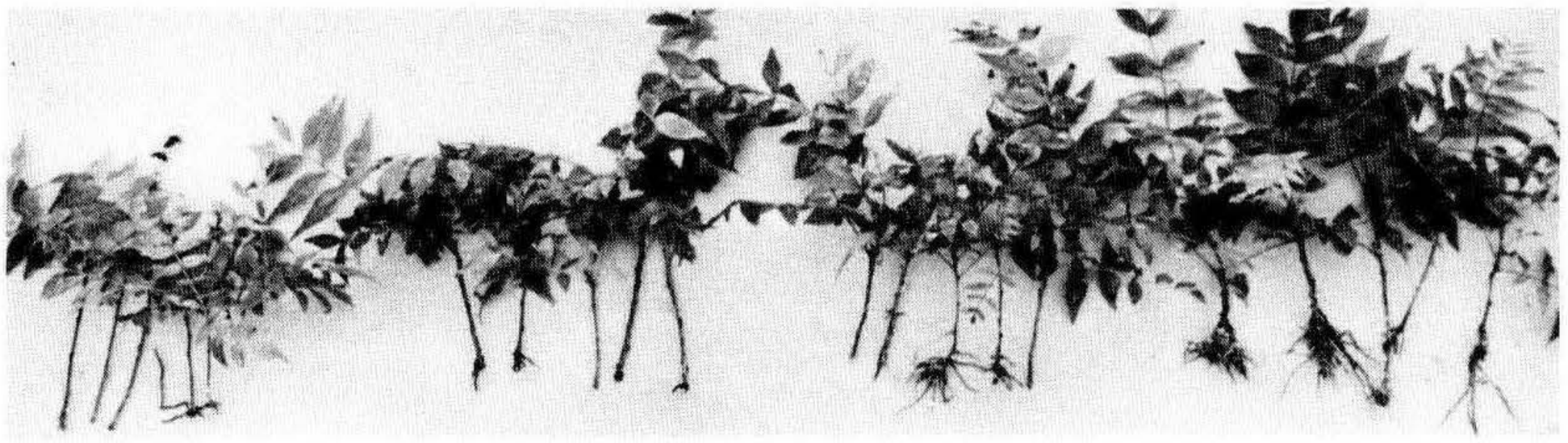

Figure 1. Rooting response of softwood cuttings of *Pistacia chinensis* treated with various rates of IBA.

A common practice in the Wichita Park Department is to sow seed outdoors in the fall with germination occurring the following spring. Seedlings, grown without disturbance in the cold frame, often attain a height of 60 to 75 cm the first summer. Plants are lifted bareroot in the fall, stored in moist packing and replanted in a nursery row where they become 2 to 2.5 meter whips the second year. Although the species does not handle well as a bareroot tree (6), no difficulty has been encountered with one or two-year-old seedlings if roots are kept moist in storage or if transplanted immediately after digging.

Table 2. Rooting of juvenile, softwood cuttings of *Pistacia chinensis* as affected by IBA concentration

IBA (conc. (ppm)	Percent rooting on dates: May 1981	June 1981	June 1982
0	20%	8%	28%
5,000	92	50	39
10,000	59	68	56
20,000	50	62	—

Container production is by far the most common method of handling Chinese pistache commercially. Their rapid growth makes the species very adaptable to container production. A 2 to 3 meter, branched tree can be produced in 2 to 3 years.

As propagation techniques continue to improve, it may become feasible to propagate Chinese pistache vegetatively to provide both male and female trees of superior growth habit and fall color. Other outstanding attributes such as drought tolerance and pest resistance should expand the desirability and use of this species in areas where it is not currently being grown.

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GLEN LUMIS: What type of root system do you get with *Pistachia chinensis* in the field?

JOHN PAIR: The container method is the most widely used method commercially. The root system will tap down if given the time. We have no problem transplanting 1 or 2 year old seedlings. We bare root them without any problems at this age but they are more difficult to bare root as an older tree.

PHILIP SOMMER: Is there a difference in growth habit between the male and female forms?

JOHN PAIR: No, however, the male form has a denser canopy which is more desirable.

HARRISON FLINT: Have you tried forcing juvenile shoots from root pieces?

JOHN PAIR: No, however, that is an excellent idea that we have not tried yet.

WAYNE LOVELACE: How did your trees survive the winter of 1981-82?

JOHN PAIR: On February 6, it went to −21°F for 4 to 5 hours. We rarely get below −10° to −15°F. Mature trees were not affected; however seedling trees died to the ground but

sprouted from the roots. Most of the seedlings survived.

JOE FOUCEK: How long does it take to obtain a saleable plant?

JOHN PAIR: A minimum of 3 years is required to make a 6 to 8 foot branched tree. For a specimen with a 1¼ to 1½ inch caliper it will take 5 to 6 years.

PHILIP SOMMER: Do you know any trees of this species growing in the Maryland or Pennsylvania area?

FRANK GOUIN: There is one at the U.S. National Arboretum in Washington, D.C.

DON SHADOW: I saw them growing in Tifton, Georgia, this past summer and they had no problems. They were approximately 20 years old.

JACK ALEXANDER: We have some seedlings at the Arnold Arboretum. Last year they were outside but mulched with pine boughs. We did get some tip dieback.

JOHN PAIR: You will often get tip dieback but it will disappear after the plants reach 10 years old. I am not recommending it for Zone 5 but am always surprised at how it survives outside its normal range.

CHARLES TAFT: You mentioned the use of 2 lbs of sulfur per cu. yd. of medium, is the right? Are you putting lime into that? What is the pH?

JOHN PAIR: Most mixes with wood chips:peat:sand (3:1:1) plus 2 lbs sulfur range in pH from 6.1 to 6.5. We do not see the need for lime in our wood chip work.

Tuesday Afternoon, December 14, 1982

The afternoon session was convened at 2:00 p.m. with Leonard Stoltz serving as Moderator.

PROPAGATION OF PLANT CULTIVARS WITH "YATSUBUSA" CHARACTERISTICS

WILLIAM N. VALAVANIS
International Bonsai Arboretum
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In Japan, horticulturists have promoted gardening with ornamentals into highly refined art forms involving both artistically trained dwarfed potted trees and Japanese gardens. To meet the demands of both bonsai and Japanese gardens horti-

sprouted from the roots. Most of the seedlings survived.

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Tuesday Afternoon, December 14, 1982

The afternoon session was convened at 2:00 p.m. with Leonard Stoltz serving as Moderator.

PROPAGATION OF PLANT CULTIVARS WITH "YATSUBUSA" CHARACTERISTICS

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In Japan, horticulturists have promoted gardening with ornamentals into highly refined art forms involving both artistically trained dwarfed potted trees and Japanese gardens. To meet the demands of both bonsai and Japanese gardens horti-

culturists have been searching for specialized plant material which will grow into "living sculpture". Japanese propagators, like Western propagators, are always searching for new or unusual plants material. Characteristics of special interest include: growth habits, size/shape, foliage coloring/shape, fruit coloring/shape, bark coloring/shape, cultural care, winter hardiness, and propagation ease. Select cultivars of numerous species have been propagated for the above reasons; however, the characteristics of growth habit are perhaps the most popular.

Definition and origin. Since the bonsai market is highly significant and economically important in the Japanese field of ornamental horticulture, many of the cultivars originally were selected and introduced for bonsai training. The Japanese term "yatsubusa" literally means "eight buds" or "cluster of eight buds". It is a rather loose term to describe plant cultivars which have the following characteristics: multiple buds, short internodes, small foliage, adventitious buds, hard wood, root rather easily, and dwarf in plant character. Generally speaking, such yatsubusa cultivars seem similar to witches' brooms and most tend to grow into tight little buns of foliage.

Although many of the yatsubusa cultivars originated as witches' brooms or their progeny from seedlings, many did not. Some originated as unusual seedlings, bud sports, and through natural hybridization. Generally the small seedlings a Western propagator might cull are just the plant a Japanese propagator seeks. Witches' brooms have even developed on bonsai specimens and have been propagated.

Table 1. Species which have "yatsubusa" characteristics.

Botanical Name	Common Name
Acer palmatum	Japanese maple
A. buergerianum	Trident maple
Chaenomeles japonica	Flowering quince
Chamaecyparis obtusa	Hinoki cypress
C. pisifera	Sawara cypress
Cryptomeria japonica	Japanese cryptomeria
Ilex serrata	Fine-tooth holly
Juniperus rigida	Needle juniper
Picea glehnii	Saghalin (Ezo) spruce
Pinus densiflora	Japanese red pine
P. parviflora	Japanese five-needle pine
P. thunbergiana	Japanese black pine
P. thunbergiana var. *corticosa*	Nishiki black or cork bark pine
Ulmus parvifolia	Chinese elm
Zelkova serrata	Japanese zelkova

Value. Plant material dwarf in character is excellent for bonsai training because of the small foliage and short internodes. However, its use does not have to end with bonsai

since Japanese gardens utilize plants which are usually confined to limited areas. Dwarf conifer gardens in the Western world and rock gardens are also two prime areas where yatsubusa type cultivars are of invaluable service. Since the size of the typical American garden is decreasing rather than increasing, plants which have a dwarf growth habit will become more important.

DESCRIPTION AND PROPAGATION OF SELECTED CULTIVARS

Generally, the same propagation techniques used in the common production of ornamentals can be used with yatsubusa cultivars. However, the bonsai propagator has special requirements necessary to produce plants for bonsai training. The methods and techniques described are used in the production of bonsai. They can be modified and simplified for the average gardener not interested in bonsai.

PINE

Pinus parviflora 'Kokonoe'. This cultivar of the common Japanese five-needle pine is popular for bonsai because of short, slightly twisted needles which are dark green, sometimes glaucous. When allowed to grow without pruning, shoots may extend to 10 inches or more. There are currently over 100 different cultivars of *P. parviflora*, many of them dwarf and in the yatsubusa grouping. The cultivar 'Zuisho', although a bit tender to cold, has superb growth habits for bonsai and develops a fat trunk in a very short period of time.

Pinus thunbergiana 'Banshoho'. Several different cultivars of Japanese black pine exist. However, 'Banshoho' is one of the best because of its growth habit. Although many other cultivars have shorter needles, they are too congested and tight to train into bonsai. This pine grafts quite easily and fills out into a globe-shaped dwarf mound in a few short years.

Pinus thunbergiana var. *corticosa* 'Kyokko'. Although this cultivar of the nishiki or cork-bark variant of Japanese black pine is not actually in the yatsubusa grouping, it is dwarf and slower growing than common nishiki black pine. The main feature is that it will root from cuttings taken in early spring. Several different yatsubusa cultivars do exist of nishiki black pine.

Yatsubusa pines are normally propagated by grafting onto a two-needle understock, including *P. parviflora*, which has five needles. The roots of two-needle pine *(P. thunbergiana)* tend to inhibit winter yellowing of foliage and can better withstand the occasionaly drying out in containers than do five-needle pines. The cultivar 'Zuisho', however, is not com-

patible with two-needle understock and must be grafted onto five-needle pine understock or rooted. The cut on the understock for scion insertion must be made low, directly into the crown of the plant, for bonsai training to avoid an obvious swelling graft union.

'Kyokko' nishiki black pine roots well, as does 'Fuji'. When rooted cuttings grow, the thick corky bark will develop on the roots as well as the trunk, thus avoiding a thin base which is objectionable for bonsai training. Cuttings of 'Kyokko' and 'Fuji' nishiki black pine are taken in early spring from the second growth of last year's shoots. Cuttings are taken with a straight cut at the basal end and treated with a 2% indolebutyric acid treatment in talc. Clean, sharp sand is used for a rooting medium and holes are pre-drilled for each cutting to avoid tearing of the delicate tissue. Cuttings are placed in a bright location, out of direct sun, and rotated to allow even light and air circulation.

Yatsubusa cultivars of pine are often air layered for bonsai training because they tend to develop roots completely around the trunk, a desirable characteristic. Although large quantities of stock plants are necessary when air layering pines, it is common practice in Japan where the bonsai market is big. Western propagators probably would not find it economically feasible to air layer yatsubusa pines since large numbers are difficult to produce. Air layers are generally made in spring. The best place to air layer a pine is directly below a whorled branch formation. Although a simple upward cut can be made to stimulate rooting, several techniques have been used for air layering bonsai. A complete ring of bark is sometimes taken from a branch to be air layered, and small flaps are made in the cuts to direct the new roots outwards. Long fiber sphagnum moss is placed under the flaps and around the area to be rooted. It is then covered with clear polyethylene until roots appear. Some cultivars of yatsubusa pine will root in one month's time. Older branches can take up to a year or two.

MAPLES

Acer palmatum 'Kiyo-hime'. This cultivar of Japanese maple is one of the finest for bonsai training because of its horizontal growth habit, ability to live in a container, and hardiness. The new growth in spring is colorful as is the traditional red of autumn.

Acer palmatum 'Koto-hime'. Although this yatsubusa cultivar has much smaller foliage than 'Kiyo-hime', it is not as desirable for bonsai because of its extreme upright growth habit. The plant is popular in rock gardens and other small areas.

Numerous other yatsubusa type cultivars exist which have red foliage, variegated foliage, and other growth habits. All are easy to graft onto *A. palmatum* understock in winter. Bonsai propagators root maples if possible to avoid graft unions. Semi-softwood cuttings taken in early summer will normally root within 6 to 8 weeks when treated with Hormodin No. 3 root-inducing hormone and placed under intermittent mist. Bonsai propagators are especially careful with the development of roots all around the base of the cutting. If roots do not develop all around the base, the plant is often discarded. Fine quality bonsai should have an even development of roots all around the trunk. 'Koto-hime' roots incredibly fast, sometimes in less than one week. Large diameter cuttings, up to 1½ inches, have even rooted and grown but later died in winter. Other yatsubusa maple cultivars which are easy to root include: 'Kashima', 'Chiba', 'Katsura', 'Murasaki-kiyo-hime', 'Beni-komachi', 'Beni-maiko' and 'Yama-hime'.

ELM AND ZELKOVA

Ulmus parvifolia 'Yatsubusa'. There are numerous "dwarf" Chinese elm cultivars, among them several yatsuba type selections. The common 'Yatsubusa' cultivar has very small but long leaves and an open growth habit. The dark green glossy leaves are attractive in spring and summer.

Ulmus parvifolia 'Yatsubusa-Hokkaido'. This is perhaps the smallest of all elms with foliage smaller than ¼ cm. Upon first glance, this elm looks like a fern! It roots quite easily but is difficult to grow. It seems to require a dormant period but sometimes dies in winter. Additional observation and experimentation is necessary. The bark develops a dark black color when the plant reaches about 10 years of age. This slow-growing elm would be ideal for an unusual container-grown plant but is too small for a garden planting. It is, in fact, too small for common size bonsai and is generally restricted to miniature bonsai under 6 inches in height.

Zelkova serrata 'Yatsubusa'. This is the only yatsubusa type cultivar I am aware of in the species. The leaves are quite tiny when container-grown but will enlarge when field grown. Specimens in the ground have reached 4 feet in height with limited pruning in 12 years. 'Yatsubusa' zelkova must be carefully watched because branches tend to grow with the common zelkova foliage.

Yatsubusa elms and zelkova are easy to root and much easier to overwinter than maple cuttings. The methods and techniques for rooting these plants are identical to those for the maples including large diameter cuttings.

Since dwarf plants are becoming more and more desirable for landscape and bonsai purposes, the yatsubusa cultivars will increase in popularity. Easy propagation and cultivation should make them profitable to grow. If more are available on the market, interest in bonsai would increase, since bonsai was the original purpose for selecting these jewels of the ornamental horticultural world.

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WILLIAM MERCHANT: My experience with a few persons who are bringing in pines from Japan is that they are bringing in 30 to 40 different types that all look the same when they are small. How can we be sure that Japanese propagators are not making switches without us knowing about it?

WILLIAM VALAVANIS: That does happen and you just have to grow them next to each other and observe them. Sometimes the differences are so subtle, like the twist of a needle, that an unskilled person would just not recognize it.

DON SHADOW: Do 'Beni-komachi', 'Beni-maiko', and similar cultivars root as well as 'Koto-hime' and 'Kiyo-hime'?

WILLIAM VALAVANIS: 'Beni-komachi' and 'Beni-maiko' will root.

DON SHADOW: What about the cultivar 'Katsura'; will it root?

WILLIAM VALAVANIS: Very easy to root.

DON SHADOW: So most of the yatsubusa type *Acer palmatum* cultivars root fairly easily?

WILLIAM VALAVANIS: Yes.

GRAFTING OF *PYRUS CALLERYANA* CULTIVARS[1]

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During my tenure as grower for Ozark Nurseries, the firm became interested in adding *Pyrus calleryana* 'Bradford' to the product line. For about 3 years we tried various methods of budding, none of which were successful. We tried "T" budding in spring, summer, and fall, as well as chip budding. None of these methods yielded greater than 15% takes.

Therefore, we decided to try whip and tongue grafting just as we were doing on *Malus* cultivars. The first year we tried this we obtained a 73% yield of salable trees and the next year a 75% yield. In addition, the grafted trees were straighter than budded ones.

During the last 2 years at Hill Country Nurseries we have grafted *Pyrus calleryana* cultivars but have not been as successful. In 1981, out of a total of 27,436 grafts, we obtained a summer live count of 62% on 'Bradford' and 43% on 'Aristocrat', P.P. #3192. In 1982, out of a total of 47,657 grafts, we obtained a summer live count of 49% on 'Bradford', 36% on 'Aristocrat', and 14% on 'Redspire', P.P. #3815. The extremely poor take in 1982 was due, in large part, to an unusually bad outbreak of fireblight in the late spring, just as the grafts were sprouting. This will be enlarged upon later.

In addition to the *Pyrus calleryana* cultivars previously mentioned, we are now establishing scion trees of the following: 'Autumn Blaze', P.P. #4591, 'Capital', *P. fauriei*, 'Select', and 'Whitehouse'. We believe that the popularity of 'Bradford' is declining and that some of the other *P. calleryana* cultivars will be in great demand to replace 'Bradford'.

MATERIALS AND METHODS

The understock used is no. 1 grade *Pyrus calleryana* seedlings. Scionwood is 1-year dormant wood, some cut from our own scion trees and some purchased. Scions are precut on a bandsaw to 7 in. in length. Grafts are made during January and February at the bench, using the common whip and tongue method. Care is taken to graft each seedling at the crown so that ½ of the graft union is in the root tissue. We believe this improves the take, although we plan to experiment with piece-root grafting. The graft union is wrapped with cloth grafting tape and the tip of the scion is dipped in rose wax to prevent

[1] Paper given by Stanley Foster

drying. The tape on the graft union is then coated with pure talc to prevent the grafts from sticking to each other when bundled. This is accomplished by sprinkling talc on a piece of paper and rolling the grafts through it. This saves much time when planting, as the grafts separate from each other freely when the bundles are broken. If this is not done, the grafting tape becomes gummy on the surface and the grafts stick tightly to each other. The grafts are grouped 50 per bundle using two heavy rubber bands, one on each end of the bundle. The bundles are then packed in used, wax-coated chicken boxes which are first lined with brown kraft paper. Cedar shingletoe is used for packing material to retain moisture. Two labels are placed inside each box and two tied on the outside. The labels show the quantity and cultivar in the box, as well as the date grafted. The boxes are then placed in cold storage at 36 to 40°F until planting time.

PLANTING

The best time to plant grafts is at peach blossom time. When there has been enough warm weather in the spring to make peach trees bloom, the ground is usually warm enough to plant grafts safely. *Pyrus* cultivars will sometimes start to grow in the graft boxes, so we try to plant them first, when peach blossoms are in the pink stage. At Tahlequah, Oklahoma, this is usually around March 25th to April 1st. The grafts are planted 10 in. apart in 54 in. rows in soil that has previously been prepared with deep tillage.

Care is taken to assure that the grafts are planted deep enough to cover the graft union with soil. This prevents injury that might otherwise be caused by late spring freezes. Behind the transplanter, a tractor with press wheels firms the soil on each row. Behind the press wheel tractor, a cultivator tractor throws soil up to the row. Rolling cultivator gangs on either side of the row are used for this because they crush any clods and leave a smooth, even ridge on the row.

FERTILIZATION

Fertilizer and lime are plowed in as the tillage is performed. The goal is to maintain a pH of between 5.5 and 6.5, with 6.0 considered ideal. Fertilizer is applied according to soil tests, with the goal being 160 lb N; 210 lb P; and 400 lb K per acre. It should be made clear that after the fertilizer is spread, the soil is disked 8 to 10 in. deep, followed by subsoiling 28 in. deep, followed by chisel plowing with 18 in. buzzard wings 12 to 14 in. deep. These high rates of fertilizer would probably not be safe if only shallow plowing were done. To bring the

soil up to the N, P, and K levels mentioned, this past spring we applied 1,000 lb of 15-15-20 per acre.

During the summer, if there is sufficient rainfall, three applications of nitrogen are broadcast at the rate of 50 lb N per acre, each application. We try to schedule these applications May 15, June 15, and July 15. This year, due to dry weather, only one application was made, about June 15.

After one summer's growth, we are able to harvest trees that range in size from 6 to 12 in. up to 5 to 6 ft., mostly in whips. In 1981, our one-year grafts ran 26%, 2 to 3 ft.; 20%, 3 to 4 ft.; and 10% 4 to 5 ft. This allowed us to turn these trees into cash less than 15 months after the grafts were made. We were even able to sell the smaller trees as well. This is an important factor to a new firm that needs to generate cash.

HERBICIDES

Immediately after planting operations, Treflan 5G is applied at the rate of 40 lbs. per acre. This material is broadcast with a fertilizer spreader and is NOT incorporated. Some hand hoeing is done to control weeds not controlled by the herbicide.

FIREBLIGHT

For the last 2 years, fireblight has been a major problem on the young grafts from the time they begin to leaf out. The problem was especially bad in 1982, and is the major reason for our poor grafting success that year. As soon as the grafts began to leaf out, we began spraying twice per week, alternating between Agristrep at 8 oz. per 100 gal. and Citcop 4E at 3 qts. per 100 gal. This did not give very satisfactory results, so we increased the spray schedule to 3 times per week. Also, at the suggestion of our extension pathologist, we added 2 other spray materials to our program. For one of our applications we used Agristrep at 8 oz per 100 gal, combined with Kocide 101 at 2 lbs per 100 gal. On alternating applications we used Citcop 4E at 3 qts. per 100 gal combined with Dithane M-45 at 2 lb per 100 gal. This seemed to be more effective than our previous program.

Fireblight does not appear to attack the older trees in our scion blocks, only the new grafts. The first 2 years that I grafted 'Bradford' pear at Ozark Nurseries, fireblight did not seem to be a problem. On those grafts, the entire scion instead of just the tip, was dipped in rose wax down to, but not including, the graft tape. Could the wax have "smothered" the fireblight organisms that might have been present on the scionwood? We are going to try this again to see if it helps.

CROWN GALL

When we dug our crop in 1981, we found that 15% of the trees had crown gall on them. This was another problem that we had not encountered in our previous experience with 'Bradford' pear. In 1982 we dipped our grafts in "Agrobacterium radtobacter 84", a biological crown gall control. At this writing, we have not yet dug our trees, so we do not know if it will prove effective. If it does not, we will have to fumigate our soil with Vapam the summer before we plant.

DON SHADOW: How wet is the shingletoe?

STANLEY FOSTER: We put it in a barrel and fill it with water until it covers the shingletoe. When we are ready to pack we pull it out and squeeze every bit of water out we can.

PROPAGATION OF TREE PEONIES

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Propagation of tree peonies by grafting is highly successful on a commercial basis. Tree peonies, which are not trees but shrubs, can be divided into 2 main types. The first to be developed were the moutans or Japanese tree peonies. These belong to the species *Paeonia suffruticosa* which is native to Northwestern China and Tibet. For several centuries the Chinese selected and improved upon the wild plants. In about the eighth century A.D., the cultivated tree peonies were taken to Japan, probably by Buddhist monks. The Japanese, through years of cultivation, improved upon them and produced a race with single and airy semidouble flowers in a spectacular color range unsurpassed by any other flower.

The second type of tree peony and perhaps the one with the greatest future is the hybrids produced by crossing the Japanese cultivars onto the small yellow species, *P. lutea*, also native to China. This hybridizing was done in this country by Prof. Saunders of New York during the later part of the 1920's and for 3 decades thereafter. His work was continued by Nassos Daphnis of the Gratwick Estate, also in New York, and more recently by other hybridizers. These cultivars are just now becoming available to the gardening public.

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The Japanese have become experts at the propagation of their cultivars by grafting. They export to this country, each fall, many thousands of one- and two-year-old plants.

It has been most difficult to import cultivars that are true to name from Japan and one generally receives an assortment of cultivars under a single name. Because of this it has become advantageous to propagate true-to-name plants in this country.

ROOTSTOCKS FOR TREE PEONY GRAFTING

Herbaceous as well as tree peonies can be used as a source of rootstocks. Most ideal are roots from the same cultivar as the scion to be grafted. Any cultivar of tree peony root can be used but this may lead to suckering with the result that the plants will then be mislabeled.

Other useful roots are those from herbaceous hybrids. Some hybrids, such as, 'Cytherea', 'Ludovica', 'Paula Fay' and other *P. lobata*[1] hybrids, form adventitious buds on root pieces so are not good because the resulting suckers may interfere with scion development. We have successfully used such roots but suckers did form on the rootstocks.

Several herbaceous hybrids do not form adventitious buds on the root pieces and are very satisfactory for rootstocks. Examples of this group are: 'Early Windflower', 'Red Charm', 'Requiem', and 'White Innocence'. These cultivars produce ample roots that readily form callus tissue which is necessary for uniting rootstock and scion. They are somewhat disease resistant adding further to their value as rootstocks.

Paeonia lacatiflora cultivars are the most important source of rootstocks. Most of our grafting is done with this species. Several of these cultivars produce an abundance of roots of the ideal size (½ to 1 inch in diameter) and show disease resistance as well. Examples of these are 'Mons. Jules Elie', 'Charles White', and 'Krinkled White'.

Rootstocks are prepare in the following manner: The clumps are dug with most of the roots attached and the soil is removed by washing with water. The terminal portions of the roots are cut off. Some of the longer roots can be cut into 4 inch sections thus increasing the number of rootstocks obtained from the clump. A good clump should produce at least 20 pieces. The rootstocks can be dug as needed or stored in slightly moistened sphagnum or other suitable media. Do not use roots from clumps that show any of the serious peony diseases, such as phytophthora or botrytis, or nematodes.

PRODUCING SCIONS FOR GRAFTING

It is necessary to maintain a block of stock plants to provide the scions for grafting. Our display garden contains about

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[1] Bot. Ed. Note: *P. lobata* is a confused name applied to several species.

200 specimen plants, all properly labeled and maintained in a vigorous, healthy condition. This garden serves two purposes. First, it is a garden in which all the tree peony cultivars propagated by us can be viewed and studied. They can be compared and tested under our severe northern climate. Secondly, it is a source of scions for propagation.

The plants are maintained in a relatively weed free condition by the use of wood bark mulch and hand hoeing. We have used some herbicides but they must be used very cautiously.

The scions are gathered daily as needed. We do not store them for more than a day or two. If stored longer they are placed in plastic bags, labeled, and kept cool.

Long, vigorous stems of the current season's growth are selected. The leaves are removed, leaving about an inch of petiole on the scion. The stems are cut into sections containing at least 2 buds. Scions containing a single bud can be used but 2 buds are preferred.

GRAFTING TECHNIQUES

Grafting operations are begun as soon as the buds are well formed on the scion wood. In our area the plants are ready by August first each year. The Japanese tree peonies are the first to form buds and are thus grafted before the *P. lutea* hybrids. Since the grafts are planted soon after being made, the grafting operations are terminated in this area about the first week of September. The grafts must callus after planting and before cold weather.

To prepare the grafts a clean cutting surface is needed. We use a clean piece of cardboard. Sanitation is very important in the grafting room.

The triangular graft is the one used almost exclusively by us. A triangular wedge, which includes the scion bud results from two downward cuts ending in a point at the base of the scion. A notch of exactly equal size is cut from the top and down the side of the rootstock. The scion is fitted into the notch, in which the sides are smooth and in close contact. The cambium layer of the scion should line up with that of the root. The scion and rootstock are bound firmly in place by wrapping the joined parts with Miracle Tie plastic tape to exclude water and pathogenic organisms which could be present in the soil.

The completed grafts are labeled and placed in a plastic bag. A small amount of barely moist sphagnum moss is added to the bags to maintain adequate moisture as well as to absorb excess moisture due to sweating.

PLANTING THE GRAFTS

We try to plant the grafts within a day or two after they are made. Preparation of the planting beds is begun about 3 months before they are used. An area is selected on a gentle slope to assure excellent drainage. The beds are cultivated to kill weeds including grasses. Slow-release fertilizer such as Mag-Amp or Osmocote is added. Generous amounts of well decayed manure and peat improves the soil texture. These specially prepared beds are 10 ft wide and as long as needed. The rows are marked across the width of the bed. The rows are spaced 2 ft apart. The grafts are planted in an upright position, with the buds covered with 2 in. of soil. They are spaced 6 in. apart in the 10 ft. long rows.

As the bed is planted it is leveled and then covered with 2 inches of wood bark chips. A sheet of black plastic is placed over the wood chips to prevent weed growth. About November first the black plastic is covered with a foot of straw or old hay to further protect against alternate freezing and thawing which would injure the graft unions.

Early in the spring, about the time the crocus bloom, the hay or straw and black plastic is removed. The grafts start to grow early in the spring following their planting. Weeds are carefully controlled and the plants watered as needed. The plants are dug at the end of the second or third growing season and shipped to customers.

SEED GERMINATION

Tree peony seeds have a double dormancy. We plant the seeds in pots containing soil. The pots are placed in plastic bags to retain moisture and held at 65° to 75°F for 3 months. During this time the hypocotyl/root axis grows.

The pots are next moved to cold storage (42°F) for 3 mo. to break epicotyl dormancy. After cold storage the pots are moved to warm conditions (60°F), with lights, for epicotyl growth. Four or 5 years are required for the first bloom. At this time the best are selected for testing and first propagation.

Japanese cultivars are fertile; however, the F_1 *P. lutea* hybrids are nearly sterile. The F_2 may be fertile at the tetraploid level.

GRAFTING *FAGUS SYLVATICA* CULTIVARS

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Careful selection of both the scionwood and rootstock is very important. The condition of both must be carefully monitored for nearly a year prior to the actual grafting. Scion wood should be growing vigorously, free from disease, and true to name. Grafting understock should be a 1 or 2 year old seedling, potted in the spring of the year it is to be grafted. Understock for *Fagus sylvatica* at Weston Nursuries is purchased from a seedling grower, potted, and grown in a cold frame until grafting time in the winter. We pot the understock into 3 inch black plastic pots. Our soil mix is made from composted leaves, peat, and perlite in equal parts. The understock is potted no deeper than it was growing in the ground, and the soil is pressed firmly to eliminate air pockets. The potted understock are placed in plastic trays that hold 16 pots, taken to a cold frame, set deeply into a sand bed and thoroughly watered. The plants in the cold frames are given the normal feeding and weed control that we use for all plants in the frames. The understock are brought inside in the late fall after leaf fall and before they freeze into the sand. The plants are placed in a 40 to 50 foot glasshouse double covered with poly. We leave the pots in the trays and set the trays on 2 inches of moist peat moss.

Scions for grafting are cut no earlier than the day before the grafts are made to ensure the freshest possible condition. The scions should be cut long enough to contain several buds with the graft made in the smooth area below the lower bud. Ideally, the scion and the understock are of the same diameter; however, matching the cambium on a least one side is imperative. Grafting cuts on the understock and the scion should be made exactly the same way in a whip and tongue graft. First a long, smooth sloping cut is made 1 to 2½ in. long. The shorter the cut, the smaller the diameter of the material to be grafted. The first cut should be made with a single stroke of a very sharp knife. A reverse cut is made on each of these cut surfaces. The cut is started downward at a point about one third of the distance from the tip and should be one half the length of the first cut. The second cut should not split the grain but follow under the first cut, in a parallel manner to obtain a smooth fitting graft. The stock and the scion are then slipped together with the tongues interlocking. As was mentioned above, it is essential that at least one side of the cambiums match and if possible both sides should match with the lower

tip not overhang the understock. The graft is held together securely with a grafting elastic that is stretched slightly and not twisted when wrapping it around the graft.

Newly grafted plants are put back into the plastic trays and placed back on the peat moss in the bench. Humidity is maintained high in the greenhouse by keeping the paths damp and syringing the grafts several times a day. *Fagus* grafts are kept in the greenhouse with the night temperature set at 60°F. The leaves are allowed to expand fully on the scion and callus tissue will be visible in several weeks. Cut back the understock about one half the first time with the final cutting back and removal of the elastic not done until just before moving the grafts to the cold frames for the hardening off process. *Fagus* grafts remain in the cold frames for several weeks prior to planting out. We apply shading over the grafts, in both the cold frame and the field to protect the leaves from burning.

DON SHADOW: What size are the deep pots that you use?

KATHY FREELAND: About 3 × 3½ inches.

DON SHADOW: Once you cut the understock off, do you wax the cut with anything?

KATHY FREELAND: No, just cut them back and put them in the cold frame.

JOERG LEISS: Do you have any problems with sunburn?

KATHY FREELAND: Sometimes, but we shade the scions in the coldframe and when planted out.

JOERG LEISS: Have you had any incompatibility problems?

KATHY FREELAND: No.

JOERG LEISS: The purple weeping form does have such problems.

PROPAGATION OF ORNAMENTAL GRASSES

RICHARD A. SIMON

Bluemount Nurseries, Inc.
Monkton, Maryland 21111

My experience is that most horticulturists do not know much about ornamental grasses. It is a group of plants that only recently has begun to gain popularity.

Bluemount Nurseries is a wholesale nursery specializing in perennials, unusual ground covers, wildflowers, ferns, ornamental grasses, and bamboo. We supply plants to garden centers and landscape contractors in seven states. Our nursery

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was started by my father in 1926 who had his early training as a grower of perennials for the original Moon's Nurseries in Morrisville, Pa. In 1960 we brought to our nursery from Germany a young nursery worker who later became a friend of a German-born landscape architect in Baltimore. They both saw the potential of ornamental grasses in this country after having had experience with them in Europe. We began to import grasses in the early 1960's and have continued to expand our collection since then.

An ornamental grass can be a very dwarf plant like blue fescue, *Festuca ovina var. glauca*, or a 16 foot giant like the giant miscanthus, *Miscanthus floridulus*, sometimes mistaken for *M. sinensis*, or *M. sacchariflorus*. Ornamental grasses have much to offer in the landscape. They have a distinct texture. Many have very lovely and spectacular plumes. Many have very strong winter interest. Most are very hardy, dependable, long-lived plants and they are dependably pest-free. They can be used for screening purposes, for mass plantings, or as accent plants. For me, it is important that an ornamental grass be a clump grower as opposed to a "runner" that can create problems in the garden. Some of the ornamental grasses do have rhizomes, such as *Spartina pectinata aureomarginata (Syn: S. michauxiana)* (prairie cord grass), or *Phalaris arundinacea var. picta* (ribbon grass or reed canary grass), and you need to know how to use them.

I wish to clarify at this point a problem that we all have when we use common names. There is confusion among grass names, especially with the name pampas grass. The true pampas grass is *Cortaderia selloana* and it is a native of Argentina. It has, in my opinion, the showiest of all plumes. You see it planted in Florida and north to Norfolk, Virginia, and in California. My experience is that it is not hardy in the Washington-Baltimore area, so we don't grow it, and I discourage people from planting it. Incidently, if anyone knows of a plant which would survive in our area, I would like to know about it. We find that many people in our area confuse pampas grass with *Miscanthus*, or silver grass. We get a lot of inquiries about pampas grass and I always ask for a description so I know how to advise them.

We propagate most of our grass cultivars by division, although we do propagate a few by seed. For division, we have to have adequate stock plants in order to generate the quantities we need because one needs more stocks for growing plants by division than stock plants for collecting seed. We plant the grasses grown by division in nursery beds 4 ft. wide by 50 ft. long. The spacing in the beds depends on the ultimate size of the cultivar planted. We make the beds with a 48 in. wide

rototiller, add lime if necessary, and fertilizer. We plant divisions, or potted plants, and then mulch the planted bed with a hardwood bark mulch, 3 in. deep. The plants are watered, then given occasional irrigations and two or three supplemental fertilizings during the summer months.

We divide our grasses in March and early April, when the plants are still dormant. It is possible to divide them after growth starts, but more attention needs to be given to the plants if the culms (stems) and leaves are already forming. We pot divisions in various sized containers, depending on whether they are for immediate sale or future stock. Generally, we do not plant bareroot divisions out for stock, not because you cannot but because we are so rushed in late March and April that we concentrate on the dividing and potting. Once the nursery selling season is over, then we plant the new stock plants out in the beds. Another source of stock plants for us is the individual clumps of grasses that are scattered around the nursery for display purposes.

Since the grasses we grow by division have various types of root systems, I will group the various types by whether we use a knife, a hatchet, or a saw, to separate the plants. We use a hard pruning saw for dividing *Arundo donax* (giant reed) and the giant miscanthus (*Miscanthus floridulis*). We use a hatchet for the other *Miscanthus* varieties, including *M. sinensis*, *M. sinensis gracillimus*; *M. sinensis variegata*; and *M. sinensis 'Zebrinus.'* We also use a hatchet on *Panicum virgatum* (switch grass), *Calamagrostis epigios var. hortorum* (feather reed grass), *Erianthus ravennae* (plume or ravenna grass), *Spartina* pectinata (prairie cord grass), *Chasmanthium latifolium* (Syn.: *Uniola latifolia*) (northern sea oats) and *Pennisetum alopecuroides* (fountain grass or Chinese pennisetum). A sharp knife can be used for *Halictotrichon sempervirens* (Syn.: *Avena sempervirens*) (ornamental oats), *Festuca ovina var. glauca* (blue fescue), *Deschampsia caespitosa* (tufted hair grass), *Carex* spp. (sedges) and *Phalaris arundinacea picta* (ribbon grass).

Techniques used to divide grasses are:

1. Dig grasses with heavy spade — roots are very tenacious.
2. Shake off as much soil as possible in the bed.
3. Shake more soil off as you work with it.
4. Divide plant in half.
5. Continue to redivide until you get the size plants you want, either for sale or for stock.
6. Save all bits and pieces for stock.
7. Some plants like *Pennisetum*, *Deschampsia*, and *Festuca* can be divided down to a single shoot with roots.

8. In some cases, if a shoot doesn't have a root connected we still stick the shoot in sand under mist; it roots readily. We only do this if we really need every available piece in order to build up stocks quickly, or if we do not have many stock plants to start with. We did this with *Calamagarostis* in the beginning.

We do grow two species of grasses by seed: *Pennisetum alopecuroides* and *Chasmanthium latifolium* (Syn.: *Uniola latifolia*. We sow *Pennisetum* in the winter in seed trays in the greenhouse and the seeds germinate quite readily, but one must be careful with mice eating the sown seed. We sow *Chasmanthium* outside in December in a seed frame and it germinates in the spring. One of the reasons we don't grow more species by seed is that we have not been able to successfully do so. Some do not seem to set seed in our area. These include *Arundo donax* (giant reed), *Miscnathus floridulus* (giant miscanthus), and *Erianthus ravennae* (ravenna or plume grass). *Miscanthus sinensis* must set seed in our area as it naturalizes here, but we have not successfully grown it from seed. I suspect the *Miscanthus* varieties will not come true from seed.

The grasses I have referred to are ones that we have in production and for sale. We have other species we are building stocks for, and some are still in the hardiness testing stages. There are many potential kinds of ornamental grasses that have merit besides the ones we grow, and we are actively trying to locate these for trial.

The ornamental grasses are an amazing group of plants but not many will grow like the giant miscanthus (*Miscanthus floridulus*) — 16 feet in one season.

No other plant, except bamboo, creates a rustling sound at the slightest breeze. Their plumes make wonderful dried arrangements and against a clear blue sky are an unforgetable sight.

JOHN PAIR: Which of the *Pennisetum* species do you consider perennial?

RICHARD SIMON: We grow *P. alopecuroides* as a perennial.

JOHN PAIR: What about *P. setaceum* (Syn.: *P. ruppellii*)?

RICHARD SIMON: It is perennial but it is not hardy. It is one that grows about 4 ft high with beautiful red foliage. It is a wonderful bedding plant and the city of Baltimore uses it as a bedding plant.

RUTH KVAALEN: Are there any of these clump grasses that have to be divided because they get too big.?

RICHARD SIMON: Yes, that is particularly true of the *Miscanthus* species. I have seen some that are maybe 15 ft in

diameter that are hollow in the center. They need rejuvenation when they get to be about 5 ft in diameter.

PROPAGATION OF TOP-GRAFTED STANDARD TREES

EDMUND V. MEZITT

Weston Nurseries, Inc.
Hopkinton, Massachusetts 01748

Nurserymen have been engaged in the production of top-grafted standards for many years. For example, the camperdown elm, *Catalpa bungei*, and more recently weeping forms of cherry, laburnum, and caragana. These are only a few of many kinds of deciduous trees grown in quantity by wholesale producers. This paper will deal mostly with top grafting of plants that are not produced commercially at this time, so far as I know, and are evergreen in nature.

