ENERGY COSTS AND BUDGETS

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Picture John and Jane in their living room. Theirs is a comfortable home in an upper middle class neighborhood, Suburbia, USA. This evening, just before the cold winter, they are again in serious discussion about their future. Fuel for heating the house in the winter, and electricity for cooling the house in the summer is becoming more limited and that which is available is more costly. They had been asked to conserve on the amount of water they used during the past summer to keep their yard healthy and inviting. The price of gasoline has increased and they are facing prospects that gasoline is not always available. Inflation is taking its toll.

John and Jane have been through a lot together. Now they have built a lifestyle that is comfortable, exciting and pleasing — they are not about to give it up easily. They have built some wealth, and they do not want their wealth in paper to be eroded by inflation. How can they maintain their lifestyle, maintain their financial position and live with inflation and fuel shortages.

Among the options open to them are the reduction of purchases of plants and other items they bought with the dollars allotted for discretionary purchases. Yet they know that they can reduce the amount of energy needed to cool or heat their house by the proper placement and use of plants (1).

Now that they are alone, they might move into a townhouse — a smaller, tighter house would be less costly to heat and cool. The yard is maintained by the homeowner's association so that their gardening will be limited to the patio using special planting systems designed especially for these situations.

John and Jane must also consider the new state law that simply states that every person occupying a building has a right to sunlight from 10 a.m. to 2 p.m., and that if they permit a tree or shrub to shade more than a small percentage of the solar collectors during these hours they will be guilty of maintaining a public nuisance and subject to fines for every day the nuisance persists. They know they can calculate the maximum height the plant can attain in their yard before it begins to shade the solar collector on their neighbor's house to the south (2).

John and Jane will not make major decisions tonight. However, their discussion begins to point out courses of action open to them. When they do make a decision, many industries could

be affected as they change their purchasing patterns and habits.

Now, let us turn to Joe and Jose. They have just reviewed the amount of fuel they used the past year for production of crops and they are trying to plot their course for the future. They are planning under the conditions that the amount of energy — fuel, gasoline, electricity, etc. will be limited, perhaps even to a maximum amount available, and that which they use will be definitely more costly. They have decided that the strategy they adopt must support the position that the available energy be stretched as much as possible and at the same time costs must be controlled as much as is feasible.

Joe and Jose know that, to cope with the energy situation in the future, they must anticipate how the general economy will go, how John and Jane will react in terms of purchasing plants, and how the energy situation will develop. Then, and only then, can they plan their course of action, using the anticipated or predicted events as mileposts for their planning.

Several courses of action, alone or in combination, seem to be feasible to our nursery managers. They realize that all decisions cannot be made simply on a cost-effectiveness basis alone because at times it may be necessary to use a more costly solution simply to stay in business. While going out of business is a course of action open to them, they definitely do not want to take it. They do know that they must take this course before they are forced into it, however, if they want to maximize the returns they take out of the business. Forced into bankruptcy by rising costs and income not keeping up is not for them.

Our nursery managers may decide on a combination of courses consisting of conservation, alternative production procedures that are less costly in terms of energy, and the use of alternative sources of energy. Future plans call for alternative products to meet the changing needs of the consumer. Also, branch operations in areas of the country or world where energy requirements are not as severe is a definite possibility.

In the short run, conservation is the only way to cope with the situation. They must depend on the same sources of energy — gas, oil, etc. Alternative sources — solar, wind, etc. — are for long run considerations. They will use all the procedures of insulation, reducing infiltration of cold air into greenhouses by plugging all leaks, and efficient use of fertilizers and other materials that require large amounts of energy to produce.

The long run solution requires the examination of business location from the viewpoint of energy needs for production and for marketing, as well as the additional land, labor and capital needs. It does not make sense to locate in an area where energy for production is less if the savings are more than used for in-

creased energy needed to market the plants. The only justification, and a poor one at that, is that the type of energy needed for production is not available at any cost, and the type of energy needed for marketing is available.

Energy requirements to manufacture plastics.

Nylon	3700 to 3900 BTU per cubic inch
PVC	1800 BTU per cubic inch
Polyethylene (low density)	1100 BTU per cubic inch
Polyethylene (high density)	1400 BTU per cubic inch

Some ways to "insulate" greenhouses.

1. Double layer of plastic sheeting, inflate.
2. Plastic over glass or fiberglass, inflate.
3. Attach plastic insulation material to glass.
4. Thermal blankets over crops.
5. On north walls, attach styrofoam on glass.

Some ways to seal openings, reduce infiltration of cold air into greenhouses.

1. Double doors with weatherstripping.
2. Air "bags" over vents, fan openings, etc.
3. Lapseal between panes of glass or sheets of fiberglass.
4. Louvers that shut tightly.
5. Heater vents have means of controlling drafts.

Energy requirements to manufacture fertilizers.

1 ton of nitrogen requires 511,280,000 BTU of natural gas.
1 ton of phosphorus requires 4,390,000 BTU of natural gas.

LITERATURE CITED

(1) Several articles and books cover this subject. A general insight can be gained from these publications.
   a. Furuta, T. 1978. Properly Placed Plants Can Reduce Energy Use. Cox Publishing Co., Arcadia, CA 91006.
   b. Nelson, W.R. 1979. Landscaping Beautifies Buildings and Conserves Energy. American Nurseryman, Sept. 1, 1979.
   c. Robinette, G.O. 1972. Plants/People/and Environmental Quality. U.S. Dept. of Interior.

(2) Thayer, R.L. Jr. 1979. Landscape Planting for Energy Conservation. Presented at SMUD Seminar "Energy Efficient Neighborhood Design," Sacramento, California, February 24, 1979.

ETIOLATION AND ROOT FORMATION

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Abstract: A review of literature pertaining to the promotory influence of etiolation on root formation in shoot cuttings is presented. Characteristic features of this phenomenon are discussed in relation to both the action of light on growth and development and to the possible role of growth substances. The interaction of ringbarking (girdling) treatment with localized etiolation of the stem, in relation to root production, was investigated and a summary of the experimental results is given.

REVIEW OF LITERATURE

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REVIEW OF LITERATURE

The inhibitory effect of light on rooting of shoot cuttings has

often been demonstrated, mainly as corollary of the fact that exclusion of light from the developing shoot promotes root formation. This situation has been shown to obtain in several unrelated species, among which are *Clematis*, (15) *Phaseolus* and *Hibiscus* (9). Gardner (7) found that to be effective, etiolation of the growing shoot should be carried out at an early stage in its differentiation and that it was preferable to exclude light completely during the initial phase of growth. Working with avocado, Frolich (5) confirmed that shoot tissue was most susceptible to the inhibitory effect of light when first formed and further showed that the degree of inhibition was proportional to the duration of exposure. Conversely, increased duration of etiolation progressively increased root formation in cuttings of *Salix* (11). It is the usual practice to exclude light only from a short proximal segment of stem, in which case root formation is confined to that etiolated section (5) — i.e., the effect is strictly localized on the stem. In this, as in those other characteristics already mentioned, the effect is consistent in its operation over the species hitherto studied, as also are changes in stem anatomy and development resulting from growth in darkness. In the etiolated stem, differentiation of secondary tissue does not proceed to completion (14). This is a consequence of the tendency of etiolation to delay maturation of the tissue (16); conversely the action of light — qualitatively the same with regard to the two aspects of growth, cell multiplication and cell enlargement — is to accelerate initiation and completion of successive phases, so that both cell division and elongation start earlier and end earlier in light. However, striking as the differences in stem structure are, and although they also are completely localized in the etiolated segment (18), investigation has not borne out the thesis that the effect on regeneration is due to reduction in amount of the mechanical tissue which would otherwise restrict root emergence (5,9).

If anatomical differences do not account for the promotion of rooting, its origin presumably lies in the alteration to the physiology of the developing shoot. In view of the well known efficacy of auxins in stimulating root formation, increase in the effective level of endogenous auxin presents itself as a possible mechanism underlying the etiolation effect. Against this thesis must be set the fact that etiolation does not so much increase root formation in a quantitative manner, as induce in the shoot a predisposition to root formation which does not otherwise exist. In his review of the factors controlling root regeneration, Haissig (8) adduces experimental results to show that IAA only initiates root primordia in predisposed cells, so that in difficult-to-root subjects, where this disposition does not obtain, IAA is ineffective; moreover the balance of evidence cited finds

against the proposal that light controls the level of auxin via the auxin oxidase system (6), both generally and in the case of root regeneration. With reference specifically to localized etiolation, Herman and Hess (9), concluded that the difference in endogenous auxin content between etiolated and unetiolated tissue did not wholly account for differences in regenerative capacity. Again, Krul (13), did not ascribe the promotion of rooting, brought about by treating bean hypocotyls with 2,4 dinitrophenol (2,4 DNP) in darkness, to the prevention of auxin oxidation. It appears that light, in reversing this promotion, acts on 2,4-DNP, degrading it to an inactive compound, rather than on hypocotyl tissue, so that this effect is not primarily one of etiolation.

Finally, considering the possible role of gibberellin, it has been shown (12), that the elongation of internodes of dark-grown plants may be the result of increased sensitivity to, rather than high levels of, endogenous gibberellin. As to root formation, exogenously applied gibberellin was inhibitory (1,2,10). However, when a range of gibberellins tested in vitro for root-inducing properties (16), they were qualitatively consistent in their action on tissue of artichoke; rhizogenesis was stimulated in darkness but inhibited in light.

SUMMARY OF EXPERIMENTAL RESULTS

A series of experiments, using as propagation material the difficult-to-root apple scion cultivar, 'Bramley's Seedling,' was begun with the object of investigating the mechanism of etiolation and root formation (3,4). Characteristics of the experimental method were: 1) treatments were applied to the stock plant only. After severance, the cuttings were rooted in conditions that were uniform insofar as possible. 2) The two treatments were: a) exclusion of light from the rooting area of the stem (etiolation), and b) interruption to the continuity of tissues external to the functional xylem (ringbarking).

Shoots were etiolated initially by starting growth of the stock plant under black polythene. When this cover was removed, etiolation of the proximal segment of the stem was maintained by wrapping it with black plastic film while the distal part of the stem continued to grow in full sunlight. Where etiolation was not continuous, root formation did not take place. Ringbarking at the stem base enhanced the effect of etiolation but did nothing to increase root formation in light-grown cuttings. The necessity for continuity of the localized etiolation was shown by the fact that to delay wrapping the stem base until five weeks after the beginning of bud extension extinguished the predisposition to root formation and a subsequent exclusion of light from the rooting segment of stem only par-

tially reversed the inhibition due to this initial exposure.

Indolebutyric acid applied at 2500 ppm increased rooting only in etiolated cuttings and the increment was small compared with that due to etiolation or ringbarking. Transposing the etiolated segment distally on the shoot did not alter the amount of root formation but simply changed the site of root emergence. However, positioning the ringbark distal to an etiolated segment reduced or completely eliminated rooting in that segment. Again, the amount of root formation was related to the length of the etiolated section of stem, increasing from nil at 9 cms etiolated to an optimum level around 7.5 cms. However, the effective length of an etiolated segment could be decreased by ringbarking it at its centre, in which case the number of roots was not reduced but they were formed predominantly distal to the excision.

The stimulus for root initiation appeared to take effect in less than five days after ringbarking but a period of 12 days elapsed before roots were visible at the surface of the stem.

In keeping with other light-dependent phenomena, it is probable that this inhibitory influence of light on root formation is exerted by specific wavebands within the range 320-800 nm. An experiment in which the usual stem wrap of black polythene was replaced by colored polythenes, which filtered sunlight differentially, did not unequivocally identify the inhibitory waveband but rather pointed to a close relationship between root production and total light energy incident on the stem. Further experimentation using artificial sources of broadband radiation failed to bring about differences in root production probably because the level of irradiation was not high enough. Inhibition of root formation in etiolated stems appears to require high levels (of the order of sunlight) and comparatively long durations, of irradiation (> one day). Work now in progress provisionally indicates that, at equal energy levels, wavebands toward the lower end of the visible range are more inhibitory than red or far-red light.

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MOBILE AERATED-STEAM SOIL PASTEURIZER UNIT

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The need for removal of pathogenic organisms in soil mixes to be used for seed germination and other propagation and growing purposes is well known and accepted (1,3,5,6,7). The

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two general methods for doing this are: (1) by chemical treatment and (2) by heat treatment. Heat, particularly steam heat, is acknowledged to be superior to chemicals for several reasons (5). In heat pasteurization, holding the soil mix at the proper temperature for the proper length of time is crucial in obtaining the desired results. It is also important that the soil mix be moist for several days prior to the time of heat treatment to obtain satisfactory killing of pathogens and weed seeds. The ideal temperature combination is generally accepted as 140°F (60°C) for 30 minutes (5,8). Temperatures lower than this will not kill the pathogens and weed seeds. Temperatures much higher will kill non-pathogenic beneficial saprophytic microorganisms, thus creating a biological vacuum. If accidental reinoculation with pathogenic microorganisms takes place an explosive increase in their numbers is likely to occur due to the lack of any competing microflora.

In addition, steaming soils at high temperatures, e.g. 212°F can cause the release of water soluble manganese from soil colloids which is toxic to plants Ammonium toxicity can also develop in soils heated to 212°F.

Other advantages in the use of steam-air mixtures for pasteurizing soil mixes, as compared to steam alone are:

(1) reduced fuel costs resulting from the lower temperatures required,
(2) quicker cooling of the soil mix which can be accomplished by continuing the air flow after the steam is turned off.
(3) less possibility of injury to the operators from steam burning.
(4) ability to heat-treat plastic pots which will withstand 140°F, whereas they would be deformed at 212°F.

Another valuable use for equipment designed to produce 140°F moist heat is in seed treatments for disease control (2,4,9).

The unit we constructed is shown in Figure 1. It is portable, being mounted on a small trailer. Basically, the unit is a stainless steel box 2½ feet wide, 5 feet long, and 3 feet deep with a capacity of ½ ton of mix. Eight inches from the bottom a perforated steel plate (with 5/32″ holes on ¼″ centers) is supported in place giving a surface, as shown in Figure 2, to hold the soil mix. The cover of the box is 1½″ marine plywood board, hinged in place, which will lift to allow excess steam and air to escape. The unit is loaded from the top by removing the covering board.

At the rear of the unit is a metal door and a metal chute for unloading, as shown in Figure 3.

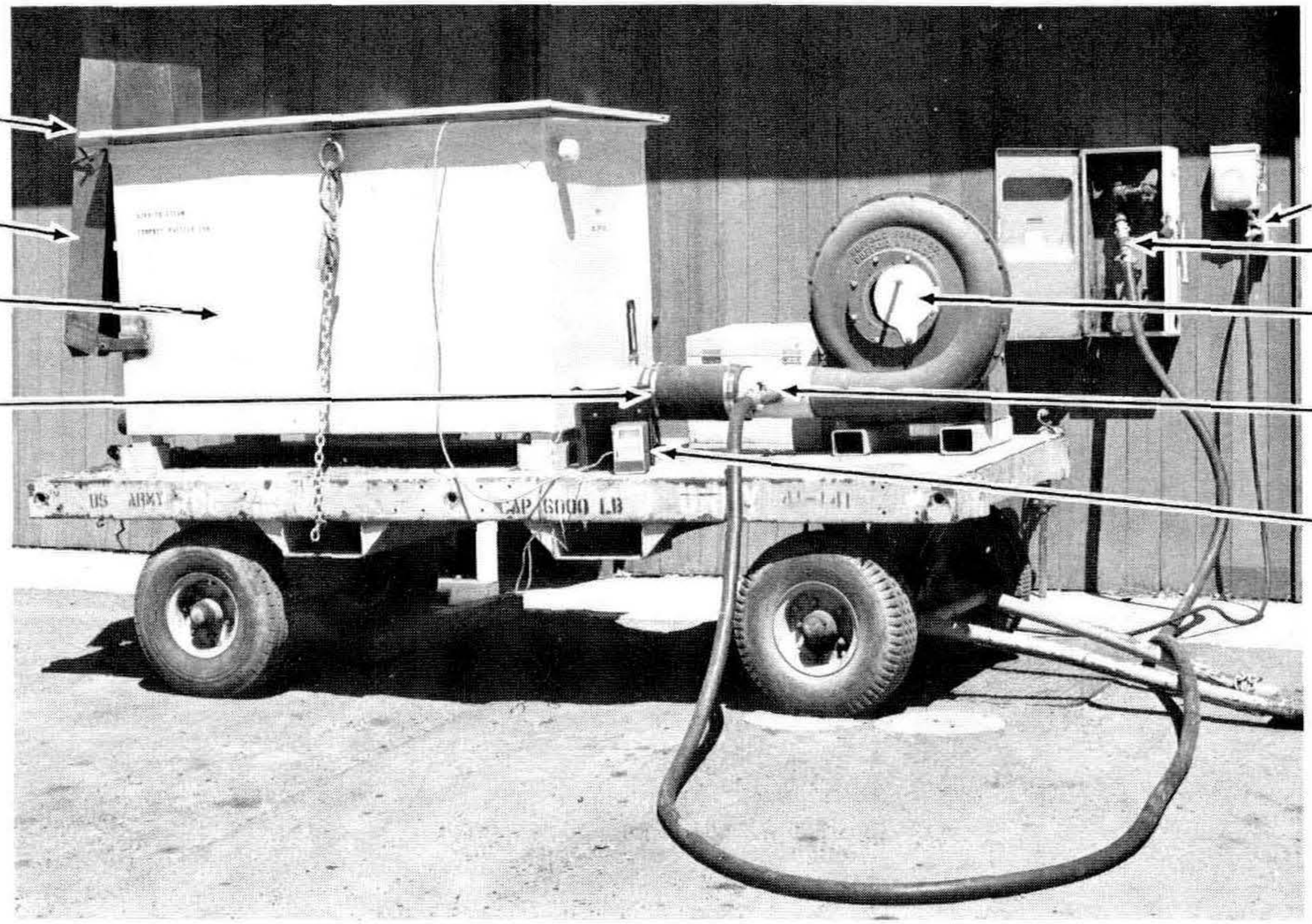

Figure 1. Mobile aerated-steam soil pasteurizer unit.