The circumstances that led to our production of top-grafted standards was the availability of greenhouse space during the first week in March when plants forced for various flower shows are removed for the spring exhibits. Our winter greenhouse grafting is completed by this time, and we have personnel and space available for several weeks before our spring season begins. We have been doing this for about 20 years, and we are finding a good market for some of these plants.

The cultivars we choose for top grafting are mostly dwarf, slow-growing, or weeping. When grafted on standards, they grow rapidly undoubtedly because of the large and strong root system they have acquired. Their ultimate size, however, is still small, and the resulting plant becomes ideal as a feature in a small garden or patio.

We containerize, or ball and burlap in plastic burlap the understock to be grafted during the summer or fall and store them in our packing shed and lean-to unheated greenhouse. While in storage branches are pruned out leaving only the limbs on which grafts will be made. After the plants are moved into the greenhouse in March, we start grafting immediately. During the last few years we have also been grafting earlier in the lean-to greenhouse after increasing the heat.

Grafting is mostly a side-cleft graft with the scion placed on the top side of the limb 2 to 6 inches from the trunk. We tie with rubber grafting strips and then seal the graft with grafting wax. Some difficulties occurs when removing the strips later on during the summer because of the wax, but we feel that waxing is necessary to insure the take. Pines generally bleed enough to seal the wound and do not require waxing as a rule.

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Humidity must be supplied either mechanically or by hand sprinkling for up to 3 weeks after grafting when the scion should be showing signs of growth. Our success is partially assured by the fact that we graft a number of limbs so that the failure of take on a few grafts on any tree still leaves enough top-grafts to make a good plant.

One of the most important procedures for successful production of greenhouse top-grafted plants is the attention given during moving them outdoors. This is done in June, preferably in cloudy or rainy weather. They are immediately shaded and misted for several days. We heal them in with sawdust in shaded woods where they are cared for by our container department. The plants are left there until the following spring when those that have survived are planted out in nursery rows.

We graft *Chamaecyparis* cultivars on *Thuja occidentalis* 'Filiformis' (Syn.: 'Douglasi'). In a few years the 5 to 6 limb grafts grow together to form a dense, mature dwarf tree many years ahead of a conventionally-grafted plant.

Pinus mugo 'Mops', or any dwarf cultivar, grafted on *P. nigra* makes a fine specimen bonsai-type head if pruned out to show its beautiful branching. Clippings that are pruned from the tree supply us with a good source of cuttings if done during the fall of the year.

Dwarf selections of *Pinus strobus* and *P. parviflora* are our most popular top-grafted standards. During their younger years the pompon effect is interesting, but not very pleasing to the discerning homeowner. Pruning out the branches that grow downward and all the twiggy growth, as the Japanese do with their pines, exposes the beautiful limbs and creates a picturesque tree. The grafts are exposed in this pruning process, but are hardly visible even to the discerning eye.

Pinus parviflora 'Hillieri' is a very slow-growing small-needled gem. Where it is grafted on several branches of *P. strobus* it soon becomes a small mature tree many years ahead of a normal grafted tree. The accelerated growth of this grafted tree also supplies plenty of scions for future grafts.

Weeping plants have more uses in the landscape when they are top-grafted. We graft *P. stobus* 'Pendula' on standards up to 10 feet. This gives the finished plant a good straight stem that does not need staking. *Tsuga canadensis* 'Pendula' and 'Cole's Prostrate' grow quite rapidly into beautiful landscape specimens when top-grafted on *Tsuga canadensis*.

Junipers are plants I know are being top-grafted, at least in California nurseries, but cultivars such as *J. procumbens*

'Nana' would probably be difficult to ship. We find *J. virginiana* 'Globosa' very good for top grafting, but are having difficulties with the weeping forms, such as *J. horizontalis* 'Wiltonii (Syn.: 'Blue Rug') and 'Douglasi', as they grow too fast and splash onto the ground.

Taxus cuspidata is a good standard for dwarf cultivars such as *T. baccata* 'Adpressa Fowle'.

Rhododendron kaempferi, pruned to a single stem, is a good stock for *R. obtusum* or *R. kiusianum* cultivars. I have seen cultivars that would be tender for us grafted as standards on the West Coast, but we can enjoy those which are hardy in the northeast for use as standards.

Some deciduous plants we find very popular are *Syringa patula* (Syn.: *Palibiniana*) grafted on *S. reticulata*, *Cornus florida* 'Pygmya' and 'Pendula' grafted on *C. florida*, and *C. kousa* 'Pendula' grafted on *C. kousa*.

Perhaps the most popular fast-growing product of the top-grafted standards is *Cotoneaster adpressus* var. *praecox* or *C. apiculatus* grafted on *Crataegus phaenopyrum*.

As you have probably observed, there is considerable cost involved both in time and labor in producing these top-grafted standards. We charge a good price for them but cannot compute our costs with any degree of accuracy. We probably do not make much of a profit, if any, on them. But we feel that the challenge of growing something different for the more discriminating customer gives us a considerable advantage over our competition.

DANIEL HARTMANN: Could you recommend any other understock for *Cotoneaster* standards than hawthorn?

ED MEZITT: I hesitate because other understocks have problems.

VOICE: What was the name of the variegated euonymous you use?

ED MEZITT: 'Sheridan's Gold'.

HARRISON FLINT: Cotoneasters can be grafted to *Sorbus* understock.

PETER GIRARD: We have used *Sorbus* and it is compatible; however, we try to use hawthorn.

DAVE BAKKER: Has anyone used parafilm instead of wax to cover grafts?

ED MEZITT: Yes, I was in Australia this past month and visited Arnold Teese's nursery. He does all his grafting using parafilm. We have some on hand and we are going to try it. In

fact, he just side veneer grafts everything. He says that the side veneer is better than the cleft.

DON SHADOW: Have you ever grafted *Chaenomeles* on Washington hawthorn or calleryana pear?

ED MEZITT: No, but we are going to do some this winter. I grafted some on *Malus* 10 years ago but they are just struggling.

DON SHADOW: I grafted 'Texas Scarlet' and a contorted form on Washington hawthorn this past year and so far they look good. I grafted *Chaenomeles* on *Pyrus calleryana* seedlings but the understock became so big that it overgrew the scion and it died.

TOM McCLOUD: Peter Girard introduced me to a yellow latex to use in place of grafting wax. I was quite impressed with it. What is the name of that, Pete?

PETER GIRARD: It has a plastic base and it is called Gold Seal out of Washington State. We find it better than grafting wax, particularly with *Acer* species which get scald if the wax is too hot. It is put on cold and is very easy to get off.

DON SHADOW: I would like to comment on the Gold Seal. I think it comes in red, green, and yellow, and I think it is terrible. I used it on *Acer palmatum* cultivars and will never use it again because when peeling off the latex the bark and cambium came with it. I use a black asphalt emulsion material called Tree Heal that is applied at room temperature. It works better because the black color absorbs heat and the union heals better and growth starts faster.

PETER GIRARD: We discontinued the use of the asphalt emulsion because we found that it can leach into the graft. A lot of times if you get a graft that fails, and take them apart, you will find that the asphalt has leached in. The Gold Seal is made especially for grafting. We have had wonderful success with it and have used it for 2 years.

JOERG LEISS: Use Gold Seal in above freezing temperatures because it will peel off.

JACK ALEXANDER: I would like to comment on parafilm. We have been using it over budding strips for 2 years and like it very much. To remove you need to make only one vertical slice.

DAVE BAKKER: Wrap the parafilm around with a little tension, then dip the graft into paraffin wax. I feel that you can get away without cutting it off because it just streches and the buds pop through.

WILLIAM VANDERKRUK: We cover our grafts with a plastic bag rather than wax. After the plastic bag is removed

the elastic will deteriorate in the sunlight.

VIRGIL DRAKE: What is the understock for camperdown elm. Can it be Chinese or Siberian elm?

JOERG LEISS: If you use Chinese elm you get a big bowl. We use a hybrid and I am not sure of the parents. There is no incompatibility problem.

Thursday Morning, December 16, 1982

The Thursday morning session covened at 8:00 a.m. with Charles Tosovsky serving as Moderator.

ROOTING *EUONYMUS* CUTTINGS OUTDOORS UNDER THERMO-BLANKETS OR UNDER GREENHOUSE INTERMITTENT MIST USING PROPAGATING MEDIA WITH AND WITHOUT COMPOSTED SEWAGE SLUDGE[1]

RICK J. LEWANDOWSKI[2] AND F.R. GOUIN

Department of Horiculture
University of Maryland
College Park, Maryland 20742

Abstract. Microfoam thermo-blankets can be used throughout the year to root *Euonymus kiautschovica* Leos. 'Sieboldiana'[3] cuttings outdoors. Microfoam thermo-blankets help in maintaining cooler temperatures around the cuttings in the summer than white copolymer alone. Euonymus cuttings taken in March will root equally as well under microfoam covered with either clear or white copolymer with or without bottom heat. However, cuttings propagated in the fall rooted significantly better under intermittent mist than similar cuttings stuck under the thermo-blankets. Compost with other materials made from lime dewatered sewage sludge and woodchips blended at ⅓ by volume significantly reduced rooting and survival as compared to cuttings rooted and grown in equal parts by volume of milled pine bark and expanded shale.

Since the 1950s propagation of cuttings under intermittent mist has become widely accepted. However, skyrocketing production costs and inherent problems with intermittent mist propagation (5,6) have led some growers to seek alternatives.

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[1] Received for publication on December 16, 1982. Scientific Article No. A-3364, Contribution No. 6436 of the Maryland Agricultural Experiment Station. This project was partially funded through a Cooperative Research Agreement between the Department of Horticulture, University of Maryland and the Biological Waste Management and Organic Resources Laboratory, BARC, USDA, Beltsville, MD. The mention of a trademark, proprietary product, or vendor does not constitute as an endorsement by the University of Marland.

[2] Former Graduate Research Assistant. Present address: Morris Arboretum, 9414 Meadowbrook Avenue, Philadelphia, PA 19118. This paper is a portion of a thesis by the senior author in partial fulfillment of requirements for the M.S. degree.

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For years propagation of certain species was done under glass, in cold frames, under lath, or beneath polythylene chambers in the fall, spring, and summer. More recently, studies by Gouin (2) have shown that cuttings can be directly rooted year round into containers outdoors beneath thermo-blankets.

The advantages of direct rooting include reduced labor requirements, elimination of transplant shock, and possibly shortens the time to produce a crop. For direct rooting to be successful, the medium used must maintain ample oxygen levels near the base of cuttings while retaining acceptable moisture and nutrient levels (3). The following studies were conducted between March, 1980, and October, 1981, to further test the thermo-blanket propagation system and to evaluate the effects of various media on the direct rooting of euonymus cuttings.

MATERIALS AND METHODS

Thermo-blankets consisted of a single layer of 0.635 cm thick Microfoam (E.I. Dupont DeNemours and Co., Wilmington, Delaware 19898) covered with 4 mil white or clear (85% and 95% light transmittance, respectively) copolymer (Monsanto Nursery film). Bottom heat during the fall, winter, and spring was supplied by rubberized heating pads (Famco Electric Co., Progrow Supply Corp., Butler, Wisconsin) laid directly on the ground.

After the initial watering, the edges of the thermo-blankets were sealed to the ground. Cuttings stuck directly into pots were inspected daily and hand watered when necessary to maintain a nearly saturated environment. Temperatures beneath the thermo-blankets were recorded at 2 hour intervals using a Digitec thermocouple thermometer (model #590JC) equipped with a 636 Scanner frame and Digitec recorder (model 6140). Greenhouse propagation was conducted on raised benches at a minimum temperature of 18°C under intermittent mist of 6 seconds every 3 minutes.

Media components included: raw sewage sludge compost (compost) made from lime dewatered sludge and woodchips (supplied by Maryland Environmental Services, Annapolis, Maryland); expanded shale (Solite) 0.318 to 0.953 cm (Solite Corp., Alexandria, Virginia); milled pine bark (bark) (Forest Products, Salisbury, Maryland); Canadian sphagnum peat (peat); and horticultural grade perlite (perlite).

Soluble salt levels were determined using a 1:5 (medium: water) dilution and measuring conductivity with a Beckman Solubridge. Media pH were measured as described by Bunt (1).

RESULTS

Experiment 1. The initial experiment was conducted to evaluate the effects of Microfoam covered with clear or white copolymer (clear thermo-blankets and white thermo-blankets, respectively), with 21°C bottom heat and with no bottom heat, and 6 propagating media combinations (Table 1) on the rooting of euonymus.

Terminal hardwood cuttings of euonymus were taken on March 19, 1980 and trimmed to a uniform length (15 cm). The cuttings were treated with 0.3% IBA powder (Hormodin #2) and stuck into 1 liter containers filled with each medium. The thermo-blankets were laid directly over the cuttings and the edges sealed to the ground. To monitor the progress of rooting, similarly treated cuttings were placed under intermittent mist in a greenhouse at the same time.

On April 25, 1980, when the majority of cuttings in the greenhouse appeared heavily rooted, the experiment was terminated and rooting was evaluated. Each cutting received a score of 1=no roots, 2=callus, 3=lightly rooted, 4=moderately rooted, or 5=heavily rooted.

Table 1. Rooting response of *Euonymus kiautschovica* 'Sieboldiana' as influenced by propagating medium.

Medium by volume				Rooting Value[y]	pH	Initial Soluble Salts
Compost	Bark	Solite	Perlite			m mho/cm
1	1	1		2.83 abc[z]	7.3	3.40 a[z]
1	1		1	2.69 bc	7.1	1.50 b
1		1	1	2.43 c	7.5	1.30 b
	1	1	1	3.19 ab	7.0	0.32 c
1		1		2.33 c	7.6	1.40 b
	1	1		3.29 a	7.2	0.34 c

[y] 1 = roots, 2 = callus, 3 = lightly rooted, 4 = moderately rooted, 5 = heavily rooted.

[z] Means followed by the same letter or letters are not significantly different at the 5% level (Student-Newman-Keuls).

There were significant differences in rooting between heated and unheated thermo-blankets or between under clear and white thermo-blankets. However, compost incorporated into the medium caused a reduction in rooting (Table 1). The initial pH levels of the propagating media were from 7.0 to 7.2 without compost and from 7.1 to 7.6 for compost amended media. The initial soluble salt levels were consistently higher in all compost amended media.

Daily maximum and minimum temperatures beneath

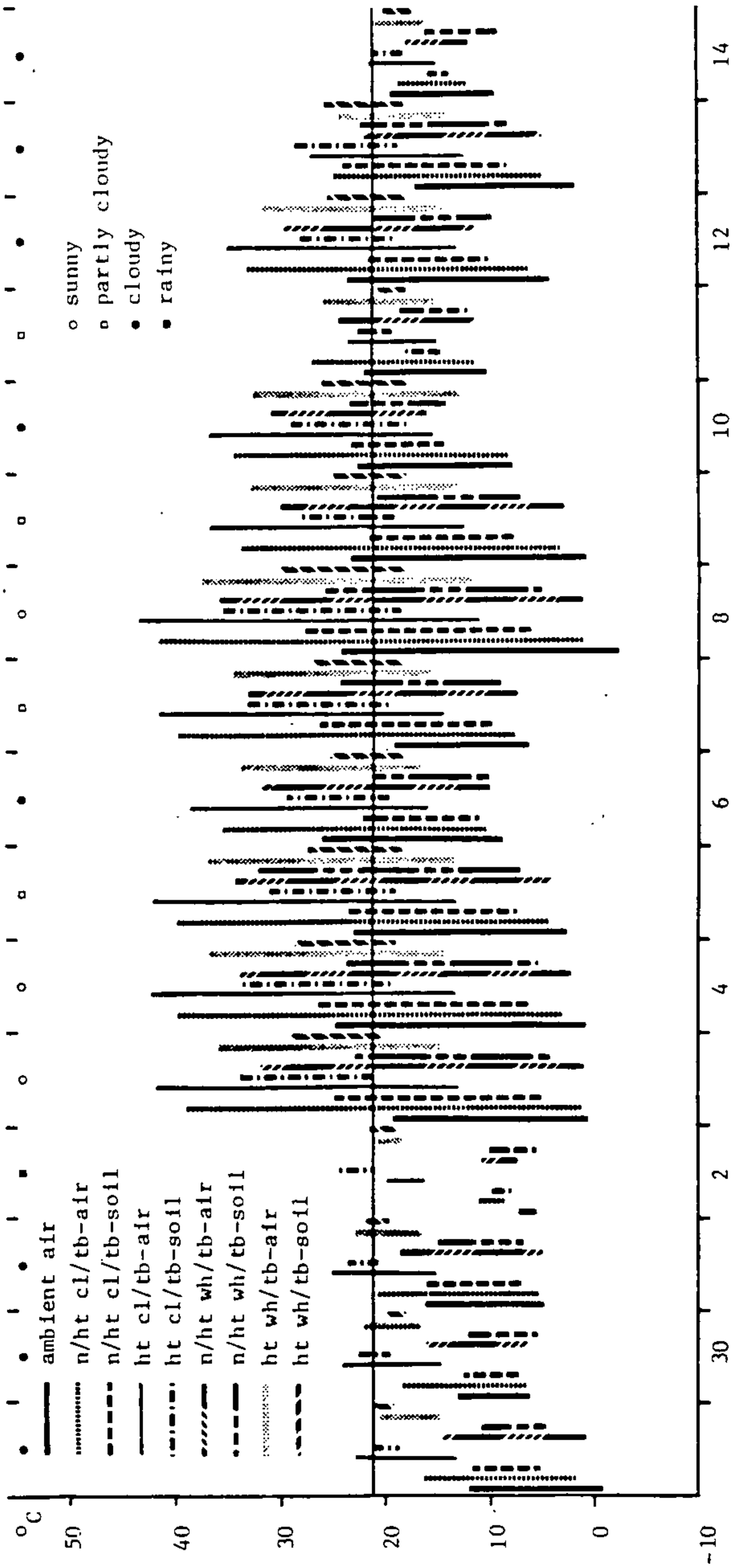
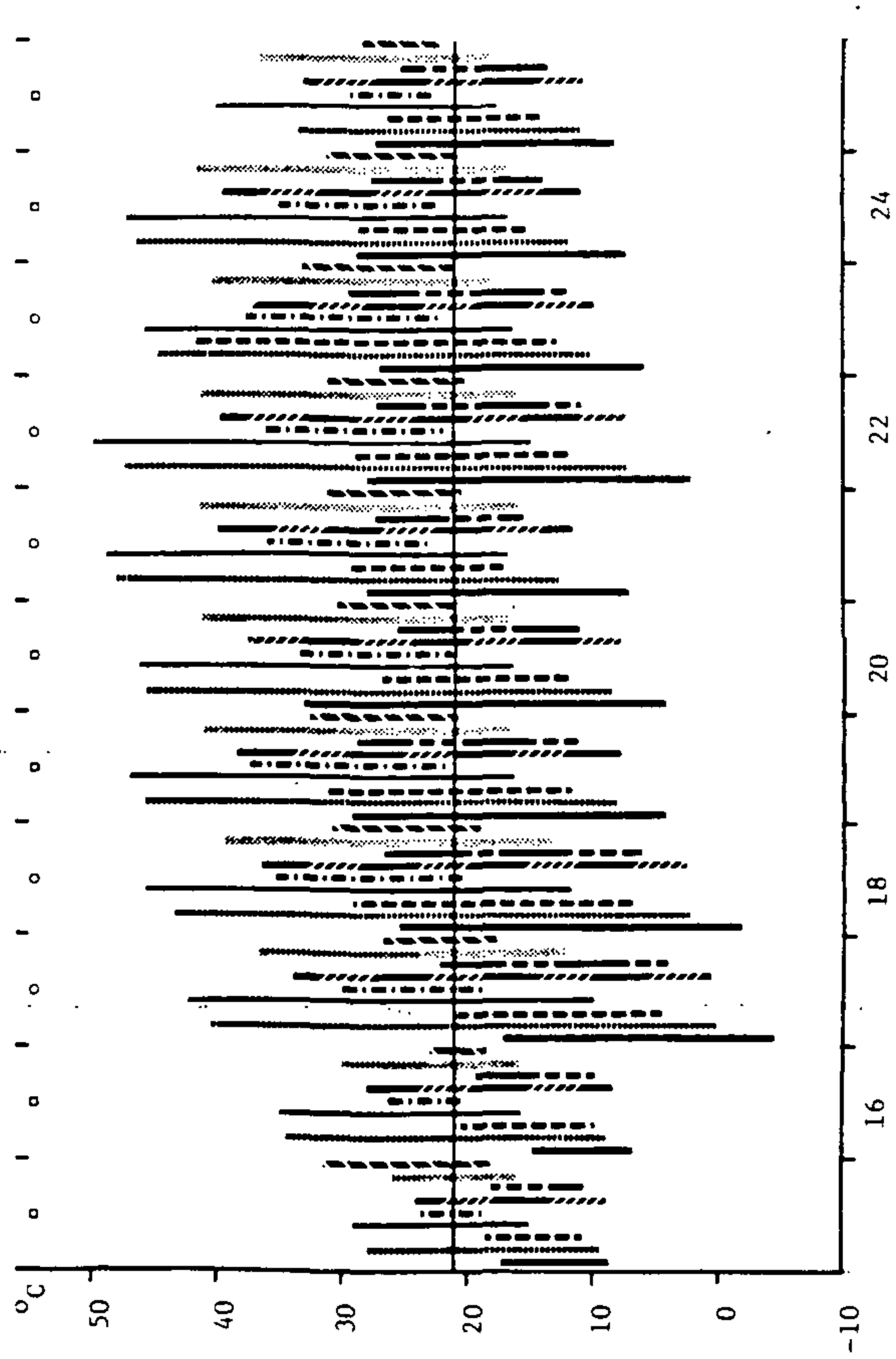


Figure 1. Daily outdoor ambient air and air and soil temperatures under clear and white thermo-blankets (cl/tb and wh/tb, respectively) coverings with and without bottom heat (ht and n/ht, respectively) as influenced by weather conditions.

Figure 1 Continued



thermo-blankets were at least 8° to 12°C higher than outdoor ambient air levels regardless of bottom heat application. Daily maximum air temperatures beneath clear thermo-blankets were 3° to 8°C warmer and soil temperatures were 2° to 6°C warmer beneath clear thermo-blankets than under white thermo-blankets with and without bottom heat. However, minimum soil temperature beneath clear and white thermo-blankets with bottom heat and minimum soil temperatures beneath clear and white thermo-blankets without bottom heat were similar (Figure 1.)

Experiment 2. The results of Experiment 1 indicated that heat build-up can occur during the early spring under clear thermo-blankets. Therefore, a more reflective white copolymer may be needed to minimize spring and summer temperature fluctuations. The objective of this study was to determine

whether Microfoam was necessary beneath white copolymer for spring and summer outdoor propagating periods.

Softwood cuttings of euonymus were prepared as in the first experiment but dipped in 0.1% IBA powder (Hormodin #1). Using the 6 propagating media from Experiment 1, cuttings were placed in 1 liter plastic containers without bottom heat under a quonset-shaped frame made of concrete reinforcing wire. The frame was sufficiently tall so that the foliage of the cuttings would not touch the thermo-blankets. After watering the cuttings thoroughly, the frames were covered with white thermo-blankets or white copolymer alone.

On August 11, 1980 the experiment was terminated and rooting and root growth were evaluated using a cm^2 grid system. Media pH and soluble salts were determined as previously described.

White copolymer alone did not provide adequate protection for spring and summer rooting of euonymus cuttings outdoors (Table 2). Cuttings beneath thermo-blankets rooted significantly better than those beneath white copolymer. As in Experiment 1, compost incorporated into the medium reduced rooting and root growth (Figure 2).

Table 2. The rooting response of *Euonymus kiautschovica* 'Sieboldiana' as influenced by covering material.

Treatment	Mean root area (cm^2)
White thermo-blanket	92.26 a[z]
White copolymer	40.23 b

[z] Means followed by different letters are significantly different at the 5% level (Student-Newman-Keuls).

Initial pH levels of the media were lower than in Experiment 1; however, the pH of media without compost remained lower (6.8 to 6.9) than that of compost amended media (6.9 to 7.3).

Air temperatures beneath both propagating units were higher than outdoor ambient air levels during the entire experiment, but air temperatures under white copolymer were from 4° to 6°C warmer to 1° to 3°C cooler than air temperatures beneath the thermo-blankets. In addition, maximum soil temperatures under white copolymer were 2° to 3°C warmer than thermo-blanket soil temperatures.

Experiment 3. The objective of this study was to compare the growth of direct stuck euonymus cuttings propagated outdoors under thermo-blankets with cuttings rooted under greenhouse intermittent mist. The treatments included: (a) cuttings rooted under intermittent mist, transplanted to 1 liter

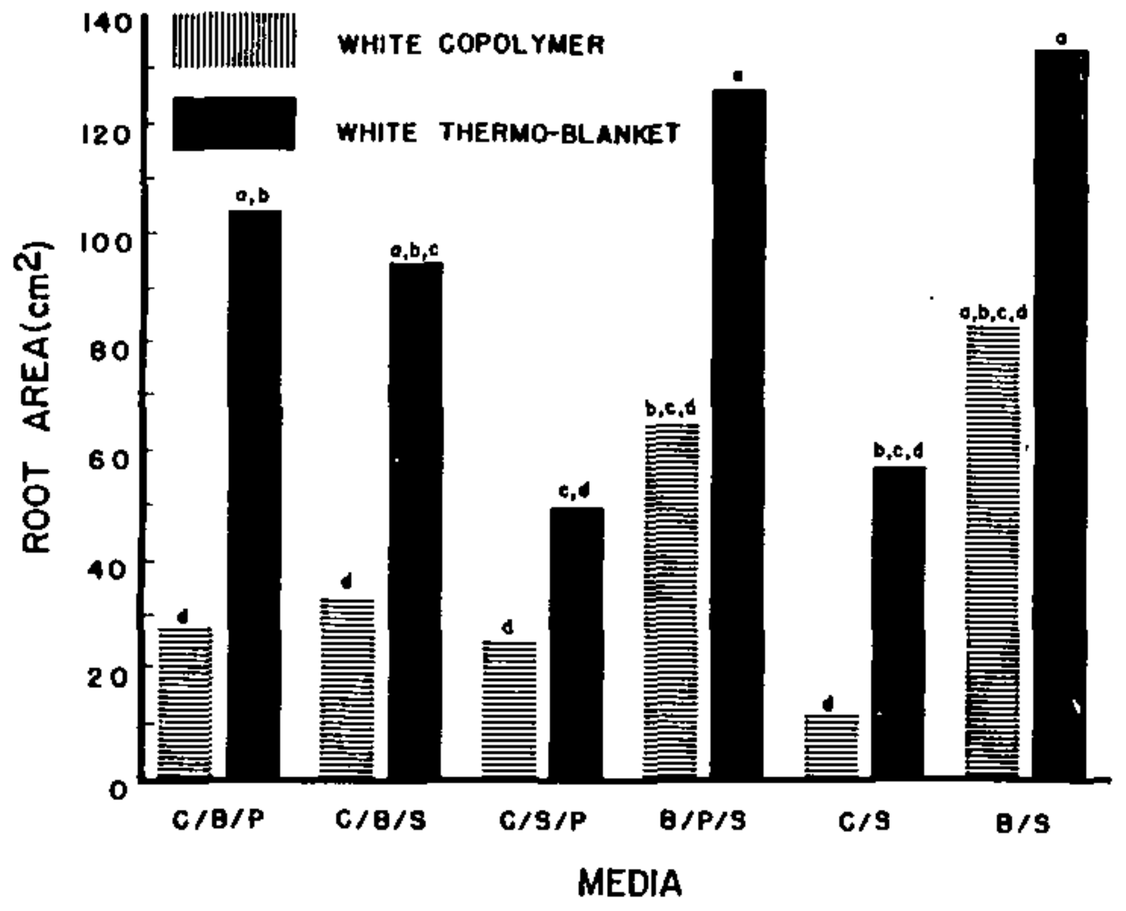


Figure 2. Root area (cm^2) of *E. kiautschovica* 'Sieboldiana' cuttings rooted in media combinations of compost (C), bark (B), solite (S), or perlite (P) beneath white copolymer or white thermo-blanket coverings. Mean separations were performed at the 5% level (Student-Newman-Keuls).

square plastic pots, and later transplanted to 2.8 liter nursery pots (System I); (b) cuttings rooted outdoors beneath white thermo-blankets in 1 liter square plastic pots and later transplanted to 2.8 liter nursery pots (System II); and (c) cuttings rooted under white thermo-blankets directly in 2.8 liter nursery pots (System III). The media consisted of bark/Solite, bark/Solite/perlite, and compost/peat/Solite.

On November 15, 1980 hardwood cuttings of euonymus were taken and prepared as described in Experiment 1. For System I, cuttings were stuck in wooden flats filled with 1:1 (v/v) peat/perlite and placed under greenhouse intermittent mist. In Systems II and III cuttings were stuck in containers as described in Experiment 2. On January 11, 1981 the rooted cuttings of System I were transplanted to 1 liter pots filled with each of the 3 media and placed in cold frames with 7.2°C bottom heat.

On March 24, 1981 thermo-blankets were removed and plants of Systems I and II were transplanted to 2.8 liter nursery pots using the same media used for propagation. All plants were moved to the nursery and watered and fertilized every 10-14 days with a 25-10-10 (Peter's) at 500 ppm of N water soluble fertilizer. The experiment was terminated on October 3, 1981 and the top of each plant was pruned level to the pot rim, dried, and weighed, and media samples were taken to determine pH and soluble salts before and after the experiment.

The propagation systems had no significant effect on the dry weight of euonymus but did affect survival. Cuttings propagated in the greenhouse had significantly greater survival

(96.3%) than either System II or III (60.6% and 67.6%, respectively) under thermo-blankets.

Regardless of propagation system, bark/Solite promoted optimum growth and survival of plants significantly. Cuttings rooted and/or grown in the bark/Solite medium had significantly higher dry weight (Figure 3) and percent survival (Table 3) than cuttings rooted and/or grown in compost amended media.

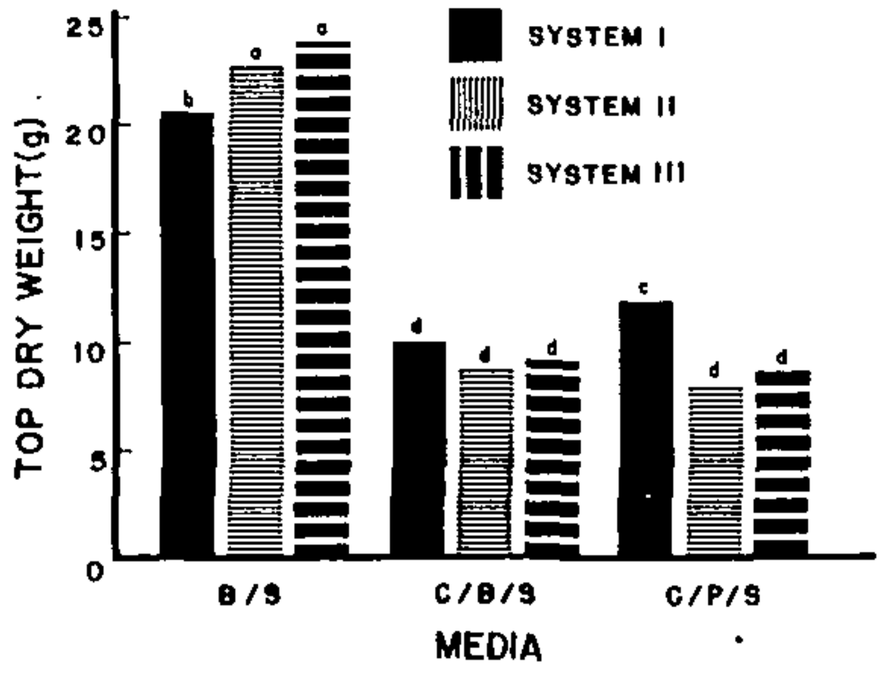


Figure 3. The influence of compost (C), bark (B), Solite (S), and peat (P) in various combinations on the top growth of *E. kiautschovica* 'Sieboldiana' rooted: under greenhouse intermittent mist, transplanted to 1 liter containers, and later transplanted to 2.8 liter nursery pots (System I); rooted under thermo-blankets in 1 liter containers and transplanted to 2.8 liter nursery pots (System II); or rooted under thermo-blankets directly in 2.8 liter nursery pots (System III). Mean separations were performed at the 5% level (Student-Newman-Keuls).

Initial pH levels of compost amended media were 5.1 to 6.6 while those of bark/Solite were 6.4. The final pH of all media was 6.6 and 6.7. The initial soluble salt levels were: 1.90 m mhos/cm for compost/bark/Solite, 1.2 m mhos/cm for compost/peat/Solite and 0.15 m mhos/cm for bark/Solite. Final soluble salt levels were similar among all media.

Though the temperatures fluctuated somewhat between the different thermo-blanket systems, in general, the minimum and maximum air temperatures were 5° to 11°C warmer than outdoor ambient air levels.

Table 3. The influence of propagating medium on the survival of *Euonymus kiautschovica* 'Sieboldiana' cuttings.

Medium by volume				Survival,
Compost	Bark	Solite	Peat	percent
1	1	1		67.1 b[z]
1		1	1	63.4 b
	1	1		93.9 a

[z] Means with the same letter are not significantly different at the 5% level (Student-Newman-Keuls).

DISCUSSION AND CONCLUSIONS

The significant reduction in rooting and growth of euonymus cuttings propagated in compost amended media indicates that these mixes are unacceptable. Soluble salt levels in compost amended media which ranged from 1.1 to 3.4 m mhos/cm possibly affected rooting and growth. This has been shown with plants grown in compost amended media. Leaching has been recommended to alleviate this problem (1,4,7), perhaps a treatment that might be used to improve rooting.

Though the pH values of media ranged from 5.1 to 7.6, rooting appeared unaffected by this fact. These results agree with those of Paul and Leiser (9) who successfully propagated euonymus in media at pH values of 4.4 to 7.0.

The nonsignificant effect of clear and white thermo-blankets on rooting of euonymus cuttings indicates that light transmittance of the coverings was not important in the early spring. However, white copolymer alone as a covering during the summer was not satisfactory. This agrees with Wong (10) who reported temperatures in excess of 35° to 40°C inhibited root growth for several days. The combination of 30° to 40°C soil temperatures and 40° to 50°C air temperatures under white copolymer suggest that reductions in root growth were temperature related.

When a bark/Solite medium was used, growth and survival of cuttings rooted directly in 1.0 and 2.8 liter containers under white thermo-blankets were not significantly different from cuttings rooted under intermittent mist in the greenhouse. This was reported previously (2).

Direct rooting of cuttings outdoors beneath white thermo-blankets can be an alternative to greenhouse intermittent mist propagation for some species. However, the potential use of compost as an amendment for a rooting medium may be limited because of the undesirable effects of high soluble salts on rooting and growth of cuttings. Successful rooting of euonymus in the bark/Solite medium does show that direct rooting can be accomplished outdoors beneath thermo-blankets with the same result as greenhouse intermittent mist. This system can reduce labor and the amount of greenhouse space needed to propagate this crop.

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PHILIP SOMMER: What was the temperature difference between the copolymer and thermoblanket? What was the high temperature outside?

FRANK GOUIN: Under the thermoblanket the high was 110°F and under the copolymer it was 150°F. The outside was 96° to 99°F.

LEN STOLTZ: What is the difference between lime and polymer dewatered sludge?

FRANK GOUIN: Lime dewatered is easier to do they tell me. It does not cost any more. The polymer is made in Germany and they will not tell me what it is. It flocculates the solids so they can be dewatered.

RAY MALEIKE: Did you use a mist system?

FRANK GOUIN: No, we just lifted the blanket up once a week and hand watered.

VEGETATIVE PROPAGATION OF PINE AND SPRUCE: PROBLEMS AND SOLUTIONS

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Abstract: Propagation of pine and spruce by stem cuttings is not a common nursery practice. The problems associated with propagation by stem cuttings are discussed and methods to overcome the problems are suggested. Also emphasized is the need for a breeding program to be coupled with a clonal forestry program. A breeding program would insure the continued development of genetically superior individuals for operational use.

With few exceptions, e.g. prostrate junipers and *Taxus* cultivars, vegetative propagation of coniferous species and cultivars by stem cuttings is not commonly used. Spruce, hemlock and pine cultivars are propagated almost exclusively by grafting. Propagation by rooted cuttings would be more advantageous because it requires less skill than grafting and is relatively inexpensive.

Vegetative propagation is beneficial for several reasons. Most importantly, all of the genetic superiority of the ortet[1] is transferred to the ramet. Sexual propagation transfers only a portion of the ortet's genetic superiority to the progeny. Compared to seedling production, rooted cuttings can produce a larger plant in a shorter period of time (29,30). For instance, eastern white pine cuttings averaged 21 cm in height 13 months from propagation (cuttings stuck January 1979, rooted by June and measured July, 1980). They were equivalent in size to 3-0 or 2-1 seedlings. Another benefit of vegetative propagation is increased unformity. Even with these benefits, propagation of spruce and pine by rooted cuttings is uncommon. This paper discusses problems innate to pine and spruce propagation by stem cuttings and offers methods by which these problems can be overcome.

Physiological juvenility and maturity in conifers. Probably the greatest single reason for the infrequent use of stem cutting propagation is the inability of physiologically mature stem cuttings to form adventitious roots (3,14). The transition from the easy-to-root juvenile phase to the difficult-to-root mature phase occurs from 4 to 12 years of age (2,5,11,13,15,23,24). Often the genetic worth of an individual cannot be assessed

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[1] The progenator of a vegetatively propagated clone is called the **ortet** (33). A **ramet** is an individual member of a clone.

before this transition. In the absence of juvenile-mature correlations, the forester's rule of thumb is that selection or assessment of genetic worth cannot be made before one-half rotation age. For instance, selection would have to be delayed until year 30 for eastern white pine grown for saw timber. Schemes to maintain juvenility until genetic worth can be assessed have been developed and are in operation (12). However, costly long term planting is required and generally beyond the resources of individual nurserymen.

Vegetative propagation of conifers for Christmas tree use has great potential. The short rotation time, about 10 years in Ohio (4), allows early assessment of genetic worth while the select tree is physiologically juvenile. High crop value and short rotation time justify the increased costs and risks associated with vegetative propagation.

How much gain can one expect? Gains of 50% can be realized by selecting the correct Scotch pine source (33). An additional 25 to 50% gain could be expected if the best phenotypes within the best provenances are vegetatively propagated. This amount of gain would make propagation via stem cuttings economically feasible.

Yearly-variation in clonal rooting response. However, even within the physiologically juvenile phase, great year-to-year variation exists in the rooting response (23,22,25,26,28). Ortet rooting response is independent of year. For instance, some eastern white pine ortets rooted well in years when average rooting response was poor, while other ortets rooted poorly in years when average rooting response was good (23).

In general, exposure to chilling temperatures has promoted rooting of north temperature conifer stem cuttings (10,15,19,25,28,32). The effect of pre- or post-severance chilling on rooting response depends on chilling temperature and duration (10,15,32) and whether it is administered at constant or fluctuating temperatures (28). Too little chilling as well as too much chilling will reduce rooting response.

To predict the time of cutting collection in which rooting is maximized and to reduce the yearly variation in rooting response, a chill unit accumulation model was developed for eastern white pine grown in North Carolina (28). The chill unit accumulation model accounted for 58% of the variation in rooting response. Alternatively, if calendar date was used to predict time of cutting collection, only 47% of the variation in rooting response could be accounted for. The model predicted optimum rooting after 1000 hours of chilling, (about mid-January in Raleigh). Cumulative chill units, rather than calendar date would be expected to be a more accurate predictor of rooting response as it measures a physiological condition.

Differences in yearly environmental conditions would affect the number of chill units accumulated on a given date, causing yearly variation in the rooting resonse. At Raleigh, the number of chill units accumulated by January 15 in the years 1977-1980 varied from 906 to 1176, about a 25% difference. Thus, the year-to-year variation in rooting response can be reduced by basing time of cutting collection on physiological condition (which can be predicted by cumulative chill units) rather than calendar date. The model needs refinement and its reliability determined by testing with different species in different geographical areas.

Root system quality. There are three measures of root system quality; number of roots per cutting, spacial relationship among roots (root symmetry) and development of tap or sinker roots.

For research purposes, a cutting is usually considered rooted if there is one root per cutting greater than one mm in length (19,29). However, for operational use, one short root per cutting is probably inadequate.

Observations of eastern white pine stem cutting root systems indicate that the number of major roots a cutting has is determined within a year from first root initiation (29). Similar fixing of the number of lateral roots within the first year has been found for seedlings (18). Further, within this same period, one root tends to dominate, having a larger diameter and length, and a greater number of secondary and tertiary roots (Fig. 1). It could be that long term performance is more closely

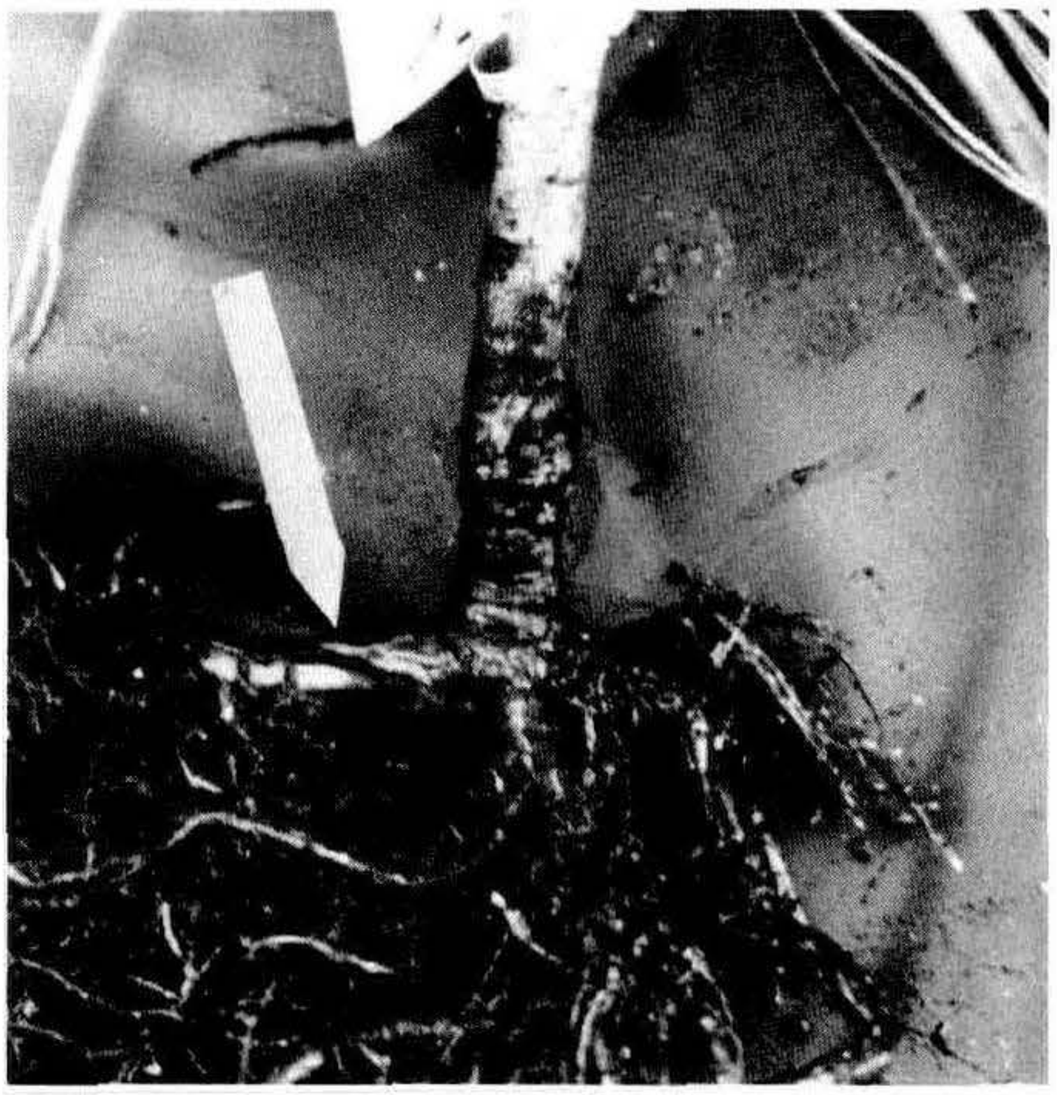

Figure 1. Root system of a 14 month old Eastern white pine rooted cutting. Within the first year one root will become dominant (see arrow), having a larger diameter and greater length than other roots.

related with the vigor of this dominant root than with the total number of roots originally initiated. The important point is that the number of major roots a pine cutting has when it leaves the propagation bench will not increase after field planting.

Often, rooted cuttings have asymmetrical root systems. Commonly, roots are initiated on only one side of a cutting, resulting in planting stock with one-sided root systems. Asymmetrical root systems are undesirable for several reasons (8,16,18): they offer less stability to the planting stock; they increase susceptibility to wind throw; they promote compression wood formation; and, if the rooted cuttings are to be dug after lining out in transplant beds, a large proportion of the root system would be lost in the digging operation. Root system symmetry does affect shoot growth. Of all the root system characteristics studied, root system symmetry was found to account for the greatest proportion of variance in shoot growth (16).

Another problem with stem cutting root systems in this case is that adventitiously initiated roots tend to grow horizontally, just below the soil surface (Fig. 2 and Ref. 22). The shallow root systems of rooted cuttings offer less stability than seedling taproots. Adventitiously initiated roots sometimes turn downward only when deflected by a barrier.

Figure 2. Rooted Scotch pine cuttings. The cutting on the left was rooted in a 4 cm diameter cylinder (a RL Super Cell). The cutting on the right was rooted in a flat. Adventitiously initiated roots tend to grow horizontally, unless deflected downard by a barrier.

The problems of lack of geotrophic response, asymmetrical root systems and few numbers of roots per cutting of vegetatively propagated pines and spruces can be solved by rooting

cuttings in containers such as RL-Super Cell[1] or Spencer-Lamaire Books[2], rather than in flats. When the elongating root strikes the container wall it is deflected downward. Because of the small diameter of these containers, the root travels only a short distance before striking the container wall, resulting in a minor root defect. Even if only one root per cutting is initiated, that root appears similar to a tap root (Figure 3 left). It is anticipated that, in addition to looking like a taproot, the adventitious root will also function as a taproot, initiating many laterally growing mother (1,31) or pioneer roots (21). Unfortunately, this may not be the case (17). One year old tissue-cultured loblolly pine plantlets, rooted in RL-Super Cells, had a less fibrous root system, with little secondary root development near the medium surface, compared with seedling root systems. The plantlets' smaller size, compared to the seedlings, was attributed in part to inferior root system development.

Figure 3. (left). A Scotch pine cutting rooted in a 4 cm diameter cylinder (R L Super Cell). It is anticipated that the long root will function as a tap or mother root, giving rise to numerous, vigorous, laterally growing roots.

(right). Coiled root system of a 2-year-old tissue cultured loblolly pine. This coiled root resulted from rooting the plantlet in a smooth-walled test tube. (Photo courtesy of Steve McKeand, Tree Improvement Specialist, Department of Forestry Resources, North Carolina State University, Raleigh).

The rooting container must have ridges on the internal walls to prevent development of circular roots. Figure 3, right,

[1] Ray Leach Container Nursery, 1500 North Maple Street, Canby, Oregon 97013.

[2] Spencer-Lamaire Industries, Ltd., Edmonton, Alberta, Canada T5K 1N1.

shows a circular root on a two-year-old loblolly pine tissue-cultured plantlet which was rooted in a smooth-walled test tube. This plant lacked stability, being blown about in moderate winds (Personal communication, Steve McKeand, Tree Improvement Specialist, Department of Forestry, North Carolina State University, Raleigh).

Whether or not the number of roots per cutting, root system symmetry, and lack of tap or sinker root development in adventitiously initiated root systems, affects growth can only be determined by field planting rooted cuttings.

The oldest eastern white pine study comparing performance of rooted cuttings with seedlings was field-planted in 1945 (22). The four planting sites each used a checker-board design, alternating seedling plots with rooted cutting plots. Unfortunately, rooted cutting clonal identity was not retained. The study was last measured in 1954. At that time survival was 83% (531 of 640) for the rooted cuttings and 89% (519 of 584) for the seedlings. There were no differences in height growth or diameter at breast height.

Two plantations, Wood County and Dane County, were remeasured in 1982 (Table 1). Survival at both locations was higher for rooted cuttings than seedlings. At the Wood County location, cuttings were taller and had greater diameter at breast height (DBH). The reverse was true at the Dane County location. If equal numbers of cuttings and seedlings are compared at the Dane County location (by deleting the smallest sized cuttings from the analysis) rooted cuttings have similar height and DBH as seedlings. A more detailed analysis, includ-

Table 1. Survival, height and diameter at breast height (DBH) of eastern white pine rooted cuttings and seedlings after 37 years[1].

Origin	Plantation Location	Percent Survival[2]	Height	DBH
seedling	Dane Co., Wisconsin	45	15.8 m.	25.9 cm.
cutting		64	13.9 (15.6)[3]	22.7 (27.7)[3]
seedling	Wood Co., Wisconsin	40	14.5	20.8
cutting		57	15.6 (17.3)[3]	22.2 (23.9)[3]

[1] Plantations were established with 2-2 seedlings and two-year-old cuttings in 1945 by Drs. R.F. Patton and A.J. Riker, Department of Pathology, University of Wisconsin, Madison.

[2] Seventy-five seedlings and rooted cuttings (150 total) were planted at the Dane Co. site, 89 seedlings and rooted cuttings (178 total) were planted at the Wood Co. site.

[3] The bracketed values were calculated for equal numbers of rooted cuttings and seedlings, eliminating the smallest rooted cuttings from the analysis.

ing wood specific gravity, will be forthcoming. On the basis of these data, rooted cuttings perform as well as seedlings. These are similar to results obtained for rooted cuttings of *Pinus radiata* (6).

Because clonal identity was not noted, the Patton and Riker study (22) could not answer such questions as: "How many roots per cutting are enough?"; "Is shoot growth affected by an asymmetrical root system?"; "How great is the within-clone variation in shoot growth?"; and "How much within-clone variation in shoot growth can be attributed to differences in root system morphology?".

In March, 1981, an eastern white pine rooted cutting-seedling study was field planted in Virginia to help answer these questions. For all ramets within a clone, the number of roots per cutting and the site of adventitious root initiation was noted prior to planting for each of the 168 rooted cuttings. Each one-year-old rooted cutting was paired with a 2-0 seedling. Two year growth data will be reported in 1983. The study is a cooperative effort between Ohio State University and two North Carolina State University Tree Improvement Cooperative members (Department of Forestry Resources, North Carolina State University and Virginia Department of Forestry).

Increasing rooting response. If rooting response of physiologically mature ortets can be increased, then clonal forestry for long rotation coniferous crops, such as saw timber, would be possible. To date, no means of increasing rooting response of physiologically mature conifers has been developed (20). Therefore, ortets need to be hedged to retain the juvenile, easy-to-root condition, until genetic worth can be assessed (12,14). However, only "good rooters" (ortets with high rooting response) can be used for clonal forestry. Thus, many otherwise superior ortets are eliminated.

Further, if rooting response of initially poor rooting, physiologically juvenile ortets could be increased, then the rapid narrowing of the genetic base associated with clonal forestry would be slowed. Too narrow a genetic base is disastrous in any breeding program. As planting stock becomes increasingly genetically homogenous, the susceptability to disease, insect and environmental factors is increased.

The genetic base in any breeding program narrows with each generation's breeding. Commonly, only the best 10% of each generation is used as the breeding population in the next generation. Therefore, if a breeding program begins with 1000 families or individuals and only the best 10% within each generation are retained for the next generation's breeding population, the breeding program would be terminated after four generations; there would be no unrelated individuals to mate

and little genetic variability to exploit.

This rapid narrowing of the genetic base would be accelerated if high rooting potential was included as an additional selection criteria. If 10% of the 1000 member base population had high rooting potential (not an unreasonable assumption) then the breeding program would be terminated in three generations.[1]

Serial propagation. A method is needed whereby rooting response of initially poor rooting ortets can be increased. Serial propagation, where cuttings are taken only from rooted ramets, might be such a method (27). If serial propagation increases rooting response, then initially poor rooting, but otherwise superior ortets, need not be excluded from the breeding program.

The possibility of increasing rooting response through serial propagation has been under study for 18 months at The Ohio State University. One hundred one-year-old *Picea pungens* seedlings were received from Evergreen Nursery, Sturgeon Bay, Wisconsin, in April, 1981. Twelve ortets were selected for superior blue needle color and placed under a 20 hour photoperiod in a heated greenhouse. The extended photoperiod induced multiple growth flushes. Terminal and lateral shoots of each flush were used to make softwood cuttings. The cuttings were treated with Hormodin #3 (8000 ppm indolebutyric acid — talc powder) and placed under intermittent mist. A 1:1 peat:perlite rooting medium was used. Rooting was evaluated 8 weeks after sticking.

For clones 10, 20, 40, 41, 46 and 55, rooting response was clearly increased with each propagation series (Table 2). For clones 27, 44 and 53, no definite pattern was evident. In these clones the decrease in rooting response for a particular propagation series was due to high cutting mortality. The cuttings, when collected, were too soft and decayed within a month after sticking. If rooting percentages for these ortets are calculated excluding decayed cuttings, then rooting response increases with each propagation series (see footnote 2 in Table 2). Serial propagation did not increase rooting response in clone 8, whereas in clone 25 rooting response decreased.

The results are preliminary and therefore need to be interpreted with caution. First, only 12 ortets were studied. Second, limited numbers of cuttings within each propagation series have been stuck. Third, rooting response was confounded with different rooting environments, and fourth — rooting response

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[1] Assuming that crossing individuals with high rooting potential results exclusively in progeny with high rooting potential. If this is not the case, then the genetic base would be narrowed even more rapidly.

was increased in physiologically juvenile stock. As mentioned previously, attempts to increase rooting response in physiologically mature ortets has not been successful. However, if the preliminary results are confirmed in additional studies then high initial rooting response need not be a selection criteria in a breeding program for clonal forestry and rapid narrowing of the genetic base need not be innate to a breeding program for clonal forestry.

Table 2. The effect of serial propagation on rooting response of twelve *Picea pungens* 'Glauca' clones.

Clone Number	Propagation Series: Number cuttings rooted/Number cuttings stuck		
	Ortet	Ramet I[1]	Ramet II
8	2/15 (13%)	2/12 (17%)	—
10	7/21 (33%)	2/3 (66%)	—
16	1/10 (10%)	—	—
20	9/32 (28%)	40/80 (50%)	—
25	17/28 (60%)	14/45 (31%)	—
27	9/19 (47%)	11/20[2] (55%)	1/2[2] (50%)
40	10/23 (46%)	8/25[2] (32%)	2/3 (66%)
41	7/15 (46%)	3/5 (60%)	—
44	9/27 (33%)	55/62 (89%)	20/43[2] (41%)
46	8/18 (44%)	4/7 (57%)	—
53	8/10 (80%)	43/67[2] (64%)	1/1 (100%)
55	10/18 (56%)	34/39 (85%)	6/7 (86%)

[1] Ramet I in the propagation series refers to rooting response of cuttings collected from previous rooted cuttings; i.e., cuttings from cuttings. Similarly, Ramet II refers to rooting response of cuttings collected from rooted cuttings collected from rooted cuttings.

[2] In these cases, a large proportion of the cuttings were collected prematurely, when shoot growth was very soft. These softwood cuttings rotted in the mist bed. Losses due to rot in subsequent collections of semi-hardwood cuttings were negligible. The losses due to rot are as follows: Ortet 27, Ramet I-7, Ramet II-1; Ortet 40, Ramet I-5; Ortet 44, Ramet II-20; Ortet 53, Ramet I-12. If the number of rooted cuttings are excluded, the respective rooting percents are as follows: 85, 100, 40, 87 and 78%.

The mechanism by which serial propagation increased rooting response is unknown. Possibly, by collecting cuttings

from rooted ramets, cuttings are selected in which the genetic information for adventitious root initiation is being transcribed and translated. Why, in these ramets the genetic information for adventitious root initiation is being transcribed and translated is unknown.

One additional benefit of serial propagation is the formation of morphological leaders. Repeated removal of terminal shoots for stem cuttings allows lateral shoots to develop orthotropic (upright) growth (7). These lateral shoots become morphological leaders which, if rooted, continue growing orthotropically.

Necessity for coupling a breeding program with clonal forestry. Asexual propagation transfers all of the genetic superiority of the ortet to the ramet, resulting in significant gains over sexual propagation. However, continued gains can only be realized when selections are made from a constantly improved genetic base. Without an improved genetic base from which to select, one is forced to look harder and harder in natural populations for superior individuals. A point will soon be reached where no great improvement can be made. Therefore, it is absolutely essential that a clonal forestry program be coupled with a breeding program. This is the only means of assuring the continued introduction of genetically superior selections. Also, a well designed breeding program can minimize and control inbreeding, thus reducing the risks associated with clonal forestry.

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PROCEDURES USED IN MAINE FOR OVER-WINTER STORAGE OF NURSERY STOCK

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FIELD PROCEDURES

There is nothing new or special about growing bare root conifers for cold storage. Before following my procedures, however, you need to understand that the Northeast region, particularly the State of Maine, is different from most other regions in the United States or Canada. The timing for any particular region needs to be taken into careful consideration. It must be remembered that within a short radius there can be considerable differences in temperatures, moisture, and other variations which need to be taken into account.

Our fertilization program commences about the middle of August and can run into September, depending on weather conditions. I utilize straight nitrogen fertilizer. We use Urea 45, and apply this at 50 to 85 lbs per acre depending on the species involved and the time of application. An example is digging and storing any species that continues to grow from spring until a good fall frost slows down the growth process. You do not want to induce growth in the plants late in the season because they will be seriously affected by cold storage. In addition, they can be hit with an early fall frost and top growth lost. Douglas fir, Norway, and white spruce need to be watched carefully in order to avoid secondary top growth developing from heavy rain plus high temperatures late in the season. Sometimes I apply fertilizer to these species in mid to late September, even the first week in October. Colorado blue spruce and Black Hill spruce cease growth by mid-August or early September. The idea of fertilizing at this time of the year is that the fertilizer will be absorbed in the root zone without forcing top growth. The energy is stored in the roots. Nitrogen in the roots helps sustain the plants and gives them a lot more vigor, not only for the following year's growth, but helps the plant through over-winter storage.

Another critical point in the field procedures is to monitor soil temperatures at a 6 in. depth throughout the areas where the various species are going to be dug for over-winter storage. We set thermometers in 3 or 4 separate areas. We also try to set the thermometers where there might be a slight variation in soil type. For instance, some soils are medium to moderately heavy loam, others might be a relatively light, sandy loam.

In general, the fibrous root systems of most conifers are

satisfactorily hardened off when the soil temperatures within the top 6 inches have achieved 110 degree days below 10°C. Another method of checking for the proper fall digging time is to dig samples of each species and find out how the white root tip growth appears. This growth should be about a ¼ to ⅜ of an inch in length or shorter and, as this white root tip shortens, it turns a slightly brownish color. With each species there is a difference in the time taken to shorten this root growth. Once you have accomplished the shortening of the white root tip and/or have accumulated 110 degree days, you should be ready to dig for cold storage. Deciduous tree and shrub seedlings usually vary somewhat from the conifer transplants. This depends on the cultural methods applied during the growing season. Usually white birch is the first species dug and is followed by larch, autumn and Russian olive, and lilac. The principal criteria used is to make certain all leaves have fallen or can be easily removed in the sorting process and, in the case of larch, that most of the needles have or will come off. All these species will stand a longer refrigerated storage period than conifers.

We dig our spruces first, followed by the firs, and then pines. We leave until last those species which tend to grow the longest in the fall, namely *Taxus*, arborvitae, and hemlock.

DIGGING METHODS

We normally dig our seedlings with the Egedal Type R lifter; they are pulled by hand, packed into boxes, sprayed lightly with water, then covered with a heavy burlap to be transported to our cold storage facility. There they are wet down after removal of the burlap from the top of the box, wetting the seedlings so that moisture penetrates the box completely. The burlap again is wet, and then the seedlings are put into a room at 35° to 38°F. Then we leave them in the temperature controlled room until such time as we are ready to grade and sort. We try to grade and pack all material for cold storage as soon as possible after digging. We try to get as much material dug in the shortest time and stored under controlled conditions until they can be put into cold storage for winter in boxes all graded, sized, and tied in bundles. When spring comes all we do is remove them from cold storage and prepare them for shipping.

With the transplant material we use the Grayco Harvester to do the bulk of our lifting for over-winter storage which digs deep enough to allow for all the fibrous roots to be dug with the plants. This eliminates any tearing of the roots and gives much better survival in cold storage. In our system of planting in the field, we plant transplants in 6-row beds and our seed-

lings are broadcast sown. We have some success in digging white birch and common lilac when they are 12 to 18 in. in height with the Grayco digger, but generally it is faster and more economical for us to lift the seedlings and pull them by hand. This eliminates quite a bit of soil that would have to be returned to the field if they are dug with the machine. We have a tractor that pulls the Grayco Harvester with two men, one on each side of the digger taking the transplants from the digger bed chain and placing them in a box. A tractor with a fork lift and water spray tank mounted on the back follows the digger. Each time a box is removed from the digging unit, it is placed on the ground, and sprayed with a fine mist; then the curing blanket, being wet, is also put on the top, and then it is loaded onto a trailer. The truck driver is responsible for marking each box of trees as to age, size, and block. As they are loaded onto the trailer a canvas covering is pulled over the boxes to protect them from wind and sun. The best time to dig is when it is neither too dry or too wet. On a windy day, you need to exercise more care and perhaps use more moisture on the seedlings in the field. Once the digging operation is under way, and the diggers are digging faster than the material is being graded in the packing shed, it is important that all boxes of trees are properly marked before being put in the controlled storage room so that the trees will be graded and sorted in the same sequence as they are dug in the field. This allows for minimal amount of time from the field to actually putting them into cold storage.

Trees that are left in the cold storage unit for any length of time prior to processing need to be checked daily for the proper amount of moisture in the boxes. If moisture needs to be added, the box is usually taken down and sprayed lightly having had the burlaps removed and then put back on again.

Prior to any digging, I make a chart of all the species to be dug. This is usually run through our computer system so I know exactly what is to be stored. Up to this point all of our cold storage material, with the exception of what is to be used for retail mail order, is contracted for ahead of time by the customer stating that he wants his material in cold storage. Then I take these figures by species and compile another chart in a sequence which I want plants dug and handled. As we go through each individual species we try to get the closest we can to the right amount of material dug. This assures that all stock by species is dug as closely to one time as possible. We generally know from our spring inventory approximately how many trees per foot per bed and by species are in the field. When we fall dig we measure every species for the amount we want dug, using our June inventory on a per foot basis of that

bed and species. This does two things; first, we know exactly the footage we dig for cold storage and our inventories can be corrected for material left for spring digging. We also can determine from the initial digging how much we need to dig to come up with shortages if any occur. The biggest factor here is that our inventories are corrected from the spring inventory to get a close count of what is left in the field. When we finish our digging, each species is recorded to exactly the number of feet dug and the number of trees from that footage.

STORAGE CONTROL METHODS

We have in our packing and shipping facility two cold storage rooms of different sizes. One room is held at 28° to 29°F throughout the winter. The other room is at 35° to 38°F to hold the stock being dug from the field until it is graded and put into frozen storage. The latter room is gradually filled with unsorted material, as the sorting crews usually cannot keep up with the diggers. Each of these cold storage rooms has thermostats to maintain a maximum variation of 3°F. At the start of our cold storage digging, the outstide temperature is watched; the thermostat in the holding room may have to be varied slightly to accommodate outdoor fluctuations. We try to maintain a 6° to 10°F lower temperature in the holding room than the average outside temperature. We control humidity in the freezing storage by keeping the concrete floor wet. Once the temperature in a room is set at 26° to 29°F, it is usually unnecessary to worry about the humidity in that room since everything is sealed in polyethylene bags and is in a frozen condition. Each night all boxes in the holding room are wet down by spraying them with water. As the room begins to fill with freshly packed material from the grading tables, the controls have to be monitored daily and, as more boxes are put in storage, before they reach 29°F the temperature has to be dropped down to 26°F to create a greater temperature difference so that the stock will freeze more quickly. When the room is completely filled, the temperature has to be watched to be sure the controls are maintaining the optimum range. When the thermometers show a constant 26° to 29°F range, then the thermostat setting can be checked and left for the rest of the winter. We do check every 2 weeks to make sure that all the boxes have adequate moisture and the proper temperatures are maintained. We have alarm systems built into our control units so that if something goes wrong, we are notified immediately. After the number one room has been completely filled with cold storage material, the number two room is gradually worked down in temperature to the desired level. That room is filled in the same manner, the only difference

being that if there is a lot of material still ungraded, then some of it has to be removed at this point to a cool area of the building. Hopefully, by that time it is the end of November or early December and certain areas of the grading room are in the 35° to 40°F range. We plan to have all of our grading tables working at maximum efficiency during the whole time. We have 6 grading tables utilizing 4 to 5 people per table. We generally work only 8 hour days.

We can store 1 to 1½ million seedlings and transplants, depending somewhat on size and bulkiness of the stored material. Once our grading is completed, we have a chart outside the large coolers where we map each box of trees, locating it by size, age, and species so that at any time during the winter material can be pulled out for shipment. We do some shipping of retail material for mail order firms and also ship material to other mail order nurseries.

We generally do not start shipping until about the first of March. The material that is coming out then is nearly all wholesale stock. We find that we can take this material from the cold storage room, pack it directly in shipping boxes, or roll it into jelly roll bundles for transportation to the customer. We do not have to thaw this material. It is not frozen hard in cold storage, so it can be handled quite readily without any damage to the branches or roots. One thing that aids in the process is not having to warm up a cooling room warmer than is warranted for an extended period of time. The material taken out, packed and shipped, reaches the customer thawed out, whether shipping by common carrier or picked up by the customer. There are no frozen materials that create problems in pulling the plants apart and preventing planting upon their reaching the customer. Usually material is taken from the coolers 24 to 36 hours prior to shipping in order to facilitate handling.

GRADING AND SORTING

All material is tied with plastic twine, the reason being that by its use there is less chance of botrytis or other molds forming where the plants are tied. Once the trees are tied in bundles they (roots only) are carefully dipped in a bucket of water to assure that all are damp. They are placed root to root in boxes at the end of the sorting table with the tops kept as dry as possible. Once a box is full, it is moved to another area of the room where boxes are prepared for cold storage. We use a 2 mil poly bag designed to fit our boxes. Our digging boxes are the same as those used for cold storage. They are basically the same as apple boxes (45 × 48 × 30 inches). We have a

smaller box we use when digging seedlings and we sometimes store smaller stock or small quantities in these boxes.

The plastic bag is opened up, put into the box and a layer of spaghnum moss placed in the bottom of the box where the roots will be placed. Depending on the size of the nursery stock that is being put in the boxes, we put 1 or 2 double rows per box. The bundles of trees should *not* be packed tightly in the box. We do not use moss between the layers of trees. If the moss has sufficient moisture you can squeeze a handful, and just get some water dripping out. The moss in the bottom of the box is sufficient for that tier of trees; on the top of the box, after the last layer of trees has been put in, another layer of moss is placed over the roots.

Having experienced a winter using cold storage material dipped in a water absorbing gel, I now have some views on the use of this gel. There are several products of this nature currently being marketed, all which have similar properties. They are all designed to help hold moisture to plant root systems to reduce transplant shock as well as to assist in water absorption capacity of soils in dry conditions.

We used this material as a spray dip on the root zone at time of grading just prior to winter storage. There were problems observed at our 29°F storing temperature in that moisture was drawn into the root zone and froze. From visual observation in March and April when the trees were removed from storage for shipping, the roots and bark were discolored. It appears they virtually drowned from too much moisture being stored in the roots. Also the trees froze much harder than without the use of this material at time of storage.

My advice at this time would be to fall dig and grade with a minimal amount of moisture. Moss at the bottom and top of the boxes will keep the proper moisture level and avoid hard freezing. At the time of shipping in the spring a root dip or light spray of the water absorbing gel will reduce transplant shock and aid in water holding capacity of the roots. This aids during dry periods immediately after grading and shipping.

We are using several of these materials in our transplant work in the fields. Our seedlings are dug early in the spring and stored at 36°F. At time of planting they are root pruned and dipped or sprayed with this material before being placed in the boxes, transported in the field, and placed on the transplant machines. Results so far indicate a reduction in transplant shock and enhance the water holding capacity of the roots, thus increasing survivability of the seedlings and transplants. We also will experiment with a long lasting residual

fungicide to reduce fungal bacteria from forming during handling and during transport from cold storage to customers.

Once the box is completely filled, the plastic bag is pulled up, and either stapled or tied tightly, and the plastic pushed down so it is flush with the top of the box. This is to make certain that when the fork lift picks up the boxes and stacks them, none of the plastic is torn.

Another method of checking for moisture content throughout the winter is to inspect a box of trees and if crystals of ice on the inside of the plastic bag occur, there is sufficient moisture in the box. Otherwise, something is amiss; there is a leak or hole in the bag and moisture needs to be added. The plastic bag is opened and gently sprayed with water and recovered with another piece of plastic. Finding how moisture leaked out, repairing it and immediately placing the box back in cold storage is essential.

Once the boxes are completely sealed with plastic, they are stacked and await transport into one of the cold storage rooms. We have designed a careful procedure to monitor the placing of boxes in the cold storage rooms. We keep all retail material in one area. All of the wholesale material is packed in tiers and placed in a sequence where, at any time during the winter, we will know exactly where the material is located. We have laid out our cooler floor plan by striping the floor in squares the size of the boxes. We letter the rows one way and number the other way. Thus we can pinpoint any box at any time, and since all boxes are tagged with the size, age, and species, we eliminate wasted time locating material. All this is recorded on our wall chart outside the coolers. The sooner the material can be put into the cold storage room the better the results.

We have found with larch, it is not essential that all needles be removed, but we do try to shake the plants and the bundles to remove as many needles as possible. With birch and lilac, we want to get all the leaves off so that when they come out of cold storage, there is no chance of *Botrytis* forming.

It is essential to have an accurate count of the material in each box. One of the best methods is to use the best people possible when packing so that you can rely on their count. Also once they have completed packing the box, the person in charge of the grading and sorting makes a tag with the date, size, age of the stock, and the number of trees in that box. The packer initials the card so that when you unpack the box you know who the packer was, and if the count is correct. If there are too many counts that are wrong, then that person should

not count stock in the cold storage boxes the next year. Once the counts have been made for each box, the person in charge of grading and sorting keeps a tab on them on a chart and the final figures for that particular group is given to me each day. Then I make a determination whether we need to dig more or if we have over-dug. I carry on my sheet a surplus material column so that when we get everything in cold storage, I go back to the office, run everything through the computer listing every species by age and size that is in cold storage. If we have a shortage or a surplus, then the office staff decides how to handle this. If we have a surplus, we can sell it for early shipment if a customer comes along and desires that material. If there are shortages, generally we notify the customer immediately that the balance of the order will be shipped as soon as we can fresh dig the stock in the spring. We endeavor to ship all material from cold storage prior to April 10th. At about that time we can fresh dig again for spring.

SHIPPING FROM COLD STORAGE

Generally we do not ship material from cold storage before March 1. Occasionally we get requests from a customer who would like their material sooner, so we have it marked and placed so we can get it out early. The first 2 weeks in March we ship large quantities of material to the southern tier of states, mostly for Christmas tree planting stock. About mid-March the temperatures in the cold storage rooms are raised to 35°F which allows for a gradual thaw of all material. The boxes at the top of the stacks thaw out more rapidly than those on the bottom, so we watch this closely. Once the temperature is raised to 35°F, it is kept constant throughout the spring shipping season. This facilitates the handling of cold storage material and also allows us to dig from the fields and store in cold storage. This allows for storage of spring-dug plants until the first or middle of June. We endeavor to spring-dig all necessary material prior to bud swelling. With a temperature of 35° to 38°F we can safely store stock up to 6 weeks with no adverse effect. In the shipping of cold storage material nothing is different from other shipping procedures.

One should not keep material any longer than necessary in storage so that it can be put into the ground promptly and prior to bud breaking in the planting area. We keep abreast of weather conditions in our shipping areas, so as not to ship to any area where we feel that it would be an imposition on the customer in having to hold the material and not being able to get it into the ground as soon as it is received.

CONCLUSIONS AND OBSERVATIONS

Our cold storage period is from November 15 to April 10, and there has not been any deleterious effect on the stored material. Any problems that have occurred are not from the refrigeration, but from some handling error. With some species there is a slowing of growth the first year in the fields, particularly Colorado blue spruce. The growth rate the first year out of cold storage is probably equivalent to freshly dug stock in the spring. This can be changed by planting cold storage stock as soon as the frost is out of the ground. With most other species we got relatively little difference in the growth pattern or the growth rate that first year out of cold storage. The biggest advantage in the whole procedure, as far as the customer is concerned, is being able to get his material and get it into the ground at the proper time for planting in his area. In Western Maine we are able to dig much of our material in the fall, put it into storage, and get it shipped out prior to our being able to dig anything in the field in the spring. This allows us to increase our production capacity by the approximate capacity of our cold storage facilities.

In the fall of 1980 we dug, for the first time, Canadian hemlock and put this into our cold storage facility. We had as good success with hemlock as with any species. We have tried storing American arborvitae and *Taxus cuspidata* (Syn.: *T. cuspidata* 'Capitata') with no ill effects.

We endeavor to make the maximum use of our cold storage facilities. We use them throughout the shipping season in the spring, and have held freshly dug stock from late April until mid-June. The cold storage facility allows shipping to the northern tier of states, as well as into parts of Canada, where their planting seasons are even later than those in Maine. Another advantage is that in the spring we can dig stock that we know is going to be picked up or shipped. When time permits, we dig ahead and get this material into cold storage. This also allows us to get material ready for customers who are going to pick up stock, well in advance of the pickup date. The customer does not have to worry about inclement weather in our area in picking up his stock when he wants it. It also allows stock being available to be shipped at a specific date in order to meet a deadline that the customer might have. Also when our spring digging season has progressed to a point where we are pretty well ahead of our shipping, we pull all our seedlings that are going into transplant beds in the spring. The seedlings are placed in cold storage at about 36°F. They can be held until such time as they are root-pruned and again ready to go back into the fields onto the transplanting ma-

chines. The coolers are kept in constant operation until all material is either shipped out or gone to the field for transplanting, which will run from June 1 to 20. Then the units are turned off, the cold storage area is cleaned thoroughly, and aired out ready for the next season's use. We turn the coolers on at 50° to 55°F the first of August in preparation for our fall transplanting. Again the seedlings are dug in the fields and placed into the boxes, utilizing the plastic bags, covered, and put back in the cold storage rooms until they are root-pruned. They then go to the field for transplanting. Anytime after mid-August, when some of the planting stock has reached a desirable point of dormancy, a customer desiring shipment can have the material dug and shipped or be ready for pickup. The use of the cold storage facilities at this time of the year is beneficial in that we can dig ahead of time for the customer, store it under the cooler conditions and keep it for 2 or 3 days. We do not like, nor do we think it is advisable, to keep transplant stock in the cooler in the fall any longer than absolutely necessary. The advantages here are for the customer to be able to obtain the stock and put it into the ground in the fall under his optimum planting conditions and thereby obtaining some fall root growth prior to complete dormancy for the winter. This will facilitate more growth in the spring than would normally be obtained by cold storage or use of freshly dug stock in the spring of the year. We generally keep the cooler at 50° to 55°F until approximately the middle of September, depending again on current weather conditions. The temperature in the cooler is gradually brought down in 4° to 6°F increments to the 35° to 36°F level as the fall progresses.

RICHARD WOLFF: Did you put a fungicide in the gel?

ROBERT EASTMAN: There is no need to put a fungicide in the box because you do not get any mold below 32°F.

ROOTING OF FRASER FIR CUTTINGS: EFFECTS OF POST-SEVERANCE CHILLING AND OF PHOTOPERIOD DURING ROOTING

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Abstract. Terminal stem cuttings from 5-year-old Fraser fir [*Abies fraseri* (Pursh) Poir.] stock plants were collected in early fall, when in a state of rest or winter dormancy. Cuttings were subjected to dark storage at 4°C for 0, 2, 4, 6, 8, 10 or 12 weeks. Following storage, and prior to insertion into a rooting medium, cuttings were subjected to one of two treatments: non-treated, and wounding + indolebutyric acid (IBA). Cuttings received short- or long-days during a 10-week rooting period. Non-chilled cuttings did not root or break bud. High percent rooting occurred after 4 to 6 weeks of chilling, whereas visible terminal bud activity peaked after a 10-week chill. Rooting was primarily contingent upon IBA treatment and chilling, although long days had a strong promotive effect when cuttings were chilled less than 6 weeks.

Tree species indigenous to temperate zones typically become dormant in early fall and resume growth only after a period of low temperatures. For some conifer species, plants or stem cuttings collected in September and October exhibit low capacity for cambial activity, root initiation, or budbreak (1,2,8,9,10). As the chilling requirement is satisfied, rooting capacity and cambial activity increase to a peak between December and April. Long days promote cambial activity, budbreak, and root initiation in dormant Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) and balsam fir (*Abies balsamea* L.) plants and stem cuttings collected in early fall, in effect, substituting in part for the chilling requirement (8,10). The compensating effect of long days tends to diminish as the chilling requirement is satisfied.

Preliminary work with Fraser fir (*Abies fraseri* (Pursh) Poir.) stem cuttings collected in early fall and rooted under 10- to 12-hour days indicated rooting percentages were relatively high following 4 or 8 weeks of constant chilling at 4°C, whereas visible terminal bud activity was increasing but still relatively low even after 8 weeks of chilling (5). This suggested different chilling requirements for rooting and budbreak.

The objective of the current study was to examine rooting

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[1] Graduate Research Assistant. Portion of a M.S. thesis by the author who acknowledges technical assistance of Layne K. Snelling, and the North Carolina Forest Service for providing cuttings. The use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service of products named nor criticism of similar products not mentioned.

capacity and visible terminal bud activity of Fraser fir stem cuttings as influenced by duration of post-severance chilling and photoperiod during rooting.

MATERIALS AND METHODS

Terminal Fraser fir stem cuttings, 16 to 25 cm in length, were collected on October 8, 1980 from 5-year-old (3+2) transplants growing under uniform fertility levels at the Joseph A. Gill Nursery (North Carolina Forest Service) in Crossnore (36° 01'N latitude, 81° 56'W longitude; elevation = 980 m). The provenance was Roan Mountain (36° 09'N latitude, 82° 05'W longitude, elevation 1900 m). Cuttings consisted of multiple shoots that resulted from previous frost damage to terminal buds. Orthotropic shoots were used to avoid the plagiotropic growth habit of cuttings taken from lateral branches (5). Only one cutting was taken per stock plant to ensure a broad genetic base in the experiment. Stock plants had experienced 3 frosts and a cumulative total of 60 hours of air temperatures below 5°C during the 3 weeks preceding collection of cuttings. They were assumed to be in a state of rest (3) or winter dormancy (4). The cumulative effect of the low temperatures in satisfying the chilling requirement for budbreak was assumed to be negligible since maximum day temperatures during that period were 18 to 27°C.

As cuttings were collected, they were sealed in polyethylene bags, placed in a cooler with ice, and transported to Raleigh. Prior to cold storage, cuttings were trimmed acropetally to 15.3 cm. A group of cuttings was randomly selected to receive no additional chilling; the others were sealed in polyethylene bags and dark stored at 4°C. Cuttings in each bag were oriented in a vertical position with terminal buds upward and the bases resting on moist paper towels.

Following cold storage for 0, 2, 4, 6, 8, 10 or 12 weeks, cuttings were trimmed to 15 cm and needles removed from the basal 4 cm. Half the cuttings received no treatment; others received wounding + IBA. Wounding consisted of 4 equidistant vertical cuts into the xylem on the basal stem, each cut about 2.5 cm in length and parallel to the longitudinal axis of the cutting. IBA was applied by dipping the basal 2 cm of each cutting into a 5000 ppm IBA solution followed by 15 minutes of drying before insertion into the rooting medium. The solution was prepared by dissolving reagent grade IBA in 50% isopropyl alcohol. Cuttings were inserted to a 4-cm depth in a raised greenhouse bench containing a moist medium of Canadian peat and sand (1:1, v/v). Intermittent mist operated 5 seconds every 5 minutes between 0700 and 1830 hours daily. Day/night maximum/minimum ambient air temperatures

were 24 ± 5 / 14 ± 4°C. Day/night maximum/minimum rooting medium temperatures at a 2-cm depth were 21 ± 3 / 16 ± 3°C. On warm sunny days, 50% shade cloth was used to maintain the ambient air temperature below 29°C. In addition to rooting and chilling treatments, 2 photoperiod treatments were utilized in the mist bed: short- and long-days.

The experimental design was a split-plot with 4 replications. Photoperiods served as main plots, and chilling x rooting treatments were randomized within each main plot. A single raised greenhouse bench was used. A replication consisted of 2 main plots, each with 14 contiguous sub-plots. Each sub-plot contained 8 cuttings. Short- and long-day treatments were randomly assigned to main plots in each replication. Short-days were imposed by placing lightproof, plywood boxes over the appropriate main plots between 1700 and 0800 hours daily. Temperature and relative humidity inside and outside the boxes were similar. Long days were effected by a 3-hour night light break with incandescent light between 2300 and 0200 hours daily. The light was supplied by 100 W incandescent lamps located 70 cm above the surface of the rooting medium and spaced 100 cm apart. This provided a radiant power density[1] of 1.9 and 2.1W/m^2 at the center and outer edge of the bed respectively, measured at the terminal buds with a Li-Cor LI-185A quantum/radiometer/photometer. Black cloth covered the bench between 1700 and 0800 hours daily.