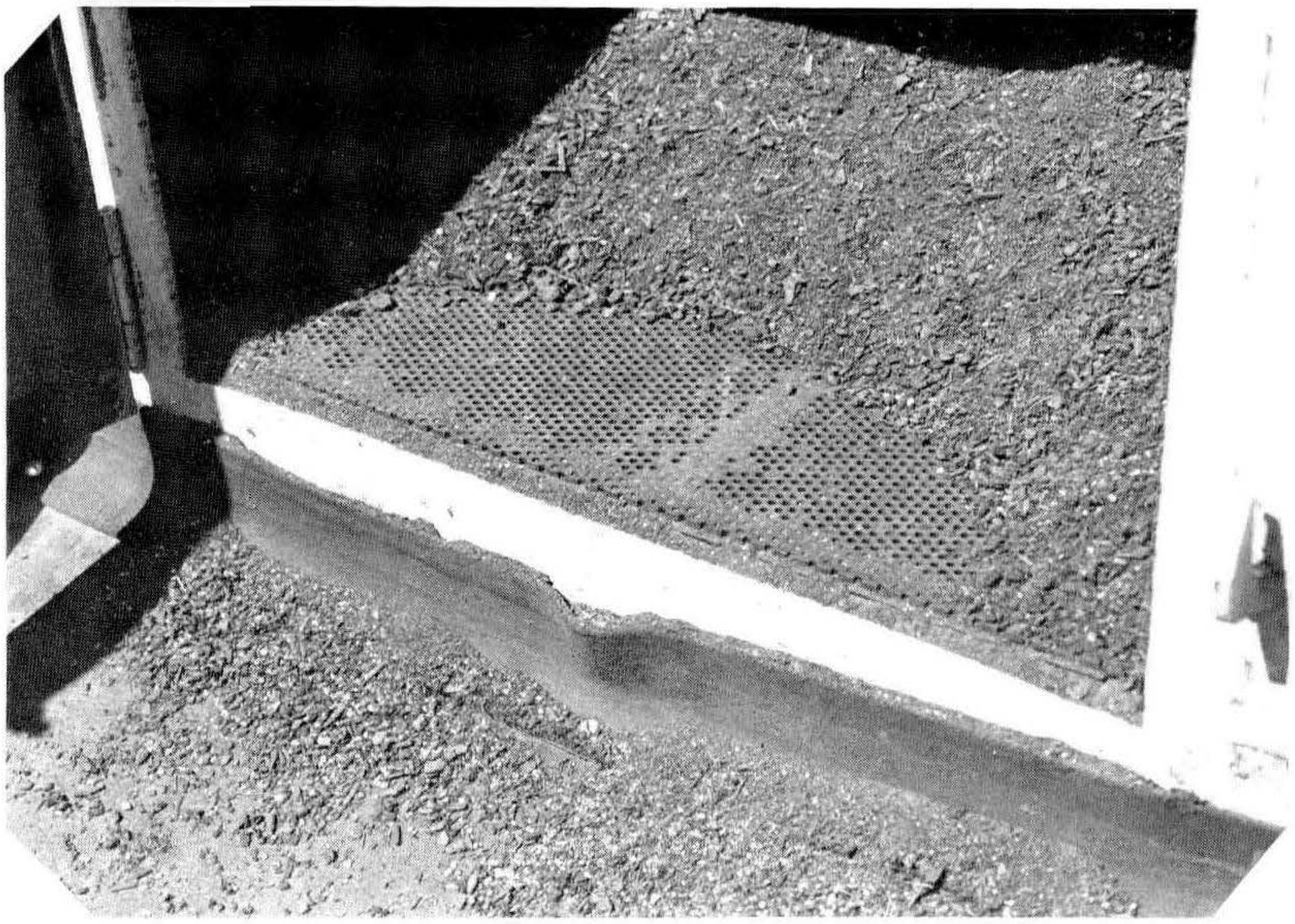

Figure 2. Interior of pasteurization chamber showing perforated plate over top of plenum chamber where steam-air mixture is introduced.

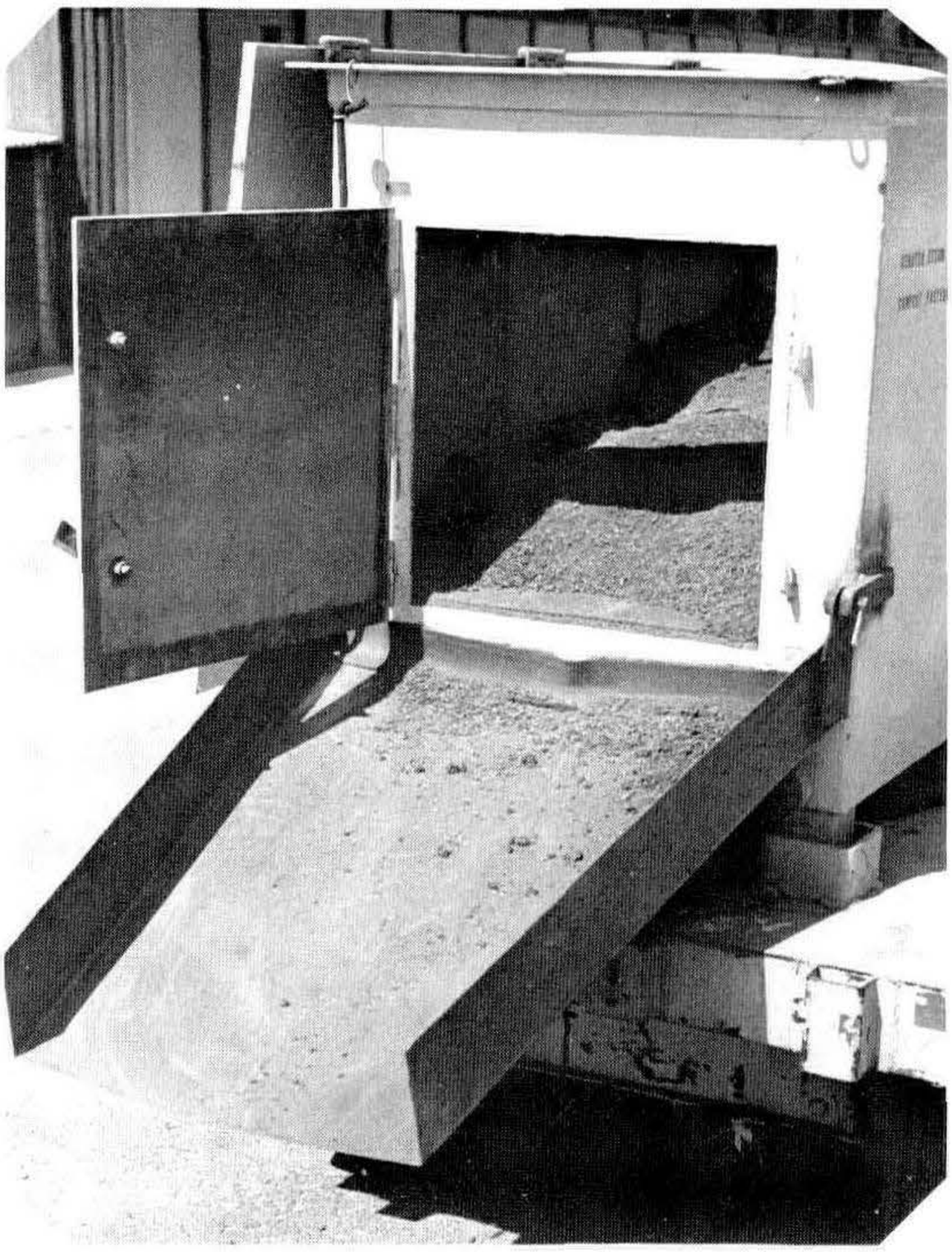

Figure 3. Rear of pasteurization chamber showing discharge door and chute for removing soil mix following heat treatment.

Air is introduced into the plenum chamber below the soil by a centrifugal blower operated by a direct drive 3 horsepower electric motor. The blower can deliver a maximum of 2,000 cubic feet of air per minute. It has an 18″ diameter wheel, 4″ wide with straight blades. An adjustment in the air intake controls the volume of air. In operation, the blower forces the steam-air mixture through the soil mix at 56 cubic feet per minute.

When in operation an air filter should be used to cover the air inlet to avoid introducing dust particles (which may contain harmful microorganisms) during the post-pasteurization cooling down period.

Steam is injected into the air stream as shown in Figure 4 and is controlled by a hand operated valve.

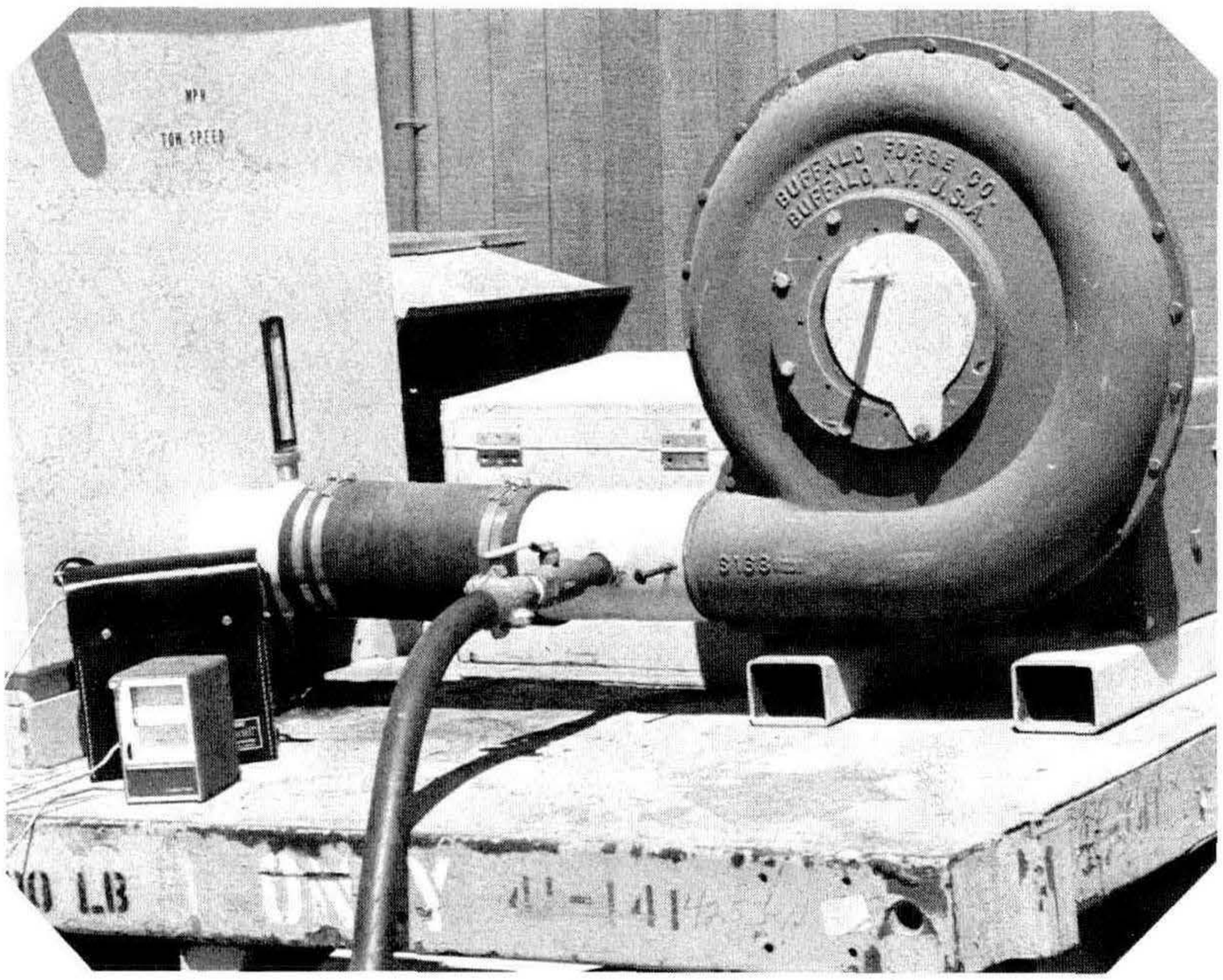

Figure 4. Close-up showing steam injection line into blower air stream together with steam controller valve. Also shown is the battery-powered portable recording thermograph.

The temperature curve obtained after the unit is started is followed by observing the chart (Figure 5) of the recording thermograph[1] (Figure 4) which has a bulb inserted into the soil mix. The unit is operated for 30 minutes after the thermograph

[1] Rustrack miniature strip chart temperature recorder, No. 2155A (0°F to 250°F) with thermocouple probe type J-1551. From Western Electro-Mechanical Co. 300 Broadway, Oakland, California 94607.

reaches 140″F, at which time the steam is turned off, but the blower is continued until the soil mass has cooled to ambient temperatures.

A special steam outlet point from a greenhouse steam supply, together with an electric outlet point, were installed for use in operating the unit (Figure 1).

This soil pasteurizing unit has been in operation for about six months with completely satisfactory results.

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NEW FUNGICIDE EVALUATED FOR CONTROL OF ROOT ROT FUNGI

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Abstract: A new fungicide, Subdue (CGA 48988)[1], has shown a high level of activity in controlling Phycomycetous root rooting fungi that attack ornamental plants. *Juniperus sabina* 'Tamariscifolia,' *Pinus radiata* and *Brassaia*

[1] Manufactured by CIBA-GEIGY Company.

reaches 140″F, at which time the steam is turned off, but the blower is continued until the soil mass has cooled to ambient temperatures.

A special steam outlet point from a greenhouse steam supply, together with an electric outlet point, were installed for use in operating the unit (Figure 1).

This soil pasteurizing unit has been in operation for about six months with completely satisfactory results.

Acknowledgements. Appreciation is expressed for the advice of R.W. Brazelton, Dept. of Agricultural Engineering, University of California, Davis, during the planning stages of this project.

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NEW FUNGICIDE EVALUATED FOR CONTROL OF ROOT ROT FUNGI

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Abstract: A new fungicide, Subdue (CGA 48988)[1], has shown a high level of activity in controlling Phycomycetous root rooting fungi that attack ornamental plants. *Juniperus sabina* 'Tamariscifolia,' *Pinus radiata* and *Brassaia*

[1] Manufactured by CIBA-GEIGY Company.

actinophylla plants growing in an inoculated soil mix and treated with Subdue had more top growth than plants growing in the untreated inoculated soil mix.

Root rotting fungi are a frequent cause of loss in the production of container-grown plants and fungicides are frequently used as an aid in their control.

Studies were conducted to determine the effectiveness of the fungicide Subdue (*N*-(2,6-dimethylphenyl)-*N*-(methoxyacetyl)-alanine methyl ester) working with *Juniperus sabina* 'Tamariscifolia,' *Pinus radiata*, and *Brassaia actinophylla*.

MATERIALS AND METHODS

Plants of each species were established in 2.25-inch square pots using a steam sterilized soil mix. The plants were then transplanted into 4-inch square pots using a steam sterilized soil mix and a water mold fungus was introduced into the soil mix except for one replication of plants for each species for growth comparison. This one replication of plants of each species were grown in the steam sterilized soil mix with no fungicide treatments being used or the fungus added.

The soil mix consisted of equal parts on a volume basis of sandy loam soil, peat, and perlite. The fungus cultures were grown on millet seed and thoroughly incorporated into the soil mix at a rate of 50 ml of a millet seed culture to 10 liters of soil mix except for *Brassaia*. With *Brassaia* 5 ml of a soil mix colonized with the fungus was introduced into each 4-inch pot 7 days before the treatments were made.

For the juniper and *Brassaia* a *Pythium* species was used which had been isolated from diseased plants of the same species. A *Phytophthora* sp. was used with the Monterey pine which had been isolated from diseased Monterey pine trees. Liners were selected for uniformity before being transplanted into 4-inch pots and treated with the fungicides. Several rates of Subdue were used (see Table 1) to establish the range of effectiveness; Truban was used at a label rate.

Table 1. Mean Fresh Weights of Plant Tops in Grams.

Treatments	Rate per 100 gal.	Juniper	Pine	Brassaia
1. Subdue 5W	2.5 oz	—	—	19.6
2. Subdue 5W	5.0 oz	5.6	9.6	18.2
3. Subdue 5W	10.0 oz	5.9	13.1	19.2
4. Subdue 5W	20.0 oz	6.2	11.4	—
5. Truban 30W[1]	10.0 oz	3.5	8.4	15.8
6. Inoculated soil mix	—	2.4	4.1	9.1
7. Steam sterilized soil mix	—	5.7	16.4	18.4

[1] 5-ethoxy-3-trichloromethyl 1-1,2,4,-thiadiazole

The chemicals were mixed in water and 80 ml of the solution was added to each 4-inch pot which is equal to 2 pints per square foot and was adequate to wet the soil volume. The pines and *Brassaia* were grown in the greenhouse and the junipers were grown outdoors in a shade house. The *Brassaia* plants were grown for 9 weeks in the 4-inch pots, the pine for 12 weeks and the juniper for 16 weeks and then the tops of the plants were cut at the soil level and weighed. The average fresh weights of plant tops are given in Table 1. With *Brassaia*, 4 single pots were used per treatment; 8 single pots were used per treatment with the juniper, and with the pine 10 single pots were used per treatment.

RESULTS

Plants treated with Subdue had more top growth than the untreated plants growing in an inoculated soil mix (see Table 1). Truban-treated plants also had improved top growth over the plants growing in the untreated inoculated mix though the growth was usually less than the Subdue-treated plants. The growth of the juniper and *Brassaia* Subdue-treated plants was comparable to the plants grown in the steam sterilized soil mix.

DISCUSSION

Findings of these studies indicate that Subdue is an effective fungicide for controlling some *Pythium* and *Phytophthora* species that can cause root rot diseases of *B. actinophylla, J. sabina* 'Tamariscifolia' and *P. radiata*.

BRUCE BRIGGS: We will now have a short question period.

CHARLES PARKERSON: John, how wide is the ring bark you used on your etiolated shoots?

JOHN DELARGY: It is 4 mm roughly.

CHARLES PARKERSON: Is that width significant?

JOHN DELARGY: I haven't done any experimentation on the width. As long as the girdling is complete — that is the essential thing.

CHARLES PARKERSON: I didn't quite follow your etiolation procedures.

JOHN DELARGY: The shoots on the plant are grown in darkness for etiolation until they are 10 cm long, then the black tent is removed. Etiolation is maintained by wrapping the lower segment with black polythene tape. But in the upper segment of stem, which is exposed to light, the effects of etiolation are reversed; it greens up. Where it is protected by the black tape it does not green up.