The experiment was initiated on October 9, 1980 and terminated April 1, 1981. Each treatment was represented by 32 cuttings which remained in the mist bed for 10 weeks. Data included the number and length of roots > 1 mm in length. Cuttings having one or more roots were classified as rooted. For each plot, the average number and length of roots per rooted cutting were computed, giving equal weight to each cutting. An active terminal bud was defined as one which was visibly swollen or had burst. Percentages were transformed with the angular transformation and data subjected to standard analysis of variance procedures.

RESULTS

Cuttings collected in early October, which received no artificial chilling, failed to root (Fgure 1A). Rooting response to chilling and photoperiod was strongly contingent upon wounding + IBA (Table 1). Percent rooting for IBA-treated cuttings increased early in the chilling cycle and reached a virtual maximum under long days following 4 weeks of chilling; 6 weeks under short days. Non-IBA-treated cuttings first rooted

[1] Photomorphogenic radiation between 750 and 830 nm.

after 4 to 6 weeks of chilling and reached the maximum after 10 weeks. Following 2 or 4 weeks of chilling, precent rooting of IBA-treated cuttings was about 2× greater under long days, but the difference between photoperiods was negligible for chilling durations ≥ 6 weeks. Percent rooting of non-IBA-treated cuttings was not affected by photoperiod at any point.

Table 1. Test of significance for the effect of post-severance chilling and photoperiod on rooting and visible terminal bud activity of stem cuttings collected from 5-year-old Fraser fir stock plants in early October.

Duration of chilling (weeks)	Parameter											
	Active terminal buds (percent)			Rooting (percent)			Root length			Roots/ rooted cutting		
	T[z]	P	T×P	T	P	T×P	T	P	T×P	T	P	T×P
0	(-)[y]	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	*	NS	NS	*	NS	NS	*	NS	NS
4	NS	NS	NS	*	*	*	*	NS	NS	*	NS	NS
6	NS	NS	NS	*	NS	NS	*	NS	NS	*	NS	NS
8	*	NS	NS	*	NS	NS	*	NS	NS	*	NS	NS
10	*	NS	NS	*	NS	NS	*	NS	NS	*	NS	NS
12	*	*	NS	*	NS	NS	*	NS	NS	*	NS	NS

T[z] = IBA treatment, P = photoperiod, T×P = IBA treatment × photoperiod interaction. (-)[y], values for all treatments were zero; (*), significant at 5% level; (NS), not significant.

The number of roots per rooted cutting (Figure 1B) was greatly enhanced by wounding + IBA, and maximum root lengths (Figure 1C) were realized after 4 to 8 weeks of chilling. Root formation in non-IBA-treated cuttings was too erratic to identify the chilling requirement for maximum rooting. Also, there was no significant relationship between photoperiod during rooting and the number and length of roots per rooted cutting (Table 1).

Non-IBA-treated cuttings produced few roots (Figure 1B) at any duration of chilling, and where present, the roots were very short (Figure 1C). IBA-treated cuttings, which produced numerous roots even following short durations of chilling, had much longer roots. Long days increased root length of IBA-treated cuttings chilled 10 weeks or less (Figure 1C). Root length under long days was virtually maximum on IBA-treated cuttings after only 2 weeks chilling; 4 weeks under short days.

Time course of visible terminal bud activity (Figure 1D) contrasted with that of percent rooting (Figure 1A). Visible bud activity was negligible through 4 weeks of chilling under long days, 6 weeks under short days. All cuttings, regardless of treatment, exhibited a sharp increase in visible bud activity for the interval between 6 and 10 weeks of chilling, and addi-

tional chilling beyond 10 weeks was of little benefit. IBA-treated cuttings subjected to long days and chilled 6 weeks or longer consistently displayed more visible terminal bud activity than those receiving short days, the absolute difference being 10 to 20%. The capacity of long days to promote bud activity was most apparent, however, for non-IBA-treated cuttings chilled 10 to 12 weeks, the absolute difference being 30 to 35% (Figure 1D, Table 1).

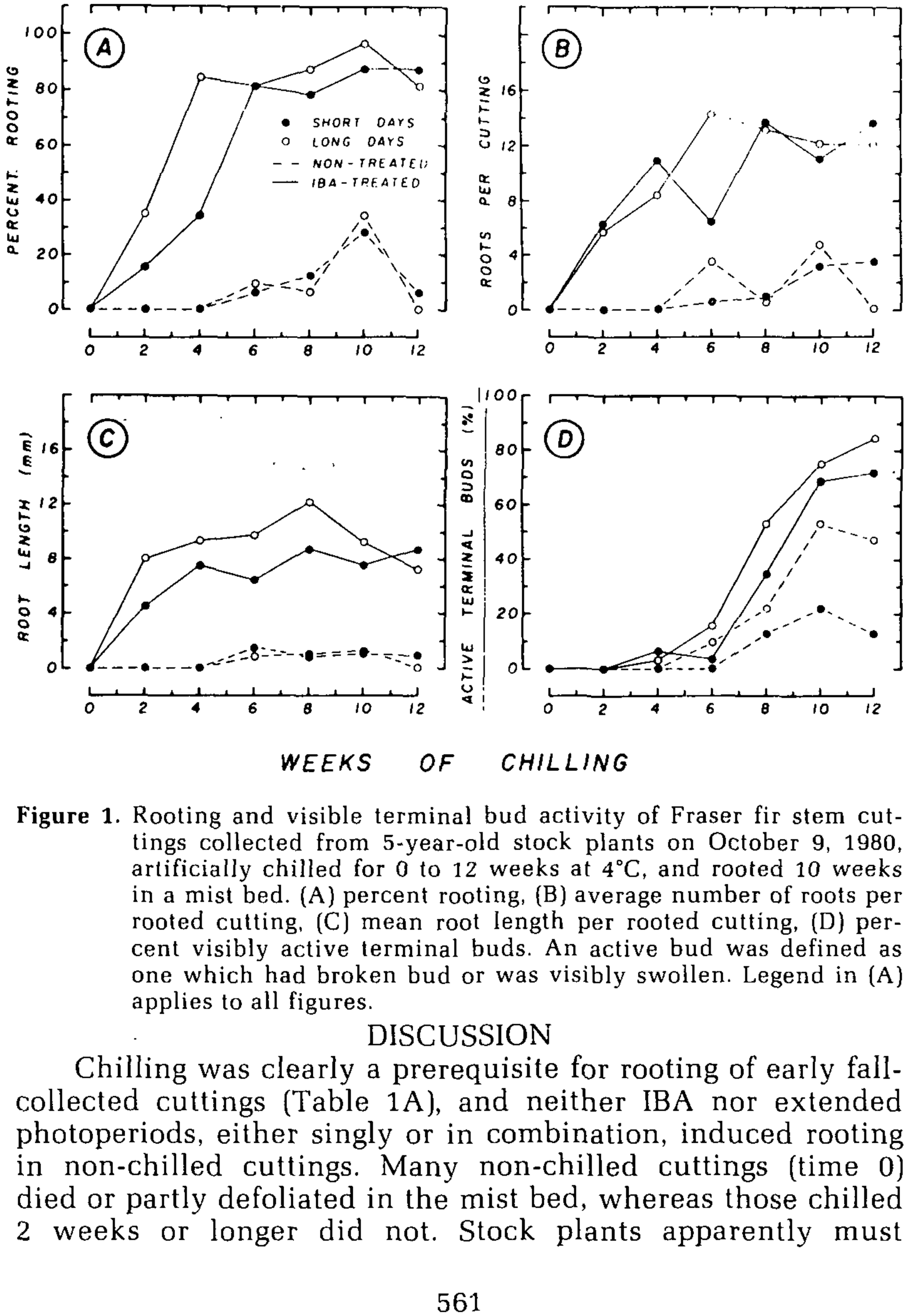

Figure 1. Rooting and visible terminal bud activity of Fraser fir stem cuttings collected from 5-year-old stock plants on October 9, 1980, artificially chilled for 0 to 12 weeks at 4°C, and rooted 10 weeks in a mist bed. (A) percent rooting, (B) average number of roots per rooted cutting, (C) mean root length per rooted cutting, (D) percent visibly active terminal buds. An active bud was defined as one which had broken bud or was visibly swollen. Legend in (A) applies to all figures.

DISCUSSION

Chilling was clearly a prerequisite for rooting of early fall-collected cuttings (Table 1A), and neither IBA nor extended photoperiods, either singly or in combination, induced rooting in non-chilled cuttings. Many non-chilled cuttings (time 0) died or partly defoliated in the mist bed, whereas those chilled 2 weeks or longer did not. Stock plants apparently must

achieve a certain tissue maturity, or attain a certain phase of dormancy before cuttings can be successfully transferred to a mist bed for rooting. Since cuttings chilled 2 weeks or longer did not die or defoliate in the mist bed, the necessary pysiological changes evidently occurred during the first 2 weeks inside the 4°C, dark cold room, and were not dependent on the presence of light or a root system. These changes had probably proceeded to an unknown extent in response to shorter days and decreasing temperatures during the month prior to collection of cuttings, and continued in the cold room.

The principal effect of long days was to increase percent rooting for IBA-treated cuttings early in the dormancy cycle; those chilled 2 to 4 weeks had 2- to 2.5-fold higher rooting percentages under long days. Thereafter, the effect of photoperiod on percent rooting was not significant (Table 1). This poses a question why long days compensated for chilling in IBA-treated cuttings, but not in non-treated cuttings. Long days might have caused the formation of substances in the buds or foliage, which subsequently interacted with auxin to promote rooting. In this regard, Lavender and Hermann (6) demonstrated that resumption of root, bud, and cambial activity in quiescent Douglas-fir seedlings was dependent upon the presence of foliage, and foliage exposed to long days appeared to export substances (not identifed) which stimulated meristematic activity.

Chilling alone does not appear to have the capacity to induce 100% terminal budbreak in Fraser fir cuttings. Maximum rooting and visible terminal bud activity for non-IBA-treated cuttings was 35 and 53%, respectively, following a 10-week chill. Much more visible terminal bud activity would have been expected late in the dormancy cycle, particularly if resumption of bud growth was due to the reduction or elimination of inhibitors within the bud as a consequence of low temperatures. Based on Douglas-fir studies, Roberts and Fuchigami (9) suggest that budbreak is tied to the internal balance of inhibitors and promotors, which is affected not solely by chilling, but other factors as well. For example, given equivalent periods of chilling, e.g., 8 to 10 weeks, IBA-treated cuttings had much higher bud activity, even under short days, than non-treated cuttings subjected to long or short days (Figure 1D). Treated cuttings also rooted in higher percentages (Figure 1A), and had greater root numbers and lengths (Figures 1C, 1D). Since auxins move primarily in a basipetal direction, the addition of auxin to the distal end of a cutting would not in itself be expected to directly affect budbreak. Obviously, however, exogenous application of IBA dramatically increased terminal bud activity as well as rooting response (Figure 1A, 1D). Per-

haps the effect of auxin on bud activity was an indirect effect exercised through root formation, but this was not investigated. Once roots are present and actively growing, acropetal transport of hormones, e.g., gibberellins (7) and other substances, could promote bud activity in terminal buds predisposed to break bud following a sufficient period of chilling. Also supporting this hypothesis is the observation (unpublished data) that visible bud activity during a 10-week rooting period decreases with increasing cutting length. This suggests that materials moving acropetally from the roots might require a longer time to reach the terminal bud in quantities sufficient to cause a noticeable change in visible bud activity.

Results (Figure 1) confirm observations that the chilling requirement for rooting is less than that for budbreak (5,9). The rooting response of IBA-treated cuttings was essentially maximum following 6 weeks of chilling, whereas visible terminal bud activity increased sharply thru 10 weeks of chilling. For non-treated cuttings, both maxima occurred following 10-weeks of chilling. Currently, it cannot be explained why the response differed for treated and non-treated cuttings. Since visible terminal bud activity was greater for all cuttings following 10 weeks of chilling, it appears the capacity to break bud hinges upon physiological changes brought about by the cumulative effects of chilling over a long period of time. In contrast, rooting occurs in high percentages following brief chilling if sufficient levels of auxin are applied. Generally, auxin and other substance(s) which promote cambial activity and rooting originate in increasing amounts from buds and foliage as the chilling requirement for budbreak is satisfied (6,8,10). In the current studies, endogenous levels of these substances in non-IBA-treated cuttings were apparently too low at all points in the chilling cycle to promote a strong rooting response. Even though applied auxin overcame the restriction on rooting, it is suspected that chilling dependent factor(s), e.g., inhibitors, prevented budbreak early in the dormancy cycle. Following a sufficient period of chilling, and reduction or elimination of the inhibitors, budbreak would be enhanced by hormones or other substances arising from the cambium, leaves, or roots. The results reported herein are consistent with the hypothesis that resumption of growth is controlled by a balance of promotors/inhibitors (9) which is affected by numerous factors, e.g., duration of chilling, and the presence or absence of a developing root system.

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JOERG LEISS: Did you compare lateral with apical cuttings?

FRED MILLER: Yes. Lateral cuttings were a problem because they continued to grow as lateral branches.

UTILIZING CAPILLARY IRRIGATION FROM THE PROPAGATION BENCH TO HARVEST

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The concept of capillary watering is an age old practice but its application to irrigation of container-grown nursery stock on ground beds outside is a new use in the U.S. This method of watering nursery stock had its beginning at the Efford Experiment Station in England and is now in widespread use in Europe (12) and New Zealand (7). Capillary watering has several advantages to overhead watering including reduced water consumption, water run-off, weeds, root (5) and foliar diseases. This procedure has been evaluated at The Ohio State University for the past several years and the following report summarizes several of these studies (10,11).

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BED CONSTRUCTION

The capillary beds were constructed 5 ft wide by 50 to 100 ft long. Studies were conducted on a soil or gravel base with a slight crown along the main bed axis to provide drainage away from the capillary mat or base. A layer of white or black poly is placed over the soil or fine gravel which had been smoothed. Poly film of at least 4 mil. thickness retains the moisture and allows its distribution under the mat or base. The capillary mat or sand is placed on the poly. Two lines of Chapin twin wall trickle tubing were placed on the mat or sand and operated at a pressure of 4 to 6 psi for several hours per day. To eliminate labor the trickle tube was operated with a time clock and solenoid valve. The plants were placed on the mat or sand. Thus, a hydrant or source of water and an electrical outlet are necessary to operate the system as outlined above. No sideboards are necessary for a capillary mat bed; however, pressure-treated 2 × 4 inch side and end walls are required for a sand bed system.

RESULTS AND DISCUSSION

Studies with container types and capillary mats. The purpose of these studies was to evaluate growth of 'Royal Beauty' cotoneaster in two container types on several capillary mats.

Zarntainer No. 300 (1 gal) and No. 800 (2 gal) with holes along the base and one in the underside and Polytainer No. 1 (1 gal) and No. 2 (2 gal) with holes only along the base were used. The medium was Metro Mix 500, a pine bark-vermiculite mix.

The mats evaluated included Water Mat (Pellon Corp.), Vattex-P (U.S. Vattex), Weed-Chek (Certain-Teed), and Eddy-mat (I.R. Young Co.). All plants were irrigated from overhead at the time of placement on the mats to initiate capillary action. If rainfall did not exceed 1 inch every 10 days then the plants were watered from overhead to reduce salts buildup.

Plant growth in containers with drainage holes along the base did not differ from containers with holes in the underside. Different size containers and different types of containers can be adequately produced on the same mat. Subsequent studies indicated that the system works very well for plants produced in flats and in containers from 3 to 10½ inches in dia. (3 gal) including poly bags. In a separate study, growth of plants in poly bags was always equal to or greater than growth from plants in rigid pots.

Growth of plants was generally satisfactory for all mats evaluated. However, the best growth was obtained in plants produced on the Pellon water mat. Drying of the mats after the

water was turned off was more pronounced in the Weed-Chek treatment. The Pellon water mat, in follow-up evaluations, has proven reusable for at least 3 years and possibly more, while other mats are more likely to tear apart when lifting plants or due to animal pawing or mechanical separation. Multiple year use from mats has been obtained in studies in England (8).

Algae growth tends to accumulate on the mats over time but this can be reduced with Clorox (3) at the end of the season or with a direct spray from a hose between the plants during the season.

A new product which has proven successful for us is available as "Capillary Sheets" and is used as a mat overlay. It's a thin black polyethylene film perforated with tiny, nearly round holes spaced ½ inch apart. The water transfers from the mat through the tiny holes to the medium in containers placed upon it. Algae growth is almost eliminated, the mat stays cleaner and should result in a longer service life. Our studies with this product, available from Evert S. Green, 14 Kenneth Avenue, North Bellmore, New York 11710 are limited to one season but our results are similar to those found in Florida (4).

Studies of irrigation methods. The objective of this study was to compare plant growth and irrigation labor costs of watering by hand, overhead sprinkers, and capillary mats. All plants, including blue rug juniper, bigleaf euonymus, 'Royal Beauty' cotoneaster, and cranberry cotoneaster produced on capillary mats were larger than those produced under overhead and hand watering. Hand watering, such as is practiced in garden centers and landscape holding areas required 7 times as much labor to irrigate during the season as the overhead and capillary systems which were about equal in requirements. Water consumption was not recorded but studies in Massachusetts indicated that capillary irrigation used 1/5 the amount of water of an overhead system (2).

In a cost appraisal of watering systems in Florida, capillary mat had a higher initial investment than an overhead system but water consumption was appreciably less (6). Sand beds will be less expensive than matting and once installed should last many years.

Media comparison study. The purpose of this evaluation was to compare growth of plants produced in hardwood bark-sand (5:1 v/v) and soil-peat-sand (1:1:1 v/v) on capillary mats. 'Wiltonii' juniper, bigleaf euonymus, 'Royal Beauty' and cranberry cotoneaster all grew better in the soil-peat-sand mix than the bark-sand mix. The reason was that the bark-sand mix tended to dry faster than the soil-peat-sand. The more uniform moisture level of the soil-peat-medium is the probable

reason for the superior growth. Follow-up studies with other media, including pine bark, substantiate the need for approximately 20 to 25% peat moss in the medium to obtain the most ideal moisture level. Some of the packaged commercially prepared media, such as Metro Mix 500, which contains peat moss, wet extremely well with capillary watering.

The fertilizer used in most of these studies has been Osmocote 18-6-12 (8 to 9 months) incorporated into the medium at potting, or surface applied. The lower rate suggested on the label has been selected in most instances. Osmocote 14-14-14 at recommended rates was the best treatment in studies in Rhode Island (1). If surface application is selected, overhead watering or an inch of rainfall every 7 to 10 days is desirable to bring the fertilizer into the root zone.

Mat vs. sand capillary comparison. The capillary mat beds were prepared as previously discussed. The sand holes were constructed with 1½ in. of sand over the plastic, and the bed levelled.

'Royal Beauty' cotoneaster grew best on capillary mat, weigela best on sand, and 'Wiltonii' juniper equally well on both. Growth of all three species was superior in the sand when the trickle tubes were placed below rather than on the top of the sand.

The weigela rooted into the sand and if left undisturbed the root system outside the container became extensive.

Root pruning on capillary sand beds. Sanitizing agents are used in England (9) for root pruning so a study with forsythia (Figure 1) was initiated to determine a non-phytotoxic root

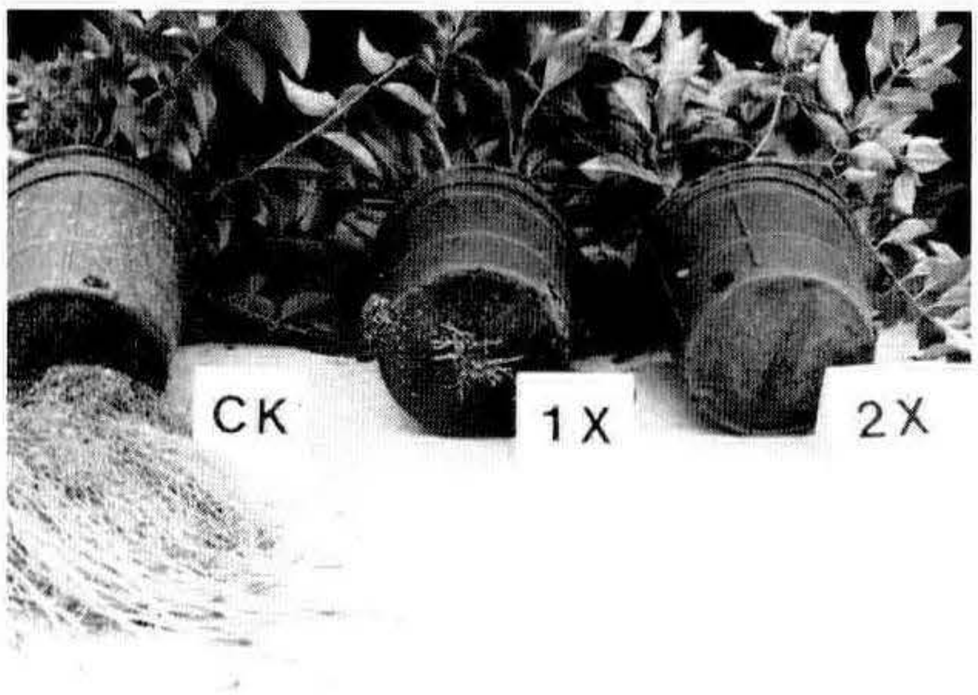

Figure 1. Forsythia container plants produced on sand capillary beds treated with Gloquat C. Left to right: Control, 1× (5⅓ oz/100 sq ft), and 2× (10⅔ oz/100 sq ft)

pruning agent for container plant production on sand beds. After many trials the only satisfactory material found was Gloquat C, the material described by Scott (9) and used in England but with limited availability in the U.S. The only source of Gloquat C is Aceto Chemical Company, Inc., 126-02

Northern Boulevard, Flushing, New York 11368. This firm acts as the distribution agency in the U.S. for the basic manufacturer. In addition to root pruning, this material supresses both algae and annual weed growth. One application lasted the entire growing season in our trials when used at 5⅓ oz/100 sq ft of bed area.

SUMMARY

In summary, capillary irrigation offers a substitute to overhead watering, particularly if water is in short supply or excess runoff poses a concern. Both matting or a sand base are acceptable for containers up to 10 to 10½ in diameter. Different size containers can be used on the same mat. To improve wetting of bark mixes approximately 20 to 25% peat moss should be incorporated into the mix. Root pruning on sand beds is necessary for vigorous rooted plants, such as deciduous shrubs. Gloquat C applied prior to placing plants on the sand is a satisfactory root pruning agent.

Capillary watering may have application in commercial container production and in retail garden centers. We suggest that this method of irrigation be given a trial if it is necessary to reduce overhead watering.

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DWIGHT HUGHES: You mentioned that there might be a problem with containers larger than 2 gal. Would you address that issue?

ELTON SMITH: The system has worked well up to 3 gal containers. Larger than that you get into plants that require a lot of water and there is just not enough draw.

JIM CROSS: Have you tried perforated black poly on top of the sand.

ELTON SMITH: No, however, that system is also available from Evert Green.

PROPAGATING SHADE TREES BY CUTTINGS AND GRAFTS

WILLIAM FLEMER, III

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Growing shade and ornamental trees from cuttings is no startling new development on the horticultural scene. For many centuries trees like willows and poplars have been grown from hardwood cuttings. With the development of mist propagation and rooting hormones it was discovered that many more genera could be successfully grown from softwood cuttings. Tree hybridization and the selection of superior clones of natural species has given much impetus to research in rooting tree cuttings and expanding the list of cultivars which can be propagated in this manner.

There are many advantages to cutting propagation over grafting, budding, and other methods of vegetative propagation. One very important factor is cost. In general it is much cheaper to make up and root a cutting than to buy or grow an understock, then pot it or plant it out in the open ground, and finally graft or bud it. After that there are the inevitable losses and the subsequent expenses of cutting out suckers and staking the shoots or scions. In general, a skilled propagator can make several cuttings in the same time that would be required to make a graft or clean, bud, and tie an understock tree in the field.

Rooting cuttings also avoids the problem of scion-understock incompatibility. This problem varies widely depending on the genus or even species of the plant to be grown. In

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Rooting cuttings also avoids the problem of scion-understock incompatibility. This problem varies widely depending on the genus or even species of the plant to be grown. In

grafting ginkgos and *Tilia cordata* clones on *T. cordata* understock for example, incompatibility is negligible but in budding or grafting clones of *Acer rubrum*, *A. saccharinum*, *Quercus rubra*, and *Q. palustris* on their own species, incompatibility is very serious and heavy losses can be sustained as the trees mature. To date, little has been discovered as to why this phenomenon occurs with some genera or species and not with others. Why should graft incompatibility be so common with *A. rubrum* and *A. saccharinum* and yet so rare with *A. platanoides* and *A. saccharum*?

Another advantage to cutting propagation is that relatively unskilled help can be trained to make cuttings much more easily and quickly than to graft or to bud. In this era, craftsmanship is at a discount and hand work is unpopular. A workable cutting crew can be trained in only a few days, because making acceptable cuttings is so simple whereas it takes weeks or even months to train a worker to make good grafts fast enough to make the operation economical. There is no problem in finding willing candidates to drive a truck or tractor, but few indeed want to learn to graft or bud.

While cutting propagation of shade trees has many obvious advantages, there are some serious drawbacks too. To begin with, there are a number of genera and species, sometimes quite closely related, which are difficult or impossible to root. *Quercus palustris* and *Q. rubra* are commercially impossible, for example. The hybrid *Magnolia* × *soulangiana* is easy to root but one of its parents, *M. denudata*, is almost impossible. *Prunus serrulata* 'Kwanzan' is relatively easy but *P. serrulata* 'Shirotae' is extremely reluctant, and *P. sargentii* is even worse.

A problem with some species is that, although they can be rooted successfully, the root system or structure is so poor that the resultant trees are unsaleable at digging time. It is possible to root *Sophora japonica* from hardwood cuttings in the greenhouse or from softwood cuttings under mist. When planted out in the field, the young trees grow on well enough, but the root system is too sparse for successful transplanting at a larger size. If the young trees are dug, root pruned, and replanted a couple of times in the production cycle good roots can be produced, but the cost of such operations far exceeds the cost of budding or grafting on seedling understocks to begin with, and also avoids the extra handling. It is possible to root *Pyrus calleryana* 'Bradford' from softwood cuttings, but the young trees develop poor, irregular root systems and are very susceptible to wind-throw when larger, either in the nursery or on city streets. *Tilia cordata*, which is subject to some wind-

throw when grown on seedling understocks, is much worse on its own roots.

Over-wintering tree cuttings is particularly difficult during the first winter after rooting for some species. Cutleaf weeping birch *Betula pendula* 'Dalecarlica (Syn.: B. *alba* var. 'Laciniata') can be quite successfully rooted from softwood cuttings. However, getting the young plants through the first winter is another matter and losses can be so severe that the leading Dutch proponants of this method of propagation have given it up. *Stewartia* species are especially difficult and *Hamamelis mollis* is even more so. *Cornus florida* 'Rubra' and C. *kousa* are practical, but the over-wintering temperature requirements are very strict and narrow. The cuttings must have enough winter cold to satisfy their dormancy requirements, yet if they freeze the bark splits and all is lost. In effect, this means that the winter temperature surrounding the cuttings must range between 33° and 40°F. The length of cold required has not been worked out for each species, but the average requirement is 90 to 100 days.

It is relatively easy to subject a few flats of cuttings or potted cuttings to these exacting requirements and many arboreta and botanical gardens have the equipment to do so. However it is another matter to over-winter hundreds of thousands of cuttings in such a narrow temperature range, and expensive facilities or very watchful care in less elaborate structures are required for success.

Another problem with some cutting-grown trees is lack of vigor in the young tree for many years after it is lined out in the nursery field. Cutting-grown young *A. rubrum* trees are almost as vigorous as buds. Cutting grown *T. cordata* clones are very slow indeed. A budded *T. cordata* can produce a whip 7 or 8 ft tall in the first summer after the understock is cut back, while a cutting-grown tree of the same clone may take 3 growing seasons to reach the same height. A seedling of *A. griseum* may put on 18 in. of growth in the second year while a cutting will only grow 3 or 4 in. Slow growth is not invariably the case, however, for a seedling poplar or willow may grow only 18 in. tall in one growing season, whereas a yearling tree of the same species grown from a spring-planted hardwood cutting may reach 9 or 10 ft in height.

For some as yet unexplained reason, young plants from cuttings of certain tree species are much less cold-hardy even when several years old than grafted trees of the identical species and clone. *Cornus florida* and its various clones are notorious in this respect, as are the various forms of *A. palmatum*. I can recall an especially cold winter in which we had a polyethylene covered house full of 2 year *A. palmatum* 'Blood-

good' trees in 1 gal. cans, half of them grafts and half own-root plants. Without exception every cutting-grown plant died and every graft lived. Evidently the bark of cutting-grown plants is somehow different from that of seedlings, as it splits readily at ground level when frozen. It would be a neat morphological problem to find out why this occurs. In any case, plants which exhibit this problem for many subsequent years always seem to be the same ones which are especially difficult to get through the first winter after rooting.

Having summarized the distinct advantages and problems encountered in growing trees from cuttings, it is worthwhile to review the various forms of cutting propagation and the trees which are readily reproduced by each method.

HARDWOOD CUTTINGS

This was historically the first method which was used to propagate trees from cuttings (See Table 1 for a list of shade trees that can be grown from hardwood cuttings). It is still by far the best method for trees like willows and most poplars. Where cuttings can be stuck directly in the open field where the trees are to be grown on, it is the cheapest of all forms of cutting propagation. It has the added advantage of being an operation in which making up the cuttings is done in the winter when the work load is lightest. Hardwood cuttings are collected after the leaves have fallen, preferably not until December or later when the wood is hardest and the food stored in the stems is at its highest point. As is true with many kinds of softwood and conifer cuttings, tree hardwood cuttings made with a "heel" often root more easily than straight cuttings. Such extra care is not necessary with species like willows and poplars which have pre-formed root primordia beneath the bark of young stems.

Table 1. Trees that can be propagated by hardwood cuttings

Elaeagnus angustifolia
Franklinia alatamaha[1]
Maclura pomifera
Metasequoia glyptostroboides
Morus alba, (M. platanifolia, possibly lobed, sterile forms of M. alba)
Malus, fruiting understock clones[2]
Platanus, all species
Populus, most species (see root cutting list for exceptions)
Prunus cistena, *P. cerasifera* purple cultivars, fruiting understock clones[2]
Salix, all species
Sophora japonica[1]
Syringa *reticulata* (Syn.: S. *Amurensis* var. *japonica*)

[1] Stick in a greenhouse with bottom heat
[2] Stick in "Garner Bin"

Rooting hardwood cuttings of fruit understocks such as plums, apples, and pears by the "Garner Bin" method has been successfully used in England. The cuttings, up to 18 in. or more in length, are made up, bundled, treated with a hormone soak and then heeled-in in special bins in which the tops are exposed to the open air but the bottoms are heated up to 70°F to encourage callusing and root initiation. When the latter occurs the cuttings, which still have dormant tops, are lined out in the open field as understock for summer budding. This intriguing method has not been so successful in the U.S.A. In part it depends upon establishing blocks or hedges of special understock clones in which juvenility is maintained by hard cutting back each winter. If the plants lose their juvenility, they will no longer root satisfactorily. Furthermore, the much colder and drier "continental" climate of central and eastern Canada and the U.S.A. is apparently detrimental although experiments in rooting 'Bartlett' and 'Old Home' pear by hardwood cuttings in California were successful. The "Garner Bin" should not be dismissed arbitrarily. It is possible that extended research, in techniques, different rooting structures and in various strengths and formulations of rooting hormones could be very fruitful. Isolated reports in rooting hardwood cuttings of *M. soulangiana* hybrids and *A. palmatum* 'Atropurpureum' indicate what is possible, although there are big unsolved problems because extensive propagation by this method has not taken hold. Serious research in this neglected corner of plant propagation is well worthwhile. In addition to cheapness, hardwood cutting propagation is valuable because such large liners are produced, a marked contrast to the feeble little plantlets which come out of the tissue culture labs.

SOFTWOOD CUTTINGS

Propagating shade and ornamental trees from softwood cuttings is not a new method (see Table 2 for a list of shade trees that can be propagated by softwood cuttings). Dr. L.C. Chadwick published a paper on rooting ginkgos in the 1920's. Japanese cherries, oriental magnolias, *M. grandiflora*, and some purple-leafed plums have been grown by this method of many years. Recently, Dr. Elwin Orton's work in rooting cuttings of *A. rubrum* clones has led to renewed interest in shade tree propagation by this method and much new work has been done. It is safe to generalize that almost all of the major shade trees are difficult to propagate from softwood cuttings. Whenever the propagator has to deal with a "difficult" species of woody plant, clonal differences in rooting ability are especially pronounced. Thus *A. rubrum* 'Red Sunset' roots easily while *A. rubrum* 'Bowhall' is difficult, *P. serrulata* 'Kwanzan' is fairly

easy but *P. serrulata* 'Shirotae' is very difficult and *P. serrulata* 'Tai Haku' is worse. A few clones of *A. saccharum* will root but most will not.

Table 2. Trees that can be propagated by softwood cuttings

Acer griseum, *A. palmatum**, *A. rubrum*, *A. saccharinum*
Amelanchier spp.
Betula pendula 'Dalecarlica' (Syn: *B. alba* 'Laciniata'), *B. nigra* 'Heritage'
Cercidiphyllum japonicum
Cornus *florida* clones[1], *C. kousa*[1] and cv. 'Summer Stars', *C. mas*
Davidia involucrata[1]
Franklinia alatamaha
Ginkgo biloba
Ilex aquifolium, *I. opaca*, *I pedunculosa*
Lagerstroemia indica
Liquidambar styraciflua
Magnolia × 'Galaxy', *M. grandiflora*, *M.* Kobus var. *loebneri*, *M.* × *soulangiana* clones, *M. kobus* var. *stellata*, *M. virginiana*
Malus, oriental species and hybrids, dwarfing understocks
Metasequoia glyptostroboides
Platanus, all species
Prunus maackii, *P. serrulata* (some clones), *P. subhirtella*[1], *P. yedoensis*
Pyrus calleryana clones[1]
Quercus robur 'Fastigeata'
Sophora japonica
*Stewartia koreana**, *S. pseudocamellia*[1]
Styrax japonica
Syringa reticulata
Taxodium distichum
Tilia cordata clones
Ulmus americana, *U. carpinifolia*, × *U. hollandica*
Zelkova serrata

[1] Cuttings difficult to bring through their first winter after rooting.

The development of mist propagation has been especially important for successful rooting of tree cuttings. Many which were considered impossible in earlier times are commercially practical today. With the perfection of mist propagation systems the addition of bottom heat for softwood propagation has become practical as well. Bottom heat is especially important in the cool summer climate of the Pacific Northwest, but even in the heat and humidity of the Middle South and the East, bottom heat makes it possible to root some species which are very difficult without it. Mist is important also because of the critical timing necessary in taking softwood cuttings of many trees. Many species and hybrids of elms, for example, will root from extremely soft cuttings taken very early in the summer but not from cuttings of more mature wood. Properly regulated applications of mist can keep these fragile cuttings turgid long enough for rooting to occur, almost an impossibility under older methods of propagation.

Supplemental lighting to extend day length to 18 hours after midsummer and on into the fall proved to be the solution to successful cutting propagation of many deciduous azaleas which were formerly considered difficult or impossible by this method. Extra light greatly increases the summer growth and winter survival of cuttings of *A. palmatum* clones, *C. florida* 'Rubra, and *C. kousa* 'Summer Stars', as well as *A. rubrum* clones. It may well be that the answer to overwintering rooted cuttings of *Betula pendula* 'Dalecarlica' *(B. alba* 'Laciniata'), *A. saccharum*, and *Stewartia* species lies in getting them to make a flush of growth, no matter how small, in the same summer in which they were rooted, the same technique which is so successful with *A. palmatum* clones and *C. florida* 'Rubra.'

With the perfection of mist propagation and the accompanying option of being able to use bottom heat safely in the summer months, the only other problem is to find new kinds of concentrations and new combinations of rooting hormones in order to expand the list of trees which can be propagated from softwood cuttings on a commercial scale. The same kind of intensive and persistant research which has made it practical to root the vast array of rhododendrons now grown from cuttings can produce equal results with shade and ornamental trees. Like so many hybrid rhododendrons a generation ago, there are quantities of tree species which will callus well under mist but never go on to root. The impetus to root rhododendrons was strong because so many are sold each year. Dozens of shrubs are sold for every shade tree and at higher prices for young plants. With the escalating costs of budding and grafting, however, the trees merit their turn for expanded research.

ROOT CUTTINGS

The third form of cutting propagation for trees is little used but is of great value for a limited list of subjects (see Table 3 for a list of shade trees that can be propagated by root cuttings). This is propagation from sections of roots stuck in rooting medium so that they form aerial shoots as well as a new root system. Root cuttings are much more difficult to gather than aerial cuttings, and this factor has limited their use. In effect, the most economical way to gather them is during the spring digging season. Large numbers of trees are then available bare-root, from which occasional roots can be cut off and placed in boxes or baskets for temporary storage until they are cut up into suitable lengths, usually 2 to 3 in. long. Root cuttings stuck or planted in the early spring begin to grow promptly without a long period of dormancy in which

they can decay, as is the risk in making fall cuttings. It is just as important to pot or stick root cuttings with the apical end up as it is to stick softwood or hardwood cuttings with the apical tip up. However, workers who would never think of sticking a leafy cutting upside down will do so with root cuttings because the difference between top and bottom is so much less obvious. With appropriate species, root propagation is so reliable that the cuttings can be potted up or set in containers when they are made with good stands resulting and effecting a considerable saving in costs.

Table 3. Trees that can be propagated by root cuttings

Ailanthus altissima (Syn.: *A. glandulosa*)	*Kalopanax septem lobus* (Syn.: *K. pictus*)
Albizia julibrissin	*Malus*, dwarfing understock
Aralia elata, *A. spinosa*	*Populus alba*, *P. grandidentata*, *P. tremula* clones, *P. tremuloides*
Asimina triloba	*Pyrus calleryana*
Diospyros virginiana	*Robinia*, all species
Gleditsia triacanthos clones	*Sassafras albidum*
Gymnocladus dioica	*Ulmus* × *hollandica*

As in other forms of cutting propagation, there are striking differences in response, even in the same genus. For example, most of the *Ulmus* × *hollandica* clones sprout well from root cuttings, whereas *U. americana* does not. In other genera like *Robinia*, all species are readily grown from root cuttings. One particularly valuable aspect of root cutting propagation is that it is a method for restoring juvenility to a plant. Thus root cuttings can be used to reestablish a stock block of juvenile plants which can then be easily grown from soft- or hardwood cuttings. For example, *Ulmus* 'Christine Buiseman' roots with great difficulty if the cuttings are taken from mature trees. However, cuttings made from the sprouts from root cuttings root rapidly and give a good stand. In the case of apple clonal rootstocks, if the juvenility of a hedge of mother plants is lost because of neglected trimming, it is possible to restore the desired juvenility to the clone by growing new stock plants from root cuttings. In the case of trees which are difficult to bud or graft and will not root from stem cuttings (male *Gymnocladus* trees are a good example), root cuttings are the most practical method of vegetative propagation. The technique will always remain a rare but useful addition to the propagator's list of methods for special purposes.

Cutting propagation of trees is no universal panacea. It has distinct advantages and some definite disadvantages as well, depending on the tree to be grown. After some years of rela-

tive neglect it is now receiving greatly increased attention and is being used on a much expanded scale. From a research point of view, the surface has only been scratched. There are dozens of important tree species which could be grown from cuttings if only the proper chemical and environmental requisites can be worked out.

PRODUCING SHADE TREES BY GRAFTING

A great many shade and ornamental trees cannot be rooted using stem cuttings and they will not sprout from root cuttings. Similarly, many of the same species, at least at present, cannot be reproduced by tissue culture. If selected clones of such trees are to be reproduced, it must be done by grafting or budding.

Wherever budding will give acceptable stands it is to be preferred over grafting because in the hands of a skilled operator it is so much faster and cheaper. Furthermore, a budded tree, in which all the energy of the large and established root system of the field grown seedling understock is concentrated behind the growth of a single bud, will be many times the height of a grafted tree at the end of the first growing season. For example, 8 to 9 ft tall whips of *A. platanoides* 'Crimson King' can be obtained at the end of one season's growth in Oregon, but the same trees grown from dormant "bench grafts" will scarcely become 18 in. tall in the same period of time. Budding or grafting can be used as a fascinating measure of the photosynthetic effeciency of different tree clones. For example, *Acer platanoides* 'Emerald Queen' or 'Summershade' can make 10 foot tall whips in one summer's growth but the variegated *A. platanoides* 'Drummondii', grown on the same understock, will scarcely reach 5 ft in height, even in the splendid growing conditions of the Pacific Northwest.

There is much to be gained by budding trees whenever they can be propagated by that method. However, not all trees can be budded and these must be reproduced by grafting, despite its disadvantages. A typical example is the European beech, *Fagus sylvatica*. It has produced a number of beautiful variants such as the several purple-leafed forms, a splendid weeping clone, a fastigiate one, and a lacy cutleafed clone. All of these must be propagated by grafting them on seedling understocks. The normal process is to pot up beech seedlings in the winter or early spring, grow them over the summer in a cold frame or plunged in outside beds, then bring them in for grafting the following February or March. If the grafted plants are set up in a sufficiently humid greenhouse, it is not necessary to protect the newly grafted plants under double sash as

used to be done in an earlier era. In parts of Holland and in Holstein, Germany, where the early spring weather is mild and very humid, beeches can be cleft-grafted on seedlings of considerable size already established in open nursery beds, using short scions of 2-year-old wood of a suitable diameter. The first year's growth of such open ground grafts is phenominal in comparison to the normal pot-grafted beeches. Unfortunately in most of the U.S.A. and Canada the climate is too dry and the temperatures rise too rapidly in the spring for field grafting to succeed, so more cumbersome and expensive greenhouse methods must be used.

For trees such as cherries, pears, and crabapples, which are much easier to transplant than oaks or beeches, grafting scions on dormant bareroot understocks (bench grafting) is the preferred method. Bench grafts are much cheaper and quicker to make than grafts on potted understocks. In addition to speed, the great saving is in the costs of the understocks. A potted seedling is already an expensive article. First, the seedling must be grown for a season in a bed. Then come the costs of potting it up and carrying it on long enough to build a good root system. Finally comes the grafting process itself, at least as much slower than bench grafting, as the latter is in comparison to budding.

Bench grafting is useful for reproducing trees which are not easy to bud. *Prunus subhirtella* 'Pendula,' for example, with its normally thin twigs and tiny, thin-barked buds is a difficult tree to bud in the open field, but it is not difficult to bench graft. *Prunus subhirtella* seedlings, when available, are much to be preferred over *P. avium* seedlings because of their much more fibrous roots and superior graft stands. Another advantage is that bench grafting is done in January and February, when the average nursery is looking for indoor work. Many nurseries which have field budding programs up to the limit of their capacity, resort to bench grafting to supplement production capability. A third advantage of bench grafting is that there is much less suckering necessary in the growing season in comparison with budding because the graft union is planted well below the soil surface, whereas a bud union is at or above the surface. In orchard apple production, bench grafting can save a year's field production time. Where inter-stem trees are desired, the stem portion of the tree can be bench grafted on suitable understocks. These are planted out and budded to the desired fruiting cultivar that same summer. Thus the three-part tree can be produced in 2 years rather than 3 years, with substantial savings in costs.

Bench grafting has some advantages in producing small trees for special purposes. For example, small branched crab-

apple trees are desirable for mail order sales. The shipping costs for normal big 2-year budded trees are exorbitant. A 2-year graft will make a nice, well branched little 3 to 4 ft tree which is substantial yet small enough for a reasonable shipping cost.

Most bench grafts are made either as splice grafts or whip and tongue grafts. The latter are slower and more difficult to make, but they hold the graft together as it is passed to the wrapper which speeds up that process. Also the greater cambial contact of the whip and tongue graft seems to result in better stands. For the normally hard-wooded trees, there does not appear to be any substitute for a sharp knife in the hands of a skilled grafter. The Omega grafting machine, though clever and speedy to operate in the hands of even a rank beginner, simply does not give acceptable stands with trees. It was originally designed for the soft, porous wood of grapevines, and there it works well indeed. Similarly, the various other European grafting machines were designed for grape grafting, which is a very large scale enterprise indeed, but they are useless for tree grafting. The pressing motion on which they operate bruises the tree wood so severely that decay instead of healthy callusing results. Also, of course, the cutting blades are extremely difficult if not impossible to sharpen. A really effective grafting machine would be a boon to the nursery industry but, given the infinite variability of scion and understock sizes, shapes, and angles, making grafts, like making babies, seems destined to be done in perpetuity in the good old-fashioned way!

There are parts of the nursery industry, especially container production of the easily rooted common broadleaf and coniferous everygreens, in which the big new corporate entrants seem poised to exterminate the small family nursery. In the production of specialty shade and flowering trees, especially those which must be budded or grafted, the conglomerate is at a serious disadvantage. In this area, propagation is as much an art as a science and it is certainly not an industrial process, and here the skillful plantsman will always reign unchallenged.

Thursday Afternoon, December 16, 1982

The Thursday afternoon session convened at 1:30 p.m. with Steven Still serving as Moderator.

FORCING GROWTH ON SUMMER-ROOTED RHODODENDRON CUTTINGS[1]

JOHN R. HAVIS

Department of Plant and Soil Sciences
University of Massachusetts, Amherst, Massachusetts 01003

The success of summer propagation of rhododendron has been demonstrated by McGuire (4) and is being used by a number of nurserymen (6,7,8) both to avoid the high fuel requirement of winter propagation and to distribute the use of facilities over the year. In our studies, we assume that the cuttings are rooted by the fall. They can be stored at a minimum temperature near freezing and planted out in the spring, or growth can be forced during this time provided fuel and energy costs are not too great.

RHODODENDRON 'NOVA ZEMBLA'

Spring growth. The forcing of 1 or 2 spring flushes on either summer or fall cuttings is fairly common (2,3), more common than is reported in the literature. The usual method of spring forcing is to raise the temperature to between 16° and 20°C (61° and 68°F), beginning in February or early March, and to maintain this high temperature through the spring. This is successful but is costly in the use of fuel. Some growers include photoperiodic lighting, at least until the end of March, but I observe that the use of light is diminishing. The objective of our studies is to find methods of conserving fuel by growing the rooted cuttings at a low temperature.

Most of our studies have been with *R.* 'Nova Zembla' cuttings that were taken in July, lifted and fertilized in October and held in a cool house. They were stored at just above freezing from December 1 until February 1, when the minimum temperature was raised to 5°C (41°F). At this temperature, growth begins between May 1 and 15 in our area. We (11) discovered, however, that if the rooted cuttings were exposed to 17°C (63°F) for only 2 weeks around March 1, without supplemental lighting, and returned to 5°C, growth began before April 1 and continued through the spring. This low temperature method saved about 50% of the heat reqirement as compared with keeping the temperature at 17°C until May 15. The growth development was delayed about 3 weeks by the low temperature, but for practical purposes, the plants were equal to high temperature plants by the end of the growing season. Both had matured a third flush of growth (1).

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[1] This research was supported by a grant from the Horticultural Research Institute and by the Massachusetts Agricultural Experiment Station.

Fall growth. In theory, there should be an advantage in producing a fall flush of growth which could be built on in the spring. We have not been satisfied with our efforts so far and do not have recommendations. However, I will share some of our experiences. The cuttings should be rooted fairly early, preferably by September 15, in order to take advantage of early fall warm weather. Bottom heat during rooting should benefit, whether out-of-doors or inside. After lifting and fertilizing, growth started readily if the night temperature was kept at about 17°C (63°F) for 2 weeks. Supplemental lighting did not hasten the start of growth on either *R.* 'Roseum Elegans' (10) or *R.* 'Nova Zembla'.

We have not obtained a large number of breaks in the fall. Longer periods of high temperature and lighting produced more fall growth but had a carry-over effect after cold storage of delaying spring growth by as much as a month (10). Scott (9) reported that night-break lighting in the fall delayed spring growth of *Cornus alba*, *Weigela florida*, and *Viburnum opulus*.

Nurserymen may consider producing one or two shoots, without pinching, in the fall by using 2 weeks of warm nights before lowering the night temperature to 5°C (41°F). The shoots can be cut back in the spring to produce multiple basal shoots.

RHODODENDRON 'PJM'

Spring growth. If 'PJM' rooted cuttings have been held at between −4° and +4°C (25° and 39°F) for as long as 2 months, and the temperature is raised to 5°C (41°F) on February 1, growth usually starts the first week of March. The plants continue to grow vigorously at the low minimum temperature. Problems with spring growth of 'PJM' probably come from taking fall cuttings which were exposed before taking, or after rooting, to enough cold to put them into dormancy, but not enough to satisfy their cold requirement to grow. Even in this condition they can be forced into growth with 16°C (60°F) and 3-hour light break in the middle of the night (5). However, such plants may not grow normally if they are returned to a low temperature.

Fall growth. 'PJM' summer cuttings root rapidly and if potted or spaced and given fertilizer in early September, some growth will be made at minimum 5°C (41°F). More growth is stimulated by providing the light break (Table 1). However, with the shearing required to force multiple breaks and the vigor with which these plants grow in the spring, I doubt that much is accomplished by forcing extra fall growth. Furthermore, 'PJM,' like 'Nova Zembla' and 'Roseum Elegans,' was

delayed in making spring growth after being stimulated with supplemental light in the fall (Table 1). For fall growth to be useful, we need to find a way to produce a large number of breaks without causing a delay in spring growth.

Table 1. Effects of induction treatments, started September 21, 1981, on fall growth of *Rhododendron* 'PJM' rooted cuttings, and carry-over effects of fall treatments on initiation of spring growth at minimum 5°C (41°F).

Treatment	Fall growth (cm)	Ave. date of start of spring growth
No induction	4.7 a[2]	March 2 a
2 wks. at 17°C	4.6 a	March 2 a
2 wks. L.B.[1] at 17°C	8.3 b	March 7 b
2 wks. L.B. at 17°C plus 4 wks. L.B. at 5°C	11.0 c	March 12 c

[1] L.B. = 1 klx (100 foot candles) incandescent light between 11 p.m. and 2 a.m.

[2] Means with the same letter are not significantly different at the 5% level.

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RAYMOND HESER: What was the fertilizer used..

JOHN HAVIS: The fertilizer used was 20-20-20 soluble at

the rate of 200 ppm N immediately after potting. Two weeks after that we used a second application.

GUSTAV MELQUIST: Was the 63°F temperature scientifically determined or could some other temperature work just as well? For most warm crops the greenhouses are kept at 60°F at night so this would actually require increasing the temperature over the normal.

JOHN HAVIS: We determined the temperature by looking in the literature, not scientifically.

PROPAGATION OF HERBACEOUS PERENNIALS

JOHN WALTERS
Walters Gardens Inc.
Zeeland, Michigan 49464

Our primary objective at Walters Gardens Inc. is to produce the perennials we need to meet the projected demand. This is not our only concern. With today's market conditions, we must look very closely at the cost of producing perennials with an attempt to keep this cost reasonable. We must be able to produce perennials profitably. Please keep this in mind as we examine the following methods of propagating perennials.

First of all, one must have a plan of action. One must write down what is to be done and how it is to be done. One must also set goals of production levels. Never rely on verbal communication. Never just guess at what you need. Never propagate more just because you happen to have a lot of propagation stock and it would be a shame for it to go to waste. Always analyze your market. Try to propagate what you think you can sell.

Setting down a plan of action gives you something to refer back to at any point in time. It also gives you the opportunity to assess your performance, giving facts in which to allow for corrections for future years.

The first method of propagating perennials that I will discuss is by seed. A large number of perennials can be produced from seed. As a general rule, if a perennial can be produced from seed, this is the most economical way to go. However, an exception to this might be in choosing a hybrid improvement of a seedling strain which would require propagation by another method.

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There are two important considerations to look at. First, the germination level of seed is affected by many variables. There is an optimal level of daytime and nighttime temperatures required for the best germination. Some cultivars are best germinated at a constant temperature. Others require alternating temperatures for maximum germination. For example, *Euphorbia epithymoides* (Syn.: *E. polychroma*) seed germinates best if day temperatures are 85°F, and night temperatures are 70°F. A certain temperature is required for the best germination in the shortest period of time. *Campanula medium* 'Calycanthema' seed germinates best if the temperature is maintained around 70°F. *Aubrietia* seed germinates best around 55°F. In both situations, germination time would increase as temperatures are changed, and possibly germination levels would decrease at other than the optimum temperatures.

Germination may occur in flushes over a period of time. Let's look at *Iris kaempferi*. These seeds are sown in trays the first of January and kept in the germination chamber until May 1. This is a long period of time for any seed. During this time, we remove seedlings which have germinated and reached the critical size. Seeds continue to germinate, and seedlings are removed approximately 3 to 4 times. The point I am trying to get at here is do not throw your potential crop away. Two years ago, 70% of our crop came out of the last batch.

Always store seeds in a cool, dry place with low humidity. Typically, if seeds are exposed to warm, humid conditions before they are sown, the germination level will decrease by the week and month. If you need to store seeds for a long time, consider placing the seed in a refrigerator in a sealed container.

Seeds of some species are "frost germinators," require low temperatures for a period of time. This conditioning of the seed is called stratification. If you do not chill such seeds, you will have poor germination or none at all. We normally chill our seed for one to four weeks — sometimes right in the bag it came in, sometimes after sowing in a tray. Seeds of some species germinate best if allowed to soak in water for 24 to 72 hours before planting. *Hibiscus* seed is an example.

The second important consideration in propagating perennials by seed is the *quality* of the seed. Because of environmental and possibly physiological considerations, the quality of the seed may vary from year to year. With certain cultivars, if you have a set goal of production, you may find yourself exceeding or coming short of your goal on a regular basis.

Let's take for example *Aquilegia* 'Spring Song' which costs $289 for ¾ oz. In 1981, 8,000 plants cost us 3.6¢ per seed. In 1982, 6,000 plants cost 4.8¢ per seed. If your goal was 8,000 plants in 1982, you have just missed that goal by 25%, and your cost has increased by 33⅓%. Underproduction can be costly in terms of lost sales. Overproduction can be held to the cost of the seed if you can restrain yourself from planting the extra seed.

Deal with the seed companies you can trust for quality and dependability. Price is not the over-riding consideration, although it is a factor. Non-delivery of ordered seeds and poor quality seeds is very costly. Usually by the time you find out you will not be receiving the seeds, or by the time you discover the germination is poor, it is too late for your planting cycle. Bargain seed prices may be a poor investment if you cannot buy with the confidence of obtaining good germination.

There are 3 methods of sowing seeds. The first is to sow directly in the field. This is an excellent method in our operation for certain kinds of perennials. A tractor is used in the direct sowing process with special "seeder" units attached and spaced to meet our requirements. There are certain requirements for direct sowing. You must have knowledge of the cultivars which would perform well in this situation and must properly prepare the land. Soil temperature must be proper for germination. Adequate soil moisture is necessary. You must know the proper depth of sowing. Finally, you must have cooperation of the environment — no bad wind storms to blow out the seeds and no sudden late frosts after the seeds have germinated.

The second method is sowing seeds directly into trays (or other containers) in the greenhouse. They are sown in rows at the proper density. This method is necessary for some perennials which require a longer period of time to reach the desired size. It allows us to basically germinate seeds all year round, but especially during January and February. Once the seeds are sown, they are placed in a controlled environment — whether a greenhouse or a growing chamber. We prefer a growing chamber because we can control the temperature, humidity, and air circulation better. Also, we can control the amount of light the plants receive once they are germinated (probably more important during short days). Hopefully, this translates into better germination and better plants in a shorter period of time. Once germinated, at the proper time the seedlings can be transplanted into "starter plugs" and later planted into the field and/or into containers.

The third method is sowing seeds into a cold frame in

early August. The purpose of this is to have young seedlings ready to transplant the following May (an example of this would be *Lavendula*). Germination can take place either in the fall or the following spring. This process can be economical if germination does not decrease by too much as a minimal amount of care is needed. There are no heating costs but the seeds still need moisture. On the other hand, this process can have problems since we do not have much control. We may have over-wintering problems and in the spring may have difficulty deciding when to take the protection off (this is a critical period). Additional problems can result from an exposure to a period of harsh weather in late spring.

Other methods of propagating perennials are by cuttings and divisions. There are important considerations to be taken here. It is a common tendency of growers to ship out the finest and best stock they have. They sometimes feel that the poorer plants will improve with additional time. At the end of the shipping season, plants which are left over become the stock plants for next year from which top cuttings or divisions are made. This is a very dangerous practice. Poor or marginal propagation stock will typically result in poor or marginal plants to sell for the next year. It is imperative that the finest and best stock plants be set aside to produce the next year's crop. These are not to be used for anything but propagation.

The timing of taking cuttings or making divisions is also very important. You normally do not want to take cuttings or make divisions just before the blooming period, since most of the energy is directed toward the blooming process and root development, making general growth minimal.

As a general rule, morning is the best time for taking cuttings or making divisions since afternoons are typically warmer and dryer. We must try to minimize stress in the early propagation stages.

Some examples of perennials we are propagating by cuttings are:

Iris (Dwarf) — Blooms early in spring (late April-early May). The best success in propagating is after the blooming period. Begin propagation in June.

Achillea 'Moonshine' — Blooms for a long period of time beginning in early summer. Propagation is best done early in the spring.

Gypsophila 'Pink Fairy' — Late spring bloomer (during June and early July). Our best success with propagation has been during August. In the spring the wood is too soft for a good rooting percentage and transplanting success. But in late summer, the condition of the plants seem just right.

Salvia 'East Friesland' — Blooms during June. After blooming, the cutting stock is too woody and the success rate decreases dramatically. It is best propagated in early spring.

Artemisia 'Silver Mound' — To maximize the amount of planters from one parent plant, we wait until early June. We can propagate earlier but the yield per plant is considerably less.

Astilbe — These are best propagated during January and February and allowed to become established in a cool poly-house. This allows for maximum growth before hot weather arrives which slows this plants growth considerably.

Dicentra 'Luxuriant' PP3324 — We have found that it is best propagated in late October and buried in the ground or in containers — growth to appear next spring.

Coreopsis 'Grandiflora' — A June bloomer. This can be propagated by division or cuttings in the spring. We choose cuttings which gives us a better stand and healthier, larger plants.

Stachys lanata 'Silver Carpet' — This hybrid is propagated by division rather than using seedlings. Since "lamb's ears" is best noted for its unique foliage flowering depreciates its appearance. The hybrid is non-flowering.

Top cuttings is the only way to economically produce some perennial species. One example is *Lamium maculatum* 'Beacon Silver'. The parent plant is in the proper condition during the cooler months of the year. The cuttings will vary in length depending upon the cultivars. Hormones can be applied to facilitate rooting, if necessary. Possibly, these can be rooted directly into the finished containers. They should be placed in a controlled environment where temperature and humidity can be regulated. Once rooted, the cuttings can be planted into the field or placed into containers.

Another method is root cuttings. This is the only practical way to multiply some perennial species. A good example is *Phlox paniculata*. A selection of the healthiest dormant plants is made in late fall. The roots are cut off the main system and divided into 2-in. sections. Keeping the top and bottom of the cuttings distinct is very important. When planting put the tops just below the soil line. These can be placed in a cool, poly-covered house. Callusing and development of new growth will begin in the spring in response to temperature. They are now ready for planting into fields or containers.

Examples of other species propagated by root cuttings are: *Filapendula vulgaris* (Syn.: *F. hexapetala*) 'Pleno', *Papaver* hybrids, *Geranium* (some cultivars), *Bergenia* (hybrids), *Gaillardia* 'Baby Cole', and *Anemone japonica*.

Division is an ideal method for propagating some perennials. Here again, you select your best stock at the proper time of year. Dividing is done by cutting with a knife or pulling apart the mature clumps. *Iris sibirica* 'Caesar's Brother' is an example. Another method is to pull stolons off the mother plant as in asters. They can be transplanted into the field or directly into containers.

Still another method for propagating perennials is by tissue culture. I would like to briefly discuss why we use tissue culture in our operation.

Tissue culture helps in building up stock of new cultivars. We are presently working on *Hemerocallis* and *Hosta* 'Frances Williams'. If we had to propagate the conventional way, which is strictly by division, it would take many years to be able to offer newer cultivars to the trade. Usually not many plants are available in a new cultivar. *Hosta* must grow for 2 years before dividing the parent stock into planters, and then it yields only 3 to 5 divisions. With tissue culture it is possible to have thousands of plants within a year's time.

With tissue culture we are able to eliminate diseases and help in the prevention of diseases. Crown gall problems occur in both *Artemisia* 'Silver King' and *Gypsophila paniculata* 'Bristol Fairy'. Tissue cultured 'Bristol Fairy' does not have crown gall nor does crown gall move into the plant if planted in a field environment (at least not for the first year).

Tissue culture also helps rejuvenate certain plants. Regression takes place in asters over a 4 to 5 year period in which the stolons (next year's plants) slowly decrease in number from 15 to 20, to 1 to 4. First generation tissue culture plants develop as many as 25 to 50 stolons.

DON SHADOW: I notice that you are offering the white form of *Dicentra spectabilis*. How are you propagating this?

JOHN WALTERS: By top cuttings.

RALPH SHUGERT: Are you using any herbicide treatment after the methyl bromide application?

JOHN WALTERS: We are using no weed control chemicals other than the pretreatment with methyl bromide, + 2% chloropicrin. We have stayed away from herbicides because of the wide diversity of herbaceous plants we grow. We are waiting for more university research in this area.

QUESTION BOX

The Question Box session was convened at 3:00 p.m. with Ralph Shugert and Bruce Briggs serving as Moderators.

MODERATOR SHUGERT: Question for Bob Eastman. Please talk about storing bareroot plants ungraded over winter as opposed to graded prior to storage.

BOB EASTMAN: My philosophy has been to grade them shortly after digging because you do not have to rehandle

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BOB EASTMAN: My philosophy has been to grade them shortly after digging because you do not have to rehandle

them. It cuts down labor costs and provides a better quality plant.

MODERATOR SHUGERT: Question for Elton Smith. Please offer comments on the possible promotion of *Phytophthora* on capillary mats.

ELTON SMITH: Initially there was concern that capillary mat watering would promote root diseases. Experience has not proven this to be true. We have not done any work on that aspect.

DAVE DUGAN: Elton, were you using chlorinated water in your capillary mat study?

ELTON SMITH: Our experiences are with chlorinated city water. However, this is not the case for other countries where this research has been done. We have not done work with actual contaminated water. I am not saying that you can not have *Phytophthora*. It is more of a problem where we have too much water.

MODERATOR SHUGERT: Question for Elton Smith. Is there a need to incorporate superphosphate into a potting medium if a complete analysis slow-release fertilizer is used?

ELTON SMITH: Phosphorus is important to plant growth. A good all around fertilizer (3:1:2) would be enough.

MODERATOR SHUGERT: Question for Elton Smith. Have there been more studies done on the coloring of the mats, especially the purplish-brown mats, that have inhibited algae growth?

ELTON SMITH: I am not sure that I can answer the question as it pertains to color. Yes, there are purplish mats that do just that. On the other hand, the florist industry has been predominately using white mats in Ohio. Indeed, algae is a problem; however, there are chemicals that can suppress it. What we have done, and I did not mention it earlier, was just hose it off between the plants.

MODERATOR SHUGERT: Is orientation (N-S, E-W) a critical factor in the location of a gutter-connected propagation facility in a northern climate for year-round propagation of a wide variety of plant types?

MARK RICHEY: We do have a small problem with shade from the gutters on our N-S house. However, it would be much worse with an E-W orientation.

MODERATOR BRIGGS: Has anyone had any experience rooting *Ilex opaca* 'Maryland Dwarf'? Have you had problems with leaf drop about 3 weeks after sticking? What do I do to prevent this from happening?

ELWIN ORTON: Letting the cuttings get dry shortly after putting them into the bench is the problem.

MODERATOR BRIGGS: What would cause most of the foliage of *Thuja occidentalis* 'Lutea' to turn brown and fall off during cutting propagation under mist?

BRUCE BRIGGS: Too wet.

MODERATOR BRIGGS: How can *Amelanchier canadensis* be rooted by cuttings.

CATHY FREELAND: Softwood cuttings with 1% IBA.

MICHAEL SCOTT: I have rooted *A. canadensis* and *A.* × *grandiflora* in the Chicago area from softwood cuttings around the first of June and treated with 2,000 ppm IBA. .

MODERATOR BRIGGS: I am troubled with leaf drop on softwood cuttings of *Prunus cistena*. This year leaves dropped after 2 weeks under mist and in 30 days the cuttings died. What did I do wrong?

JOERG LEISS: There is a leaf fungus on *P. cistena* and it is a good idea to spray the stock plants for it. We found that it is one of the causes.

DAVE BAKKER: Spray Benlate on the cuttings after the mist goes off in the evening and allow them to absorb it over night.

JOE FLUCEK: That plant can be propagated easily from hardwood cuttings in the fall of the year. We stick them in the ground and mulch them in.

CLAYTON FULLER: We solved the problem by simply leaving them under the mist for only 4 to 5 days and then moving them from the mist to a side bench in the propagating house where they still get humidity.

MODERATOR BRIGGS: How do you propagate Douglas fir from cuttings?

ROBERT TICHNOR: Young plants root better than older ones and it is also very clone specific. Plageotropic growth can be a problem and it takes a number of years to straighten them out.

BRUCE BRIGGS: October and November are poor months for taking cuttings and spring is the best.

MODERATOR BRIGGS: In growing *Viburnum carlesii* and *V.* × *carlcephalum*, is it true that the cutting method of propagation has the following disadvantages as compared to those grown by grafting on *V. lantana:* (1) Less winter hardiness the first winter and possibly subsequent years; (2). Considerably slower growth?

WILLIAM FLEMER: We grow them from seed which is the best method. They grow many times faster with no suckering from the understock. You do have to select the seed parents for big flowers and leaves. *Viburnum carlesii* roots and grows slowly from cuttings. *Viburnum* × *burkwoodii* and *V.* × *juddii* both root and grow readly from cuttings.

DON SHADOW: *Viburnum* × *juddii* is a much better plant with us than *V. carlesii*. Do not remove the rooted cuttings but allow them to grow through the next growing season.

MODERATOR SHUGERT: Our container-grown Exbury azaleas retain their leaves well into November. This is past the time we place them in cold storage. It is a problem?

JIM CROSS: It is not a problem in plastic huts. The leaves will naturally fall with no problem.

MODERATOR SHUGERT: Question for William Valavanis. Please comment on grafting *Pinus parviflora* on *P. thunbergii*.

WILLIAM VALAVANIS: No problem. Take the understock in December and graft in January.

MODERATOR SHUGERT: Question for Bill Flemer; Have you rooted *Celtis occidentalis* from softwood cuttings?

BILL FLEMER: We have had no success in rooting cuttings. We bud the clones and grow the species from seed.

MODERATOR SHUGERT: Question for Dennis Stimart: Could you expand on encouranging growth on *Acer griseum* to aid overwintering the first season? I am having a problem after rooting stem cuttings.

DENNIS STIMART: I have a student who is working on over-wintering *Acer palmatum* rooted cuttings and we are finding that if the plants are not fertilized after rooting they over-winter beautifully. The same thing is happening with *Cornus florida*. I have a hunch that if you do not fertilize a lot of these woody species they will over-winter well.

DICK WOLFF: I think we can substantiate what you said, particularly in the case of nitrogen late in the season. We will use phosphate, however.

MICHAEL SCOTT: I have rooted *A. griseum* the past 2 years and we do not fertilize past mid-August with the rooted cuttings. We store them at minimum heat (34°F).

MODERATOR SHUGERT: I am having trouble obtaining economic stands of *Syringa*, French hybrids, from softwood cuttings. What am I doing wrong?

JOERG LEISS: Everyone has problems. We take our cuttings in June, just after the flowers fade, apply number 3

hormone powder, and place them under mist in a greenhouse.

CARL ORNDORFF: The simplest way to get 100% stand is to use root cuttings and direct stick in December in a cool house just above freezing until spring. By June you should have 18 to 24 in. plants. If you put them in the field you will have heavy plants by the fall.

MODERATOR BRIGGS: What is Chloromodin?

BRUCE BRIGGS: If you look in past IPPS Proceedings you will find that information.

CHARLES ANDERSON: Dr. Hindamin writes in the *J. Amer. Rhododendron Soc.* that he has been using triacantinol at 1/10 mg per liter and has been increasing his rooting. In Chloromodin you have triacantinol and some auxins.

RALPH SHUGERT: Mr. Anderson, on the label of that product it says a natural food extract. How do you account for that?

CHARLES ANDERSON: Triacantinol is extracted from alfalfa.

MODERATOR BRIGGS: Question for Brent McCown. Could you elaborate on methods you are using to maintain cultures that are episodic in their growth habit?

DEBORAH McCOWN: Brent feels that if you do not have juvenile tissue you are not going to be able to overcome the episodic growth problems. With something like oak you can possibly cut it back and stimulate juvenile growth.

RICHARD ZIMMERMAN: In France they are grafting desirable woody plants onto seedings and repeating this process until reversion is obtained.

MODERATOR BRIGGS: Has anyone micropropagated lilac?

GLEN LUMIS: Virginia Hilderbrant has completed a masters degree and can provide information on lilacs. Her address is Horticultural Research Institute of Ontario, Vineland Station, Ontario, Canada.

MODERATOR SHUGERT: Could Bruce Briggs describe his pallet system of propagation?

BRUCE BRIGGS: We use a box that is 4 × 6 ft with 6 in. sides. The box is elevated during cutting placement which makes it easy to work. The box is placed on the floor which is heated.

MODERATOR SHUGERT: What is the understock for viburnum standards?

ED MEZITT: We have never grafted viburnum standards

but *V. lantana* would be a good choice.

VOICE: *Viburnum lentago* is a good understock.

ED LOSELY: We find that *V. lantana* is good for *V. carlesii* and related types.

JOERG LEISS: *Viburnum lantana* suckers no matter what you do.

MODERATOR SHUGERT: Is there a difference in winter hardiness among *Pyrus calleryana* cultivars?

MICHAEL YANNY: We have a nice specimen of 'Select' at the Wisconsin Arboretum. The flowers are not hardy but the tree is substantially. At Johnson's Nursery we have ordered in whips of 'Bradford' and 'Greenspire' for the last 2 years and they have all had bark splitting problems.

NEW AND USEFUL PLANTS

JACK ALEXANDER, MODERATOR

MODERATOR ALEXANDER: Our first speaker today on this topic is Kurt Tramposch.

KURT TRAMPOSCH: *Lamium* spp. are members of the mint family and are useful as shade-loving groundcovers because of their variegated foliage, rapid growth, and undemanding cultural requirements. An excellent review of *Lamium* spp. can be found in the 1981 summer edition of the *American Rock Garden Society Bulletin*. Because of their aggressive nature most *Lamium* spp. should be used with discretion.

A commonly cultivated taxon is *L. maculatum* which produces an invasive, dense low carpet in a short time and has purplish flowers throughout the summer.

An English introduction, named *L. maculatum* 'Beacon Silver', is more restrained and produces a mass of silver leaves in the shade.

The most widely cultivated species, *L. galeobdolon*, (now reclassified as *Lamiastrum galeobdolon*) is commonly known as yellow archangel. I have found this ground cover to be an attractive trouble-free species that is useful to brighten shady areas of the garden. It tolerates poor soil and shade as deep as that under mature hemlocks, but does not do well under full afternoon sun. Its welcome foliage appears very early in April and clusters of bright yellow flowers are produced by the end of the month in Boston. *Lamiastrum galeobdolon* must be kept away from other plantings as it can be surprisingly prolific.

Five years ago I was given a new cultivar of *L. galeobdolon* by my father. This, as yet unnamed cultivar, enjoys the advantages of the species without its invasiveness. Its leaves have a mottled variegation varying slightly from that of the species. The plant stays compact, with flowers and leaves about ⅓ that of the species. It layers out as it spreads, very similar to *Vinca*, and is readily propagated. I have found it to be trouble-free and hardy to −25°F in zone 5b west of Boston. It deserves wide distribution and I would be happy to provide plants to anyone who would care to propagate it.

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MODERATOR ALEXANDER: Our next speaker is Joerg Leiss.

JOERG LEISS: *Buxus* 'Green Gem' is a natural hybrid between *B. microphylla* var. koreana and *B. sempervirens, Buxus microphylla* var. koreana being the female parent.

The plant was selected from a seedling population of about 40 plants. It grows into a perfect round ball and is hardier than our *B. microphylla* var. *koreana* 'Winter Beauty'. It roots readily and makes-up 2 to 3 years faster than *B. microphylla* var. *koreana*. It maintains the dark green color of *B. sempervirens* and does not exhibit the excessive seed pod production of *B. microphylla* var. *koreana*.

Tilia cordata 'Green Globe' was found when we were still growing seedling *Tilia* into standard trees. *Tilia* seedlings are extremely variable and show growth sizes from 2 to 3 ft bushes to 4-in. caliper trees in the same age and population of seedlings. To exhibit the branch pattern and shape, the tree is either budded on a *Tilia* understock at 6 or 7 ft or top-grafted, top-grafting being preferable.

MODERATOR ALEXANDER: Our next speaker will be Jim Cross.

JIM CROSS: *Cornus kousa* 'Lustgarten Weeping' originated as a chance seedling in the Long Island, N.Y. nursery of Baier Lustgarten. The parent plant is a very low, wide-spreading form with branches arching just off of the ground in a manner similar to a classic deciduous cotoneaster. Its apparent growth rate, flowering habit, and fall foliage color are like the species. Like the species, it sets flower buds well in full sun and very sparsely, if at all, in dense shade. The flowers are of normal size but are better presented because of the low arching position of the branches. The plant at 12 years is 10 ft wide and 2½ to 3 ft high.

Cornus kousa 'Elizabeth Lustgarten' originated as a chance seedling in the Long Island, N.Y. nursery of Baier Lustgarten. The parent plant has developed no apical leader and takes on a distinct weeping habit which is of a quite graceful nature. It gains in height only from the upward arch of new side branches. At 12 years it is about 7 ft in height and 4 to 5 ft in width. Other characteristics are as stated for its sister plant, 'Lustgarten Weeping'.

Both plants graft and bud very well on *Cornus kousa*.

MODERATOR ALEXANDER: Harold Pellett will next show us some hardy plants from Minnesota.

HAROLD PELLETT: A few plants that I feel warrant additional consideration for use include:

Lonicera alpigena 'Nana' is a very nice dwarf honeysuckle with very rich dark green foliage. The foliage is quite coarse-textured. It is somewhat slow growing and thus probably not a good moneymaker.

Another possible small growing honeysuckle is a compact selection of *L. caerulea* now being evaluated in the NC7 trials. It has done well for us and in the Dakotas, but not as well in Wisconsin for Ed Hasselkus.

Prunus maackii is now being grown by nurseries in our area primarily because of its showy copper-colored winter bark.

Tilia mongolica is a tree that caught my attention. I like its slightly exfoliating bark and in comparison to littleleaf linden, it's not quite so

dense and formal. The few plants I've seen have a slightly pendulous branching habit.

Aesculus '*Autumn Splendor*' is a tree that we named a few years ago but, at present, it isn't available in the trade. It can be propagated by grafting. It has an excellent dark green foliage without late season discoloration or defoliation that commonly occurs with Ohio buckeye. It develops an excellent maroon red fall color.

Acer rubrum 'Northwood' is a recent introduction of ours. It comes from a northern Minnesota seed source and was introduced primarily for its adaptation in Minnesota and possibly other northern states where other currently available cultivars of red maple are not reliably hardy. It has an excellent branching habit and is a fast grower. We have applied for a patent on this tree.

Forsythia 'Northern Sun' will be a 1983 introduction that has been reliably flower bud hardy for us. It does get quite large and is not of equal plant quality as *F* × *intermedia* clones, where they are reliable. It's probably a hybrid between *F. ovata* and *europaea*.

We are continuing our breeding efforts to develop hardy deciduous azaleas. Four clones are currently being propagated for introduction. 'Pink Lights' and 'Rosy Lights' are selections from the original northern lights hybrids, which are currently available as F_1 hybrids. 'White Lights' will be introduced to the retail trade in 1985. The fourth cultivar currently in propagation has not been named as yet but we plan to continue the Lights series of names to help identify plants as being from our program and thus possessing a high degree of winter hardiness. The 4 clones currently in propagation are hardy to −40°F. We have selections of many other colors under evaluation and are optimistic that we will eventually have a wide range of colors available that are winter hardy in Minnesota.

MODERATOR ALEXANDER: Ruth Kvaalen will next present a promising plant.

RUTH KVAALEN: Landscapers often seek relatively small, low maintenance, pest-free shrubs that do not spread or outgrow their allotted space rapidly. *Andrachne colchica* fits this description. A member of the euphorb family and native to the Caucasus area of Asia, this plant is sometimes called Caucasian spurge. Authors say its height is up to 3ft, but the plants I have observed grow no taller than 15 in. The plants form low mounds of fresh green foliage.

The principal ornamental effect comes from the foliage, which changes little from spring through autumn. Leaves are oval, ½ to ¾ in. long, closely spaced alternatively along the stem. The textural quality is medium fine, with a somewhat delicate appearance.

Andrachne colchica is monoecious, with staminate and pistillate, yellow flowers produced on new wood throughout the summer months. However, the flowers are tiny and are born in leaf axils, so they contribute little to the landscape value of the plant. Fruits are white and also very small.

Its neat, mounded habit and its size make this plant a good landscape candidate. A clump at the Morton Arboretum, planted before 1930, is now about 8 ft in diameter. Another clump, planted in 1957, is about 3 ft across. Height is about 15 in. Soil at the site is a heavy clay with poor drainage.

The species grows well in ordinary soil in full sun or partial shade. It has no apparent insect or disease problems. Propagation is from seeds or by softwood cuttings.

Andrachne colchica is hardy throughout USDA hardiness Zone 5 and possibly in considerably colder areas. Test plants in Zone 3b at the Minnesota Landscape Arboretum have come through at least one winter very well. The twigs may be selectively pruned or even cut back close to the ground in the spring.

As of this date, I know of no commercial sources. Check arboreta or botanical gardens for cuttings or seeds.

MODERATOR ALEXANDER: Thomas Pinney has three plants to show us.

THOMAS PINNEY: *Betula platyphylla* var. *japonica* (University of Wisconsin P.I. 235128). This beautiful non-exfoliating, pure white-barked birch was collected in 1956 by Dr. Creech as seed in open fields at 1780 m above Shefuyu Onsen, Japan. The plant has an upright broad pyramid form and matures at 50 to 60 ft. The leaf is a shiny green and arrow shaped, turning to a bright, clear yellow in the fall. Plants have a wide geographic adaptability from −30°F to 120°F (Northern Wisconsin to Oklahoma). Leaves remain on plants even during prolonged temperatures of 120°F. It is highly resistant to bronze birch borer. These plants continue to thrive at the University of Wisconsin Arboretum in Madison after 27 years. All other white-bark birches have succumbed to the bronze birch borer. This selection was not part of Dr. Santomours tests reported in the December 1, 1982 issue of *American Nurseryman*.

Juniperus horizontalis 'Wisconsin'. This plant was selected by Dr. Ed Hasselkus of the University of Wisconsin in 1964 near Brooks, Wisconsin. It is a male plant with a mixture of scaly and needled blue-green foliage which turns to a battleship gray in fall. Maximum height is 8 in. No twig blight has been observed. It mounds slightly with a good radial habit and is fast growing.

Rosa × *rehderana* (Polyantha Rose) 'Nearly Wild'. This plant is a cross between 'Dr. W. Van Fleet' × 'Leuchtstern.' Buds are small, deep pink, with curling petals that open to a large, single pink flower. These are borne even during cutting propagation and are profuse, often reaching over 100 blooms at any one time. Mature plants are 4 × 4 ft. It makes an excellent hedge as it continues to bloom all season until freeze up. It grows well in a container with excellent blossoms and is hardy to Zone 4. No pests or diseases have been observed.

MODERATOR ALEXANDER: I have 3 rare birches to show next.

JOHN H. ALEXANDER III: I have for several years been very impressed with an Asiastic, white-barked birch, *Betula ermanii*. It is a rare species in this country, seldom seen outside of botanical gardens. In Japan it is the most common of birches and its range extends over much of northeast Asia.

E.H. Wilson reported seeing *Betula ermanii* trees in Hokkaido that were over 65 ft tall having a girth of 13 ft. He also wrote that the trunk frequently branched only a short distance from the ground before rising to form a broad-crowned tree.

This same species also grows at high elevations, but there it may be reduced to a low, broad shrub. In the wild it grows in a wide range of conditions and displays considerable diversity. Having such diversity offers

the opportunity to select, for cultivation, forms showing superior growing habits and perhaps insect resistance.

The bark of *Betula ermanii* may be grayish to lustrous white and is often tinged with a hint of reddish-brown or pinkish hue. It peels off in white, horizontal strips and, in my opinion, it is equal to the best of the white-barked birches.

Propagation experiments at the Arnold Arboretum with seed collected in Japan showed that 3 months of cold stratification prior to sowing yielded the best rate of germination. The number of seedlings resulting from cold stratified seed was more than four times that of unstratified seed.

Another birch which I find very attractive is the botanical variety *Betula ermanii* var. *saitoana*. The range of this variety is essentially restricted to the Korean island of Cheju where it has been collected on Mt. Halla at elevations of 3900-6500 ft.

There are two plants of *Betula ermanii* var. *saitoana* in the collection of the Arnold Arboretum; I know of no others in cultivation on this continent. The principal difference between this variety and the typical form of *B. ermanii* is one of leaf size and structure. Its leaves are smaller with fewer veins.