CARL PERLEBERG: Is there a chance that you could do the same thing by painting the stem with black asphalt paint?

JOHN DELARGY: I think so, as long as there is no toxic effects from the paint. Of course, the essential feature is the exclusion of light. Anything that would exclude light would achieve the same effect.

VOICE: What is the man's name with the paper from the thirties who experimented with etiolation?

JOHN DELARGY: Dr. F.E. Gardner (Proc. Amer. Soc. Hort. Sci. 34:323-329. 1937).

WESLEY HACKETT: Have you thought about how the basal ringing is promoting the rooting? It doesn't seem to fit in with the idea of a promoter moving from the apex with the leaves.

JOHN DELARGY: I imagine it dams up the promoter. So instead of flowing on into the branch in which the shoot is borne, the rooting promoter(s) accumulates in the etiolated segment. Sugars and amino acids, I believe, are known to accumulate above girdling cuts.

WESLEY HACKETT: The ring is made a long time before taking the cuttings — is that right?

JOHN DELARGY: The ring is made about 15 days before taking the cuttings.

VOICE: Ring barking without etiolation, what is the effect?

JOHN DELARGY: It is completely without effect. No rooting occurs on the apple shoots without etiolation.

CARL PERLEBERG: How old are the oldest plants that you have growing and how well are they growing?

JOHN DELARGY: I have never followed through to see how the plants grow.

CARL PERLEBERG: So you have gone all this way and you do not know if they will grow in the field?

JOHN DELARGY: Well, this etiolation effect seemed to be so striking that it was more important to me to determine the mechanism of the effect rather than try to use it commercially. It is so cumbersome and laborious, as it stands now, that the commercial possibilities are nil. It is not practical to use it. It seems more important to try and understand what is going on so that some use may be made of it later based on a complete understanding of the mechanisms involved rather than try to employ the method as it now stands.

VOICE: Did you find any large differences among the apple cultivars you have tried?

JOHN DELARGY: No, but Gardner did. He found no cul-

tivar which did not respond. Some responded better than others.

VOICE: Was there any correlation with the standard size vs. dwarf apple trees?

JOHN DELARGY: I can't recall that this comparison was made.

PHILIP McMILLAN-BROWSE: Was the length of the cutting that you took determined by individual length or did you take the cutting flush with the stem and thereby incorporate the complete girdled area?

JOHN DELARGY: We usually took the cutting in the center of the ring bark so it would be on the new wood. Of course, other control cuttings would have to be taken at comparable positions.

PHILIP McMILLAN-BROWSE: So you didn't take the cuttings completely back to the old wood?

JOHN DELARGY: No, I did not.

PHILIP McMILLAN-BROWSE: I ask the question because it is very evident that with the apple you get an increase in rooting potential if you incorporate the base of the shoot in the cutting.

JOHN DELARGY: I have known about this but it didn't seem to be important particularly with these cultivars.

VOICE: What is the intensity of light on them?

JOHN DELARGY: The intensity of light, the total quantity of light — the photon flux — the higher it is, the less the rooting which eventually took place. Obviously, when you use black polyethylene you exclude all light and rooting is at a maximum. Conversely, when you use material which lets more light through, rooting is at a minimum.

TOM WOOD: Recent work along this line at East Malling Research Station, England, was explained at a nurserymen members day only last week. They were doing the same thing with black polythene tents on apple stock plants. They treated the plants for 3 weeks without light and then took the shoot growth, irrespective of whether they continued the etiolation at the base of the stem, or not. They used foil to cover the base of the shoots. They found that they could get the same amount of rooting whether they used foil or not; similarly, they could go back six weeks later and use any regrowth that had taken place after the first batch of cuttings had been taken; these would root also. So I think that the development along these lines is that whatever happens when the initial period of darkness takes place carries throughout the season.

BRUCE BRIGGS: There are some people at East Malling that have done a lot of work in this area. There are indications — I hope it has been published — that possibly part of this phenomenon has to do with the condition of the tissue, as sunlight seems to destroy something that is essential in root initiation. At East Malling they found they could substitute some chemicals for those that seemed to be destroyed by sunlight. So this is another approach to part of the etiolation effects.

Let's take rhododendron plants grown both in the north and in the south. You can go into a lathhouse with low light and take cuttings and usually they will root much better than those taken out in the hot sun. Their explanation over at East Malling was that sunlight destroyed some rooting factor in the cuttings. In shade, the rooting chemical lasted longer and you could take the cutting over a longer period of time.

VOICE: For the aerated steam unit do you have an automatic shutoff when the temperature reaches 140°F?

HUDSON HARTMANN: No, we shut the steam off manually when we see that the temperature has reached that point. We could make it more automated than we have done here.

VOICE: Have you investigated how uniform the temperature is throughout the soil mix?

HUDSON HARTMANN: Yes, it is important to see that the temperature is the same throughout the mix — that you don't have hot spots. One of the problems is that there could be a blowout, where the force of the steam-air going up through the mix could open up a hole and the steam-air would go out through the hole. Some of the units have the plenum at the top with the steam-air introduced at the top moving down. Then if you have a blowout the loose soil tends to fill up the hole.

VOICE: Is the soil being agitated inside the chamber?

HUDSON HARTMANN: No, it is not agitated. The mix is fairly loose, but it is not agitated during the pasteurizing treatment.

VOICE: Do you have any trouble with the holes in the plenum chamber being clogged up, or excess soil getting down into the plenum?

HUDSON HARTMANN: We haven't so far. The size of the holes and their distance apart is quite critical. There are certain limits to it or there could be trouble.

BRUCE BRIGGS: Over in Australia, on our recent IPPS tour, we were looking at all the forms of aerated steam used for soil pasteurization. A man with us on the tour said "We have known that principle for forty years and we have used it in the

lumber business." They found that when they were drying lumber in the kilns that if they mixed air with their steam heat the lumber dried about four times as fast as with heat alone. You better look around and see what your neighbor is doing and use some of his procedures at times.

MIKE SMITH: I have a question for Wes Humphrey about this compound, SUBDUE. Have you done experiments under field conditions with one-time application once the plants are established? For most crops, unless you are talking about a very expensive crop as rhododendrons or higher priced azaleas, two to three month reapplications scheduled throughout the term of the crop would be prohibitive for most crops. Generally, we are interested more in either preventive applications or routine applications on those we know to be trouble plants. We need one-time applications as soon as the plants have been established a month or two in the can; we try to get away with one corrective application when we see the first signs of symptoms of water molds.

WES HUMPHREY: Good question, Mike. As far as the work that we have done under grower's conditions, no. Typically there we have been using either a 60 day or 90 day retreatment. Work that we did, however, say under greenhouse conditions or *under our conditions there at the South Coast Field Station* with the junipers, that was just a single treatment. The same thing was true with Monterey pines that we worked with at the South Coast Field Station. There we carried those through for a reasonable period of time depending on the species and then we harvested that particular crop. So, there was only a single treatment and we got a favorable response. What we are doing now, and the work that we did last year under field conditions, no — it was repeat treatments. Your point is well taken and one that would be a good thing for us to evaluate under field conditions.

Bruce, let me mention a couple of other things that were brought up during the break that some of the rest of you might be interested as well in relation to this particular material. Somebody asked, "is it going to be released under an experimental permit use basis". The answer is — no. The material is far enough along, close enough to registration, that the company hopes to have a full label product available for any and all use by ornamental producers soon after January, 1980. So they don't, as with many other materials, expect to produce a fair amount of it for purposes of experimental use. The other thing was about its effect on *Rhizoctonia*. I may not have made that clear in the presentation that I made. It is not effective on *Rhizoctonia*. It is only effective on the Phycomycetes, a particu-

lar group of fungi which include *Pythium* and *Phytophthora* and some other fungi of that type. If *Rhizoctonia* is a concern, and you are not controlling it by good clean culture, then another fungicide would need to be brought in for control of that disease.

JUDY GARLOCK: You mentioned sensitivity; some crops are sensitive. How do we recognize symptoms of sensitivity to SUBDUE?

WES HUMPHREY: One thing to watch when the product does become available is what is stated on the label. One of the plants that shows sensitivity at normal label rates is variegated euonymus, where the variagation is on the margin of the leaf. There the chemical causes an additional bleaching of that tissue that doesn't have any chlorophyll in it. On *Monstera deliciosa*, with some work that we have done, using repeat applications at label rates, we experienced some additional chlorosis — marginal chlorosis on the leaves.

BRUCE BRIGGS: In both Europe and Australia this chemical is being used. We found in Australia they were not too excited about it in controlling *Phytophthora cinnamomi*. Wes, have you checked it on this? What form of *Phytophthora* were you working on? They were disappointed, it wasn't giving that good a control; but it was really excellent on mildew.

WES HUMPHREY: It would be good for downy mildew, but it isn't worth using for powdery mildew. This material is effective on *Phytophthora cinnamomi*. There is enough good evidence to show this. But even though it has an eradicant property it does not mean that if the plant has a root system that is highly contaminated or highly infected with the fungus that you are going to work miracles. It is no miracle material; none of them are. What I am saying is this — it is far better used on a preventive basis. But it also has the ability to do some eradication. If you have an avocado tree growing out in the field that has dropped all of its leaves, and it looks like a dog, no — better jerk that tree out of there and plant a young, fresh tree and use the material as a preventative to gain control of *Phytophthora*.

It is interesting that Bruce picks up this information from discussions in Australia, then one of our plant pathologists returns from Australia with the information that this material in the field looks pretty good on controlling *Phytophthora* on avocados, so it is reported to be effective there.

BRUCE BRIGGS: When we brought the subject up, there were about 100 nurserymen from Queensland in the room, including Ed Bunker; we got our information from people who had been working for a couple of years with SUBDUE. I think

you want to consider that there is a difference on how you use it, where you are located, the weather conditions, and everything else — so look at the whole package.

JAY ALLISON: This is for Hudson Hartmann. How does your steam aerator differ from commercial equipment, like the Lindig steam aerator?

HUDSON HARTMANN: In principle, it would be about the same. It is one that we decided that we would build ourselves rather than buying a commercial one, but they all do the same thing. They have an air stream going in with steam injected into it. I don't think there is any really great difference in principle.

RALPH SHUGERT: Wes, do you have any idea about costs of SUBDUE? Secondly, have you experienced any control of *Phomopsis* — thinking of its use on *Juniperus sabina* 'Tamariscifolia' primarily.

WES HUMPHREY: Let me answer the last part first. *Phomopsis* — no! don't expect it to do a thing for you there. Not active with this group of fungi.

Pricewise, from what I understand in talking to CIBA-GEIGY'S technical people is that SUBDUE isn't going to be any cheaper than other products now available but it will be competitive with what is now on the market. You will be, in effect, paying a higher price for the actual chemical you are paying for now in the formulated Lasan or Truban. But the activity level of SUBDUE is 30 to 40 fold over the other materials so it doesn't make a lot of difference, but you could be buying a lot of diluant to use with it.

RALPH SHUGERT: Will there be more systemic action with this chemical?

WES HUMPHREY: No, I would not expect so. Let me take just a minute to explain what is probably a question in your mind. The material is formulated as an EC, but with a trade name they will call RIDOMIL. That will be the formulation they will register for agricultural use. What I am saying is that the RIDOMIL label will be for agricultural use, the SUBDUE label will be for ornamental use.

VOICE: I want to know what determines the 140°F temperature required to get rid of the pathogens and yet not eliminate the beneficial mycorrhizal fungi?

HUDSON HARTMANN: Well, there has been a great backlog of work that has been done by plant pathologists over the years; it was 40 to 50 years ago that this work was originally started and a lot of follow up work has been done. Some of the articles by Dr. Baker, which are cited in my paper, de-

scribes these studies. There has been really a tremendous amount of work done by the plant pathologists, and 140°F for 30 minutes is the point arrived at which kills most pathogenic organisms but not most beneficial ones.

HOWARD BROWN: Bruce, I don't have a question but I thought it would be appropriate to elaborate on what Tok Furuta brought out here in regard to nitrogen fertilizer from natural gas. We face a real problem in the state of California now. Natural gas is the main heat source for the production of ammonia, to result in nitrogen fertilizer. Two years ago we had eight major companies manufacturing nitrogen fertilizers. Because of the rapid increase in the price of natural gas, all but two of those companies have gone out of business. Mexico and U.S.S.R. are making a great deal of nitrogen fertilizer now, selling it in the state of California and, I imagine, in the rest of the United States, for much less than our local people can manufacture it for. The California State Board of Agriculture recently passed a resolution sent to the Public Utilities Commission, and other governmental agencies, recommending that the price of natural gas be frozen for at least one year for the manufacturers of nitrogen fertilizers — Union Chemical Company and Valley Nitrogen — so that they can continue to make nitrogen fertilizer domestically. What would happen if we got to the point where we were depending upon an OPEC type of arrangement for purchase of nitrogen fertilizers?

PLANT PROPAGATION IN VIRGINIA

CHARLES PARKERSON

Lancaster Farms
Suffolk, Virginia 23435

Lancaster Farms is a small wholesale container nursery located in the southeastern tip of coastal Virginia (zone 8b on the U.S.D.A. Plant Hardiness Zone Map). Production is centered around twenty genera of broadleaf evergreens and ten genera of coniferous evergreen plants. Propagation is mainly by cuttings using three different time schedules. Coniferous evergreens are propagated between January 1 and February 15. Broadleaf evergreens for 1 gallon production are made during December, and broadleafs for 2 and 3 gallon production are made between June 15 and September 15. A few items are propagated by seeds or division.

Propagation Decisions. A propagation system starts with a basic decision as to the type of production that works best for

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Propagation Decisions. A propagation system starts with a basic decision as to the type of production that works best for

one's business and climate. Since the bulk of our efforts are directed to plants for 2 and 3 gallon production, this paper will concentrate on this system. For many years cuttings were rooted into 2¼" rose pots during the summer and carried over in plastic houses, being transplanted into 1 gallon containers the following spring. These plants were grown until fall or the following summer when they would be shifted into 3 gallon pots, being ready for sale the following spring after a flush of growth. During the winter of 1977, we suffered severe plant losses due to winter freeze damage. This caused us to take a hard look at our production cycle. Plants, in general, were in our system for one winter as a 1 gallon plant and two winters as a 3 gallon plant. We were forced to reduce this winter exposure; consequently, for the spring 1977 planting season, we took 2¼" pots and planted directly into 3 gallon pots. At the time we thought this was a bold move. Well, it worked and we found a way to eliminate one winter exposure. After reading an article by Sidney Meadows (3) in THE PLANT PROPAGATOR, we shifted production from 2¼" pots to larger 3" pots and began to use multiple cuttings per pot to ensure that a big liner was produced.

Propagation Structures. Our basic propagation structure is a simple poly pipe house 30 ft. wide by 96 or 144 ft. in length. Benches are not used. Pots are set on a base of #5 crushed stone 3 inches deep. A high quality city water used in the propagation area eliminated the need for special high pressure pumps, boosters, back-ups, etc. A Buckner #1124-4 Midget rotary nozzle delivers 0.78 GPM at 40 PSI to provide both misting during rooting and watering of the plants once rooting has occurred. The nozzles are spaced 16 ft. between lines and 9 ft. between nozzles. A 100 mesh in-line filter is installed in each house to ensure that small particles in the water do not clog the nozzles. These rotary nozzles are not perfect — a little too much water during the propagation phase and a little too little during the growth of the liner — but they provide a happy medium that we can manage. Fertility is supplied by injectors into the water lines after rooting.

Houses are covered with a 4-mil co-polymer film in the fall. We expect to get one full year's service from this one cover.

Preparation. All houses are clean and ready to start the propagation process around the middle of May. Houses are filled with 3" pint plastic pots and the growing medium is dumped on top of the pots and struck off with a board and broom. The medium used is ground pine bark and sand to which the following has been added per yard: 12 lbs dolomite lime, 3 lbs 20% superphosphate, 3 lbs gypsum, and ½ lb fritted

minor elements. Every effort is made to have the air pore space at least 25% by volume (4). Once the rooting medium has been added to a house we do not allow the material to dry out but keep it moist. Depending on the crop of cuttings to be made, shade cloth (either 63% or 78%) is applied over the poly.

Making and Sticking Cuttings. We are so thankful for the Plant Propagators Society for giving us the opportunity to see what other nurseries are doing. In 1974 the Eastern Region toured Greenleaf Nursery in Oklahoma. They have a system of making cuttings that we have adopted. This procedure for making cuttings is explained in detail by Kenyon (1) in a talk presented to this group during 1974. Briefly, this is what the system includes: Each employee is issued the following: carpenter's nail apron, an adequate supply of #12 rubber bands, color coded labels (Economy slip on type 5″ in length), and a pair of Snap-Cut #118 hand snippers. The rubber bands are placed into one pocket of the apron and the coded labels in the other. All production is on a piece-work basis. The worker makes cuttings in the field preparing them by cutting to size (in most cases 5″ — the same length as the label), removing the lower leaves, and placing into packs of 25 along with his color coded label. The base of the pack of 25 cuttings is held with the rubber band. The bundles are stored in an ice chest until picked up from the field and transported to the greenhouse for sticking.

There is a separate crew for making and sticking cuttings. This summer (1979) the rate for most broadleaf plants was $9.00 per 1000 for making the cuttings and $2.00 per 1000 for sticking. Depending on the cultivar and condition of the cutting wood, IBA quick-dip hormone treatment is used. We make up the IBA solution using crystalline IBA and alcohol, as described by Machen (2). Cuttings are stuck to a depth of 1 to 2 inches and watered well. Mist applications are regulated by a series of time clocks and electric timers.

The house is placed under a regular preventive spray schedule. Shade cloth is removed in October. Fertility is supplied in liquid form until a tissue level of 2.0% nitrogen is reached. The houses are left unheated until late February at which time unit heaters are installed to prevent freezing until planting in the field. Planting in 2 and 3 gallon pots starts after the first full moon in April, which is the last frost date in our area. By this time, we have had one flush of growth and have started building the nitrogen level in the plants for the next flush. By September many of these plants are ready for sale in the smaller sizes that we offer. They are, for example, *Ligustrum lucidum*, 15/18″; *Euonymus kiautschouica* 'Manhattan' 18/24″; *Ilex crenata* 'Rotudifolia' 12/15″. However, the bulk of the crop is

ready for sale after a flush of growth the following spring.

Broadleaf Propagation for 1 Gallon Production. Cutting and media preparation are the same as above. Cuttings are made during December, stuck into deep flats, and placed into a poly house with hot water pipes in the floor. The cuttings are spaced about 2 inches apart. Humidity in the house is maintained by a light mist and by hand sprinkling of the leaves and floor surface during the heat of the day, and at night by mist until the plants are rooted. When roots begin to form (usually by early January), feeding begins. A nice sized bare-root liner is ready for the gallon can by early April. These bare-root liners grow vigorously. I have often called this the 60 mile-per-hour theory.

The summer-rooted liner develops roots, makes a flush of fall growth, and then is stopped by winter cold. It takes this plant forever to get started growing again in the spring, for it starts at zero speed. On the other hand, a cutting made in the early winter produces roots easily. It is then left unchecked and hits the field at planting time already going 60 m.p.h., making flush after flush of growth. This rooted cutting makes a nice plant for sale in September.

Coniferous Evergreen Propagation: The propagation of junipers and other coniferous evergreens is done during the months of January and early February. Cuttings are prepared as described except that all receive an IBA quick-dip. The cuttings are stuck into the same medium that has been described, inserted 1½ by 1½ inches apart into 3 gallon pots, and placed into an unheated poly house. You might ask — why 3 gallon pots . . . why not beds or liner pots? Well, in our system it is what works best. In the past we used ground beds but sanitation was a problem. It is easy to become locked in on a greenhouse for a particular crop with these beds. Flats work very poorly for us because we seem to need additional depth to promote good rooting. Shade is applied to the house in March to reduce heat and plastic is removed in mid-April. All plants are rooted by early June and the pots are moved out of the hosue if the space is needed for another crop of cuttings. The rooted cuttings are planted into 2-gallon containers during July and placed in the field can-to-can. In the late fall, after winterizing of the broadleaf crop, these 2-gallon plants are spaced then are ready for sale the next summer.

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NURSERY PRODUCTION IN ENGLAND

TOM WOOD

Oakover Nurseries Ltd., Potters Corner, Ashford, Kent, England

INTRODUCTION

Among United Kingdom nurserymen there is an increasing awareness in the need for specialization in the containerized market for Garden Centres, which is particularly attractive to marketing groups, and the awareness of the need for purpose-grown stock particularly smaller feathered trees, potted shrubs, and herbaceous plants.

Specialist producers are now concentrating either on landscaping and its plant requirements, high quality choice or up-market plants for the plant enthusiast, heavy standards and larger specimens for local authorities and, in particular, indigenous trees and shrubs which are used in considerable quantities for conservation and the landscaping of industrial developments and roadworks. It is in this last specialist need that we have developed our production technique and it is by relating our own experiences to meet this need that I hope to convey something of our own particular part in nursery production in England. Our development is very closely linked to our participation in the International Plant Propagators Society, with considerable involvement and exchange of ideas and I hope to demonstrate this as we go along. I would, therefore, like to introduce Oakover Nurseries. We are some 80 acres in extent, primarily on greensand which is ideally suited to the production of nursery stock and forest trees. We were formerly a forest nursery and developed seedbed and transplant techniques based on forestry systems. This involved standardization of equipment and the development on the tractor bed system commonly used by the Forestry Commission and commercial forestry producers (1).

THE NEED — BRITISH GROWN NURSERY STOCK

Some ten years ago we started to collect indigenous seeds to meet the demand for this type of material; this need had been created by a greater public awareness of our diminishing tree and hedgerow population due to modern methods of agriculture and to industrial development.

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During the early 1970's there was considerable activity in the need for conservation of our natural resources. This activity has further increased with the disastrous arrival of Dutch elm disease which has, in many cases, denuded the countryside, and demanded immediate remedial action in the form of increased amenity planting, particularly of such genera as *Tilia*, *Fraxinus* and *Quercus*. Our development as a nursery has, therefore, been guided at all times by the necessity to fill this need.

Such plants were formerly produced in vast quantities on the continent of Europe and imported cheaply; however, a devaluing British pound has meant that in order to remain competitive the quality of some continental stocks has deteriorated and our producing nurserymen, being fully aware of the value of quality in understocks and its effect on the final product, have, in expressing their dissatisfaction, turned to alternative suppliers. This realization of the need for high quality at all stages of production has been largely fostered by the increased communication amongst nurserymen and the ready exchange of ideas at conferences and meetings. Therefore, home production competes most satisfactorily for this supply and conditions are right for expansion and development of this specialist production.

Having mastered some of the early problems involved in increasing our range we then looked to the more specialized requirement of the nursery industry and today we are producing understocks and seedling liners for our own nursery industry. Having established the need we are now confident and are turning over the greater part of our nursery to this type of production.

The Seed. Our early experiences involved the collection of home produced seed, the establishment of contacts on the continent and at home where seed could be purchased, and visiting other nurseries to obtain details of their experiences and requirements. The subject being very poorly documented we have relied very much on the work of our own men and, in particular, that of Dennis Fordham who is now involved principally in seed collection and production from seed. He has undertaken considerable work on the storage, dormancy breaking and stratification treatments and, in particular, calculations of bed density to produce the optimum size of plant required by the Trade and has presented a paper on this work to the G.B. & I. Region (2). He has progressed his techniques since this presentation and much of the new material I have today relates to his experiences.

We have built up a large dossier on seed collection noting

proven good sources of reliable performance and detailing optimum timings for observations of crop and collection arrangements. The subsequent extraction treatment and storage of seed is now handled systematically to ensure maximum collection from our home supplies. This is the most important single factor in our production as availability of seed in Europe, and in England in particular, is by no means certain from year to year and, as many species do not store well, our own ability to collect is reflected in the continuity of supply that we can offer to our customers. There are very few reliable seed suppliers for woody species and the seed supplied is often of indifferent quality.

We have improved our handling and treatment techniques and, with experience, are getting greater control, particularly during the imbibing period when temperature and moisture levels over variable durations must be considered for each species (3). The use of warm and cold stratification to facilitate embryo development and seedcoat breaking, together with hot water treatment for waxy pericarps and imbibing periods to enhance and speed up germination are now standard practice and, whilst we have avoided the use of acids, we have used gibberellin to assist in germination of stored seeds, such as *Nothofagus*. We still employ natural dormancy breaking by using the autumn sowing method with *Viburnum*, *Cornus* and some *Prunus* species. With the larger difficult-to-store seeds such as *Aesculus*, *Castanea* and *Quercus* we are grading the seed to size to produce evenness of stand prior to autumn sowing.

In all of our sowing the aim is to produce the optimum number of plants that will give either height or stem diameter at the end of a predetermined period and these factors are considered in all calculations of bed density. Our normal cycle of production is one or two years with intermittent undercutting.

Site facilities. The nursery must be capable of accommodating these operations. As many take place during the winter period the site must be well drained and upon sandy soil; in addition a sheltered position is desirable. Facilities and equipment to provide these needs are necessary and the provision of windbreaks is essential to ensure optimum growth.

There must be a readily available supply of water, particularly at the time of sowing when treated seeds will be near the point of germination and are at a most vulnerable time. Water will also be needed to feed the crop and to replace any deficit in the natural rainfall, but particularly when undercutting operations are considered during the main growing period. One cannot overstress the need for good water on a seedling nursery. Good buildings are also essential, in particular a large

grading and packing shed where material can be handled safely during the winter months and the high quality graded plants can be kept safely prior to dispatch. Cold store facilities are also an advantage and we hire such a facility for our material. Machinery to reduce the work load and handle the crop quickly is also important and must be tailored to suit the system of growing. Our machines are, therefore, all of the standard bed width that we have adopted and include gritting or sanding machines, undercutting and lifting equipment and planters for the transplanted crop. We also have a specialist lifting machine for this crop.

Land preparation. We grow our crop on a three year rotation, with two producing years plus one fallow (4). It is during this fallow year that pernicious weeds are removed, the land is sub-soiled and added manure ploughed in and cultivation undertaken prior to sterilization; we do the latter using Basamid at a rate of 340 lbs per acre to control autumn weed seeds and some nematodes. The increased growth resulting from sterilization more than justifies the cost. Having sterilized in early autumn the beds are left to go "stale" to await the earliest spring sowings.

All sowings are made broadcast and seeds of the small-seeded species are covered with ¼" grit. Sowing densities are calculated by germination tests carried out under glass some 4 to 6 weeks before sowing. For the coarse seeds a cut test is used (these are often sown in autumn in raised beds which give good water drainage and are covered with the nursery soil). Bed densities are all calculated on the basis of these tests and it is our aim to sow the minimum number of seeds that will produce the maximum density of uniform plants to the size that we require. Sowing densities have changed over the last few years in most cases giving a reduced population and an increase in the quality of the product. This is particularly important where understocks are being grown, as opposed to the forest trees and amenity plants that we were formerly producing, wastage levels being far higher in the intensive grading operation of stocks.

Aftercare. Protection of the seedbeds with netting is necessary for most species. We use different nets for different birds, having found that the larger seeds attract larger birds and are not hazarded by the smaller birds which may pass through the larger net; however, on smaller seeds very fine netting is necessary if losses are to be avoided. These losses have greater significance than the numerical reduction of plants. The subsequent reduced density can result in over-sized or badly feathered plants where the calculated density is changed by this factor; e.g. feathers on *Betula pendula* (*Syn.*: *B. alba*) or *Sorbus*

aucuparia where a clean stem was required for budding or grafting.

Irrigation water is applied on a fairly dry regime in order to encourage good rooting. Frost protection may be given on tender species such as *Acer campestre*, *Fraxinus excelsior*, or *Hamamelis virginiana*, where late radiation frosts are a hazard.

Feeding the crop is done using an organic 7:7:7 fertilizer at 7 to 10 day intervals during the growing season. Undercutting commences in July, using a straight Egedal cutting blade; this is designed to produce a dense fibrous rooting system. This technique is applied to both one and two year seedlings and may result in some thickening of stem diameter due to reducing extension growth. Top trimming of some species such as *Crataegus* has also been undertaken.

Pest and disease control is carried out by overhead spraying as a matter of routine, the main problems being aphid, red spider and associated mites and also mildews; for the latter a regular 7 to 10 day programme of Benlate and Dinocap is used.

Potted liners. There has recently been a trend towards container-grown trees, either as self rooted plants or as bench-grafted specimens. We are now producing pot grown liners to meet this demand. Certain *Acer* species, *Liriodendron*, *Eucalyptus* and several conifers including *Taxodium*, *Pinus*, *Cedrus*, *Ginkgo* and *Cupressus* species are treated in this way. It is our normal practice to either direct sow or sow in trays under glass and prick off into final pots of 7 or 9 cm. These are then grown on under polythene tunnels or shading tunnels before being hardened off in frames or unclad tunnels. Marketing of such liners is undertaken at the end of the first year when they have reached a height of 12 to 36″ according to species.

Harvesting & Dispatch. This starts in late October with the undercutting, lifting and clearing of the 2 year crop and the undercutting and selected thinning of the 1 year crop. Selected one year and, in some cases, two year seedlings are used to re-line out to produce a transplanted crop, but many seedlings are graded out for direct resale. The criteria used are stem diameter and height, in the case of understocks, and height and ability to feather in the case of amenity plants. The graded plants are bundled and packed into polythene bags and may be held in a strawed condition outside in open weather or in cold store prior to dispatch.

We deliver all of our own plants using our own transport; this service is very much part of our whole production and is a major consideration with our customers. It is our hope to increase our range of plants to provide a self-sufficient service to our industry, grading to our own grower requirements upon

their own recommendations following consultations. As our industry progresses and becomes more specialized this communication and understanding becomes more and more important and we make a point of regularly meeting with our customers for this purpose. It is in this last respect in the creation of better knowledge and understanding in the spirit of true cooperation that the role of I.P.P.S. features in the progress of the nursery industry.

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SEXUAL FLEXIBILITY IN PLANTS

PHILIP A. BARKER[1] and D. CARL FREEMAN[2]

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Finding and producing non-fruiting trees is an important way of providing buyers with improved selections of landscape trees, but unexpected sex expression of trees can thwart such aspirations. Notwithstanding a possible mixup of budwood, an ephemeral change in the sex of a tree or any other plant can occur. Typically non-fruiting individuals occasionally may shift towards femaleness and bear fruit. In other cases, plants that normally have female sex expression, may shift in some years towards maleness and have only male flowers and, of course, *no fruit.*

From an ecological viewpoint, there seems good reason for expression of sexual flexibility in plants. Because of immobility, plant survival depends on the ability to cope in place, whatever the environmental stresses may be. Charnov and Bull (3) proposed that "labile sex determination (not fixed at conception) is favored by natural selection when an individual's fitness (as a male or female) is strongly influenced by environmental condi-

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tions and where the individual has little control over which environment it will experience."

Despite the probability of a plant's inherent traits to shift sex according to environmental constraints, sexual stability is critical in producing non-fruiting clones of trees. Incidents of sex shift and possible physiological bases for this shift are presented here to support the use of genetically uniform rootstocks to control sex expression of trees producing for landscape purposes.

SHIFT TOWARD INCREASED FEMALENESS

Several commercially produced tree clones are unique for their fruitlessness because they have exclusively male or asexual flowers. But occasionally some trees of these typically non-fruiting clones also will have female flowers that develop into fruit (Table 1). Noteworthy are clones of silver maple (*Acer saccharinum* L.), green ash (*Fraxinus pennsylvanica* var. *lanceolata* (Borkh.) Sarg.), thornless honeylocust (*Gleditsia triacanthos* forma *inermis* (L.) Zabel.), and prairie crabapple (*Malus ioensis* (Wood) Britt.). Without exception, these examples of fruiting or increased femaleness of typically non-fruiting clones were associated with severe drought or unusually low winter temperatures.

Table 1. Fruiting of typically non-fruiting tree clones.

Clone	Sex of typical flowers	Age of trees (estimated years)	Location (U.S.A.)	References*
Acer saccharinum 'Silver Queen'	Male	12	Michigan	2
		15	Iowa	5
		4	Nebraska	1
Fraxinus pennsylvanica var. *lanceolata* 'Marshall'	Male	4	Illinois	3
		4	New Jersey	4
Gleditsia triacanthos forma *inermis*; variously named clones	Male	4	Illinois	3
		4	New Jersey	4
Malus ioensis 'Plena' (Bechtel crab apple)	Asexual, flowers double	10	Utah	6

* Personal communication: 1, Howard Edmondson, Marshall Nurseries, Arlington, Nebraska; 2, Clifford Emlong, Emlong's Nursery, Stevensville, Michigan; 3, Alfred Fiore, Charles Fiore Nurseries, Inc., Praire View, Illinois; 4, William Flemer III, Princeton Nurseries, Princeton, New Jersey; 5, Larry Sjulin, Interstate Nurseries, Hamburg, Iowa; 6, Douglas P. Walton, retired, Porter-Walton Nursery, Salt Lake City, Utah.

Clones that characteristically bear only a moderate amount of fruit also may exhibit erratic sex expression. For example, the original tree, or ortet, of the Moraine ash (*Fraxinus* 'Moraine'), located in Dayton, Ohio, bears only meager amounts of fruit (pers. communication, John Siebenthaler, Siebenthaler Nursery, Dayton, Ohio). A group of 47 trees, or ramets, of this clone are located in Berkeley, California. They were planted in 1963 as 8- to 9-foot budded stock on green ash seedlings grown from seed collected in Kansas and Oregon. Apparently the degree of femaleness, as suggested by fruit yield, was markedly different among these trees in both 1978 and 1979. The most pronounced difference was in 1978, following two years of severe drought, at which time 8 of the trees had abundant fruit, 7 had no fruit, and the others had amounts varying between these two extremes (Figure 1). The variable degree of fruiting might be linked to site differences, but there was no significant correlation between fruit yield and tree size for either year.

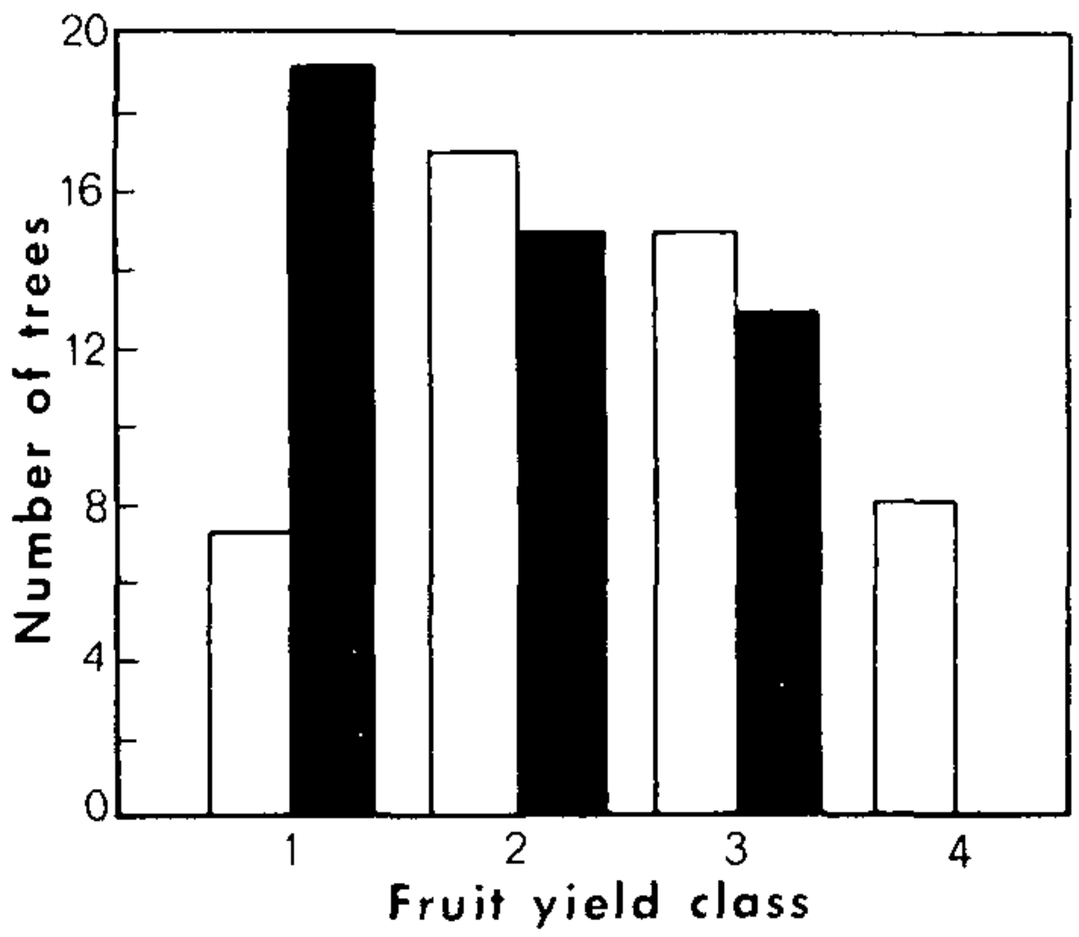

Figure 1. Frequency of fruit yield classes in 1978 (open bars) and 1979 (closed bars) of 47 *Fraxinus* 'Moraine' trees in Berkeley, California. Fruit yield classes: 1, none; 2, meager, 3, moderate; 4, abundant.