One of these two specimens at the Arnold Arboretum is at 10 years of age, little more than a shrub. Five feet tall and single stemmed for only a few inches, it has brownish bark, becoming white.

The other individual, also 10 years old, is a beautiful small tree of about 8 ft. It has a clear bole for only about a foot, but all the major branches display white bark shredding in thin strips. Its small leaves and slow rate of growth make it appear as a miniature. The site chosen for it among dwarf conifers accents this appearance.

Whether dwarf or slow growing, it is not a plant for everyone, but may be just right for the spot where most other white barked birches would soon be too large.

Another birch species that is not widely known is *Betula davurica*, a native of Manchuria, northern China, Korea and Japan. A 72 year old tree at the Arnold Arboretum is approximately 35 ft tall and 40 ft wide.

Betula davurica has bark that exfoliates in attractive, shaggy, brownish-gray flakes. It is often compared to our native river birch. Although their bark is somewhat similar, *B. davurica* lacks the graceful arching and twiggiiness of *B. nigra*. *Betula davurica* does tolerate drier, poorer soils than does the river birch. Seed germination trials at the Arnold Arboretum were most successful with seed which received 3 months cold stratification prior to sowing. This treatment yielded approximately 6 times more seedlings than did unstratified seed.

It has been suggested that both *Betula ermanii* and *B. davurica* may show resistance to the bronze birch borer. They may, but clearly much more testing is in order before we can ascertain any real resistance.

MODERATOR ALEXANDER: GARY KOLLER sent along one plant to show.

GARY L. KOLLER: Bladder-senna, (*Colutea* × *media*, is underappreciated and overlooked as a medium sized shrub. It is capable of thriving in full sun on dry, gravely infertile soils. In fact, it will grow and self sow to colonize sites too inhospitable for many more refined "ornamental" plants. Bladder-senna is the perfect plant for restoring the banks of fresh highway cuts; it may adapt to mine spoil reclamation; it is useful in planting islands

and spaces at shopping malls; and it is perfect for semi-wild urban park lands.

Colutea × *media* is probably a hybrid of *C. arborescens* of Southern Europe and *C. orientalis* of Asia. It is hardy to approximately 10°F. *Colutea* grows quickly into a rounded upright shrub 6 to 10 ft tall. At the Arnold Arboretum, peak flowering occurs in mid-May with scattered blossoms appearing throughout the summer. Flowers are pea-shaped and range in colors from the typical butter yellow to those which blend through markings or tints of copper, pink or reddish-brown. Flowers are followed by large, thin walled, inflated pods which exhibit colors of solid lime-green to those richly tinted with pinks and bronze. The seed pods are highly ornamental from June through early September, then they begin to ripen and turn straw-brown in color. The ornamental qualities of these inflated bladders compete successfully for attention with many flowering shrubs.

Seeds are prevented from germination by a hard seed coat which can be overcome by mechanical scarification, or with a 1-hour sulfuric acid bath, or by steeping the seeds in hot water for 24 hours. Seedlings germinate quickly and grow rapidly. Plants develop a thin, rangy root system which makes transplanting difficult. However, they might adapt to container culture and a fruiting plant in a container should have great sales appeal for garden centers.

In the landscapes bladder-senna thrives in the poorest, most infertile soils and at sites subject to high levels of atmosphereic pollutants. They will not tolerate much shade nor heavy, poorly-drained soils. They are reported to be subject to attack by aphids. Presentation of plants in more manicured and refined landscape spaces is enhaced by tightening up growth with rejuvenation pruning in early spring.

If individuals with superior ornamental characteristics occur in your seed lots they can be maintained vegetatively by cuttings.

Thursday Evening, December 16, 1982

The thirty-second annual banquet was held in the Ambassador Ballroom West of the Amway Grand Plaza Hotel, Grand Rapids, Michigan.

On behalf of the Society, a graduate student award was presented to Mr. Fred Miller and his advisor, Dr. Frank Blazich, North Carolina State University, Raleigh, North Carolina.

AWARD OF MERIT

Presented by Ralph Shugert

This award exemplifies the true meaning of our beloved Society's motto "to seek and to share", because truly the award this evening goes to two loyal, devoted, and dedicated IPPS, Eastern Region members. My words this evening are not going to be lengthy. Although those of you who know me may find that statement hard to believe. The brevity of words in no manner is intended to reduce the magnitude of the meaning of the award to the recipients.

Undoubtedly, some in the room tonight must wonder what is an Award of Merit? In one word it is appreciation. It is the

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method by which the Eastern Region recognizes the contribution of individual members within the Society. This is appreciation for excellent research shared with members, or for a commercial propagator who shared a technique to increase the rooting success with a particular plant. The appreciation is also acknowledgement of service. The timeless extra hours that few people are aware of, such as, committee assignments, a phone call to help a fellow propagator with a serious immediate problem, and the willingness to do what needs to be done at that time.

Tonight we are all honored to be a part of a happy and joyous moment to share this prestigious award with two gentlemen this evening. For the benefit of our guests, our Society is a harmonious blend of the academic and commercial. Coincidentally this evening our two recipients also reflect this blending. It is unique in the history of our Society that two awards are shared with two segments of our organization.

I am proud to present this highest honor we have to two loyal devoted Society members tonight. To avoid confusion I am proceeding in an alphabetical order and promise just a few words. The first gentlemen I would ask to come forward is a person who has done unique and inspiring deeds for the Society. He is only the second person to serve two terms as president of the Eastern Region, the other being Jim Wells! He is also the only person to have served two terms as president of the International Board. He is dedicated, intelligent, caring, and also a close friend. Larry Carville, Tolland, Connecticut — would you come forward please?

The second recipient is also a past president of the Eastern Region. He has spent his life teaching and watching former students grow in the industry. Dr. John McGuire — will you please come up?

Friday Morning, December 17, 1982

Leonard Stoltz served as moderator of the morning session

CONSTRUCTING AND MAINTAINING DISEASE-FREE PROPAGATION STRUCTURES

CARL ORNDORFF

3819 Calvert Place
Kensington, Maryland 20895

The intent of this paper is to assist propagators of woody plants in designing propagation facilities, correcting problems

method by which the Eastern Region recognizes the contribution of individual members within the Society. This is appreciation for excellent research shared with members, or for a commercial propagator who shared a technique to increase the rooting success with a particular plant. The appreciation is also acknowledgement of service. The timeless extra hours that few people are aware of, such as, committee assignments, a phone call to help a fellow propagator with a serious immediate problem, and the willingness to do what needs to be done at that time.

Tonight we are all honored to be a part of a happy and joyous moment to share this prestigious award with two gentlemen this evening. For the benefit of our guests, our Society is a harmonious blend of the academic and commercial. Coincidentally this evening our two recipients also reflect this blending. It is unique in the history of our Society that two awards are shared with two segments of our organization.

I am proud to present this highest honor we have to two loyal devoted Society members tonight. To avoid confusion I am proceeding in an alphabetical order and promise just a few words. The first gentlemen I would ask to come forward is a person who has done unique and inspiring deeds for the Society. He is only the second person to serve two terms as president of the Eastern Region, the other being Jim Wells! He is also the only person to have served two terms as president of the International Board. He is dedicated, intelligent, caring, and also a close friend. Larry Carville, Tolland, Connecticut — would you come forward please?

The second recipient is also a past president of the Eastern Region. He has spent his life teaching and watching former students grow in the industry. Dr. John McGuire — will you please come up?

Friday Morning, December 17, 1982

Leonard Stoltz served as moderator of the morning session

CONSTRUCTING AND MAINTAINING DISEASE-FREE PROPAGATION STRUCTURES

CARL ORNDORFF

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The intent of this paper is to assist propagators of woody plants in designing propagation facilities, correcting problems

in existing facilities, and to point out correctable situations that may involve disease problems. The views are not those of a pathologist, but those from a profitable production nursery. The ideal propagating conditions are hospital and laboratory sterile standards; however, one must be practical and profitable, which may require making reasonable compromises. Emphasis is placed on preventive measures, not cures by the continuous use of fungicides or other remedies applied on the cuttings or plants after troubles have started. Difficult propagating subjects are not avoided, but are a major part of the production schedule.

The use of fungicides on cuttings is rarely necessary if growers select designs, materials, and methods which prevent diseases from becoming established and provide conditions that both stimulate cuttings to root rapidly and support root growth. The propagation structure should be low cost, low in maintenance and designed to produce as many crops as possible. The systems should approach full automation. As a test, any propagation facility that can not be closed and locked for one full week is not very efficient. This does not mean that propagation facilities should not be checked regularly for mechanical failure or power outages.

Wood Structures. Wood structures and propagation benches should be constructed of decay resistant materials. Treated white cedar, fir, or good grades of pine are equally good as cypress or redwood lumber and much less costly. Copper-base wood preservatives, used as a dip or painted on, make home treatment of lumber economically feasible, especially if the wood preservative is purchased in quantity by the drum. Thirty years of constant use with propagation facilities has proven the effectiveness of wood preservatives, Propagation beds over 25 years old, that have never been dry since being built, are still sound.

In addition to protecting the wood from decaying organisms, copper-base wood preservatives also serve as a permanent fungicide. These preservatives are not toxic to plants. For maximum uptake, water-base wood preservatives (1) should be used only on seasoned dry wood. It may be used on wet or green wood, but it is less effective. Water soluble copper-base wood preservatives are less costly and have proved to be equivalent to petroleum solvent copper-base materials. The availability of pressure treated lumber may eliminate the need to treat your own. It should be noted that in addition to excessive cost, the producers do not claim fungicidal benefits, any longer life expectancy or non-toxicity to plants.

Metal parts. All structural metals, not galvanized, includ-

ing the plumbing and heating materials should be painted with metal primers containing iron oxide and zinc chromate to inhibit rust. Like copper-base wood preservatives, these primers are also effective long-term fungicides. Do not apply enamel paint over primed metals, because it will defeat the fungicidal effect of the primer. All nails, screws, and bolts used in construction should be galvanized or made of brass.

Walks. Poured concrete, wood, stone chip, or gravel walks often create physical hazards, maintenance and disease problems. Porous building block, 8″ × 8″ × 16″, laid dry on a coarse sand or pea gravel base make a safe permanent walkway that will not accumulate water. The blocks may serve as an edging for ground beds, especially if under elevated propagating or growing beds. If the need to control algae on these block walkways should develop, sprinkle or spray copper sulphate solution annually, preferably at the start of warm weather. Because of the porous characteristic of the block, the surface normally remains dry, making it difficult for algae to develop, thus providing a safe skid-proof surface.

Propagation bed drainage. Poor rooting and stem decay can often be attributed to poor drainage through the bottom of the propagation beds. These beds should be so constructed that gravitational free water from either automatic misting or from hand watering can flow freely though the bottom. Six inch wide boards arranged crossways in the bottom of the bed should be spaced one inch or more apart. A ⅛ in. mesh galvanized hardware cloth should be placed over the boards to retain the propagating medium without interfering with drainage. The life expectancy of the hardware cloth is 5 to 10 years, depending on the mineral content of the water. Design the width of the propagation beds to accommodate the width of the hardware cloth to minimize having to cut the wire, thus exposing sharp ends. A few strategically placed staples may be needed to keep the hardware cloth in place before covering with medium.

Propagation bed depth. Because automatic misting often applies more or less water than needed, the side boards of the propagation beds should be over 6 inches high, so as to accommodate at least 6 inches of medium. Compensation is made for irregularities in the misting pattern due to foreign substances or slight imperfections in the misting nozzles. This increases stability to the moisture content of the medium. A slight reserve area of moisture is held at the lower depth of the medium, which may be withdrawn by capillary action to stabilize dry spots. This reserve area in a deep bed is low enough so as not to endanger the cuttings. When using a deep medium, should the ground beds below the propagation beds be used,

near non-drip conditions may be maintained by careful adjustment of the misting system.

Automatic misting. Minimum operational cost and maximum efficiency in a propagation house means use of automatic misting. A well designed and programed system can exceed the best that can be or will be done by hand watering. This reduces the probability of plant diseases. The spacing and height of misting nozzles is critical, if mist is to be applied uniformly. Before purchasing misting nozzles, it is important to know your water pressure and pressure fluctuations. Suppliers charts are available. Adjustable oil burner type brass nozzles with stainless steel inserts and on-off valves under each nozzle provide flexibility, near uniform misting, and minimum maintenance problems. Mounting these nozzles on vertical standpipes, at least ½ in. diameter, from feed lines, ¾ in. diameter or larger, located on the floor of the beds, makes for a trouble free system. All feed lines should be of sufficient size to maintain equal pressure at the extremities of the system.

All feed lines should have fine screen filters incorporated with the electric control valves and with each nozzle. The smallest amount of grit or foreign matter may distort the mist pattern giving a source of wet or dry spots. Copper piping is more trouble-free than galvanized. Deep well water is preferred to surface pond or stream water. Grit particles and disease contaminated waters may be avoided.

Timing controls for misting. With automatic misting, two types of timing controls are advisable. For summer softwood cuttings, a one-second interval, variable adjustment time clock is recommended. During autumn, winter and spring when firmwood cuttings are propagated, a humidity control system is adequate. Both of these mist control systems should be wired in series with a 24 hour time clock and the two systems made switchable. The humidity control system may be needed only for 4 to 6 hours during some winter months, while the 1-sec. clock may be fully activated 12 to 14 hours during high temperature summer months (2).

Automatic ventilation. Ventilation in propagation houses is extremely critical, especially for summer softwood cuttings. An uniform non-dehydrating system in a propagation facility may be achieved by using a vacuum exhausted (negative pressure) system. (3) Outside ambient air is brought into the building and uniformly distributed through large punched airtubes and exhausted gently with large slow speed fans. This type of ventilation has very low dehydration, is easily installed, does not require special equipment, requires low maintenance, and has a low operating cost. All ventilation should be controlled

by a thermostat, in series with a 24 hr. time clock, to prevent the exhaust fans from running continuously on hot summer nights.

Timing coordination for misting and ventilation. Foliage diseases, especially on softwood cuttings in summer, may be reduced by coordination of the late day, cut-off time of the misting and ventilation systems. If several night hours of the 24 hour daily cycle can be without moisture on the foliage, leaf disease may be reduced. Timing the mist system to cut off 15 to 60 minutes before the ventilation system turns off is usually adequate. Determination by trial is necessary, since local conditions, equipment, and buildings are variable. The misting should turn on shortly before the ventilation in the mornings.

Rooting media. One of the more controversial subjects in propagation is the selection of the rooting medium. Required is a material that is light, easily handled, low cost, has a middle limit for passing and retaining moisture but coarse enough to exchange gases, offers physical support, is sterile, and compatible with all plant families. After trying 30 to 40 materials or combinations, dustless perlite has been my material for nearly 35 years. The use of perlite made it possible and practical to go to automated control. In processing, perlite is heated to 3300°F, therefore is more sterile than most materials available. There is no need to use it for long periods, since it has high salvage value as a mulch in growing areas until contaminated and then may be combined into the potting soil mixtures before fumigation.

Crowding in the propagation bed. Crowding in the cutting bed is a frequent source of plant disease problems. Cuttings having large leaves may have the outer ends of the leaves reduced up to 50% without deleterious effects. This may allow up to 50% increase in count. Using light wooded small cuttings to increase count is a fallacy.

Shading. Excessive shading may also contribute to plant diseases. Flame proof polypropylene net shading, preferably about 50% shading, placed on the outside will be needed from April to October. Any shading during the winter is unnecessary and may be detrimental at times. Sprayed shading compound lacks uniform density and is difficult to schedule a programed removal. Additional short term spot shading on new cuttings may be made by using light weight open weave (Dutch type) burlap, placed directly on the cuttings and kept moist by the misting system until acclimated.

Sanitation and fumigation. Work areas and equipment may be cleaned by using a chlorine laundry bleach solution.

Soil mixes for potting cuttings and seedlings and for seed sowing may be sterilized inexpensively and safely with methyl bromide gas in pressure containers. A dump truck with a tight bed makes an excellent inexpensive portable versatile fumigation chamber. If well sealed, porous potting mixtures may be fumigated to a depth of 30 inches by increasing the normal dosage rate by 100 to 150%, based on the density of the mixture. This is not practical and not recommended for large quantity operations, such as for container potting mixtures.

Heating propagation structures. Heating since the energy crisis is an extremely controversial subject that does have a bearing on disease control. The ideal conditions for rooting firmwood broadleaf and coniferous cuttings in the cold season is a medium 10°F warmer than the overhead temperature. Hot water fin radiation immediately under the beds provides this condition as well as gives the most constant non-fluctuating temperatures. Extremely varying temperatures retard rooting and also encourage development of foliage diseases, especially when the thermostats call for no ventilation to reduce the condensation.

Automatic controls. Controls for heating, ventilation, misting, lighting, and security should be near to or in the area being controlled. Automatic controls make the need for a central control panel obsolete with their only function to impress the uniformed. Central control panels increase line resistance, make trouble shooting difficult, increase installation and maintenance costs, and can prolong downtime.

I have discussed many subjects that you may consider to have no bearing on propagation disease problems. These suggested methods have produced, however, a propagation environment that has required no use of fungicides on the cuttings or plants for over two decades.

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MICHAEL DODGE: Are your houses oriented north-south?

CARL ORNDORFF: Yes.

TOM McCLOUD: Have you ever had a problem with snow load on your houses?

CARL ORNDORFF: The slope is 1 in. per foot. On one end we have had snow drifts 4 ft. deep. The fiberglass sagged a little, however no structural problems developed. The other end is swept clean by the wind.

ORNAMENTAL PLANT PROPAGATION IN JAPAN

BARRY R. YINGER

R.D. 2, Box 120

York Haven, Pennsylvania 17370

Japanese nurseries are among the best places in the world to observe a great diversity of cultivated plant species and variants, but they are much less rewarding for those who are intent on broadening their knowledge of propagation techniques. In Japan even the most prosperous nurseries rely on propagation techniques which many American nurserymen would consider primitive, inefficient, or inappropriate. When we do find imaginative propagation techniques in Japan we often observe them among hobbyists or in small, specialized nurseries, and then used to create a certain aesthetic effect rather than as a means for what we consider efficient production. It would surprise no one here to see pines grafted in Japan, but the Japanese practice of grafting scions of *Pinus parviflora* on stock of *P. thunbergiana* to combine the distinctive foliage of the former with the handsome bark of the latter might strike some of us as an excessive effort for an aesthetic effect.

The use of grafting to produce a pot of *Pereskia* with a dozen or more kinds of assorted cactus appended to its branches or to add branches at strategic points on the trunks of imperfect bonsai takes the use of grafting well beyond the point to which most American nurserymen are willing to go to make a sale. Yet examples of this kind of effort can be found in almost any ordinary nursery or garden center. The situation in Japan is often the reverse of the situation here where large aggressive nurseries are frequently in the forefront in the development and application of novel propagation techniques. This difference is a reflection of many of the fundamental differences between the Japanese and American approaches to ornamental horticulture and nursery production.

A basic feature of Japanese nursery production which has a strong effect on the choice of propagation techniques is the relatively small demand for plants for garden use as we perceive it in the West. Few families in Japan own more than a

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A basic feature of Japanese nursery production which has a strong effect on the choice of propagation techniques is the relatively small demand for plants for garden use as we perceive it in the West. Few families in Japan own more than a

miniscule plot and many have no garden space at all. As suburban families acquire automobiles what little outdoor space there is is likely to be given over for its care and storage. Most customers are therefore only interested in plants in pots, and most of these plants will never be planted in the ground. Even trees and shrubs are far more likely to spend their entire lives in a pot on the fire escape or along an alleyway than as part of a garden planting. For example, a common New Year's item in Japan is a large dish garden containing a twisted specimen of *Pinus parviflora*, a heavily-budded plant of a cultivar of Prunus mume, a small plant of *Nandina domestica*, and a dwarf *Sasa* accompanied by *Adonis amurensis* and other seasonal material. Virtually none of these plants will be maintained after the holiday season. So small is the demand for garden trees that a 2-meter tall *Magnolia* × *soulangiana* cultivar with a root ball costs less than a 1-meter long budded branch of the same plant for use in an ephemeral flower arrangement.

This situation affects the Japanese approach to propagation in several ways. One effect is that there is very little regard for the long-term suitability of the propagation method; thus the long-term compatibility of scion and understock and the garden hardiness or durability of the understock is not always considered. Japanese nurserymen will sell a slim scion grafted to an enormous understock knowing that it will never heal properly. The maximum number of flowers or fruit on the smallest possible plant is a market advantage and, if grafting will induce this, then it will be the technique used regardless of any other considerations.

A lack of garden space combined with the Japanese people's intense interest in plants requires the Japanese nurseryman to produce a variety of plants unthinkable in this country. In the nursery district of Angyo more than 6000 kinds of plants are produced in nurseries with a total area of 1100 acres, and one small nursery there grows over 600 kinds of ericaceous plants. Japanese interest in the widest possible range of novel, exotic, and bizarre plants makes it most difficult for many nurseries to propagate large numbers of plants under uniform conditions which permit economies of scale. Some very large nurseries in Japan resemble what we would consider a hobbyist-fanatic's home operation expanded beyond our wildest expectation.

The traditional organization of the Japanese nursery encourages the choice of the most labor-intensive propagation methods. Most Japanese nurseries are still family operations, often several generations old, in which all family members take an active role. Additional labor is had cheaply by taking

young men as apprentices from remote rural areas; these men are offered room and board and a small salary in return for training and the chance to make contacts in the nursery business. In Angyo in 1980 the labor cost for the installation of a typical suburban garden was 21% of the cost of the job, about $2.25 per hour for skilled apprentice labor. This low labor cost discourages efforts to introduce labor-efficient propagation facilities and procedures.

The incredibly high cost of land in Japan makes space requirements the primary consideration in many nursery operations. In 1981 land in the nursery district of Angyo cost an average of more than 1½ million dollars per acre. It is very expensive to use land to maintain stock plants of trees and shrubs; thus the need to make a little propagating material go a long way is another force encouraging the widespread use of grafting. In the case of bamboo, the space required to maintain stock for division has led to the development of techniques to grow some bamboo species from culm cuttings. One large nursery now grows its entire stock of *Bambusa glaucescens* (often called *B. multiplex*) from one-node culm cuttings.

The very large number of small nurseries in Japan (over 500 in the 1100 acres of Angyo alone), plus the heightening of already intense competition because of static demand, encourages a *kamikaze* approach to plant introduction which influences the choice of propagation technique. A desirable new plant is propagated as quickly as possible in order to get a large number of plants on the market at a high price before other nurseries can propagate the plant and drive the price down. In this case the technique of choice is usually grafting of the smallest possible scion onto the largest possible understock. After the introduction of *Kalmia latifolia* 'Ostbo Red' into Japan several years ago, the first plants sold cost more than $50 for a single shoot grafted very high on a stem of ordinary *Kalmia latifolia*. Three years later a husky cutting-grown plant cost about $5.00. The cost of propagation had no influence at all on the choice of propagation technique. The decision to graft the early plants (in an unsatisfactory way) was based only on the desire to have large plants in a very short time. The decision to grow much better plants later from cuttings reflected the fact that there was by now a most severe shortage of *Kalmia* understock rather than any desire to grow a plant of better quality. I have purchased plants of *Hamamelis*, for which the understock is expensive, with the cultivar I wanted grafted on top and as many as four other grafts between it and the understock. Each of the grafts represented a cultivar grafted the season before which did not sell and was reworked for the following season.

A final and important influence on propagation of ornamentals in Japan is climate. The summer rainy season gives the Japanese nurseryman the opportunity to grow most of his cuttings outdoors with at most a simple frame and rice-straw mat shading. The almost daily showers from late spring through early August create an atmosphere of high humidity and good air circulation that many mist house owners would envy, and the mild winters are easy on newly rooted plants. Even some rather difficult subjects such as two-needled pines are grown from cuttings in open fields.

The traditional approach to propagation and nursery practice is undergoing change in Japan. The birth rate is low and labor costs are rising; each year it becomes more difficult to find young men to serve as apprentices. Many small nurseries are disappearing, and urban pressures on the traditional nursery districts near Tokyo, Osaka, Nagoya, and Kurume are forcing others to consolidate their operations in rural areas further from the cities. Some nurseries are beginning to experiment with European and American propagation systems which are less labor-intensive. Changing lifestyles are increasing interest in simpler, more uniform "Western" style planting for public areas and private gardens. We can expect that the Japanese will come to apply their technical finesse in this area as well as those spheres in which they have already adapted.

A revolution has already occurred in Japan in the propagation and production of specialty fruits and vegetables grown under plastic, and it will not be long before the approach to the propagation and production of ornamental plants is similarly affected. Let us hope that the matchless diversity of ornamental plants available in Japanese nurseries is not a casualty of that change.

BRUCE BRIGGS: A few years ago I understood that about 80% of the field nursery production in Japan was for bonsai. Is that still true?

BARRY YINGER: Bonsai enjoys periods of popularity and also down cycles in popularity. Currently I understand that it is quite popular. It is an extremely important part of the Japanese industry.

BRUCE BRIGGS: I understand that in some parts of Japan that they take cuttings of pine and put them in the river to leach out factors that inhibit rooting. The cuttings are then rooted in open fields. What type of pines are they doing this with?

BARRY YINGER: *Pinus densiflora.*

COLD TREATMENT OF *TAXUS* CUTTINGS

RALPH SHUGERT

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The effect of a cold treatment on rooted cuttings of woody ornamentals is very difficult to document from readings of past Proceedings. To be specific, in 1955 Charlie Hess reported that *Cornus florida* 'Rubra' required 1,000 hours at 32 to 45°F temperature to break bud dormancy. In 1958, Hank Weller presented an excellent paper relative to taking moderately rooted cuttings of *Buxus*, *Euonymus*, and *Ligustrum* and placing them in poly bags at 34°F for 4 months prior to field planting. Harvey Templeton, in 1957, also discussed *Viburnum carlesii* relative to dormancy after rooting. In 1966 a K.D. Holmes briefly reported on September stuck *Taxus* that were lifted as rooted cuttings in February, stored in poly bags at 36°F, and then spring-planted into transplant beds. The following year Andy Adams reported on azaleas stored as rooted cuttings. As recently as October 1982, during the Western Region Conference, Dennis Connor spoke on rooting kiwifruit cuttings, giving them a cold treatment for 30-days and then potting off the rooted cuttings.

In 1979, Dale Deppe, then the propagator at Zelenka Nursery, began testing the effect of a cold treatment on rooted *Taxus* cuttings. In April 5,000 rooted cuttings from each of 3 cultivars were lifted and placed in cold storage at 34 to 36°F. In June they were planted at the same time as freshly lifted plants. That same year he pulled various quantities of rooted *Taxus* cuttings at 2 week intervals from March 10 to May 22. His 1979 evaluation showed that 60-days of cold treatment gave a far superior summer flush of growth than the control plants, or those that were cold treated for either a shorter or longer period.

Based on Dale Deppe's studies it was decided that the Zelenka Nursery would set up a project to further explore this fascinating topic. On April 8, 1981, a total of 200,000 rooted cuttings were lifted, given 60-days of cold treatment, and planted into 10-row liner beds under lath shade. The evaluation of these 200,000 showed a strong flush of new summer growth, approximately 3 to 4 inches, while the control non cold-treated rooted cuttings showed the usual ½ to 1 in. summer growth flush. To say the least, the implications of this study were exciting. The nursery is scheduled to stick approximately 2,400,000 *Taxus* cuttings annually, and they were scheduled to grow 3 years under shade, and then to the field to grow into saleable sizes.

Based on the results of Deppe's 1979 tests and the quite pleasing results in our 1981 tests, a decision was made to lift 300,000 cuttings in early April of 1982, store them at 34°F for 60-days, and plant them into the transplant beds, with the balance of the crop coming directly from the greenhouse. Accordingly, on April 2, 5, 7, and 8, of 1982, a total of 352,387 rooted cuttings from 10 cultivars, were lifted and stored in waxed poultry boxes with moist sphagnum moss, at 34°F. They were then planted into the transplant beds on June 4 and 5, of 1982, with the control plants directly from the greenhouse benches planted the same dates. Once again, to our complete satisfaction, the summer flush of the cold-treated rooted cuttings was conservatively three times the flush of the greenhouse-maintained *Taxus* cutting crop. To show our confidence in this program it is contemplated that in April, 1983, about ⅓ of the entire crop presently in the greenhouse will be lifted in April and stored for the 60 day period. It is quite conceivable that in a few years 50% of the November/December stuck crop will be lifted in April, stored at 34°F, and lined out to the transplant beds for 2 years rather than the present 3 year program. The economic implications of a million units lined out for 2 years rather than 3 years are obvious.

An additional benefit of this program is the opening of bench space. For many years our nursery was not able to turn two crops annually in the raised benches which have the advantage of bottom heat as well as mist capabilities. Since the nursery has a wide variety of deciduous flowering shrubs, over-wintered in polyhouses, the cutting wood availability early is almost unbelievable. Many of us, myself included, have experienced over the years the remarkable and incomprehensible theory of juvenility. When one takes cuttings of almost any species of deciduous plant, from container-grown plants under winter poly covered, the rooting percentages virtually is mind boggling. If you are experiencing poor economic rooting percentages give strong consideration to using the juvenile cutting.

All of us at Zelenka Nursery are content with the concept of the cold treated *Taxus* cuttings. At this nursery all of the bottom heated, raised benches are devoted to *Taxus*. By removing half of the crop in April, and sticking deciduous softwood cuttings which can be rooted in 90 days, increased productivity of this bench space can be realized.

I am firmly convinced at this point that the 60 day cold treatment program will definitely have an economic impact. I feel that after we have rooted the *Taxus* cuttings, we can then interrupt that cutting's growth habit by giving it a certain number of days of chilling. When this cold-treated cutting

then is planted in a liner bed, the plant then "wakes up" and makes a growth flush that is not comparable to a cutting taken directly from a bench which has not been cold treated. We have not experimented with any other species in this manner. Since *Taxus* is a very important crop for this nursery, if we can eliminate one year's growth from the time we stick the cutting until we harvest the saleable plant, we have saved a considerable amount. The aim, of course, of everyone in this room is to produce the best quality plant in the shortest period of time.

As everyone in the room is aware, the motto of the International Plant Propagators' Society is "To Seek and To Share". It is through papers which have been published in past Proceedings that we learn of techniques which help us to be a better professional in the science of plant propagation. Much data has been tested and tried by propagators before us and I know that there are a myriad of techniques and practices on the horizon. It is my hope that these remarks might be of benefit to some of you in the room who are saddled with a shortage of bench space, and a propagation list that won't fit the benches. You might wish to do some testing by removing early and then early sticking that second crop. I cannot tell you conclusively that the 60-day period is right for you, but I would use it as a guide for any areas of the country that experience the cloudy days during the winter that we experience in Western Michigan. If any of you do some testing during the spring of 1983, I would be quite interested in your results.

GLEN LUMIS: I agree with you on the chilling. Do they flush right after you put them out?

RALPH SHUGERT: We see the flush quite early.

GLEN LUMIS: In the next year did you notice any reduction? I noticed some?

RALPH SHUGERT: No, we did not. With that growth the first year we feel we are building a sufficient root system.

BRUCE BRIGGS: With some tissue-cultured plants, such as apple, if you give them a cold period for 30 days after rooting, they grow better.

JOERG LEISS: We have been cold-storing our *Taxus* cuttings for 3 years. We do it so that we can get away from having to shade.

LARRY CARVILLE: I have a question on the availability of deciduous material in your polyhouses during April and May. What state of growth will the plant material be in at this time?

RALPH SHUGERT: Last year we had, I believe, 7 genera

from the 15th of April to the 1st of May showing new growth of 4 to 8 inches.

LARRY CARVILLE: So the amount of new growth depends upon the genus and species.

RALPH SHUGERT: Yes. Our weather is very dark in December, January, and February, but when the days lengthen and the sky opens up in the spring the plants just take off.

DIRECT STICKING OF CUTTINGS IN GRO-PLUGS®

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Abstract. Many deciduous cuttings can be directly stuck into Gro-Plugs® and successfully rooted. This method greatly reduces stress encountered in transplanting the rooted cuttings into the field or container.

At the 1980 IPPS Eastern Region meeting we reported on the practical application of Gro-Plug® systems in growing ornamentals (1). That report primarily dealt with seedling-grown conifers. This report will give our experience in directly sticking softwood cuttings into Gro-Plugs®. This system allows us to overcome the problems of a short season here in northeastern Wisconsin and still transplant softwood cuttings out to the field or container the same season. We have used this system on many species and cultivars of *Berberis, Cornus, Cotoneaster, Euonymus, Lonicera, Physocarpus, Potentilla, Ribes, Rosa, Spiraea, Salix*, and *Weigela*.

CUTTING WOOD

Selection. Selection of proper cutting wood material is of paramount importance. The art of exactly when to take a cutting must be left to the individual propagator and the environment in which he is working. Cuttings should be taken only from true-to-name mother plants.

Cutting preparation. We take our cuttings in June as early as the wood is ready. The cutting wood is watered with Physan 20 at the rate of one tsp. per gal. of water. The wood is then rinsed with fresh water. We make the cuttings with two or more nodes and approximately 3 to 5 inches in length. The basal cuts are made ¼" below a node and the lower leaves are stripped off. The tops are pruned, in the case of shrubs, to force lateral growth.

from the 15th of April to the 1st of May showing new growth of 4 to 8 inches.

LARRY CARVILLE: So the amount of new growth depends upon the genus and species.

RALPH SHUGERT: Yes. Our weather is very dark in December, January, and February, but when the days lengthen and the sky opens up in the spring the plants just take off.

DIRECT STICKING OF CUTTINGS IN GRO-PLUGS®

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Abstract. Many deciduous cuttings can be directly stuck into Gro-Plugs® and successfully rooted. This method greatly reduces stress encountered in transplanting the rooted cuttings into the field or container.

At the 1980 IPPS Eastern Region meeting we reported on the practical application of Gro-Plug® systems in growing ornamentals (1). That report primarily dealt with seedling-grown conifers. This report will give our experience in directly sticking softwood cuttings into Gro-Plugs®. This system allows us to overcome the problems of a short season here in northeastern Wisconsin and still transplant softwood cuttings out to the field or container the same season. We have used this system on many species and cultivars of *Berberis, Cornus, Cotoneaster, Euonymus, Lonicera, Physocarpus, Potentilla, Ribes, Rosa, Spiraea, Salix*, and *Weigela*.

CUTTING WOOD

Selection. Selection of proper cutting wood material is of paramount importance. The art of exactly when to take a cutting must be left to the individual propagator and the environment in which he is working. Cuttings should be taken only from true-to-name mother plants.

Cutting preparation. We take our cuttings in June as early as the wood is ready. The cutting wood is watered with Physan 20 at the rate of one tsp. per gal. of water. The wood is then rinsed with fresh water. We make the cuttings with two or more nodes and approximately 3 to 5 inches in length. The basal cuts are made ¼" below a node and the lower leaves are stripped off. The tops are pruned, in the case of shrubs, to force lateral growth.

STICKING

Media. We use our regular growing medium containing (by volume) Canadian peat moss, coarse perlite, and coarse vermiculite, (2:1:1). The medium is amended with calcium nitrate, treble superphosphate, potassium nitrate, calcium carbonate, dolomite limestone 80-90, GU-49, and Micromax. The formulation of our medium was previously described (1). We use ½ the recommended rates of GU-49 and Micromax. The pH of the medium is adjusted to 5.5 at equilibrium by using ½ our standard increment of calcium carbonate and dolomitic lime as described previously (1). The medium is pre-moistened to an optimum level for root initiation during the batch-mixing process.

Trays. The trays we use are our 73-cell groove tubes (1). Twelve of these trays fit our pallet rack. Two people can then easily handle a pallet rack which contains 876 cells.

Treatment and insertion. After the cuttings are made, they are dipped for one second in a 1,000 IBA quick-dip. They are then given a second dip into a powder containing 10% Benlate/Captan dust (2:1) in talc. We have found that the separation of the IBA and fungicide has been beneficial in our softwood program. The cuttings are inserted approximately 1 in. in the cell. We use 1 to 3 cuttings per cell depending on the item. Some types of cuttings may require the use of a dibble in forming a hole. Our reasonable expectancy for production is 4 trays per hour per person when making and inserting 1 cutting per cell and 2.5 trays per hour per person when inserting 3 cuttings per cell.

ROOTING CULTURE

Structure. After sticking the cuttings, the individual trays are placed on pallet racks in a polyhouse. A white opaque poly covering (approximately 50% shade) is used for approximately ⅔ the length of the house but excluding the bottom 4 ft on each side. The entire house is then covered with a 50% Saran shade. This results in approximately 75% shade under the poly, and good side ventilation. The poly prevents rain from waterlogging the medium. The ⅓ of the house covered with only the 50% Saran cloth is used in the first step of hardening off.

Humidity control. Since a growing medium is being used, rather than a rooting medium, precautions must be taken to prevent the medium from becoming waterlogged. In the past we have used the standard intermittent mist system, but with a great deal of manual control. Under the brightest conditions we would use a maximum of 2 seconds every 6 minutes.

Truly, humidity control is an art and must be constantly monitored by the propagator. Under cloudy, cool conditions no mist is used. The pH of the mist water has been adjusted by the use of sulfuric acid to 6.0 ± 0.2. Presently we are looking at a fogger or a boom mister as a replacement.

Integrated pest management (IPM). IPM begins with sanitation and good housekeeping. We apply fungicides every 7 to 14 days depending upon conditions. We use a Captan and Benlate mixture, or Dithane with a spreader-sticker, or Bravo without a spreader-sticker. They are applied on a rotating basis. After rooting has begun we add Malathion to each application. The crop is monitored for aphids, white flies, and root rot. Pentac, Resmethrin, and Banrot are used, respectively.

HARDENING-OFF CULTURE

Timing and structure. When visible rooting begins after 2 to 4 weeks, we start the hardening-off process. The first step is to move the pallet racks to the one-third of the polyhouse which has only 50% shade. They remain in this area a maximum of 3 weeks. They are then taken outside into the direct sun, where they will remain for an additional 1 to 3 weeks before going to the field or container operation.

Humidity. One of the key factors to successfully hardening off these plants is humidity control. Again, it is an art and must be closely monitored by the propagator. In the shade area the propagator will mist the plants by hand depending on weather conditions. This will also vary by species and cultivar. Once the rooted cuttings reach the outside, they will be misted only the first two or three days if conditions require. At that point they are subject to whatever humidity the weather conditions provide.

Fertilization and pest control. Fertilization begins with the amendments we have added to our medium. We begin a liquid N, P, and K application as soon as the cuttings reach the shade hardening-off area. This is done through an injector system where the pH of the water is first adjusted by sulfur acid to pH 6.0 ± 0.2. The liquid fertilizer contains 150 ppm N, 88 ppm of phosphorus and 130 ppm of potassium. Considerably less phosphorus may be satisfactory for other growers. The plants are fertilized each time they are watered. Integrated pest management continues throughout the hardening off process.

TRANSPLANTING

Containers. By mid-July we are able to transplant the fast-rooting items directly into containers. The plugs are carefully removed from the trays so as not to break the plug. There is little or no stress in transplanting and a constant fertility pro-

gram is continued. In our container operation we use a 100% hardwood bark medium. Most of the items are put into 2-gal. containers and by July or August of the following year they are ready for sale.

Field. The faster rooting items are ready for transplanting to the field in early August. The slower items are planted by the end of August. By the time the plants are transplanted to the field, they have developed a very solid root system and quickly become established. The plants are mulched with bark or wood chips to prevent heaving. By the following fall they will be excellent heavy liners.

SUMMARY

Disadvantages. This system does require more rooting space. Since the medium is a growing medium rather than a rooting medium care must be exercised to prevent it from becoming water-logged.

Advantages. Many deciduous softwood cuttings can be successfully direct stuck and rooted in Gro-Plugs®. This system greatly reduces the stress in transplanting and hastens establishment of the rooted cutting in the field or container. As a result, it helps to overcome the difficulty of our short growing season and eliminates over-wintering storage problems of rooted cuttings. Further, the system is very flexible as small amounts of plants can be easily grouped for special environmental requirements.

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ROBERT EASTMAN: A comment on the depth of your tubes and the problem of roots occasionally growing up. We are using tubes with a minimum depth of 3½ inches and we have never had that problem.

"CHANGE-PURSE" BUDDING OF NUT TREES[1]

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A new technique for budding nut trees, called "change-purse" budding, involves a single cut on the stock which is opened much like the flaps of a change-purse. When properly done change-purse budding has a success rate of 85 to 95%. This budding technique has been used for black walnut, English walnut, butternut, heartnut, and pecan.

In Kentucky the budding is generally done from June 1 to July 20. The time is controlled primarily by the availability of buds in proper condition. When the bud is cut from a current year's shoot, the pith area should be solid and green in color. As growth of the new shoot proceeds the green color of the pith is gradually lost and dark pigmentation increases until the pith is nearly charcoal in color. The ideal shield bud for change-purse budding has green pith and *a large plump bud.* Shields with a yellow pith and *slight* pigmentation will also work but once pigmentation of the pith becomes dark the buds should not be used.

Making the stock cut. The stock cut is made on the south or southwest side of the stem. Choose a smooth area on the stock between buds, preferably where the stem is concave. The concave section of the stem is preferred so that when the bud shield is set in place it will be held more firmly than if set on the convex side of the stem. A single vertical cut is made 3 to 5 in. long, depending upon the size of the stock and the length of the shield bud to be set (Figure 1A). It is very important that the stock cut be made no deeper than necessary to open the slit. If the knife goes in and cuts into the wood tissue lying beneath the cambium, bleeding is likely to occur and the bud will be lost. A thick bladed knife helps avoid cutting into the wood. After the cut is made the stem is slightly flexed to increase the concavity of the stock, a thumbnail is inserted into the center of the slit and flaps are pulled out to open the slit (Figure 1B). A thumbnail does less damage when opening the edges of the flap than a knife blade and there is less chance of cutting into or hitting the wood and inducing bleeding.

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[1] The investigation reported in this paper (82-10-299) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with the approval of the Director.

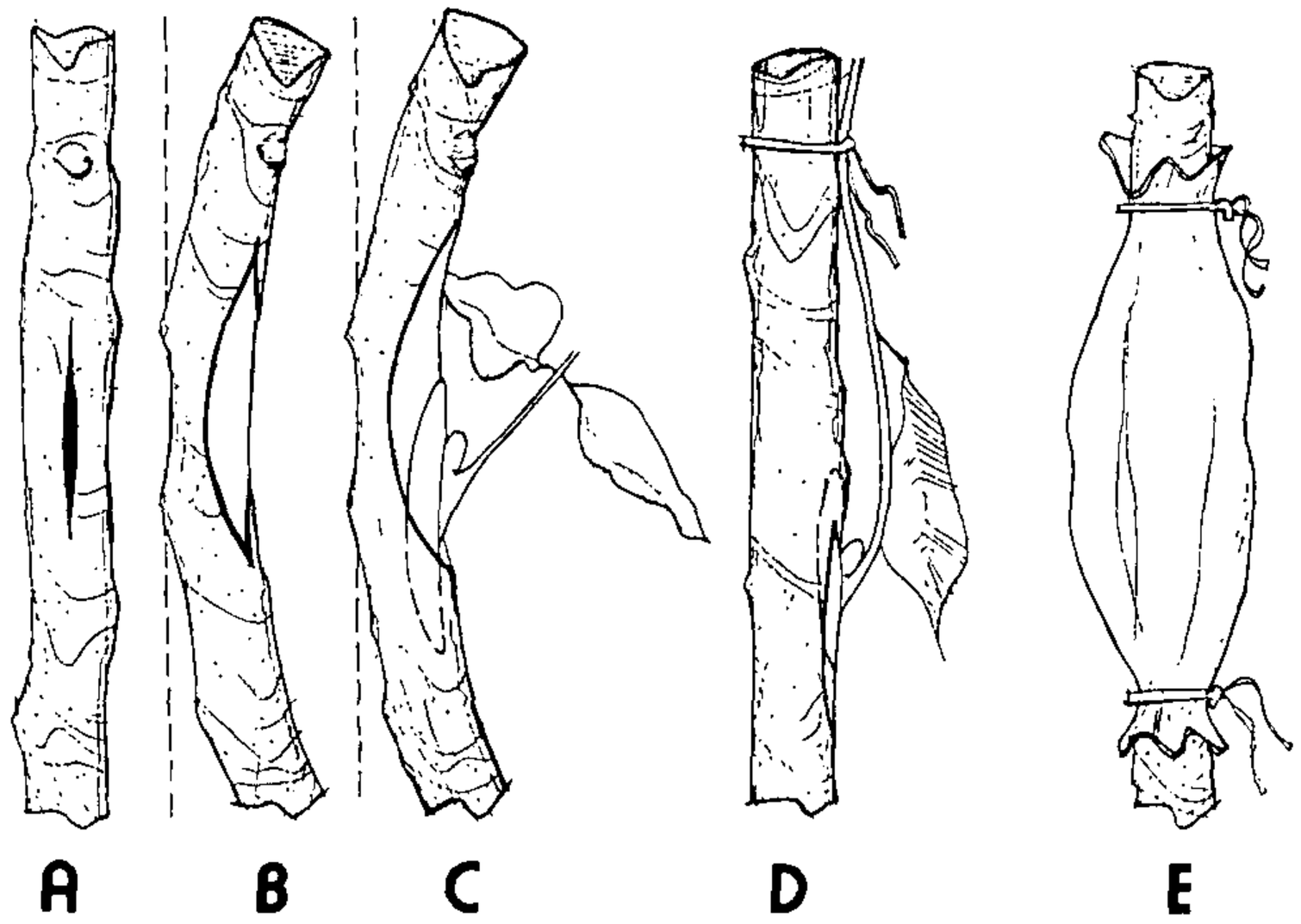

Figure 1. Steps in making the "change-purse" bud. A. Single cut 3 to 5 in. long on south or southwest side of stem. B. Stem is flexed and flaps of cut are opened. C. Bud shield is pushed downward until entire shield is beneath the flaps. D. Bud shield is pushed upward, tied in and leaf rachis tied to stem. E. Entire area is overwrapped with plastic film and tied at top and bottom. The author wishes to express appreciation to Ms. Jan Cervelli for making the drawings.

Selecting the scion and making the bud cut. Select a current year's growing shoot with one or more *plump buds*. The lowest, more mature buds, seldom break and produce leaves but the less mature plump buds are readily forced. Reduce the leaf over each potential shield to 4 to 6 leaflets. If the lower 2 leaflets are quite small use 6 leaflets, or remove the 2 lower small leaflets and retain 4 leaflets above. Leave a ½- to ¾-in. piece of rachis above the upper pair of leaflets. Cut the shield 1¼ to 2 in. in length. If the leaf base is particularly broad and heavy, as occurs on English walnut, two light notches may be cut from the sides of the leaf base so that it will fit better under the bark flaps of the stock. While holding the shield bud by the petiole, remove a *thin* strip of tissue along both sides of the upper half of the shield. This will better expose the cambial region of the shield to that of the stock giving better and faster knitting of the two tissues.

Inserting the bud. With the bud ready for insertion firmly flex the stock to force and hold open the slit. At the widest opening insert the base of the shield, pushing it downward until the shield is beneath the flaps (Figure 1C); then push the shield upward until it meets resistance and the upper portion of the shield has contacted undisturbed internal tissue of the stock. Release the stock and the flaps should pull tightly against the shield, holding it firmly (Figure 1D).

Tieing in the bud. For tieing in, 8 × ⅜-in. budding bands are preferred since the stock may be as large as ¾ in. in diameter and the shield up to 2 in. long. Grafting tape can be used but this necessitates the labor of removing it later. The shield should be firmly bound but not so tightly that the band extends the full limit of its stretch. The bud is not covered and it is not necessary to bind the entire stock cut. With the shield tied in, the leaf is pushed up against the stock and the stump of the leaf rachis left above the upper set of leaflets is loosely tied to the stock with a piece of masking tape or Twistem (Figure 1D).

Closing in the bud. Pieces of polyethylene plastic about 10 × 12 in., or a 1 qt. poly freezer bag slit open is used to close the bud in until it has healed. The leaflets are folded downward along the trunk and the plastic is loosely over-wrapped using 2 to 3 turns to entirely enclose the leaf and shield. The plastic is tied shut at the top and bottom using small budding bands, tape, string, or Twistems (Figure 1E). The plastic prevents drying, maintains the turgidity of the leaf, permits light to enter and allows some photosynthesis to occur in the retained leaf. One-third to one-half of the foliate top of the rootstock is removed at the time the bud is set. This checks top growth and allows more reserves for cambial activity for healing in the bud.

Aftercare. Between 7 and 10 days after setting, the buds should be inspected and those with yellowed or dehisced leaves should be opened, the leaves removed and the plastic retied. At 14 to 20 days the plastic is opened at the bottom to allow some air circulation to acclimate the bud and/or leaves which haven't dehisced to lower humidity conditions. Twenty-one to 30 days after setting the bud the plastic overwrap is entirely removed and the top of the rootstock is broken over or cut off 4- to 6 in. above the bud to force it into growth (if it has not broken yet). The band should also be cut at this time. Once the bud has broken and made 4 to 8 in. of growth the stub may be removed. Keep all rootstock shoots and buds removed.

The success rate using this technique will vary but having vigorous rootstocks and learning to select the proper buds should result in 90% success with English and black walnuts, 80% or more with pecans, and 70 to 80% with butternut and heartnut.

CHRIS GRAHAM: Is the color of the poly important?

LEN STOLTZ: I have only used clear. I feel you would not want to use black, because you want light to help maintain the

leaf so the bud can utilize material stored in the leaf and also manufacture food.

LARGE-SCALE PRODUCTION OF BLACK SPRUCE CUTTINGS FOR PROGENY TESTS

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A program for the large-scale production of spruce cuttings has been ongoing in Ontario for 4 years. This work has been based on preliminary studies by Rauter (7), Armson, et al. (1), Perez de la Garza (4), and Fung (3). The program was initiated in 1979 when approximately ½ million rooted cuttings were produced for operational outplanting (1). This program was so successful that in 1980, it was decided to build a new facility for the production of spruce juvenile cuttings for the Ontario Tree Improvement Program.

The purpose of this new program is to clone spruce seedlings for progeny testing. Seedlings of full-sib origin are grown and, as they develop, cuttings are taken from them and propagated. New cuttings are later taken from the original seedlings and also from the first rooted cuttings. This cycle is repeated until 140 ramets of the same age are produced from each clone. After rooting, these last cuttings are used for progeny outplanting tests in Northern Ontario. Presently both black spruce (*Picea mariana* [Mill.] BSP) and white spruce (*Picea glauca* [Moench.] Voss.) juvenile cuttings are propagated. The 140 ramets per clone can be achieved more rapidly with juvenile black spruce seedlings because they grow faster and cuttings taken from them root faster than juvenile white spruce seedlings.

The objective of this paper is to outline the cultural techniques by which the 140 black spruce ramets per clone are produced.

Production cycle. The first attempt at production of black spruce cuttings for progeny tests in 1980 required 5 cycles of cuttings and nearly 3 years to achieve the 140 ramets per clone objective. Since then our growing techniques have been improved and we have been able to reduce the length of the production cycle. In the cycle described here, 1900 seeds were sown in October 1981 for one progeny test (Table 1). One month later a germination survey showed 45% survival or 850 ortets. A germination rate of 45% for spruce seeds produced by artificial techniques is not unusual. The seedlings were grown

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until March, 1982, when the first cuttings were taken from them. The cuttings were rooted by mid-May and were then grown until August, 1982. The seedling ortets were also grown until August and a second set of cuttings were taken from both the seedling ortets and the first cuttings to produce the 140 cuttings per clone.

Table 1. Production cycle of black spruce cuttings for progeny tests in 1981-82.

Date	Activity	Total Number	Number/Clone
October, 1981	Seed Sown	1,900	
November, 1981	Germination Count[a]	850	1
March, 1982	First Cutting[b]	35,700	42
August, 1982	Second Cutting[b]	119,000	140

[a] Seedling ortets grown in standard round 130 mm pots until June, 1982, then repotted to standard round 150 mm pots.

[b] All cuttings in Fir Cell Leach Containers.

Ortet propagation. The operation of this program is carried out in two gutter-connected greenhouses with an approximate bench capacity of 660m^2. With this bench space we can sow approximately 4350 black spruce seeds and with 50% viability, we expect to produce 2150 clones with at least 140 ramets per clone for progeny planting tests. Since each progeny test includes approximately 800 to 1000 clones, we can produce black spruce cuttings for 2 separate progeny tests in a one-year period.

Seeds were sown in mid-October, 1981, in Jiffy 7 pots and, after germination, the 850 seedlings were potted into standard round 130 mm pots. The growing medium consisted of sphagnum peat and vermiculite (1:1 v/v) amended with Unimix[1] and dolomitic limestone added at the rate of 2.4 and 4.5 kg/m^3, respectively. The seedlings were grown for 19 weeks under a 24-hour photoperiod supplied by natural sunlight supplemented by artificial lighting at 5000 lux intensity.

The supplemental light was supplied from 4:00 pm to 8:00 am daily with high pressure sodium lamps. The greenhouse temperature was artificially maintained at 21°C minimum throughout the growing period; at times the temperature did reach 30°C during the day. The seedlings were fertilized with balanced nutrient regimes usually twice per week at 100 ppm nutrient concentration based on N.

[1] Unimix is a potting fertilizer formulated for peat/vermiculite mixtures and sold under the trade name, Peter's Soluble Fertilizers.

The fertilizers were provided as follows:

Weeks 1,2,3	Seed germination
Weeks 4,5,6	N-P-K (9-45-15)
Weeks 7,8,11,12,15,16,19	N-P-K (20-20-20)
Weeks 9,13,17	N-P-K (15-15-18)
Weeks 10,14,18,20	Leached, no fertilizers
Week 21	N-P-K (15-15-30)
Week 22	N-P-K (9-45-15)

The trees were grown actively for 19 weeks after which they were conditioned for cutting. The supplementary lighting was then turned off and the growing medium was leached of all fertilizer salts. In the 21st week, a fertilizer high in potassium, N-P-K (15-15-30), was applied to the seedlings to increase their sturdiness. A fertilizer high in phosphorus (9-45-15) was applied to the seedlings in the 22nd week to promote better root development in the cuttings. Twenty-two weeks after sowing, the seedling ortets averaged 34.8 cm in height and 5.2 mm in root collar diameter (Figure 1).

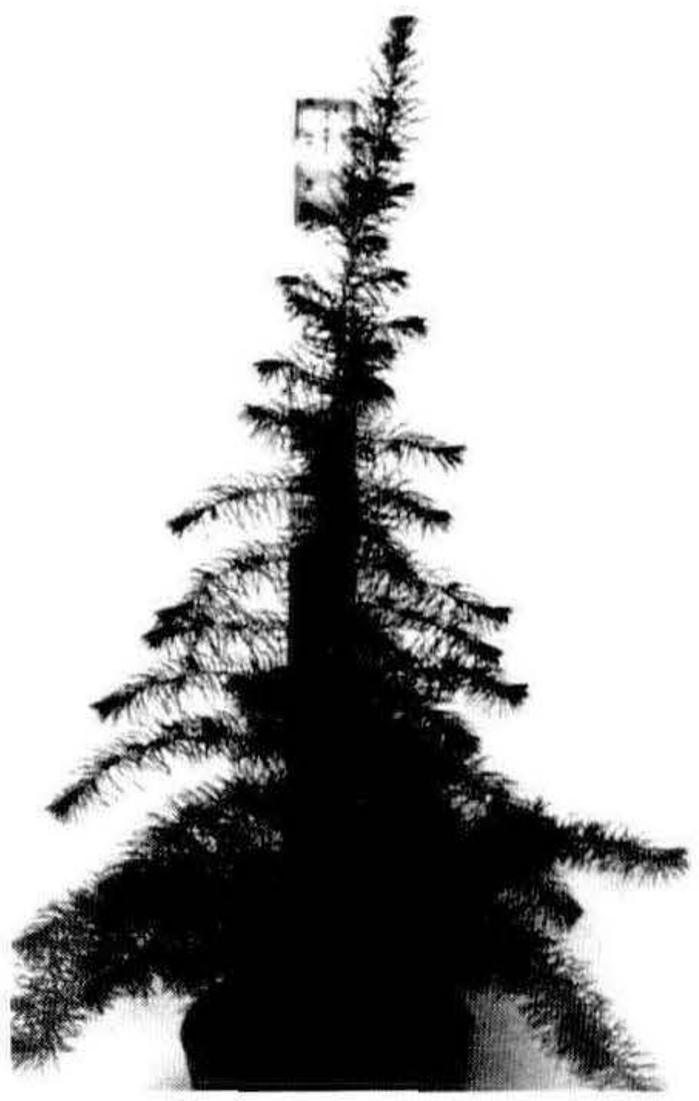

Figure 1. Typical black spruce seedling just prior to taking cuttings at 23 weeks.

Cutting production. In the 23rd week (March 22 to 26, 1982), the first cuttings were taken from the ortet seedlings. Two people working together prepared and planted the cuttings. With a razor blade, one person excised all of the cuttings off each seedling. Cuttings consisted of all the growing tips including leader and lateral branches; they averaged 4.5 to 5.0 cm in length and 1.0 to 3.0 mm in basal diameter. The other person planted the cuttings with a stick so that the cuttings were inserted about 1 cm into the soil. The stick had a pointed end which was used to make a hole in the rooting medium to

insert the cutting and a blunt end which was used to pack the soil down around the base of the cutting.

Until recently, the process of rooting juvenile black spruce cuttings at Orono involved plucking the lowermost needles from the base of cuttings prior to planting. Plucking the needles by hand was very time consuming and expensive in manpower. The needles were pulled off very carefully in order not to strip the stem bark in the process. When the cuttings were damaged in this manner, they often rooted, but they usually took longer and rooted from above the damaged portion of the stem. It has recently been shown (6) that the removal of the lowermost needles from the base of black spruce cuttings prior to planting is unnecessary and is often detrimental to their rooting ability. The same study showed that planting depths between 0.5 and 2.5 cm into the rooting medium had little effect on rooting as long as the cuttings were well-planted initially.

Root promoting substances were not required to root the juvenile black spruce cuttings. The cuttings were planted into a moist mixture of 1:1 shredded sphagnum peat moss and medium grade vermiculite in Leach Fir Cell Containers[2]. These were used for two reasons: 1) The perfectly aligned rows of cells provide an easy way of maintaining clonal identity; and 2) The cells can be separated individually to arrange trees in any field planting design. Prior to planting, the rooting medium was drenched with the fungicide, Quintozene, to eliminate soil fungi.

Two workers were able to cut and plant approximately 300 cuttings per hour while labelling and documenting their work at the same time. The number of cuttings that each seedling yielded varied between 10 and 88, but they averaged 42 per clone (Table 1).

The rooting environment. When the leach tube trays were filled with cuttings, a fine fog nozzle was used to mist the cuttings. Following misting the trays of cuttings were immediately placed on benches in rooting tents. The rooting tents were constructed on rolling benches inside the greenhouses. These tents consisted of a sheet of clear polyethylene supported by a metal hoop and nylon cords. One layer of white Terelyne shade cloth (55% shading) was placed over the polyethylene to provide shade during rooting.

The rooting tents maintained very high humidity surrounding the cuttings. Aluminum water piping and nozzles were installed above and below the rooting tents. These water lines were controlled by timers which provided approximately

[2] Registered Trade Name of Ray Leach Cone-Tainer Nursery.

60 seconds of mist every 30 minutes. This arrangement was successful in maintaining the high relative humidities required for rooting without getting excessive amounts of water onto the rooting medium. The sheets of polyethylene trapped the moisture sprayed from under the benches. The mist sprayed from above the rooting tent dampened the shade cloth. This moisture mostly evaporated but some of it eventually dripped to the floor and thus contributed to increased relative humidity in the greenhouse. We attempted to maintain the humidity in the rooting tents at approximately 85 to 90%, although many times it was above or below these values. Misting from above the rooting tents with cold water also enabled us to control the temperature inside the rooting tents.

Tending the cuttings. The cuttings required 8 weeks of very close tending during which time, temperature, moisture, relative humidity, light, and disease conditions were closely regulated in the rooting tents. A 24-hour photoperiod was maintained; it consisted of natural sunlight during daylight hours supplemented by fluorescent lamps at 500 lux intensity at night. Temperature was maintained at a minimum of 20°C and temperatures up to 30°C were tolerated as long as the relative humidity was also high. When the temperature was excessive, the polyethylene sheet was lifted for a few minutes to remove the hot air. Light misting of the cuttings by hand with a fog nozzle was done up to 3 times daily depending on weather conditions. The objective was to place water droplets only on the foliage. Heavy misting was avoided because it leads to saturation of the growing medium, reducing aeration and increasing the likelihood of disease. The main disease problem in rooting black spruce cuttings is attack by *Botrytis* spp. To prevent this fungicides were applied once a week for 8 weeks. Benlate and Rovral were applied individually in alternative weeks.

Terelyne shade cloth was used in rooting black spruce cuttings. We have noticed that under excessive light such cuttings do not root well, and the same is true for low light conditions (6). There must be sufficient light to sustain some photosynthesis, otherwise the carbohydrate supply will diminish to the point where cuttings will not have the capacity to root. On any given day, we attempted to maintain a minimum of 3,000 lux and a maximum of 13,000 lux, at the brightest time of the day in our rooting tents. This could mean removing the shade cloth from the north side of the rooting tents, or using lighter shade cloth, when the intensity was too low. Also, portions of the greenhouses, where the light intensity was consistently below the minimum level, were not used for rooting black spruce cuttings. When the light intensity at the

brightest time of day was higher than 13,000 lux, shading was increased over the cuttings.

Rooting the cuttings. Weekly sampling of the cuttings showed that most of the rooting occurred in the 5, 6, and 7th week. By the tenth week, 97% of the 35,700 cuttings had rooted. At this time, the cuttings underwent a 2-week conditioning period to allow them to adjust to greenhouse conditions. During this time, misting was slowly withdrawn, ventilation periods were increased, exposure to sunlight was increased, and normal fertilization was resumed. This was done progressively so that by the end of the 2-week conditioning period, the polyethylene and shadecloth were entirely removed from the rooting tents (Figure 2).

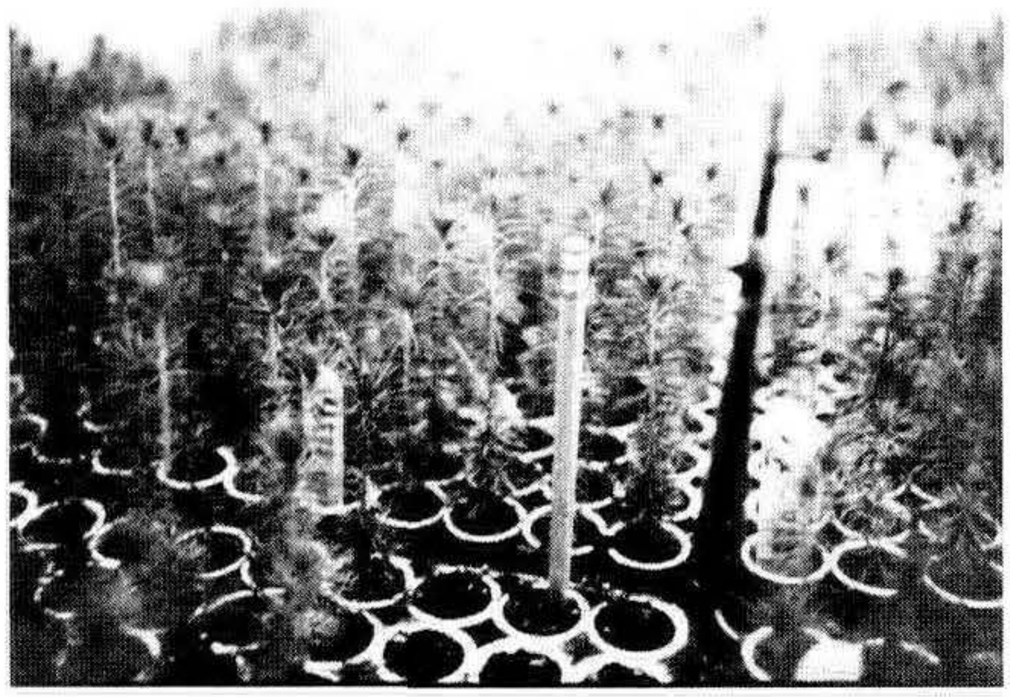

Figure 2. The first cuttings taken from black spruce seedling ortets 12 weeks after planting.

The second cutting. After the first cuttings were taken in March, 1982, the seedling ortets were returned to pre-cutting growing conditions in the greenhouse, i.e. 24-hour photoperiod and regular fertilization, as described previously. They were repotted in June into standard round 150 mm pots to ensure that they would continue growing freely until August. A second set of cuttings was taken in August from both the seedling ortets and the first cuttings to produce the 140 cuttings per clone. A total of 119,000 cuttings were planted in August, 1982. By mid-October approximately 90% of them had rooted. These will be grown over-winter in our greenhouses and will be ready for outplanting in progeny tests in the spring of 1983.

Plantation surveys of black spruce cuttings planted in 1979 and 1980, in comparison tests with seedlings, have shown that cuttings survive and grow as well as seedlings.

Future production at Orono. It appears that the next cycle of black spruce cuttings for progeny testing will be carried out by taking only one set of cuttings to achieve the 140 ramet/clone objective. We have improved our growing techniques and feel that black spruce can be grown from seed to a height

of 60 cm and a root collar diameter of 10.0 mm in 7 months. Black spruce seedlings of this size will normally yield approximately 140 cuttings each.

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THE ROOTING STIMULUS IN PINE CUTTINGS

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Abstract. Occurrence, distribution, and function of the "endogenous root-forming stimulus" (ERS) were examined in jack pine (*Pinus banksiana* Lamb.) seedling cuttings via surgical treatment and application of indole-3-butyric acid (IBA). Removal of terminals or needles markedly reduced rooting, indicating that both terminals and needles contained substantial amounts of ERS and that ERS was rather generally distributed in the cuttings. However, terminals contained much more ERS per unit dry weight, compared to needles. ERS consisted of an auxin and non-auxin component. Applied IBA did not replace the effects of terminals on rooting and, therefore, was largely ineffective when non-auxin ERS was limiting. Auxin ERS was initially required for the development of callus in which primordia initiated. Subsequently, auxin and non-auxin ERS were required for primordium development. However, limiting the supply of non-auxin ERS was primarily responsible for reduced rooting after terminals were removed.

About 100 years ago the idea arose that chemical factors in the aerial portion of plants controlled the formation of roots (26). Subsequently, it was learned that auxin, indole-3-acetic acid (IAA), and one or more non-auxin chemicals accumulated

of 60 cm and a root collar diameter of 10.0 mm in 7 months. Black spruce seedlings of this size will normally yield approximately 140 cuttings each.

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About 100 years ago the idea arose that chemical factors in the aerial portion of plants controlled the formation of roots (26). Subsequently, it was learned that auxin, indole-3-acetic acid (IAA), and one or more non-auxin chemicals accumulated

in the bases of cuttings during propagation (4, 28). Together, auxin and the non-auxin factors comprise the "endogenous root-forming stimulus" (ERS), which is the primary initiator and controller of adventitious rooting (16, 28).

Most research concerning the nature, location, and functions of ERS has been conducted with dicotyledonous species, whereas less work has concerned conifers. Jack pine (*Pinus banksiana* Lamb.) is a commercially important forest tree in the North Central U.S. and Canada, but is extremely difficult to propagate from cuttings when ortets reach the age of 5 to 7 years (25). The present work examined the occurrence, distribution, and some functions of auxin and non-auxin ERS in cuttings of jack pine. The present examination was conducted as part of a comprehensive study to determine the relationships between the "predisposition" of cuttings to root, cellular "competence" to form root initials, and ERS. These relationships are described in the following rationale.

The potential for adventitious rooting increases concomitantly with what has been termed the "predisposition" of cuttings to root (14). Cuttings are predisposed to root after minimum anatomical and physiological thresholds have been exceeded (14). See Figure 1. Various types of cells form root primordium initials, depending on the species of plant and type of cutting (14). However, only a few cells of the anatomically suitable type within a cutting will form root initials, which indicates a special physiological status plus the particular cellular morphology. This cellular morphology and physiological status makes some cells "competent" progenitors of root initials, but the ontogeny and nature of the competence re-

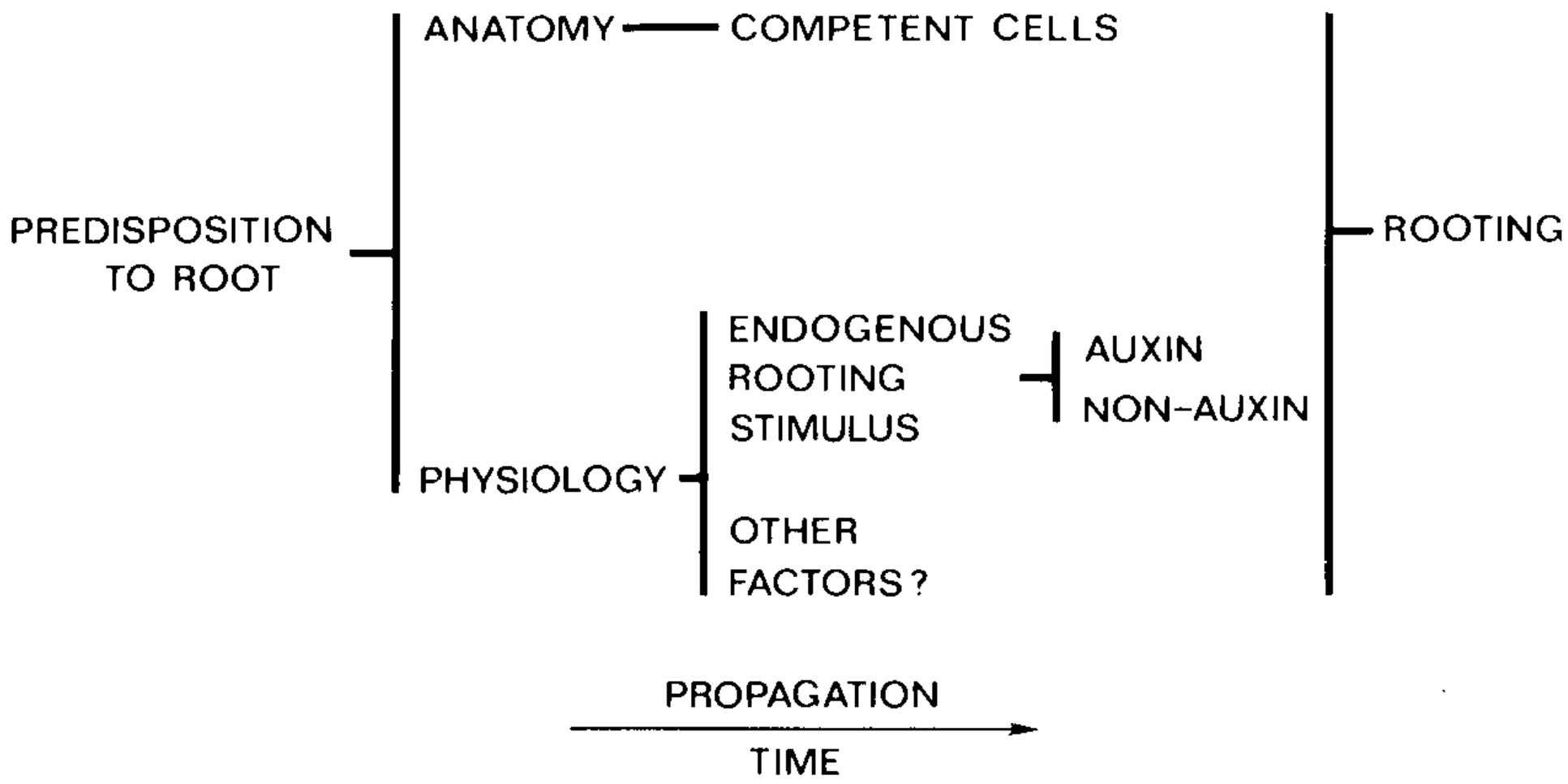

Figure 1. Relations between some anatomical and physiological factors that determine the ability of cuttings to complete the rooting process.

main obscure (14). See Figure 1. Nevertheless, the presence of competent cells is part of the minimum status that predisposes cuttings to root (14). See Figure 1.

Rooting occurs in two different ways, depending upon the species of plant. In "non-callusing" species, such as pea (*Pisum sativum* L.) and bean (*Phaseolus vulgaris* L.), primordia initiate from competent cells that exist at the time a cutting is severed (9). See Figures 1 and 2. In "callusing" species, which initiate primordia in or adjacent to developing callus tissue, competent cells do not exist prior to propagation (14). See Figures 1 and 2. In comparison with many non-callusing species, callusing species have ortets with a long life span, undergo secondary vascularization (wood formation), and require relatively long periods for successful propagation of cuttings. See Figure 2. Compare Figure 4 with Figure 1 of (16). For example, jack pine cuttings root slowly and initiate primordia only in or adjacent to basal callus tissue formed during propagation (20), even in cuttings from seedlings as young as 20 days old (5,21,27). Based on the foregoing, the predisposition of callusing species to root depends both on normal plant development and the presence of factors that allow the formation of callus, which directly or indirectly yields competent cells (14).

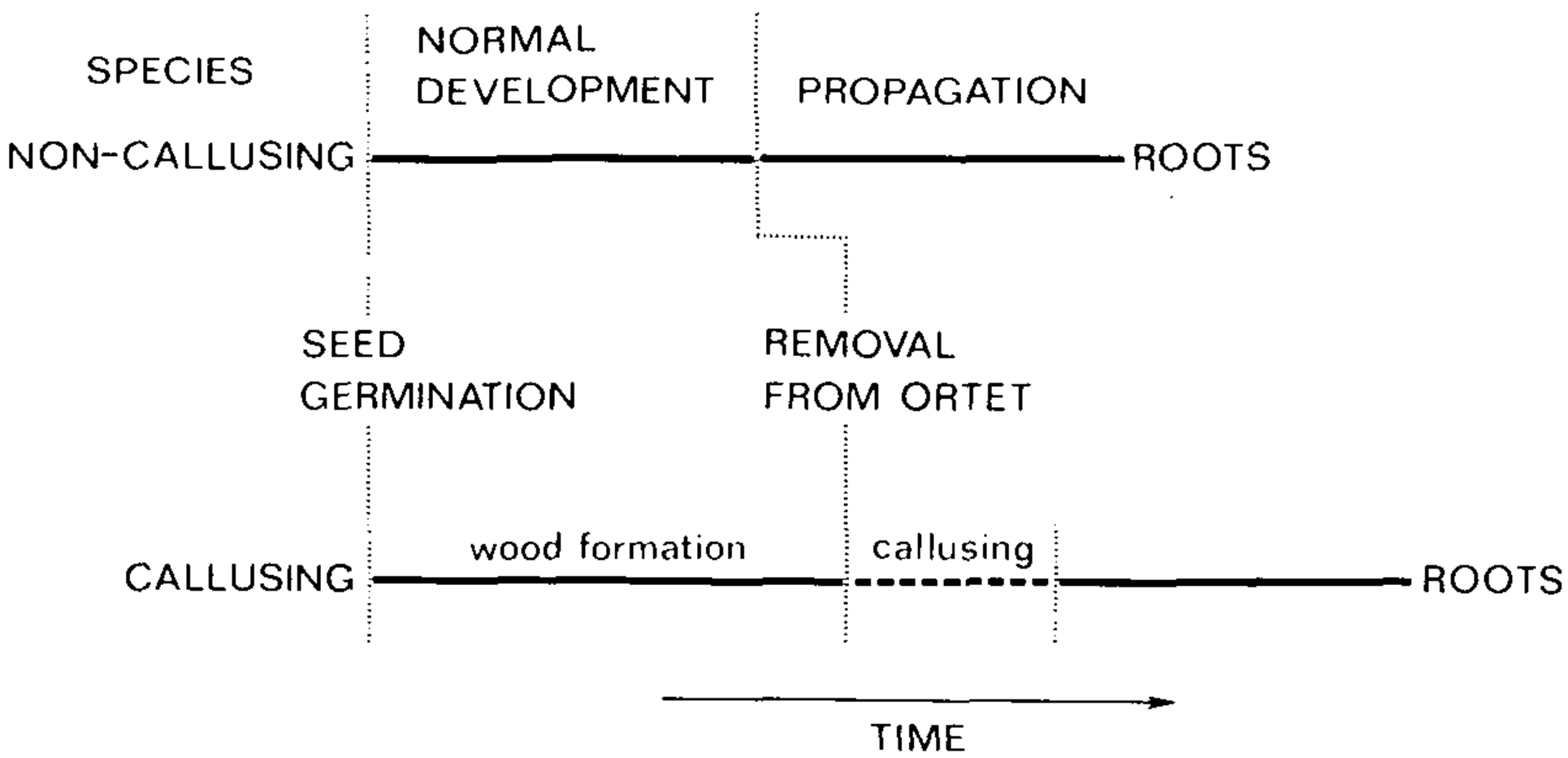

Figure 2. Relations between normal plant development and rooting characteristics of cuttings from species that do and do not initiate root primordia in or adjacent to callus tissue.

Formation of root initials requires physiological stimulation in the form of ERS (16). See Figure 1. Auxin and non-auxin ERS exist in leaves, embryonic shoots, and cotyledons (1,3,6,7,10,11,12,13,15,24); are basipetally transported in the cutting [(4) and previous references]; and are separately required for initiation (auxin ERS) and development (non-auxin ERS) of primordia (7,11,12,13,14,15). The minimum physiological status that predisposes non-callusing species to root is the

presence within cuttings of enough auxin and non-auxin ERS (Figure 1). In callusing species, the minimum additionally requires factors that promote callus formation (i.e., the development of competent cells).

The actions of ERS on primordium initiation-development appear to occur in substantially different time-frames in non-callusing and callusing species, although these matters are largely unstudied. In non-callusing species, the basipetal movement of ERS occurs quickly, resulting in root primordia after 1 or 2 days propagation [compare Figures 1 and 8 of (16)]. However, in callusing species, either the basipetal movement of ERS is delayed or the actions of basipetally transported ERS on primordium initiation are delayed, awaiting callusing and the development of competent cells. For example, significant production of callus requires 7 days in untreated and at least 2 days in auxin-treated jack pine seedling cuttings [see Figure 6 of (18)], and rooting occurs substantially later (18). See Figure 4.

Shortly after the discovery of auxin, it was learned that applied auxin often stimulated adventitious rooting (4,28). However, cuttings of certain age classes or species of plants have shown little or no positive response to applied auxin, which resulted in their classification as "poor or non-rooters" (2). Such species apparently lack sufficient non-auxin ERS, an essential predisposing them to root for which applied auxin cannot substitute (11). Based on available information, only normal plant development predisposes cuttings to root and only modifications of normal development can enhance or diminish a prevailing predisposition to root. For example, etiolation and surgical treatment both modify normal plant development and can enhance or diminish rooting responses, respectively (7,8,10,11,16,22,23).

MATERIALS AND METHODS

Jack pine seedlings were grown from a single lot of open pollinated seed in a growth chamber and propagated in a greenhouse (17). Cuttings were made from 90-day-old seedlings that were randomly selected for treatment (as described in Table or Figure captions). In some experiments, "needles" or "terminals" were removed before or after cuttings were severed from the original seedling root system. The terminal consisted of the terminal bud and about 1 cm of subtending stem plus needles (Figure 3). Therefore, some needles remained on those cuttings from which "needles were removed" (Figure 3). When used, indole-3-butyric acid (IBA) in 100% ethanol was applied as a one μl drop to the apical stump of cuttings from which terminals were removed or in 100% ethanol by the basal quick dip method [(19), see Table and Figure captions].

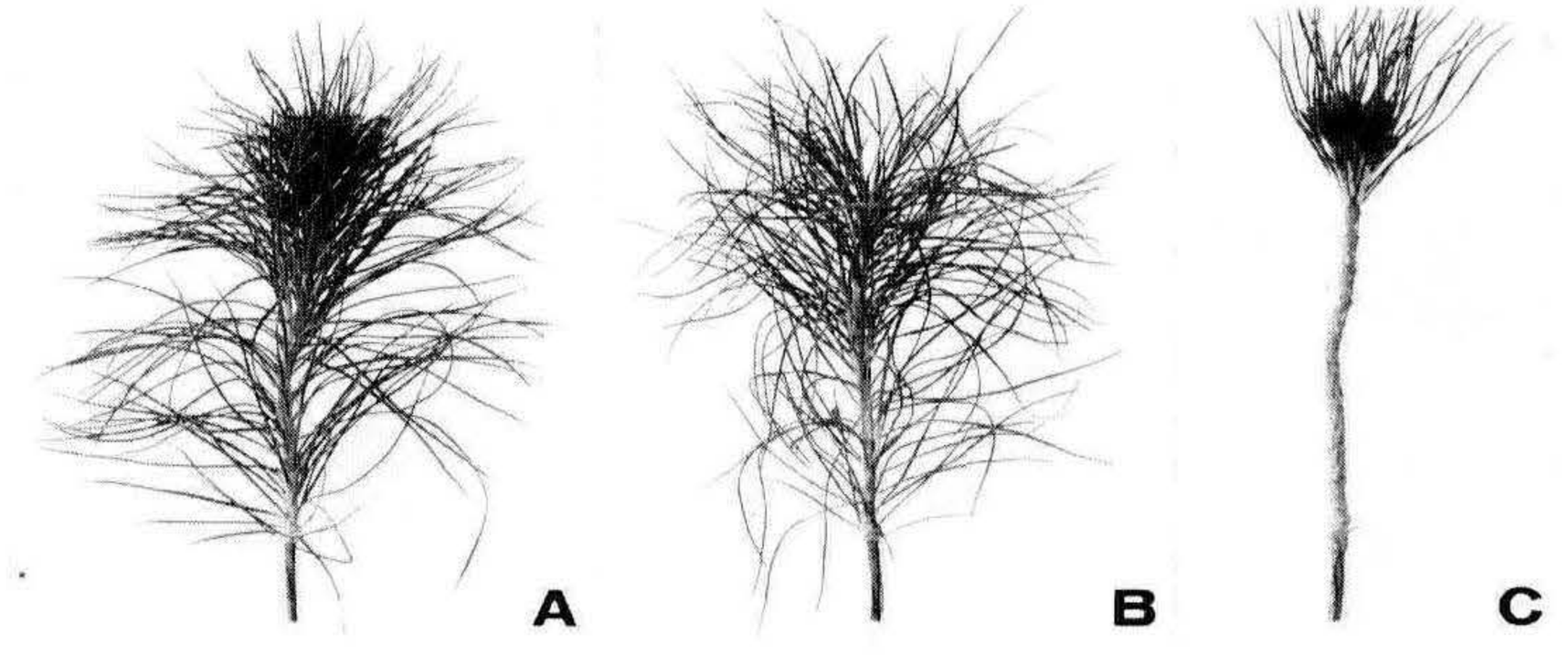

Figure 3. Jack pine cuttings produced from 90-day-old seedlings: (A) untreated, (B) terminal removed, (C) needles removed.