A shift towards increased femaleness has also been reported in conifers. At Wooster, Ohio, male plants of three dioecious species of yew (*Taxus*) have occasionally had a branch that produced fruit (14). At Philadelphia, Pennsylvania, following a drought year, conelets of several species of the monecious spruce (*Picea* spp.) appeared to be basically male but had female tissue of varying amounts. That is, instead of being typically male, some conelets were bisexual (22).

SHIFT TOWARD INCREASED MALENESS

Ephemeral or periodic shift of either an individual plant or a plant species towards increased maleness is also evident. We

monitored the sex expression of 46 trees of canyon maple (*Acer grandidentatum* Nutt.) in native stands in northeastern Utah in two consecutive flowering years, 1977 and 1979. The 1977 flowering coincided with a severe drought that had lasted for several months. Precipitation was more normal in 1979. During each of the two years 8 of the 46 trees had only male flowers and 26 had both female and male flowers (Figure 2). Sex expression differed from year to year in the remaining 12 trees. In 9 of them there were only male flowers in 1977 and both female and male flowers in 1979. The reverse was true of the other 3 trees; they had female and male flowers in 1977 and only male flowers in 1979. A male-flowering tree selected in 1977 from these 46 trees would thus have had over a 50-percent chance of fruiting in 1979.

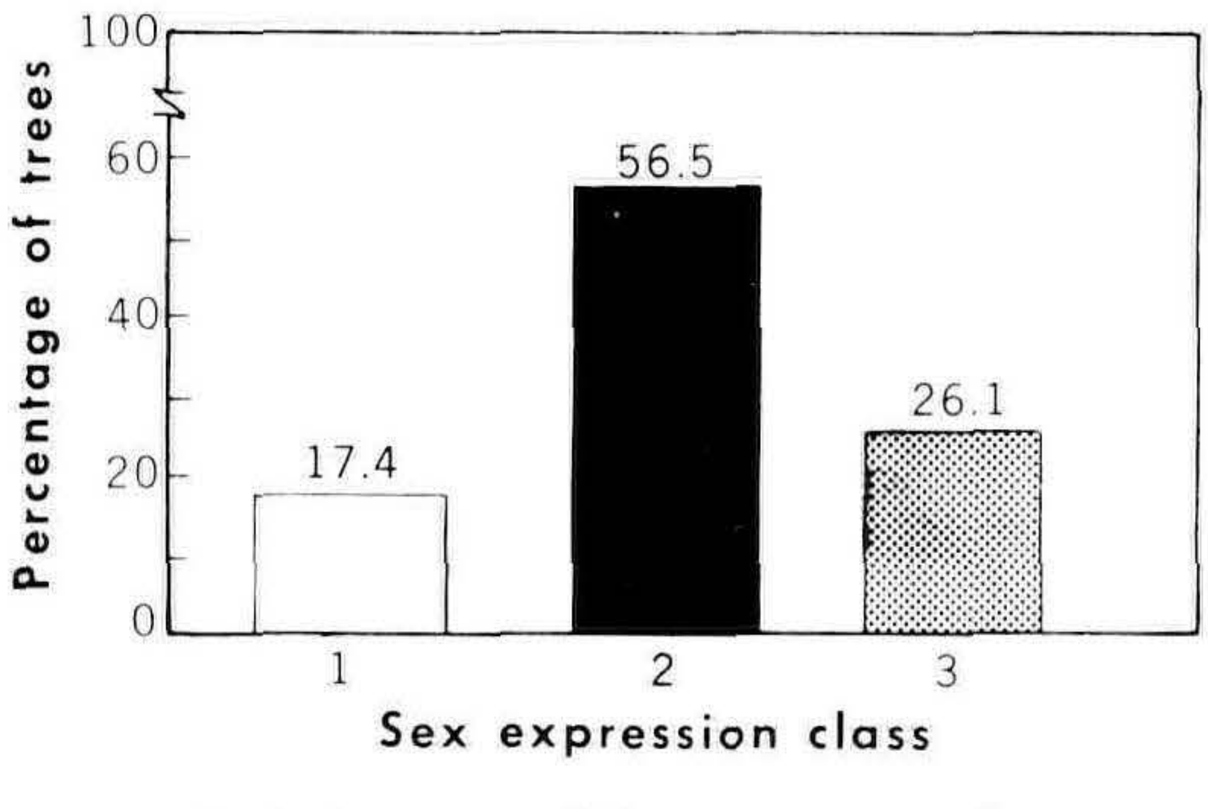

Figure 2. Frequency of 46 *Acer grandidentatum* trees by sex expression class: 1, only male flowers, 1977 and 1979; 2, both female and male flowers, 1977 and 1979; 3, sex conversion; only male flowers one of the years and both female and male flowers the other year.

These findings are supported by numerous reports of increased maleness in various plant species when grown under arid versus more favorable soil moisture conditions. Male plants of five dioecious species in natural stands in Utah were most abundant on sites considered to be under intense water stress (5). Among a group of Norway maples (*Acer platanoides* L.) planted in Stockholm, Sweden, exclusive maleness was higher on poor, dry soil than on more moist sites (25). In the generally dioecious bog myrtle (*Myrica gale* L.) proportionately more male plants have been found in dry areas than in wet areas of peat moors in the United Kingdom (4).

Ordinarily, the earliest flowers on young cucumber (*Cucumis* spp.) plants are male; then with advancing age of the plant, female flowers are also produced. Again, the expression of exclusive maleness in cucumbers was stronger and of longer duration in plants grown in dry, versus wet, soil (18).

Some plants provide evidence that stressful temperatures

promote maleness corresponding to the effect of drought stress. McArthur (17) observed significantly fewer female plants in a plantation of the dioecious shrub *Atriplex canescens* (Pursh) Nutt. following a mild fall and then a winter of unusually low temperatures as opposed to previous years of more normal temperatures.

PHYSIOLOGICAL BASES FOR SEXUAL FLEXIBILITY

Several deductions can be made from these reports of apparent sexual flexibility in plants. First, the phenomenon is evidently not unusual. As reasonably large populations of plants are observed over successive years and under a wide range of climatic conditions, certain plants within many species will undoubtedly be found to vacillate in their sex expression from year to year. That the sex of plants is genetically fixed is not always valid.

But if sex expression in plants is not genetically fixed, then how is it regulated? Evidence suggests that a delicate balance in critical hormones influences sex expression. A shift in this hormonal balance mediates a corresponding shift in sex expression (2,16). An increase of one hormone (from endogenous or exogenous sources), or a decrease of another, may alter the sex expression of a plant.

Cytokinins may be the most important group of hormones regulating sex expression of plants. These plant hormones are essential in the meiotic cell division of pistillate tissue of undifferentiated flower buds in grape (*Vitis*) (20) and spider flower (*Cleome*) (13), species of two widely separated genera. The ratio of cytokinins to gibberellins was recently reported to determine the sex of individuals of spinach (*Spinacia oleraca* L.) and hemp (*Cannabis sativa* L.) (2). In these two species, female plants resulted from a proportionate abundance of cytokinins.

Roots are considered a major site of biosynthesis of cytokinins (2,15). Apparently the rate of cytokinin synthesis or transport is strongly influenced by root environment (24). For example, root systems subjected to water stress (drought) export lowered amounts of cytokinins via the xylem sap to the shoot system (11,12,19). Similarly, the cytokinin supply becomes depressed when roots are subjected to other stresses such as salinity (9,10), flooding (1,21), and heat (8,9). The similarity of response to diverse environmental stresses suggests that plants have a common regulatory mechanism which responds to environmental stresses, and this mechanism involves rapid change in hormonal balance within a plant (24).

Hypothetically, then, an ephemeral shift in sex expression in plants is the result of an unusually stressful environment that

affects biosynthesis of cytokinin and possibly other hormones in the roots which in turn affects the balance of hormones in the shoot tips when flowers are sexually differentiating.

This hypothesis could account for the apparent shift towards increased maleness in the canyon maple, discussed above. That is, the drought preceding the 1977 flowering season inhibited cytokinin biosynthesis in the roots and export to the shoots. Consequently pistil development was inhibited, resulting in repressed femaleness. In the case of all male-flowering plants that year, the cytokinins possibly dropped to a threshold level that precluded pistil development in any of the flowers.

But how does this hypothesis explain those instances cited where typically male and asexual plants fruited? It is possible that cytokinins normally are near a threshold level and that environmental stress lowers that level even further; auxins (6,7), or other feminizing hormones, respond to this hormonal change by accumulating to a proportional level that affects sex expression.

In the case of each of the tree clones and the canyon maple, shift in sex expression has been observed in only a portion of extensive populations from virtually the same environment. This phenomenon can perhaps be attributed to the root system of each plant which was of seed origin and therefore genetically different from the others. As such, each root system probably had a varying influence on hormone balance in the roots and, therefore, on sex expression of the plant. Some root systems may have been genetically more capable than others of affecting sex expression of the top, as shown in grape plants (23). When the same clone of a Sultana grape (*Vitis vinifera* L.) was grown on three different rootstocks, the plants on one rootstock had the highest concentration of cytokinin in the sap, the most grapes per bunch (probably due to the most female flowers per inflorescence), and the highest yield by weight. Further evidence demonstrates that cytokinin affects sex expression: the gene for femaleness in the herbaceous annual *Mercuriales annua* L. was discovered to be the gene that controls cytokinin biosynthesis in the plant (16).

Indeed, if sex expression in plants is influenced by the amount of biosynthesis in the roots of cytokinins or other hormones, then stabilizing sex expression in typically non-fruiting clones that occasionally fruit may be achieved by homogeneous or genetically uniform rootstocks or by propagating clones on their own roots.

In summary, because of the plant hormone-environment interactions that apparently influence sex expression in plants, sexual flexibility in naturally occurring plants may be quite

common. But a shift in sex expression in commercially produced clonal plants in which sexual stability is desired is a breakdown in quality control. The problem may be prevented by clonal rootstocks or by "own root" production of clones, but the effectiveness of either practice needs to be determined.

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MAXIMIZING SEEDLING GROWTH UNDER MIDWEST CONDITIONS

HUGH STEAVENSON

Forrest Keeling Nursery

Elsberry, Missouri 63343

The economics of nursery production today call for growing the plant to desired size and finish in the shortest possible time. I suppose this would be true with any nursery crop, save possibly bonsai. And even here, to be economically feasible, the rule would apply.

One of the more sage nurseryman put it this way: "We used to take two or three years to produce a gallon can plant. Now they never see a birthday."

We are in-ground, or field growers. A specialty with us is hardy deciduous tree and shrub seedlings of which we grow several million and almost 100 species. About 100 acres, or one-fourth of our nursery area, is devoted to seedling production. These find their way into a number of markets in 49 states — for canning and field lining, for understock, for various conservation and highway plantings. Many are of ideal size for mail-order nurseries, for packaging, for hedging and other direct uses.

With few exceptions, it is desirable, indeed economically necessary, to produce the largest seedling in the shortest possible time.

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Of even greater importance is the fact that the younger seedling is a superior performer. Time and again, over the years, we have observed that, size for size, a one-year seedling is far superior to a two-year or older seedling as to survival and growth upon transplanting. The presumption is there is less shock in transplanting the younger plant.

For example, one-year bald cypress (*Taxodium distichum*) seedlings transplant readily. Two-year cypress seedlings are almost impossible to transplant. One year oaks (*Quercus* spp.) transplant much better than two- or three-year seedlings. One has to be some kind of a genius to get satisfactory survival with two-year seedlings of white or scarlet oak, for example. Redbud (*Cercis canadensis*), hawthorns (*Crataegus* spp.) Chinese chestnut (*Castanea mollisima*), birch (*Betula* spp.), most dogwoods (*Cornus* spp.), *Rosa* spp., mountain ash (*Sorbus aucuparia*) all move with ease as one-year subjects but become problem children when they remain in the seedbed longer.

Sweet gum (*Liquidambar styraciflua*) and tulip tree (*Liriodendron tulipifera*) must be harvested with care even as one-year subjects but are almost worthless as older seedlings.

One should never accept silver maple (*Acer saccharinum*) liners older than one year. It is a challenge to get sugar maple (*A. saccharum*) seedlings to the desired size in one year, but they are definitely superior where this can be accomplished.

Many understock growers believe they need two-year Norway maple (*A. platanoides*) to get suitable caliper for budding, but with the right seed source and cultural practices, we have produced Norway maples of very adequate size in a single season.

Because of this general superiority of the one-year seedling, we take several steps to push our seedlings to desired size in a single growing season. This, of course, involves suitable seed source and proper timing and/or pre-treatment of the seed. (The subject of seed source, or provenance, as well as virus-indexing is of critical importance. But this is another topic).

Generally speaking, we want emergence to occur as soon as possible after danger of the last killing frost. Seedlings respond best to their natural growing cycle; in addition, the longer the growing period the greater the growth.

Of paramount importance is to locate seed beds on a choice horticultural soil with ideal soil and air drainage. The production of seedlings is such an intensive, costly pursuit that nothing could be so penny wise and pound foolish as to accept any but the best agricultural site and soil. In our case this is the first row of hills hugging the Mississippi flood-plain. Here the

wind-blown loessal soil is the deepest and coarsest, occurring in narrow ridges where soil and air drainage are excellent.

Again, this intense culture (about 50 times as intense as general farm cropping) justifies a fertility and soil building program as best we know. We like to go through a perennial sod crop of brome grass or fescue for two or more years, using this period to make additional of major or minor elements to bring the chemical fertility level and pH to an ideal, balanced state. During this period the land may be grazed (and repeatedly fertilized) but no forage is otherwise removed. The fibrous root growth of these perennial grasses is unbeatable for building soil structure.

This sod crop is then plowed under at least six months before preparing seed beds. Depending upon the season, a green manure crop of grain sorghum or rye may be grown and plowed down during this intervening period.

Now the soil is in prime shape, both chemically and physically, for growing seedlings.

But our soil building process does not stop here. At any one time at least half of our seed-bed area is in green manure crops. The one we really dote on is a hybrid grain sorghum called 'Tri-span.' This is a fantastic grower, jumping up to six feet in a matter of six or eight weeks. In addition to a large amount of forage to turn order, 40 tons or more of dry matter per acre, the vegetation is so thick and heavy that weed growth is completely suppressed, thus depressing weed population in the seed-beds that follow. We mow the 'Tri-span' three to five times during the summer, allowing a build-up of organic material on the soil surface.

We like to allow 'Tri-span' to grow right up to the time of seeding the nursery crop. This means a tremendous amount of "trash" to work into the soil surface by discing and does make a somewhat rough, lumpy seed-bed. But the resulting soil aeration has a definite beneficial effect on seed germination, emergence and seedling growth. Indeed, the increase in germination percentage of this practice has allowed us to substantially reduce our seeding rate. With the sky-rocketing cost of tree and shrub seed, this is a most important plus.

Anyone who has surveyed in-ground growers across the country is aware that many of the best of them use tremendous quantities of animal manure with cover crops preceding their nursery crops. There is no question that such manuring results in lush, vigorous growth of nursery stock far beyond what can be accounted for by the fertility elements contained in the manure. Space does not permit a discussion of these extra benefits, but they are profound.

The only trouble is that manure is often not easy to obtain and is costly to haul and apply. Several years ago we tied in with an "egg factory" operating with 40,000 layer chickens. The chicken manure accumulates in a large vat as a slurry and must be pumped into a tank truck and hauled away almost daily. By agreeing to take the product throughout the year, the hennery operator actually subsidizes us to keep it hauled away. During the days we can't get on our nursery fields with the tank truck we spread the stuff on our pasture lands. It does stink to high heaven and we try to catch the wind blowing away from neighboring residences to keep peace in the community.

We apply four 1500 gallon tank-loads of the slurry per acre. This gives us, in nutrients, about 264 lbs actual N; 324 lbs P_2O_5; 112 lbs. K_2O; 3700 lbs. calcium; 200 lbs. magnesium; and small amounts of copper, zinc, iron and boron.

All seed are sown on or near the soil surface, rolled in with roller with narrow corrugations and covered with a bark-sawdust mixture. We apply as heavy an application of this mix, through a flail-type spreader to shred the bark, as we can and still permit germinating seedlings to emerge. The rule of thumb with a covering of soil or sand is twice the diameter of the seed; however tree and shrub seedlings will readily emerge through a much thicker layer of bark-sawdust — at least four or five times the seed diameter.

There are obvious benefits from such a heavy organic mulch cover. Many weed seedlings are suppressed. Surface moisture is retained. Porosity of the soil profile is improved. Moisture penetration is facilitated. Soil erosion and seed-bed washing are reduced. Soil temperature and moisture at the seed germination zone are more uniform, resulting in even stands of seedlings.

Then there are other profound benefits from these organic additions. The organic level and structure of the soil is enhanced. Indeed, it does take a lot of extra N to prevent nitrogen deficiency as the soil organisms break down the bark-sawdust applications, but this is like putting money in the soil bank — the interest pay-back is great with such a high-intensive crop as seedlings.[1]

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[1] How much added nitrogen is needed to off-set any "nitrogen starvation" as a result of bark-sawdust mulching will vary with the kind and proportion of bark and sawdust. Bark breaks down much more slowly than sawdust and is not such a nitrogen "grabber" H.A.J. Hoitink in discussing composting of bark states; "Pine bark generally requires 1 lb actual N per cubic yard to avoid nitrogen deficiency on plants produced in the mix after composting. Hardwood bark in the Midwest requires at least twice as much N per cubic yard."

On the other hand USDA studies point out that "hardwood" sawdust

Perhaps more important is the affect these organic additions, including the chicken manure, have on the soil fauna and flora. Though root nematodes are common with many species we have been free of these pests for years and until recently couldn't account for this happy state. Then Dr. John B. Gartner of the University of Illinois, visiting the nursery, pointed to the work of Hoitink, *et al*, which demonstrated that hardwood bark in a growing medium had a profound effect on the suppression or elimination of nematodes.

The role of mycorrhiza in stimulating growth is well recognized. For whatever reason most species of plants, following generous chicken manure applications, exhibit heavy mycorrhizal mantles. Presumably this is a factor in the growth response from the manure application.

One observes the stimulating effect of high organic soils in other situations. Seedling growers in Tennessee and elsewhere have followed a practice of sowing their seed in the duff of freshly-cleared forest land. Here the growth can be phenomenal and weed competition almost non-existent. This practice does present the problem of constantly finding new forest land to clear.

It goes without saying that proper soil moisture and pest control must be maintained to achieve maximum growth.

Though our annual rainfall (35+ inches) is adequate for normal plant growth, it does not necessarily come when needed. Summer drought periods occur virtually every year and supplemental irrigation is a must. We have considered every type of irrigation system available and are convinced that solid-set rotary sprinklers is the most feasible for our seed-bed type production. This system has been highly developed by people on the West Coast, and we have adopted it whole cloth for our own use.

Regular spraying is done as required to control specific insect and disease pests. The most pernicious pest in slowing

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contains only about 0.2 percent nitrogen and must be brought up to approximately 1.2 to 1.5 percent values if initial harmful effect on crops is to be avoided. This would require the addition of approximately 24 lbs of nitrogen per ton of dry wood.

From a practical standpoint the addition of needed N or P or other elements is no great problem. As a surface seedbed covering bark-sawdust mixes do not "blot up" N as when these fresh materials are worked into the soil. Furthermore, the cost of fertilizer is such a small percent of the total cost of producing a seedling crop that frequent applications will be made to the soil at a high-level optimum for plant production. Under our fertility program we rarely see any indication of nitrogen hunger to the crop from bark-sawdust applications.

growth with a number of our species is leaf hopper. When kept under control, growth will double or triple with some maples, sophora, wisteria, koelreuteria, some oaks and certain other species.

Aside from sanitation and cultural practices to hold down weed populations, there are two basic approaches to controlling weed competition. One is soil fumigation; the other is herbicides. We have used fumigation and have nothing against this procedure. However, the complex of herbicides now available seem to make this route more feasible for us. Herbicides are treacherous, of course, and one error can be disastrous. But by working closely with our college people, herbicides have reduced hand weeding to a minimum with minimal hazard to the crop.

Lastly, control of seed-bed population is essential to producing the size plant desired. We used to shoot for a stand at digging time of around 25 or 30 plants per square foot. Now the typical stand is down around 10 p.s.f. With particularly high-value crops such as Carpathian English walnut the stand will be two or three plants p.s.f. Stand population is controlled almost entirely by seeding rate, as thinning is usually impracticable.

ROOTING OF DORMANT CONIFER CUTTINGS

LARRY CARVILLE

Horticultural Associates
P.O. Box 235
Tolland, Connecticut 06084

The information presented herewith is based upon my experience as a propagator at wholesale nurseries in the Northeastern U.S. The methods described are generally acceptable by most successful growing operations east of the Mississippi River. Specific references to Rhode Island Nurseries, Middletown, Rhode Island result from my recent eleven years in their employment as Production Horticulturist.

One of the keys to successful propagation is to do things at the proper time. This is true whether it involves taking cuttings, transplanting into beds, or any of the other myriad operations associated with nursery production. At Rhode Island Nurseries, between 600,000 and 750,000 units are propagated each year with a labor force of seven full-time employees in the propagation department. All cuttings are taken from plants growing in fields of the parent operation.

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Propagation Methods. This discussion will concentrate on propagation of conifer cuttings taken during their dormant period. Webster's Dictionary defines dormant as; "inactive; as in a resting or torpid state."

The following plants are propagated as dormant cuttings during the winter season:

Chamaecyparis obtusa cultivars
C. pisifera cultivars
Juniperus chinensis 'Pfitzerana'
J.c. 'Hetzi'
J. communis 'Hibernica' (Syn.: *J. communis* 'Stricta')
J. squamata 'Meyeri'
J. horizontalis 'Plumosa'
Thuja occidentalis cultivars
Taxus × *media* cultivars
T. cuspidata 'Densiformis'
T. baccata 'Repandens'

The objective in producing coniferous evergreens is to take a small cutting from clean stock plants, put roots on them and four to six years later have a quality plant that may be offered to the trade for a profit.

The medium used for rooting cuttings is sharp washed sand. This medium is put in greenhouse benches which are constructed of concrete, are closed on the sides and have bottom heat available. Temperature at the base zone of the cuttings is maintained at 66 to 68°F. Several different root promoting hormones are used, depending on the plant species and the degree of "rootability." Hormones include Hormex powders number 3, 8, 30 and 45, as well as "Jiffy-Grow" in liquid form.

Cutting material is gathered from field plants in November in the Northeast. Temperatures at this time of the year dip into the low 30's in the evening and days are bright and sunny with the highs around 50 to 55°F. A killing frost can be expected as early as November 20th.

Cuttings are stored in a large cooler maintained at 38 to 45°F. Sufficient material is taken on schedule so that cuttings will be available during inclement weather. All conifer cuttings are treated in much the same manner prior to sticking. Bottom needles are either stripped from the base of the cuttings or cut away using scissors or a knife. The basal end is given a fresh, sharp cut, moistened slightly and dipped into the dry hormone. Excess powder is tapped off the cuttings and they are ready for sticking. In the case of the liquid "Jiffy-Grow," cuttings are dipped into the 4 to 1 solution for 10 seconds, allowed to dry and then are stuck in sand. About 10,000 to 12,000 cuttings can be prepared and stuck in a day by having four men in the headhouse making cuttings and two men up on the benches sticking. These cuttings will remain in the greenhouses all winter with occasional fungicidal sprays and periodic heavy drenching with water.

Dormant conifer cuttings respond best if the sand is permitted to dry slightly between watering. A heavy watering is given *once a week under normal conditions during the early rooting* schedule. Water is applied from a hand held hose until excess water drips from the bottom of the benches. Watering is done early in the morning and all foliage is dry before late afternoon. Wet foliage in a closed, heated house is an invitation to fungus and diseases during the dark, cool winter days. No top ventilation is given to the cutting houses until late February or early March when roots are established. Ventilation is then provided to retard top growth, harden the cuttings and to control development.

By early April, the houses are ventilated daily and watering must be done on a regular basis. Cuttings are allowed to develop in the benches throughout April and May while ground beds are being emptied to receive these new liners. No fertilization takes place while the cuttings are in the greenhouse benches.

Preparation for Planting. In early June, when danger of frost has passed, the cuttings are prepared for the transplant beds. All conifer cuttings are handled in a similar fashion. Plants are pulled from the sand in bunches of 10 to 20, sand is shaken from the roots, cuttings are graded, roots are trimmed *and the new growth is pruned. Cuttings are then plunged into a* solution of 1 to 40 Rapidgro (soluble fertilizer), drained, and then packed into planting boxes. These plants may be planted either by machine or by hand. Since the forced new growth is very sensitive to full sunlight, lath shade is applied over the plantings as soon as practical. Fifty percent shade is maintained over all *Taxus* cultivars for the first two summer seasons.

New Developments and Methods. Recent experimentation with plastic "Styro-Blocks," "Speedling" trays and container-rooting of dormant conifer cuttings has shown many advantages over the conventional closed bench, bottom heat method. Another factor contributing to the development of new methods is the escalating cost of energy. Most growers in the Northeast are returning to cold frame production of conifers and are scheduling around-the-year sticking. Although the rooting cycle may be lengthened to 14 or 16 months, the unit cost of production may be appreciably lower.

SUMMARY

Any system of rooting may be acceptable to any given propagation facility. Factors such as cost, labor force, available capital, turn-over time, and market demands must be carefully analyzed. There is no perfect method for every grower. Experi-

mentation is part of the challenge in propagation and only the basic techniques remain static.

DON DILLON: We have time now for a question and answer period for the papers that have just been given.

VOICE: Charlie, could you go over your juniper propagation again?

CHARLES PARKERSON: We try to do it the easiest possible way. We copy Greenleaf Nursery's system. Look for the article that Austin Kenyon wrote back in 1974, in the IPPS Proceedings (Vol. 24, p. 64). We copy him in total, except the size of our cutting is 5 inches; we use a little brown wood at the base. He said use electrical tape on your fingers — we might use masking tape on our gloves to rip off the lower leaves. We don't prune off the leaves; we just rip them off, and do use IBA quick-dip solution on the cuttings. Because of the bundles that we are dealing with — bundles of 25 cuttings — we can't get a rooting powder to get good coverage, so we do liquid dips. We stick them in, and then hand water them. We don't put any shade on the house — this is in January. When we get to about the last week in February we start getting some higher temperatures; if the temperature is above 32°F at 8 o'clock in the morning, we will air one end of the greenhouse; if above 40°F by 10 o'clock we will air the other end of the greenhouse. We don't have any of these expensive fans and louvers to get all broken down — we just open the doors. Then the last week in February we put about 65% shade cloth over the top of the house because heat seems to be our biggest problem. Then we are on mist — and we watch it closely right on through; when we get around the first full moon in April, we take the plastic cover off and leave just the Saran cloth on. Some of these cuttings are slow to root. I wish I could figure out how to do like my friend from England does in rooting Leyland cypress, but we can't root this worth a darn. We have a lot of problems but we are learning a lot all the time. Basically we use Greenleaf Nursery's methods.

IAN TOLLEY: What temperatures can you maintain in your houses with your heaters, bearing in mind the outside temperature. How much wind do you get on that structure? I am thinking of the 60 mph winds we had that flattened one that was almost identical.

CHARLES PARKERSON: The wind — 112 mph wind will take one down, because we have experienced that. But the heaters; we used to heat everything. Above all, heat them, we thought. We tried to put lights in there too. It just didn't work for us. Look, we were thinking just like Dr. Furuta, down the line. We said we must learn how to operate with the minimum amount of heat. This year the heaters went on only twice. We

had set the thermostats to come on at 35-36°F. We rotated around, my secretary and everybody else — we take a night. Tonight is your frost watch night. We don't trust those thermostats, because it is so critical so each of us spends a night down there. We are only talking about keeping above freezing and, basically, the critical time comes from about 4 o'clock in the morning until 8:30. It is that little period that we are concerned with. A very minimal amount of heat is needed if at all. If necessary, we do use some water. We believe in water for frost protection.

LES CLAY: What kind of media are you using?

CHARLES PARKERSON: We are very fortunate in our area. We have aged pine bark from a mill, already aged. There was a talk (IPPS Proceedings, Vol. 28, p. 370) given last year at the Southern meeting on the use of pine bark as a growing medium that you should look up. The trouble with fresh pine bark in our areas is of ever getting it wet. Once it dries out you are in real trouble. We do anything that we can to make sure we get 25% air space in the medium. We don't like a whole lot more than that because we are wasting water, but we don't want any less than that. That is the range that we want. There was a talk given in Chicago several years ago; I can't remember the chap's name but he was from Wooster, Ohio. He gave a test for determining air-filled porosity, and there are several easy techniques to determine that.

VOICE: On your burlap for winter protection, is this suspended above the plants or laid directly on the plant?

CHARLES PARKERSON: When we were experiencing a real freeze, I went home and we listened to our public broadcasting channel. It was about zero degrees outside, and I was all torn up inside; every plant that I owned was dead or dying and the banker was calling, etc. Do you know what was on that TV program? How to make an igloo. Maybe I can learn something from the Eskimo. So we put this burlap over the top of the plants and down the sides using junipers which have no frost problems in our area. The plants are all winterized by jamming them as close together as we can, and then this water is added. The water is frozen; we try to put somewhere around ⅛ of an inch of ice on top of this burlap at night before we go home. It can be accomplished very quickly. When we come back in the morning the ice is all gone. That ice layer is totally gone. It has been sublimated right out into the atmosphere. So the cold isn't taking moisture from our leaf surfaces, it is taking it from the burlap. So it seems to be working. I am not sure of all of the physics that goes with it, but it is a system that has worked very well for us in the last couple of years. Yes, we lay the bur-

lap right on the plants.

ARDA BERRYHILL: Three questions. One, does the burlap stay on day after day, or do you take it off every day. Another one, how many unrooted juniper cuttings do you place in your 3 gallon pot, and the third one, is there bottom heat under those 3 gallon juniper pots?

CHARLES PARKERSON: The burlap goes on just before Christmas, and it stays on until the first part of March. We process a fair number of roses; we handle them in the latter part of February so, as needed, we take the burlap off of some plants. They stay on one gallon plants the longest. They would be the very last thing they would come off of.

In regard to spacing of the juniper cuttings, read Mr. Austin Kenyon's article again; he gives bed spacing on his junipers. I have a template made up that is the same size as the pot with a bunch of nails in it. So we say we are going to use the blue board today. So they use the blue board to make indentations giving the spacing we need. Let's say that the space for Bar Harbour juniper is one thing, San Jose juniper, of course, would have to have a wider spacing. We color code everything. We use the yellow one, we use the green one, we use the blue one, the black one, or whatever; then people can't make a mistake.

For your third question — no, there is no bottom heat in these houses.

ALBERT NEWCOMB: Tom Wood, what pre-treatments do you give your seedbeds before seeding?

TOM WOOD: What I should have explained is that we grow this crop on a three year rotation, which means that we produce a one year seedling, then we produce an undercut 2 year plant, which may be transplanted or may be thinned out. At the end of two years we clear the crop; it is in that third year — which is actually more important than growing the crop — that we do our soil preparation. To start with, if necessary, we use Round-up herbicide on any pernicious weeds. Then we do a dry fallow, which is cultivation followed by a heavy dressing of farmyard manure; we put on at least 60 tons to the acre. This is plowed in and we then sterilize with Basamid. We use a sterilant which kills mealworms, but more important it kills weed seeds. Having done all this in the autumn and sealing the ground over by rolling it, we leave the seedbeds stale, and by that I mean we just run over the ground with a tractor and mark out the spaces where the beds are to be. Then in the spring, as the seed comes out of stratification — and that is why there is an odd collection of plants — as the seed is ready we sort of rake down the beds, and work in a little bit of superphosphate

and sow direct. So there is a certain amount of hand preparation following that basic year of preparation.

VOICE: I am curious about your direct seedling method. The seeds must be stratified, yet you plant them in an active state of development. Do you have a set schedule for planting?

TOM WOOD: The short answer is no — we do not have a set schedule. What we have done is this: we have endeavored to split our seed bed area into two or more lots so that as the seeds come on they can go into a respective area. We can control seeds that are dry stored before they go into an imbibing situation. So if we have seeds that are virtually dormant, we can then, by knowing the number of weeks of imbibing or pretreatment that they need to bring them to germination, determine what our sowing date will be. We do this with some species, particularly where frost hardiness is a problem.

But, in the main, we are still in the stage where we go through the normal stratification, say of a species like *Prunus avium*, the sweet cherry; we have summer stratified it, then we have been giving it a cool period in the winter, until the pits start to crack and break. We may have to sow in February and this is why we have to put frost protection on top. At the moment the seed becomes active we can't hold it back. One of the advantages of having it active is that you reduce the field factor. If the seeds are nearly at the stage of germination and we sow them, often appearance of the seed above the surface of the soil takes only 5 to 7 days. As that period is a very short one, it means that predators or rodents and things that would eat it while it is at its most vulnerable stage have only those 7 days. If we sow it when the seed is dormant and it takes 2 months to germinate then they have a long time to find it and have a go at it. The advantage of getting the seed to a germinable stage is paramount when field factors are concerned and this is most important when you are considering the density of the seedlings. It is not just the seedlings that you lose if the birds eat them or if the mice eat them, it is the fact that the seedling density changes. Instead of getting a nice straight stem for somebody to stick a chip bud onto or to use in some way to line out, if the density is reduced you finish up with a plant that is feathered all the way up. Nobody wants that, so the low density is not just the loss of plants, it is the quality that is impaired by the low density as well.

RALPH SHUGERT: What, if any, herbicides are you using on your seed beds after the seedlings are up? Secondly, you didn't show a slide or I didn't catch it of *Tilia cordata*. If you are in *Tilia cordata* production, what is your formula?

TOM WOOD: Answering your last question: We have grown *Tilia cordata* but we still experience difficulty. We can break dormancy of *Tilia*, but invariably we do it by natural means; in other words, we give it warm treatment to break the seed coat down in the summer, then we give it cold treatment for embryo development in the winter. We find that the seed germinates in March, which is still in our frosts. Probably the way to do it would be under glass; it is an important species so we have tried it but we are not really successful with *Tilia* at the moment. So I really haven't a lot of experience on that. We can do *Tilia platyphyllos* quite well.

About the other question on herbicides: there are very few herbicides we can put over the bed after sowing. We do pre-emergent use of paraquat and if there are coarse seeds such as *Quercus* and *Aesculus* and *Castanea*, which we also grow, we make up a cocktail of paraquat and simazine, which we can apply because the seeds are at a sufficient depth that we can put simazine over the top; otherwise it is hand weeding.

RALPH SHUGERT: Tom, one other question, how do you handle *Taxus cuspidata* seed?

TOM WOOD: We don't grow *Taxus cuspidata*, but we do grow *Taxus baccata*; I don't know whether it is similar, but we have had no experience with *Taxus cuspidata*.

PHILIP McMILLAN-BROWSE: I was going to ask whether Phil Barker had considered the age factor in relation to sex reversal in plants because, as you have already heard, I am interested in the sexual interests of plants since I am interested in seed production. Certainly in Europe we have found that in Asiatic maples, for example, that the young plants tend to produce male flowers and the proportion of female to male flowers increases with age so that, very often, old plants tend to be predominantly female.

The comment I was going to make, Mr. Chairman, was simply to give you an example of "to seek and to share" in the Charlie Parkerson tradition. About two years ago Phil Baker gave a paper in your Region on the propagation of *Acer grandidentatum*. It is a plant that I never heard of so I wrote to him for some seed. He sent me two samples of seed and I would like to report to you now that I have got a nice little family of 200 seedlings of *Acer grandidentatum* in the U.K., which is probably the first time it has been introduced there from the wild since it came in way back in 1880.