Surgical treatment can remove the possible influences of both auxin ERS and non-auxin ERS, whereas applied auxin can mimic the effects of auxin ERS (1,7,8,11). Therefore, rooting data were evaluated in the following ways (16): 1) effects of ERS alone — determined from the difference between data for non-auxin-treated, surgically-treated cuttings compared to non-auxin-treated, non-surgically-treated cuttings; 2) effects of auxin treatment alone — determined (a) from data for non-auxin-treated, non-surgically-treated cuttings compared to auxin-treated, non-surgically-treated cuttings; or (b) from data for non-auxin, surgically-treated cuttings compared to auxin-treated, surgically-treated cuttings; 3) combined effects of ERS and auxin treatment — determined from data for auxin-treated, non-surgically-treated cuttings compared to non-auxin-treated, non-surgically-treated cuttings; 4) non-auxin ERS — determined from data for non-auxin-treated, non-surgically-treated cuttings compared to auxin-treated, surgically-treated cuttings; 5) auxin ERS — from (2b) above.

Experiments were repeated at least twice in time and data were analyzed via paired comparisons with a Mann-Whitney U-test and sometimes with correlation analysis. The following presentation has been limited to statistically significant ($P > 0.95$) differences between means or to statistically significant ($P > 0.95$) correlations.

RESULTS

Basal application of IBA resulted in earlier rooting (between 10 and 16 days), more roots per cutting, and a higher percentage of rooted cuttings, all in comparison with untreated cuttings at the same time (compare same days, IBA-treated vs. Untreated, Figure 4). For both IBA-treated and untreated cuttings, rooting percentages, number of roots, and basal fresh weight were positively correlated with time; number of roots and basal fresh weight were positively correlated with rooting percentages; and, number of roots was positively correlated

with basal fresh weight (Figure 4). Finally, rooting percentages and basal fresh weights were positively correlated in comparisons of untreated with IBA-treated cuttings (Figure 4).

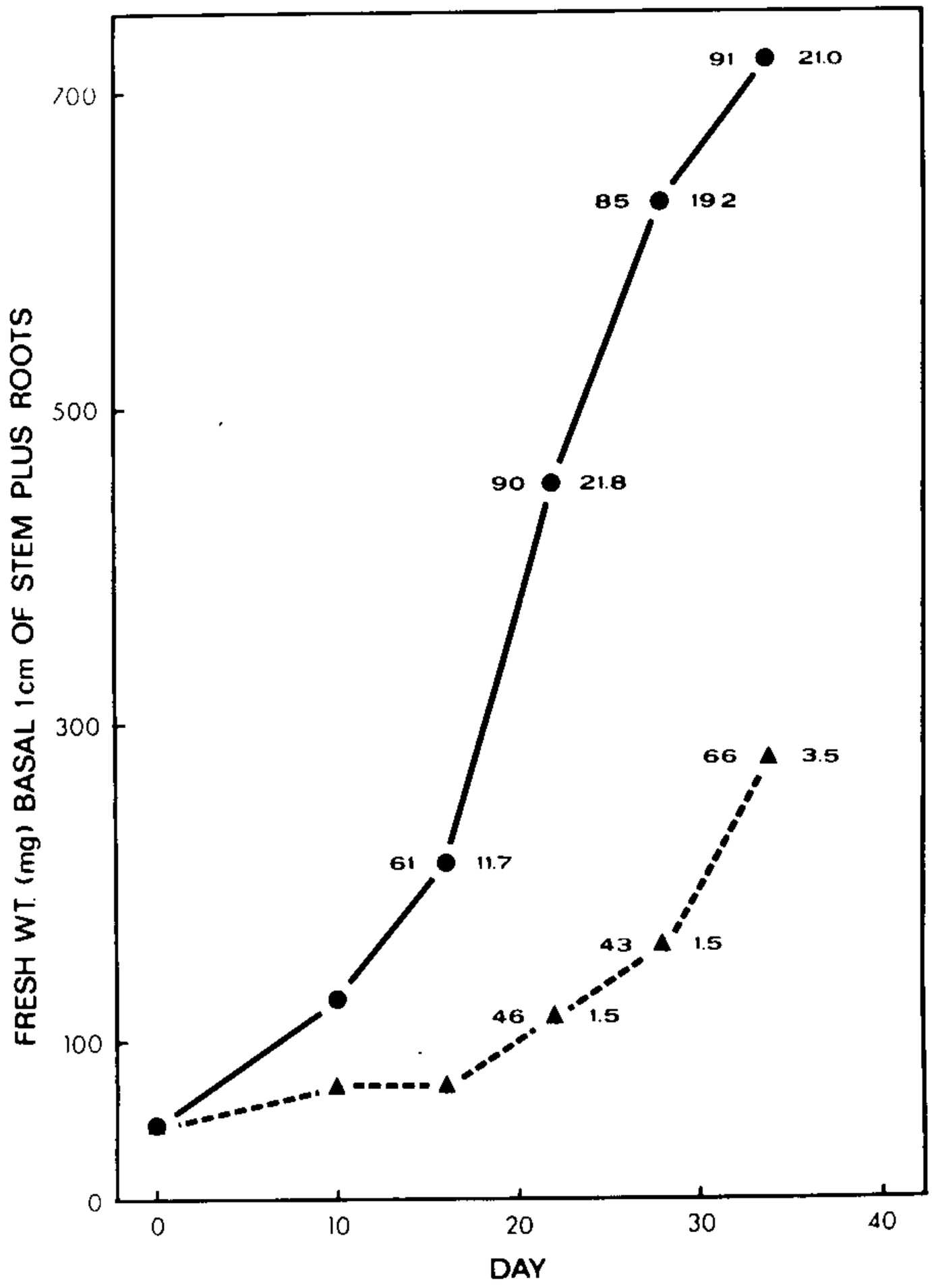

Figure 4. Effect of indole-3-butyric acid (IBA) treatment on fresh weight of basal one cm of stem plus roots of non-surgically-treated, 92-day-old jack pine seedling cuttings. Treatment by basal quick dip in 100% ethanol with (circles) or without (triangles) 25 mmol/l IBA. For each day, percentage rooted (left) and mean number of roots per cutting (right) appear adjacent to symbols. No rooting was found on days without numbers next to symbols. At day 10, mean fresh weights for untreated and IBA treated cuttings differed significantly ($P > 0.95$, $n = 100$) from each other and from the mean for day 0. Mean number of roots per cutting differed significantly between treatments at and after day 22.

In the experiment to determine the general locations of ERS in jack pine cuttings, removing needles or terminals (Figure 3) on the individual test days resulted in fewer rooted cuttings, fewer roots per cutting, and shorter roots per cutting, compared to the control, except when needles were removed

at day 10 (Control vs. Needles Removed and Terminal Removed, Table 1). Lesser rooting after removing terminals, compared with no treatment, was also found in other experiments (Tables 2-5).

Table 1. Rooting data after 44 days propagation of 89-day-old jack pine seedling cuttings. Cuttings were untreated (Control), or their terminals or needles were removed at the indicated times after cuttings were severed from the original seedling root system. Data are means expressed on a per cutting basis. Means with different letters differed significantly ($P > 0.95$, $n = 30$). Means for pooled data for all treatment times for Terminal Removed and for Needles Removed differed significantly ($P > 0.95$, $n = 210$).

Time of treatment	Percent rooted	Number of roots	Longest root length (mm)
	Control		
—	93%	4.2a	30.5a
	Terminal Removed		
+ 1 min	23	0.6b	3.4b
+ 2 days	43	1.1b	10.8b
+ 4 days	70	2.0b	18.0b
+ 6 days	63	1.8b	14.0b
+ 8 days	40	1.0b	9.8b
+ 10 days	70	2.0b	17.0b
+ 12 days	57	1.3b	16.1b
Mean	52	1.4	12.7
	Needles Removed		
+ 1 min	60	1.8c	13.9c
+ 2 days	77	2.8c	18.1c
+ 4 days	53	1.4b	13.2b
+ 6 days	67	2.5b	26.0b
+ 8 days	67	1.9b	15.7c
+ 10 days	80	3.1a	24.6a
+ 12 days	83	1.9c	21.2b
Mean	70	2.2	19.0

Overall, removing needles was less effective in diminishing rooting (i.e., ERS) than was removing terminals. Firstly, removing needles early in the experiment (up to +2 days) or late in the experiment (+8 to +12 days) resulted in either more roots or longer roots per cutting, or both, compared with removing terminal (needles removed vs. terminal removed, Table 1). Secondly, removing needles resulted in more roots per cutting and longer roots per cutting, compared with removing terminals based on a comparison of pooled data for all days that each treatment was tested (compare means, Needles Removed vs. Terminal Removed, Table 1). Thirdly, the mean percentage of rooted cuttings during the whole experiment (+1 min to +12 days) was greater when needles were removed than when terminals were removed (compare means, Needles Removed vs. Terminal Removed, Table 1).

Table 2. Rooting data after 41 days propagation of 93-day-old jack pine seedling cuttings. Cuttings were untreated (Control), or their terminals were removed at the indicated times after cuttings were severed from the original seedling root system. Data are means expressed on a per cutting basis. Means with different letters differed significantly ($P > 0.95$, $n = 40$).

Time of treatment	Percent rooted	Number of roots	Longest root length (mm)
	Control		
—	80%	2.2a	26.0a
	Terminal Removed		
+ 1 min	30	0.6b	8.1b
+ 1 day	32	0.8b	10.9b
+ 2 days	32	0.7b	6.2b
+ 3 days	35	0.6b	7.7b
+ 7 days	48	0.9b	9.2b
+ 8 days	28	0.5b	2.3c
Mean	34	0.7	7.4

The time at which terminals were removed after cuttings were severed from the original seedling root system had no effect on the number of roots or root length per cutting (+1 *min through +12 days, Terminal Removed*, Table 1; *see also* Tables 2-5). Similar results were obtained when terminals were removed up to one hour before cuttings were severed (Table 4). However, removing terminals 1 day before cuttings were severed, compared to removal later, resulted in better rooting, although results were somewhat conflicting. In one experiment, removing terminals 1 day before cuttings were severed resulted in a greater percentage of rooted cuttings, number of roots per cutting, and root length per cutting, compared with treatment from 1 hour before to 1 min after cuttings were severed (−1 day vs. −1 min and +1 min, Table 4). Also in the foregoing experiment, a greater percentage of rooted cuttings and longer roots per cutting were obtained when terminals were removed one day before cuttings were severed, compared with treatment 1 day after cuttings were severed (−1 day vs. +1 day, Table 4). In a second experiment, a greater percentage of rooted cuttings was obtained when terminals were removed 1 day before cuttings were severed, in comparison with treatment 1 min or 1 day later (Terminal Removed, Table 5). *However, no differences were found in number of* roots or root length per cutting (−1 day vs. +1 min and +1 day, Terminal Removed, Table 5).

Application of IBA to the cut apex of cuttings after removing terminals increased the number of rooted cuttings but, with few exceptions, had no effect on the number of roots or root length per cutting, compared to removing terminals alone (compare same days, Terminal Removed vs. Terminal Removed + Apical IBA, Table 5). However, when data for all

treatment times were pooled, which greatly increased sample size, IBA treatment significantly increased rooting, using all bases of comparison (compare means, Table 5). Nevertheless, IBA treatment did not fully counteract the negative effects on rooting of removing terminals (Control vs. Terminal Removed + Apical IBA, Table 5).

Table 3. Rooting data after 33 days propagation of 90-day-old jack pine seedling cuttings. Cuttings were untreated (Control), or their terminals were removed at the indicated times before (−) or after (+) cuttings were severed from the original seedling root system. Data are means expressed on a per cutting basis. Means with different letters differed significantly ($P > 0.95$, $n = 150$).

Time of treatment	Percent rooted	Number of roots	Longest root length (mm)
	Control		
—	57%	1.8a	17.5a
	Terminal Removed		
− 1 min	21	0.6b	2.9b
+ 1 min	15	0.3b	2.2b
+ 1 day	21	0.5b	3.9b
Mean	19	0.5	3.0

Table 4. Rooting data after 38 days propagation of 95-day-old jack pine seedling cuttings. Cuttings were untreated (Control), or their terminals were removed at the indicated times before (−) or after (+) cuttings were severed from the original seedling root system. Data are means expressed on a per cutting basis. Means with different letters differed significantly ($P > 0.95$, $n = 50$).

Time of treatment	Percent rooted	Number of roots	Longest root length (mm)
	Control		
—	82%	3.3a	43.4a
	Terminal Removed		
− 1 day	54	1.7b	31.9b
− 1 hour	38	1.0c	20.7c
− 1 min	38	1.2c	18.2c
+ 1 min	32	1.1c	16.0c
+ 1 day	28	1.5b	20.2c
Mean	38	1.3	21.4

A final experiment tested the effect of removing terminals combined with immediate apical or basal application of IBA on fresh weight of the basal 1 cm of stem prior to macroscopically visible root development. Basal fresh weight of control cuttings and cuttings from which terminals had been removed increased initially at day 9, compared to day 0, and were equal during the test (C vs. TR, Figure 5). Apical and basal application of IBA after removing terminals resulted in faster and greater increases in basal fresh weight, compared with non-IBA-treated cuttings (Figure 5). However, apical application of IBA was less effective than basal application (Figure 5).

Table 5. Rooting data after 33 days propagation of 93-day-old jack pine seedling cuttings. Cuttings were untreated (Control), or their terminals were removed at the indicated times before (−) or after (+) cuttings were severed from the original seedling root system. IBA (5.7 nmol per cutting) was apically applied to some cuttings immediately after the terminals were removed. Data are means expressed on a per cutting basis. Means with different letters differed significantly ($P > 0.95$, $n = 30$). Means for pooled data for all treatment times for Terminal Removed and Terminal Removed + Apical IBA differed significantly ($P > 0.95$, $n = 300$).

Time of treatment	Percent rooted	Number of roots	Longest root length (mm)
	Control		
—	80%	2.8a	20.2a
	Terminal Removed		
− 1 day	37	0.8b	3.9b
+ 1 min	17	0.5b	3.2b
+ 1 day	17	0.3b	1.0b
+ 2 days	23	0.6b	2.5b
+ 3 days	40	1.0b	5.9b
+ 4 days	27	0.4b	1.3b
+ 5 days	20	0.6b	2.3c
+ 6 days	33	1.0b	6.5b
+ 7 days	40	0.7b	3.8b
+ 8 days	27	0.5b	3.6c
Mean	28	0.6	3.4
	Terminal Removed + Apical IBA		
− 1 day	47	1.7b	9.6b
+ 1 min	28	0.7b	3.5b
+ 1 day	30	1.2b	6.6b
+ 2 day	33	1.1b	4.2b
+ 3 day	33	2.0b	8.6b
+ 4 day	33	1.2b	6.5b
+ 5 day	43	1.4b	6.8b
+ 6 day	30	1.5b	10.5b
+ 7 day	43	1.0b	3.1b
+ 8 day	53	1.8b	8.2b
Mean	37	1.4	6.8

DISCUSSION

The present results indicated that removing needles or terminals (Figure 3) greatly reduced rooting of jack pine seedling cuttings and, therefore, substantially reduced levels of ERS. On a per part basis, terminals contained substantially more ERS than needles, assuming a linear relation between rooting data and concentration of ERS (compare means, Table 1). On a dry weight basis, the content of ERS in terminals was even greater, compared to needles, because the dry weight of terminals was about one-half that of needles (data not shown). Overall, the data indicated that ERS was rather generally distributed in jack pine seedling cuttings, probably because all of

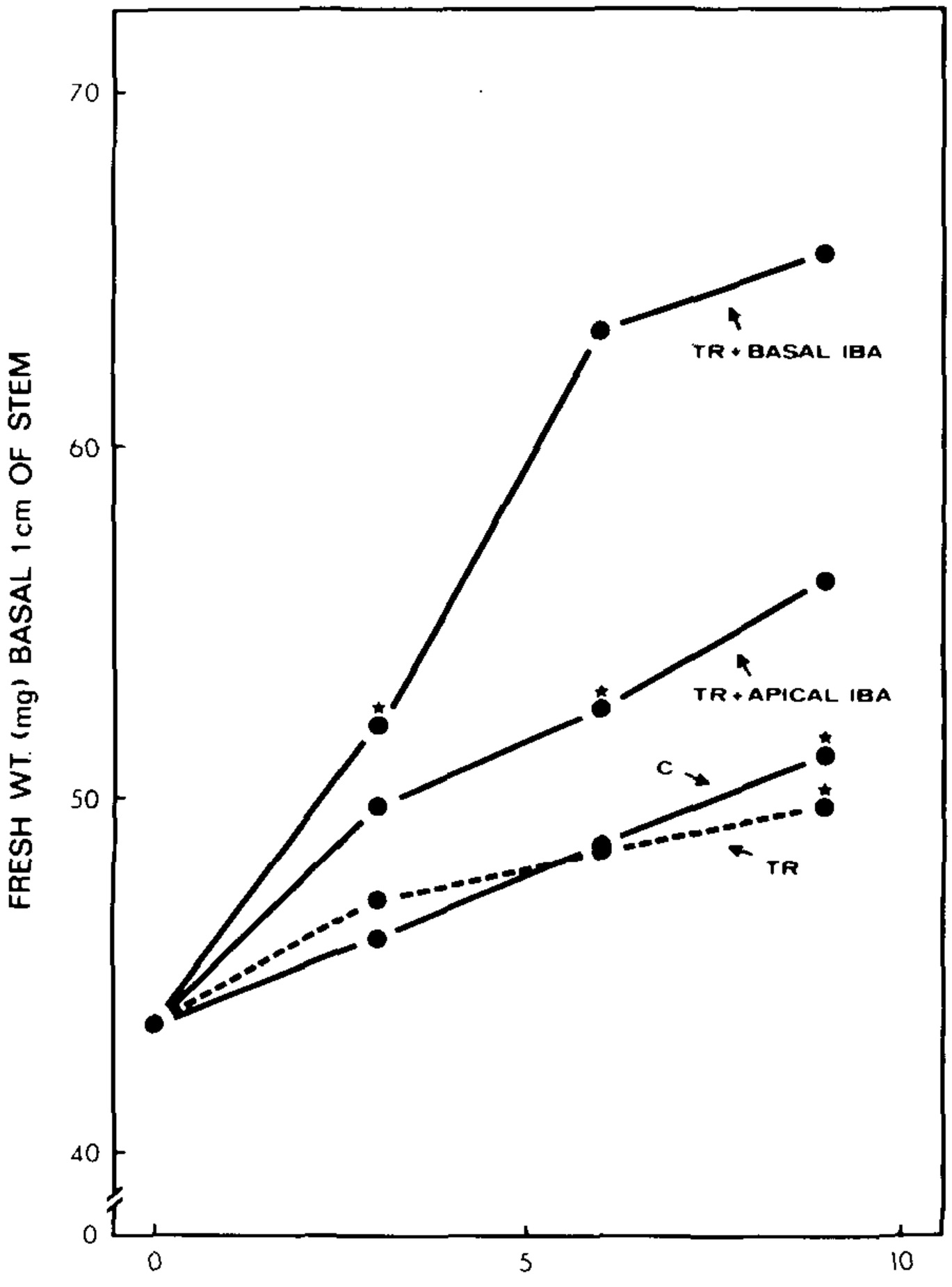

Figure 5. Effect of indole-3-butyric acid (IBA) treatment on fresh weight of basal one cm of stem of 92-day-old jack pine seedling cuttings. Terminals were not (C) or were (TR) removed immediately after cuttings were severed, immediately after which some cuttings were apically (+ Apical IBA, 500 nmol/cutting) or basally (+ Basal IBA, 25 mmol/l) treated with IBA in 100% ethanol. Stars indicate the initial significant ($P > 0.95$, $n = 30$) change within each treatment in comparison with day 0. By day 8, means for TR + Basal IBA and TR + Apical IBA differed significantly from means for C and TR, which were equal.

the needles were relatively young and borne on the entire epicotyl (Figure 3A).

The present experiments indicated that auxin ERS enhanced rooting of jack pine seedling cuttings. For example, basally applied IBA increased rooting, in comparison with untreated cuttings (Figure 4). However, applied IBA only partially replaced the effect of terminals (i.e., ERS). As an example, apical application of IBA to cuttings without terminals enhanced rooting, in comparison with similar non-IBA-treated

cuttings, but rooting of the IBA-treated cuttings was still markedly less than in control cuttings with terminals (Table 5). Therefore, ERS in jack pine seedling cuttings consisted of an auxin and a non-auxin component, and applied IBA would not substitute for the non-auxin component, as determined for other species (cf. previous references).

Partial removal of ERS by surgical treatment could have reduced rooting in the present tests by: 1) limiting the rate of callus formation, thereby delaying or preventing the differentiation of cells that were competent to respond to ERS; 2) reducing levels of auxin ERS and/or non-auxin ERS too much to support primordium initiation-development, even though competent cells were present; or 3) a combination of (1) and (2). The following three observations indicated the correctness of postulate (2) and, additionally, that diminished rooting occurred mostly because surgical treatment lowered levels of non-auxin ERS.

Firstly, applied IBA only partially reversed the deleterious effects on rooting that resulted from removing terminals, as discussed previously. Secondly, significant callusing occurred in control cuttings with terminals as early as day 8 in the present experiments, and rooting occurred between day 16-23 (Figure 4). Other tests with identical cuttings have detected a significant increase in basal fresh weight at day 7, when weights were determined daily (18). If removal of terminals (i.e., limiting ERS) had primarily influenced callus formation, the surgical treatment would have been increasingly less deleterious to rooting as the period of propagation increased before treatment. However, the results indicated that rooting was equal when terminals were removed from 1 hour before to 12 days after cuttings were severed from the original seedling root system (Tables 1-5). Thirdly, basal fresh weight was identical in non-IBA-treated cuttings with or without terminals (Figure 5) but removing terminals reduced rooting (e.g., Table 1).

Thus, removing terminals seemed to reduce rooting by direct effects on primordium initiation-develpment. Nevertheless, formation of competent cells was determined by influences of auxin ERS. Firstly, basal application of IBA to non-surgically-treated cuttings resulted in greater callusing-rooting, compared with similar but non-IBA treated cuttings (Figure 4). And, callusing-rooting by untreated and IBA-treated cuttings were positively correlated (Figure 4). The foregoing results indicated that applied IBA acted in the same manner as auxin ERS but, probably because of the higher auxin levels attained at the base of cuttings, applied IBA enhanced the "normal" callusing-rooting responses. Secondly, application of IBA to

cuttings without terminals increased basal fresh weight, in comparison with similar non-IBA treated cuttings (Figure 5).

In summary the present results indicated for jack pine seedling cuttings that: 1) ERS was more generally distributed throughout the cutting than has been reported for dicotyledonous species (cf previous references); 2) non-auxin ERS was the limiting factor in adventitious rooting; and 3) auxin ERS had roles in both callusing and primordium initiation, whereas auxin ERS is only needed for primordium initiation in non-callusing species.

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SUPPLEMENTAL LIGHTING IN THE PROPAGATION OF DECIDUOUS AZALEAS[1]

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Abstract. Literature pertinent to the influences of light intensity, light quality and photoperiod on propagation of ornamentals is presented. Direct effects, as well as effects mediated through the stock plant are discussed. In addition, research is reported which illustrates improved microcutting production and rooting when hardy deciduous azalea microstock cultures were illuminated with reduced light intensities, or when subjected to 2 weeks of red light after 2 weeks of far-red light prior to rooting.

REVIEW OF LITERATURE

Light influences propagation success in many ways. In addition to the obvious advantage of greater carbohydrates and other substances necessary for rooting which may be produced by any treatment enhancing photosynthesis, it is clear that light has many other striking effects. These may include: direct stimulation of rooting by light intensity or photoperiod modifications; a change in amount of cuttings produced and/or improved rootability caused by different stock plant light treatments; improved growth and survivability of cuttings as a result of lighting; and improved tissue culture productivity induced by various stock plant and culture irradiance techniques.

1. *Direct Effects of Light Intensity on Rooting of Cuttings.* Many reports indicate that reducing light intensities under which cuttings are being rooted improves rooting percentage and root quality. Loach and Gay (17) have demonstrated that irradiance levels of 20 and 40 Wm^{-2} were superior to higher levels for rooting *Forsythia* and *Weigela* and they suggest that "light levels in glasshouses are super-optimal for root initiation," and therefore, shading would aid rooting of cuttings through much of the year. Biran and Halevy (4), reported that reducing light intensity by 50% for dahlia stock plants helped improve rootability of cuttings. Cultivars varied in their response to various shading treatments. However, shading only the base of the cuttings improved the rooting percentage and number of roots per cutting. Etiolation has also been used to improve rooting of some difficult-to-root species. A particular-

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ly interesting illustration of such rooting enhancement in avocado was reported by Frolich (9).

2. *Photoperiod Effects on Rooting of Cuttings.* Long-day (18-hr) treatments are stated by Bhella and Roberts (3) to encourage rooting of Douglas fir (*Pseudotsuga menziesii*) and Lanphear and Meahl (16) reported that *Juniperus* cuttings rooted better under long-day (LD) than short-day (SD) regimes. Similar results were stated for *Populus* × *robusta* by Wareing and Smith (25). Nitsch (20) suggested this to be the case for a wide spectrum of woody species and Waxman (26) in 1965 listed similar results for *Cornus florida*.

3. *Effects of Light Intensity on Stock Plants on Rooting of Cuttings.* Hansen (10) is well-known for research with pea cuttings in which he has repeatedly demonstrated that reduced stock plant irradiance levels, as low as 4 Wm^{-2} significantly increased root number per cutting. Similar reports by Anderson and Carpenter (1) with chrysanthemum, Biran and Halevy (4) with dahlia, and Moe (19) with *Campanula* can be noted. Although these researchers worked primarily with herbaceous species, Johnson and Roberts (15) have obtained similar responses by shading *Rhododendron* stock plants. They hypothesized that since lower light levels caused reduced flower formation, the improved rooting may have been related to less competition for materials necessary for rooting.

4. *Influences of Stock Plant Photoperiod.* Direct effects of photoperiod supplied to the stock plant on rooting of cuttings have been demonstrated by Hentig (14) with several herbaceous species and azalea, and by Bachelard and Stowe (2) with *Acer rubrum* and *Eucalyptus camaldulensis*. In most cases, this improvement was a result of LD treatments. Such an effect could, of course, be related in part to increased photosynthesis in the stock plant and thus result in cuttings containing more substances necessary for rooting.

Perhaps a more interesting and potentially useful effect is the use of LD, either by day extension or night interruption, to keep stock plants vegetative during times of the year when they normally would become dormant. Short-days are a major cause of woody plant dormancy, so LD-induced vegetative growth results in a continuance of cutting supply. In 1957, Flint (8) reported such a response with geraniums and chrysanthemums, and Heins *et al.* (11) have also presented similar results for chrysanthemums. Waxman (26) with *Cornus florida*, and Henny and Read (13) with deciduous azaleas, also increased the number of cuttings produced by stock plants subjected to LD treatments. More recently, Economou (7) and Read *et al.* (22) have reported this approach with several

woody species for increasing explant material for micropropagation techniques.

5. Stock *Plant* Response to Light *quality*. Another interesting approach is the use of light *quality* modificatons of the stock plant environment. Heins *et al.*, (11,12) reported that chrysanthemum stock, when given night irradiation with red or incandescent light sources, showed enhanced rootability of cuttings. Stock plant irradiance with red light, followed by incandescent irradiance of the cuttings was the most effective. They also demonstrated an enhancement of number of cuttings produced as a result of stock plant irradiation with red light, which was attributed to increased axillary bud activity.

6. *Light Effects on Success of Micropropagation*. Dunwell and Perry (6) reported that *Nicotiana tabacum* plants grown under 8-hour photoperiod and high light intensities had increased haploid plantlet production. Enhancement of protoplast yield by use of reduced light intensity has also been shown for tomato mesophyll (5). Dunwell and Perry further proposed that, "This may have wider implications in tissue culture . . . endogenous hormone levels could be changed by manipulation of the environment." The concept of influencing tissue culture success by stock plant light quality treatments had been reported by Read *et al* (21) whereby red light applied for 30 minutes at the end of a 10-hour day caused a near doubling of plantlets produced by petunia leaf discs. Tucker (23) had earlier demonstrated that a 5 min daily treatment of tomato plants with far-red light suppressed side shoot development. This was thought to be related to a cytokinin:auxin ratio. This could be related to the observation of Van Staden and Wareing (24) who demonstrated that red light illumination of *Rumex obtusifolius* seeds resulted in an increased amount of extractable cytokinins and that this response could be reversed by immediate application of far-red light. These observations encouraged a further consideration of red light as a factor to enhance microshoot production in tissue culture systems with deciduous azaleas.

MATERIALS AND METHODS

Recultures of Accessions 620014 and 800374 hardy deciduous azaleas (HDA) were used as the stock materials to receive the light treatments. These recultures or microstock cultures (MSC) were produced by harvesting microcuttings from previously cultured HDA shoot tips under conditions described by Read *et al.* (22) and by Economou (7). The resulting tissue was placed on new medium and subjected to various light treatments as follows.

Light intensity experiment: By use of shading material in combination with cool-white fluorescent bulbs, 10, 30 and 75 $\mu Em^{-2}\ s^{-1}$ light intensities were achieved. After culture under these levels for 6 weeks, microcuttings were harvested and direct-rooted in peat:perlite:vermiculite (2:1:1) medium in a humid chamber (R.H. = 90%). Data were taken after 3 weeks on root quality (scale of 1-3, with 3 = best), root length and percent rooting.

Light quality experiment: Monochromatic fluorescent tubes providing red (R) or far-red (FR) (GTE Products, Corp., Sylvania Lighting Center, Danvers, Massachusetts 01923) light were utilized. MSC were placed under red light for 2 weeks followed by far-red light for 2 weeks, or the reverse; microcuttings were rooted as in the light intensity experiment. Data taken included root number, root quality (scale of 1-3), and percent rooting.

RESULTS AND DISCUSSION

Lower light intensity (10 or 30 $\mu Em^{-2}s^{-1}$) proved to be superior to the higher irradiance level for microcutting production (Table 1). The increased root formation and growth is clearly shown in Figure 1. A possible reason for such im-

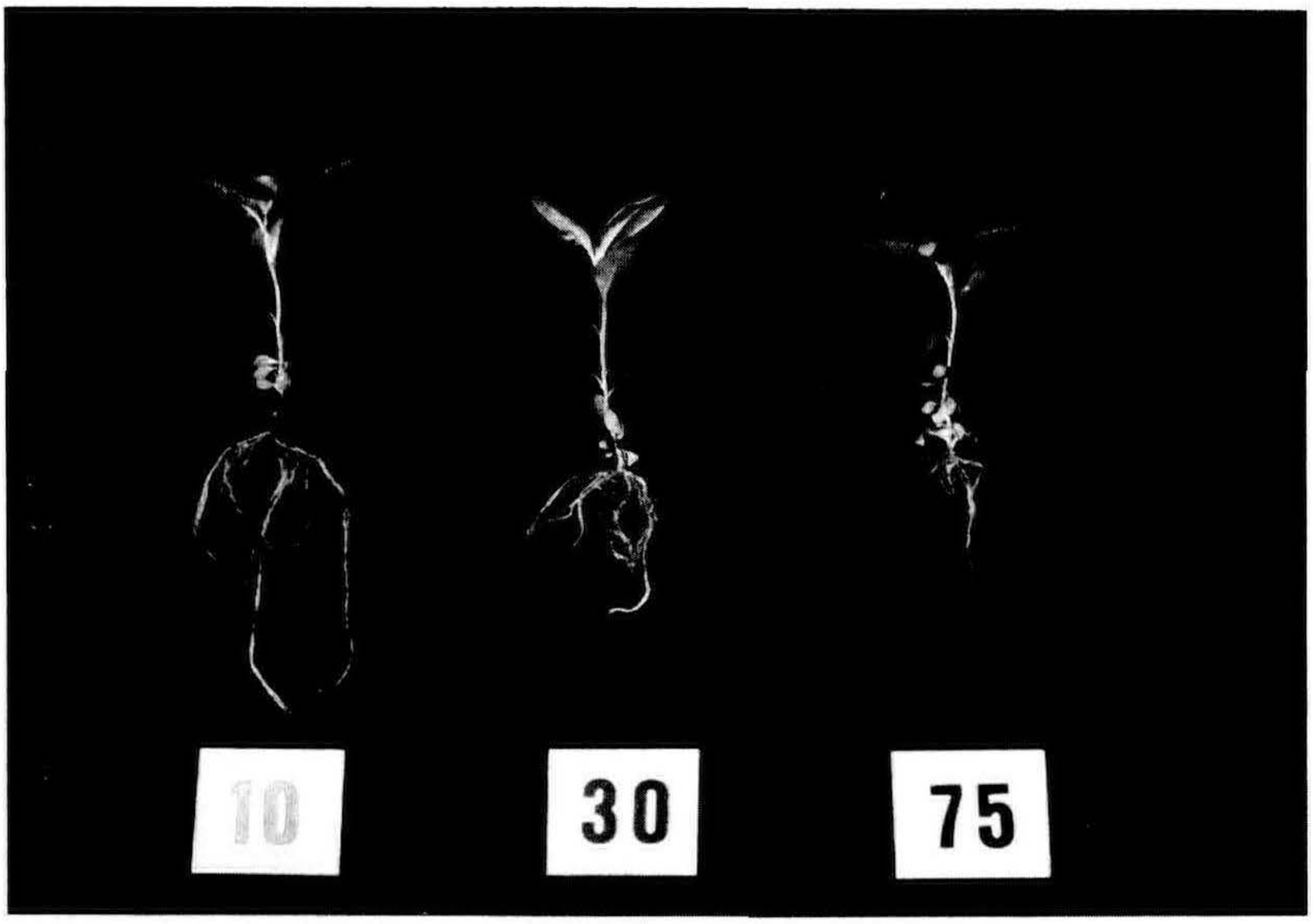

Figure 1. Rooting response of hardy deciduous azalea Accession 800374 microcuttings harvested from recultured *in vitro*-derived shoot cultures which were grown under different quantum flux densities (light levels).

Table 1. Rooting of azalea Accession 800374 microcuttings harvested from recultured *in vitro*-derived shoot cultures which were grown under different quantum flux densities.

Quantum flux density ($\mu Em^{-2}s^{-1}$)	Mean No. of rooted microcuttings[z]	Average percent rooting
10	35.6	88.3
30	32.6	81.7
75	26.3	65.8

[z] All microcuttings rooted under 85 $\mu Em^{-2}s^{-1}$ (400-700nm), 3 replications of 40 microcuttings per treatment, 6 wks in rooting medium.

Table 2. Effect of sequential culturing from different light qualities on microcutting production from recultured *in vitro*-derived shoots of azalea Accessions 620014 and 800374.

	Clone					
	Accession 620014			Accession 800374		
Light treatment[z]	No. of microcuttings	Length (cm)	Quality rating	No. of microcuttings	Length (cm)	Quality rating
red, far-red	61.8b[y]	3.7b	2.4a	49.6b	1.9	2.2a
far-red, red	46.8a	3.5ab	3.0b	30.8a	1.9	2.9b

[z] 24 hrs daily for 2 wks under each light source.

[y] Mean separaton within columns by HSD, 1% level; 10 cultures per treatment.

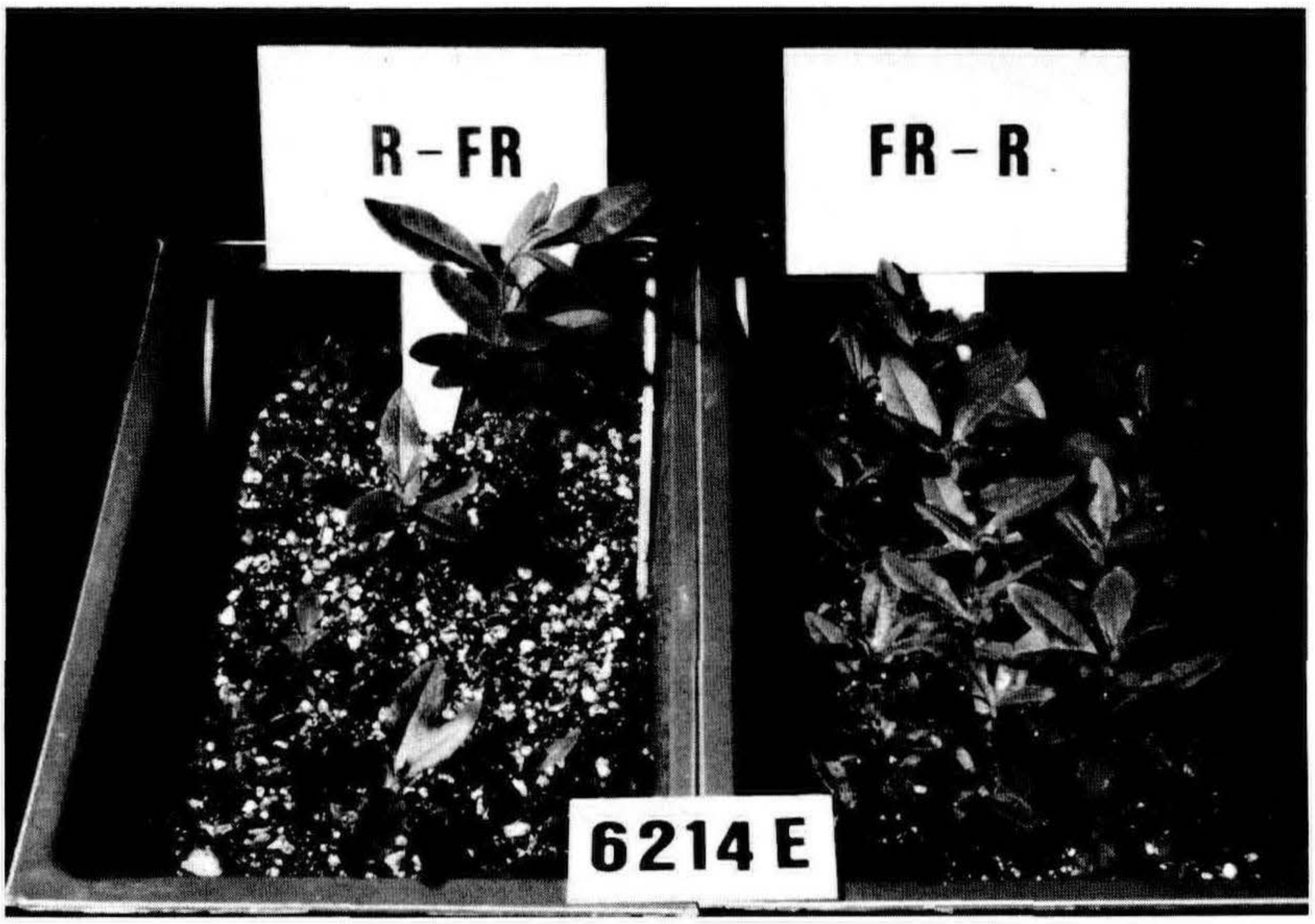

Figure 2. Response of microcuttings taken from cultures receiving different sequences of red (R) and far-red (FR) light.

proved rooting could be that more endogenous root-promoting substances (possibly IAA) accumulate in tissues of MSC which receive low levels of irradiance, since IAA is known to be reduced under high light levels (18). Stock plants grown under two weeks of R following two weeks of FR produced microcuttings with a higher percentage rooting than R followed by FR (Table 2 and Figure 2). Again, such responses are hypothesized to be related to changes in endogenous hormone levels since they are somewhat like those reported for light quality influences on petunia stock plants prior to tissue culture, but more research is necessary to better understand these changes. However, it is clear that light intensity and possibly light quality, can be manipulated by the practical micropropagator of woody plants. It is also recommended that propagators utilize day extension or night interruption to obtain additional softwood growth for use as cuttings or micropropagation explants. Further application of such long-day treatments to cuttings or microcuttings, once rooted, should lead to increased survivability of such propagules.

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