PHIL BARKER: That is, indeed, good news to hear. I hope that your plants continue to survive and provide many people with lots of pleasure.

HUGH STEAVENSON: Phil, on some of the so-called seedless plants that do produce seed as you described, if you take the seed and plant them and produce seedlings — what will happen to those seedlings? Will they be normal as far as seed production is concerned or will they revert to the parent characteristics of being seedless?

PHIL BARKER: I will answer Hugh's question first because that is the easiest one for me, and then I will go back to Philip's. I have had no experience with germinating seeds produced from what are typically male plants. It would be my belief, however, that those seeds would probably germinate and develop into a satisfactory seedling if they have the hormone composition that seeds of that species generally have. This is a question that might be observed by somebody else, too.

Now back to the earlier question — had I considered the age factor and the sex reversal in plants? Yes, indeed. I am well aware that, in many species, the young plants have a predominance of male flowers and, with increasing age, these plants have proportionately more female flowers. The examples given in my Table 1 are age-referenced with that in mind. The maples (*Acer grandidentatum*) that we studied in Utah were in a mature phase of growth.

VOICE: Hugh, how do you get sugar maple seedlings up to a desirable size in one year?

HUGH STEAVENSON: Seed source is extremely important. For example, in our area (Missouri) we have gotten seed from the northern states — say Michigan. From these we just get small plants in one year. Sugar maple is also native in our area and if we can get local seed we will get 2 to 3 times the growth that we will from the northern seed. That is one factor, and then the various practices that I have suggested; obviously you want to secure germination as early as you can in the spring. The seedlings will take a certain amount of frost. You want the longest possible growing period, you want the right cycle so the plants are growing at their natural cycle, which means early spring germination and with these various factors of growth stimulant through good soil drainage, plenty of nutrition, and plenty of water. In the case of the maples, one deterent of growth in Missouri is the leaf hopper. We have got to control leaf hopper. We will get 2 to 3 times the growth of the maples — sugar maple, Norway maple, and certain other species, when we control leaf hoppers.

DON DILLON: How do you control leaf hopper?

HUGH STEAVENSON: Various systemics. Orthene and various other systemics. Here in California I understand you don't

have leaf hopper.

VOICE: What sort of bark do you use in your seed beds? Is it fresh bark?

HUGH STEAVENSON: It is generally fresh because we pick it up about as fast as we can. Yes, it is fresh. Really no problem. It is all hardwood. It will be a mixture of oaks, soft maple, sycamore, most anything. It doesn't make any difference.

VOICE: Do you broadcast sow all of your seed beds, or do you drill the seeds?

HUGH STEAVENSON: Because of the problem of changing seeders with a variety of species, we mostly hand seed. We have been looking at a lot of drills, I am sure we are going to come to some drill usage but there is such a tremendous variation in seed size. There are very tiny seeds; then up to acorns and walntus and so forth. No one seeder is going to handle all those different seed sizes. We do weigh out the seed, to cover what might be a 400 foot seed bed. We have girls that can do a reasonable job of spreading the seed broadcast. Then, some of the heavier seed, like acorn, Kentucky coffee tree, and so on — we do use drills to get them down in the ground a little bit. With conifer seeds there is no problem. Weyerhaeuser and the forestry people use drills for conifer seeds, but with broad-leaved deciduous seed there is such great variation in seed character and seed size that it is a real problem to use a mechanical drill.

PHIL BARKER: Gibberellic acid has been shown to enhance growth of *Acer grandidentatum* seedlings. Have you tried this with sugar maple seedlings?

HUGH STEAVENSON: No, Phil, maybe we are missing a bet. Thanks for your suggestion.

VOICE: It appears that you have a fairly good stand of *Tilia* seedlings. How do you overcome inhibiting factors in germination of *Tilia cordata* seed?

HUGH STEAVENSON: *Tilia* is a rough one, particularly *T. cordata*, as Tom Wood has suggested. Really every now and then we can get a darn good stand, but it is tough to come through with an economic stand of *Tilia cordata*. As you suggested, *Tilia platyphyllos* is somewhat easier and *Tilia tomentosa* may be still somewhat easier. *Tilia americana* is even worse, though. Basically, we like to get the seed when we can in the winter time; of course, it has got to have the seed coat softened — unless you are using artificial scarification of some sort. We sow the seed in June to get seed coat break-down in summer, and then we get the after-ripening of the embryo the following winter. One thing about *Tilia*, the seeds seem ready

to germinate at the first break of spring, always before the last killing frost, and it takes a lot of protection to get them through that frost period. There is a fungicidal treatment of *Tilia* seeds that gives much better stands. We are looking into it. But *Tilia cordata* is a real toughie.

ED JELENFY: Larry Carville, how about root pruning in the field. Do you do this?

LARRY CARVILLE: Essentially what is done is that we plant a rooted cutting in a nursery bed for two years. After two years the two-year liner is lifted, graded, trimmed and sized and planted in the field by another planting machine. Let us stay with just *Taxus* for a while. The four-year-old *Taxus* plant is then lifted from the field again, graded, trimmed, and then again transplanted. This transplanting of the four-year-old is done manually. We make furrows in the field, we mark the field, we plant with a nursery spade. When that same *Taxus* is 5 to 6 years old we have two options: it can be sold as a 5 year liner, 10 to 12 in., or 12 to 15 in., or it is then lifted and transplanted one more time. Each time we transplant and trim the roots, we are trimming the top, grading the plant. At Rhode Island Nursery, when *Taxus* is sold they are sold pretty much by size, and when a field is dug and, I am talking about 100,000 *Taxus* to a certain block, you generally size out all 18-24's, 24-30's. Because of the constant handling and grading, quality in the field is insured. The other process is obviously to do continuous shearing and trimming of the plant. It is expensive, it's high labor, but if you have a quality product, there is a quality market that wants your item.

VOICE: Two questions with regard to your transplanter. First, can you adjust the spacing between plants with the transplanter? Secondly, is it compatible with the "plug" production?

LARRY CARVILLE: Concerning the spacing on that particular planter, which is one from Europe and which was referred to earlier by Tom Wood, we have tremendous flexibility in determining the distance between the plants in the row. We can do very little about the distance between rows; that is set at 6. It is a 50 inch bed. But we could space within the row anywhere from 2¼ inches up to 10 inches. You do this with the gear changes; there are 12 different gear changes. You can set up any type of planting spaces. The point that you bring up is obvious — we were lessening our density of planting when we went to the machine planter. We made up for it in terms of the production schedule that we could take, the number of plants that could be planted. Fortunately, there was sufficient land available so that we could expand.

The second point that you brought up — could this particular planter take plugs? Yes, we can plant the plugs that come out of the Styroblocks. We had a very nice 5-inch column of cuttings on a peatlite mix; they went through the planter very well. It could not be used for planting grafted plants because we had that heavy root ball on it; they would just fall over as the heavy wheel went around. We had another planter that we used for grafted material which would insure that the understocks went well into the soil.

HUGH STEAVENSON: Larry, you were referring to Rhode Island Nursery. It is just a beautiful example of the old and tried ways. If you are traveling East and want to see an example of really the standard in *Taxus* and other production, you want to stop and see Rhode Island Nursery. East of the Rockies, to grow *Taxus* we refer to Rhode Island Nursery for the standard of excellence in that type of production. One of the things that they do is to plow manure under as heavy an application as they can plow under. Then they get a lush green finish on their *Taxus* when some of their neighbors, who don't use manure on their *Taxus*, are producing plants somewhat on the yellow side. It is something to see, and if you are out there, have Larry show you what Rhode Island Nursery is doing.

IRRIGATION REQUIREMENTS OF TRANSPLANTED CONTAINER-GROWN PLANTS

N.P. MATHENY, R.W. HARRIS, J.L. PAUL

Department of Environmental Horticulture
University of California
Davis, California 95616

Container-grown plants often fail to establish in the landscape because of desiccation. Transplanted container plants can suffer from lack of water since they usually have a large top (leaf surface) compared to the volume of the rootball in the container. In the nursery, they are irrigated frequently to keep up with evaporative demand. When transplanted, the rootball provides almost all the water for transpiration until roots have grown into the surrounding soil. Because of the limited amount of available water in the rootball, the plant requires frequent irrigation until it is established and can exploit the surrounding soil for water. Infrequent irrigation after transplanting can therefore result in moisture stress.

Moisture Relations in Transplanted Rootballs. After planting, water supply to the top is limited not only by a relatively

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Moisture Relations in Transplanted Rootballs. After planting, water supply to the top is limited not only by a relatively

small amount of water in the rootball but water may be further limited by water loss from the rootball to the soil surrounding the rootball (Figure 1). Soil at the bottom of the container is saturated (all pores filled with water), and the moisture content decreases with height. When the rootball is removed from the container and planted in the landscape, however, the soil surrounding the rootball can withdraw moisture from the rootball as the surrounding soil drains to field capacity or if the surrounding soil is drier than the rootball. Water will be transferred between the rootball and soil as long as moisture films are continuous.

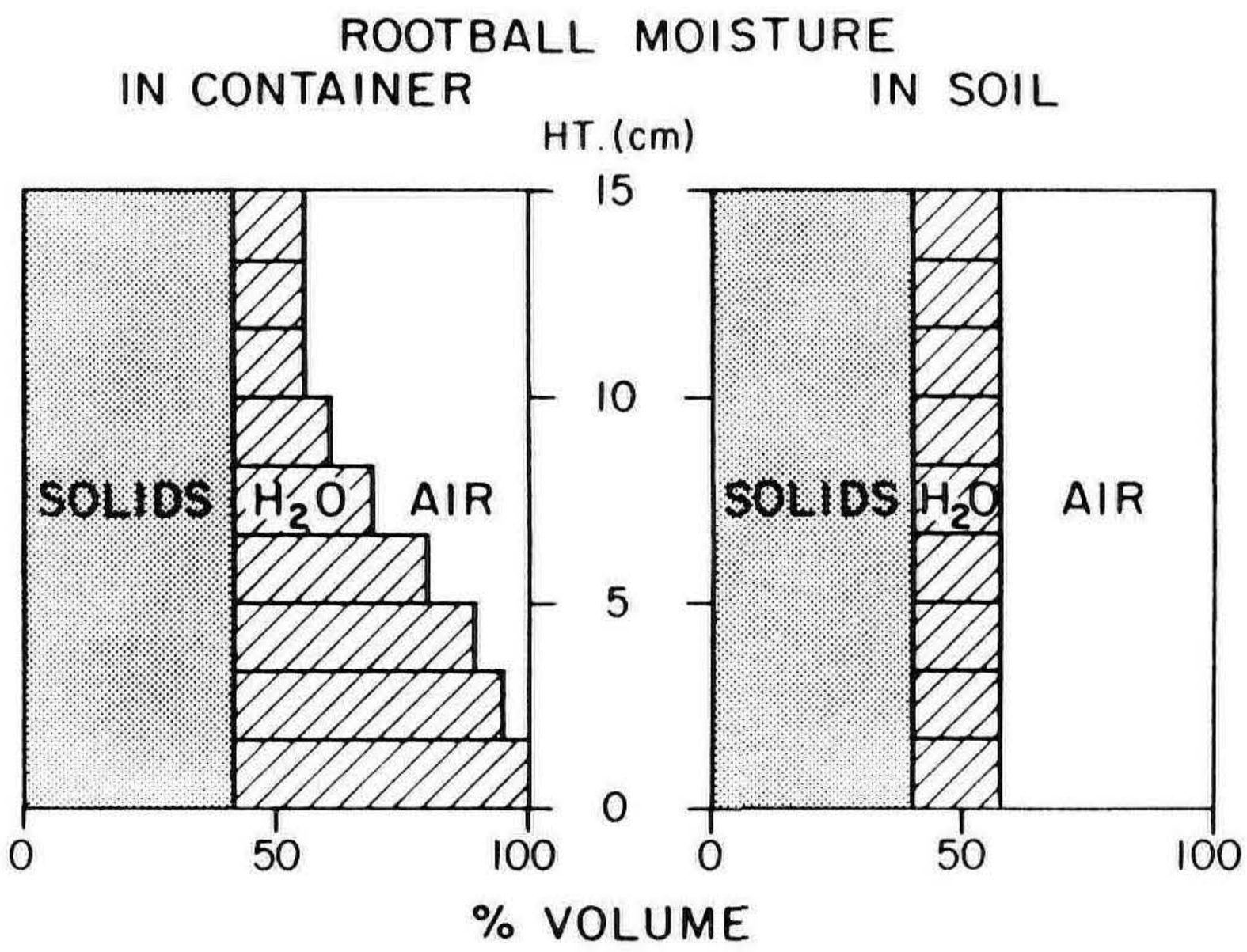

Figure 1. The soil moisture content profile of a container mix following irrigation of a rootball in a container and a rootball transplanted into the soil. When a rootball is placed in the soil, water drains from the rootball into the soil and may even be withdrawn below the field capacity of the rootball by the surrounding soil. Adapted from Spomer (3).

Because less water is retained in a planted rootball, a transplanted plant can dry out in a shorter time than when in the container (2,4). Costello and Paul (2) reported that 24 hours after irrigation, a loss of 85% of the water in transplanted one gallon rootballs compared to a 38% loss in containers. Thus, plants in containers that are irrigated every 2 to 3 days in the nursery would need to be irrigated every 1 to 2 days when planted in the landscape. Daily irrigation of many landscape soils, however, results, in the soil remaining too wet, creating a poor environment for root growth and function. If frequent irri-

gation of the rootball could be done without wetting the soil surrounding the rootball at each irrigation, the soil adjacent to the rootball would be more favorable for root growth and function (1).

In this report two field experiments are discussed which investigate the effects of irrigation on plant establishment. The first experiment was carried out in the summer of 1978 and the second experiment in the summer of 1979. Shrubs grown in U.C. mix (⅓ coarse sand, ⅓ redwood sawdust) in one-gallon containers were used. In the first experiment the objective was to evaluate the benefits of frequent irrigations confined to the rootball compared to frequent and infrequent irrigations to the basin.

1978 Experiment. Comparing root and top growth of *Escallonia rubra* given frequent or infrequent irrigations.

In July, 1978, 15 one-gallon *Escallonia rubra* (Ruiz & Pav.) plants were planted at each of two locations: one with a sandy loam soil and one with a clay loam soil. Thirty-inch diameter basins were built around each plant and filled with 30 liters (8 gallons) of water. A collar of plastic garden edging was placed at the top of the rootball and pushed into the soil at the soil/rootball interface on five of the plants. The collars were filled with 1.8 liters (0.5 gallon) of water every 2 days (Figure 2). Five plants were watered every 2 days by filling the basin with 30 liters of water, and 5 basins were filled every 4 days. For 3 weeks following planting, wilting, necrosis due to desiccation (burning) and plant survival were recorded.

Results. There was no visual difference between the response of the plants in the sandy loam from those in the clay loam, so the data from both locations were combined. All of the plants irrigated in the collar and all of the plants watered every 4 days wilted between each watering. After 30 days, 20% of the collar treatments and 30% of the 4-day basin plants had died, with those surviving showing severe leaf damage. One half of the basin plants receiving 30 liters of water every 2 days wilted between waterings the first week and showed slight foliar damage.

After the first three weeks of the experiment the number of days between irrigations was increased as indicated in Table 1.

For 3½ months after planting, trunk growth and root growth were measured. The trunk growth was not significantly affected by location, although root growth was significantly better in the clay loam soil. The percent increase in trunk crossectional area was significantly greater in those plants irrigated by basin every 2 days (Figure 3), but not between irrigat-

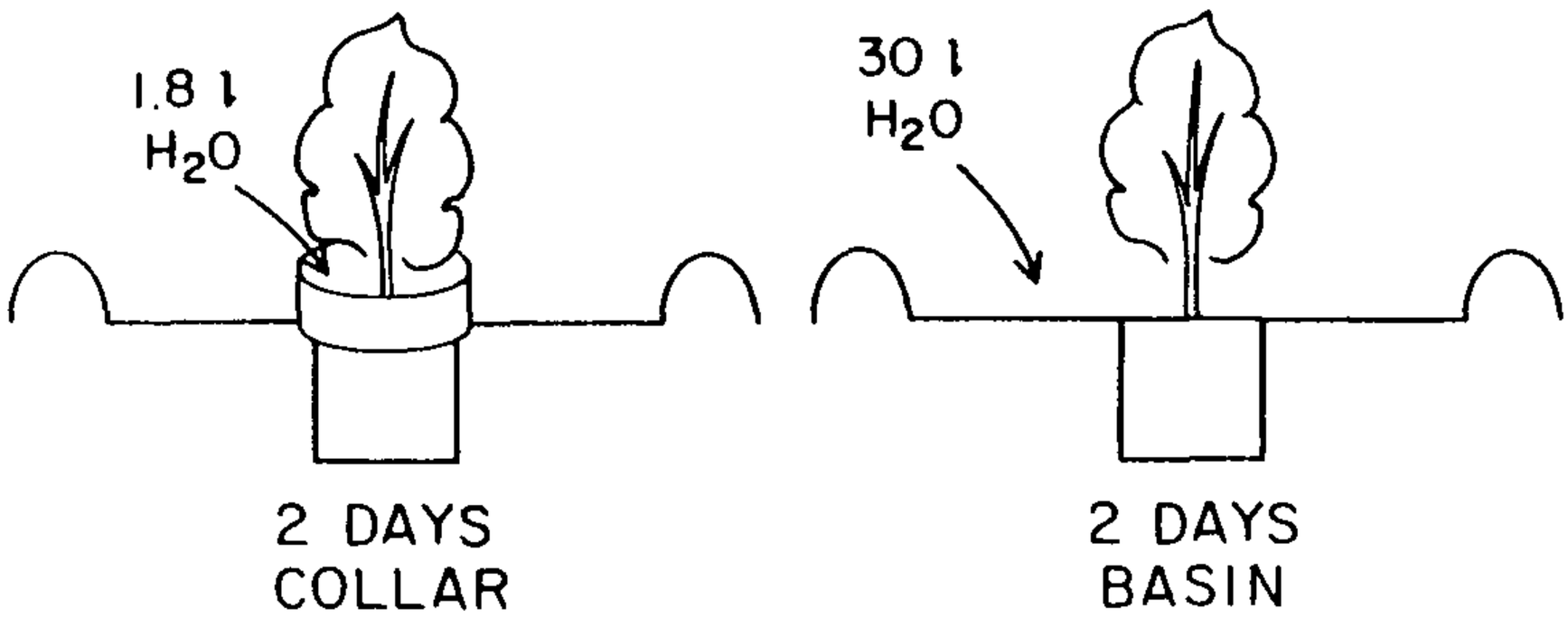

Figure 2. Treatments for the 1978 experiment. One-gallon *Escallonia rubra* plants were transplanted into the field soil and irrigated by filling the basin with 30 liters of water or by filling the collar at the top of the rootball with 1.8 liters of water.

Table 1. Water Schedule for the 1978 Experiment.

	TREATMENTS		
Date	COLLAR	2 DAYS/BASIN	4 DAYS/BASIN
July 20-Aug. 16 (3½ weeks)	2 DAYS/ 1.8 Liters of Water	2 DAYS/ 30 Liters of Water	4 DAYS/ 30 Liters of Water
Aug. 17	30 Liters of Water	30 Liters of Water	30 Liters of Water
Aug. 21-Sept. 5 (2 Weeks)	4 DAYS/ 1.8 Liters	4 DAYS/ 30 Liters	8 DAYS/ 30 Liters
Sept. 6	30 Liters of Water	30 Liters	30 Liters
Sept. 7-Oct. 28 (7 Weeks)	8 DAYS/ 1.8 Liters and 16 DAYS/ 30 Liters	8 DAYS/ 30 Liters	16 DAYS/ 30 Liters

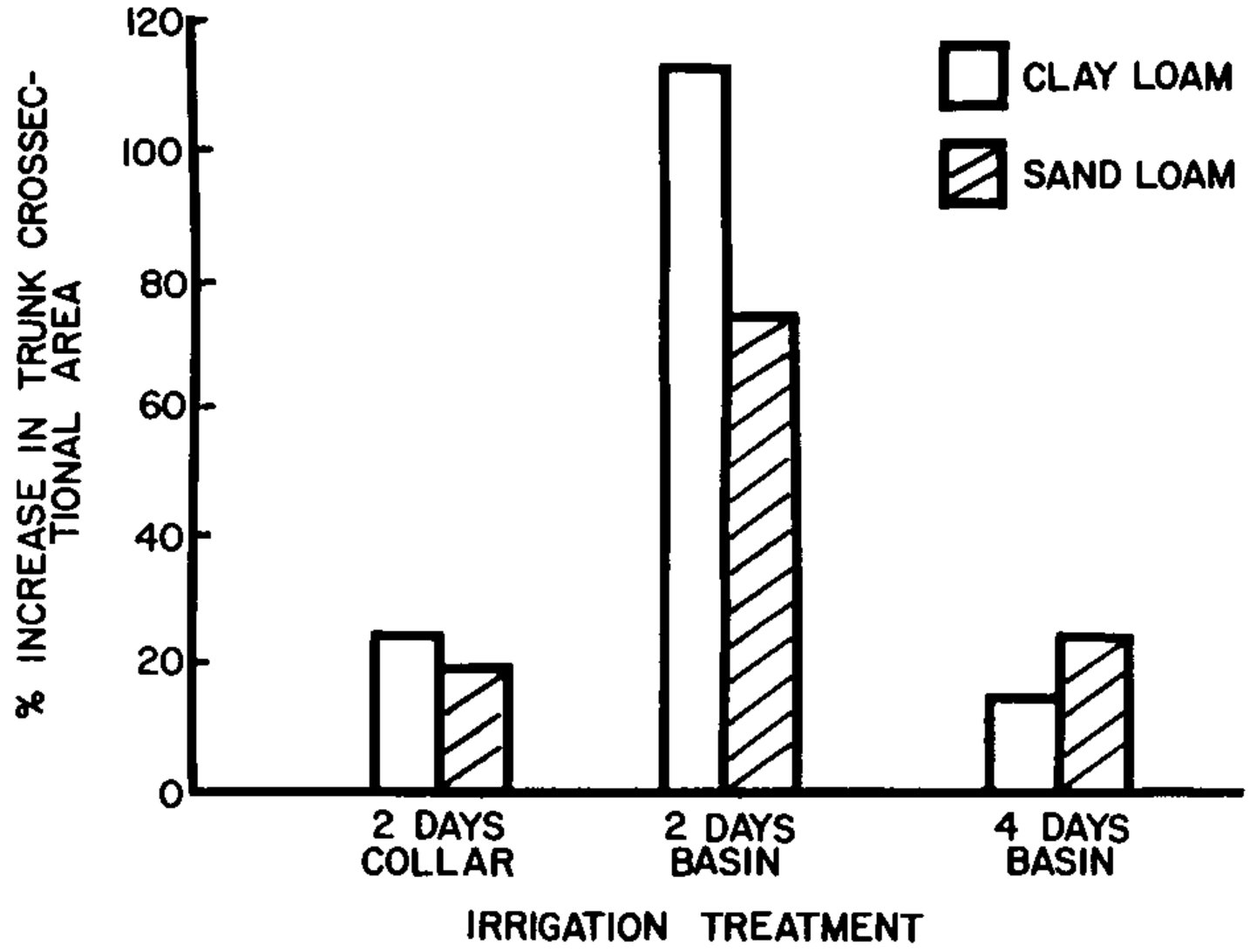

Figure 3. Percent increase in trunk crossectional area of *Escallonia rubra* in response to irrigation treatment in a clay loam soil and a sand loam soil.

ing the collar every 2 days and the basin every 4 days. The same relationship held true for the total number of roots.

The results indicate that water applied only to the rootball every 2 days was not sufficient to keep up with transpirational demand. When the basin was filled every 2 days, the soil remained above field capacity and wet enough to supply water to the rootball. If the surrounding soil was not rewet more often than every four days, even though it was at or near field capacity, the soil could not supply water fast enough to the rootball to prevent wilting and leaf injury.

1979 Experiment. Evaluating treatments to prevent or reduce the transfer of water from the rootball to the surrounding soil.

One way to reduce the loss of water from the rootball would be to break continuity of moisture films between the rootball and soil. A material with coarse pores placed between the rootball and field soil could act as a barrier to water movement due to its low conductivity of water. Preliminary experiments showed that using sand and pea gravel sleeves between the transplanted rootball and the field soil significantly reduced water movement out of the rootball during the first 48 hours following irrigation.

The 1979 experiment was designed to evaluate the effect of a sand sleeve and frequency of irrigation on root growth of *Laurus nobilis* plants. Sand was chosen as the backfill material

(sleeve) because it would be a better medium for root growth than gravel and should be effective in reducing water movement out of the rootball.

In June, 1979, 72 one-gallon *Laurus nobilis* L. plants were planted: 24 with the rootball in contact with the soil and 48 surrounded by a 2 inch sleeve of sand (Figure 4). Half of those in sand were watered by filling the 30-inch basin with 20 liters of water and half by filling a collar at the top of the rootball (as described in experiment 1) with 2 liters of water. All plants were irrigated either every 3, 5, or 10 days to determine the effect of slight, moderate, and severe water stress on root growth. To monitor soil moisture changes, tensiometers were installed with the sensing tip near the middle of the rootball. Tensiometers were also placed in the field soil 2 inches from the rootball, or 2 inches from the sleeve. The moisture release curve (tension vs. moisture content) was determined for the container mix and using the tension values as a function of time, the volumetric moisture content of the container medium was estimated.

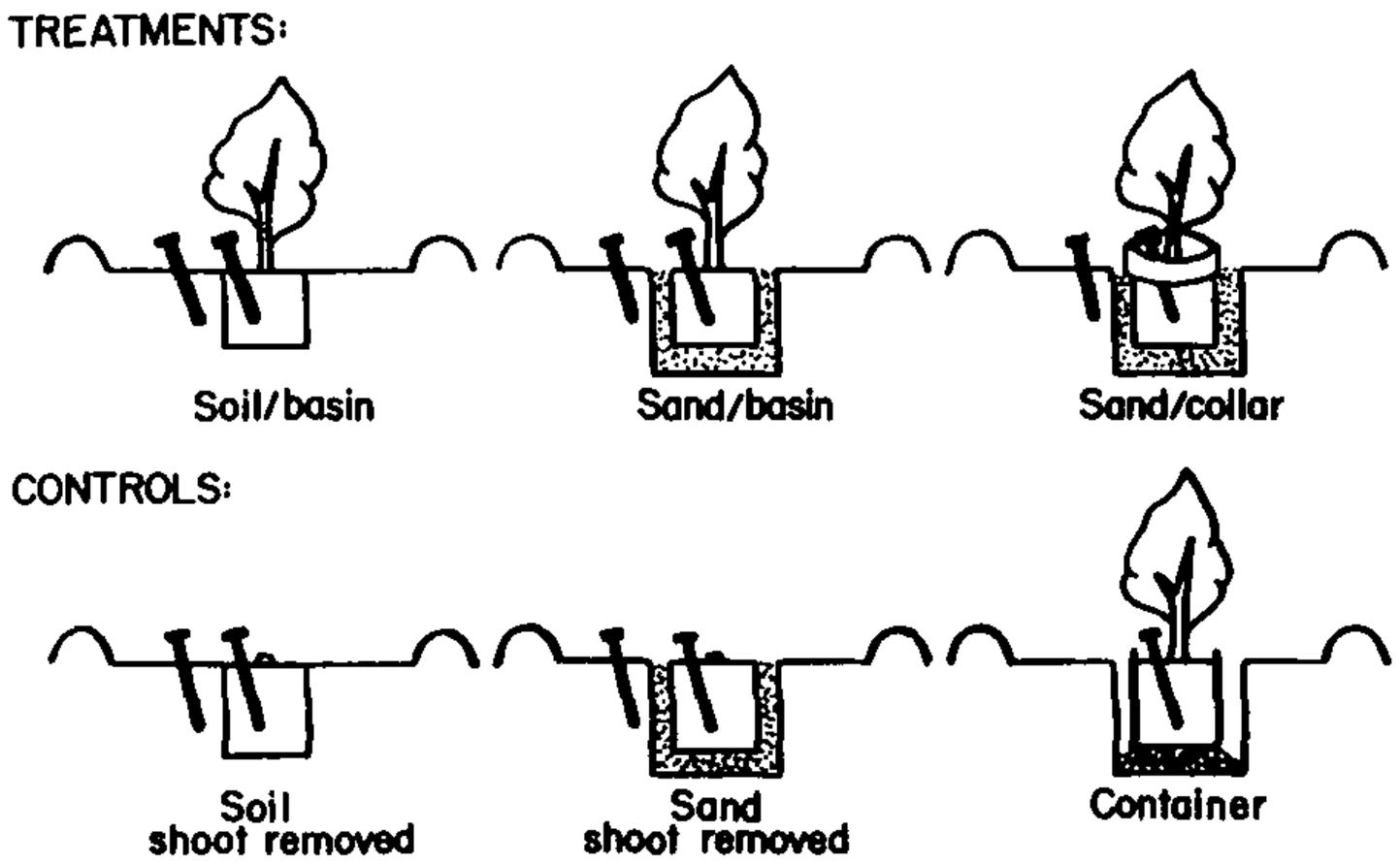

Figure 4. Treatments and controls used in the 1979 experiment. The treatments were irrigated every 3, 5, or 10 days with 8 replications in each treatment. Tensiometer placement in the rootball and surrounding soil is shown.

Three controls were used to help analyze the soil moisture changes in the transplanted rootballs. The transplanted rootballs lost water through drainage into the surrounding field soil and evapotranspiration. To eliminate transpiration losses, the tops of two control plants were removed. One rootball was planted in contact with the field soil (soil/shoot removed) and one in a sand sleeve (sand/shoot removed) with tensiometers installed in the rootball and adjacent field soil. Finally, moisture losses due to evapotranspiration were estimated by putting a tensiometer in the rootball of a third plant left in the container. The con-

tainer was placed into a hole in the ground to keep the rootball at temperatures similar to the transplanted rootballs. About 2 inches of pea gravel were placed in the bottom of the hole so that neither the bottom of the can nor the drainage holes were in contact with the soil.

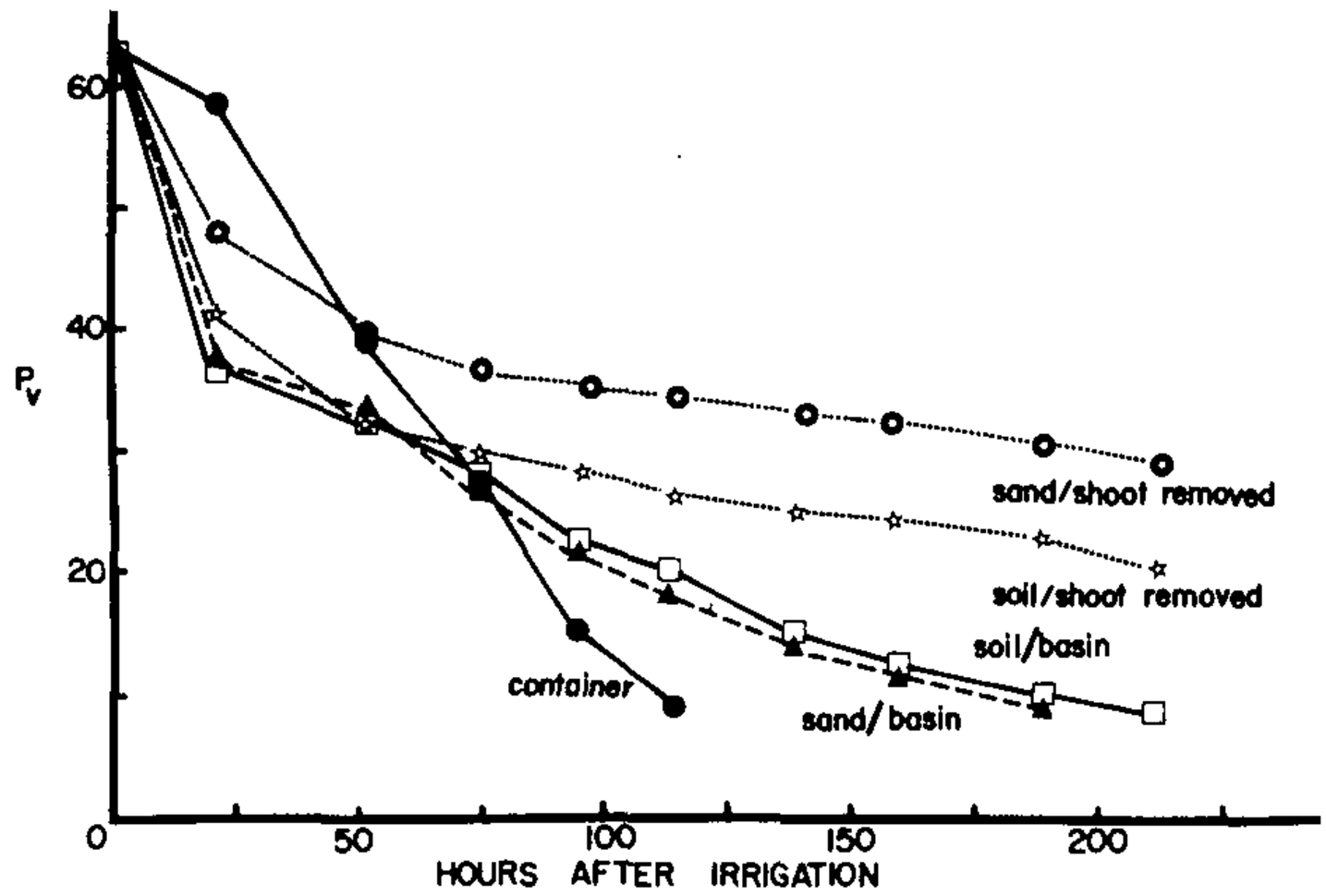

Figure 5. Percent volume of the rootball occupied by water as a function of time after one irrigation cycle for transplants watered every 10 days.

Results. The moisture content of decapacitated rootballs remained higher when surrounded by sand than when in contact with the soil even 212 hours after irrigation (Figure 5). This confirmed the previous finding that moisture transfer between the rootball and the soil could be reduced if a coarse-textured material is placed between the rootball and the soil. However, there seems to be no advantage in using this treatment with an intact plant since there was little difference between the moisture content in the rootball surrounded by sand or soil. No explanation is apparent.

The rootball in the container maintained a higher moisture level than any of the transplanted rootballs for the first 54 hours after irrigation because no moisture was lost to the surrounding soil. After 54 hours, moisture levels fell below those of the transplanted rootballs. The moisture in the rootball in the container was depleted to the wilting point 119 hours after irrigation, while in the transplanted rootballs the moisture content stayed above the wilting point for 188 hours in the sand/basin treatment and 212 hours in the soil/basin treatment. This suggests that water moved from the field soil into the transplanted rootballs. Costello (1) also found that water moved from the surrounding soil into the rootball, although the transpira-

tional demand for water soon exceeded the rate at which the soil could supply moisture to the rootball. The *Laurus nobilis* plants used in this experiment had a relatively smaller leaf area to rootball ratio compared to the leaf area of the *Liquidambar* plants used by Costello (1). Because of the lower water use per rootball, apparently the field soil could supply enough water to the rootball to keep the plants from wilting between irrigations in the present experiment. However, if the plants had a large leaf area and water use per container was high, it is probable that the field soil could not supply water to the rootball fast enough to prevent wilting.

Five weeks after planting, the plants were dug, and the number of emerged roots, root length, and root dry weight were measured.

Root growth was best in the 5-day irrigation treatments and the 3-day sand/collar treatment (Table 2). The poorest growth was from the 10-day sand/basin and sand/collar treatments. The 3-day soil/basin and sand/basin and the 10-day soil/basin treatments were intermediate in the amount of root growth.

Table 2. Growth of roots emerging from 1 gallon plants of *Laurus nobilis* rootballs within 5 weeks after planting.

TREATMENT	TOTAL ROOT Length (cm)	NUMBER OF ROOTS	ROOT DRY WT (mg)
IRRIGATION FREQUENCY			
3 DAYS			
Soil/Basin	118.1^{ab*}	58.2^{ab}	11.5^{ab}
Sand/Basin	159.9^{ab}	70.6^{ab}	15.7^{ab}
Sand/Collar	203.2^{b}	94.6^{ab}	25.1^{ab}
5 DAYS			
Soil/Basin	187.4^{b}	93.9^{b}	29.2^{b}
Sand/Basin	279.9^{b}	110.9^{ab}	29.1^{ab}
Sand/Collar	250.5^{b}	102.2^{ab}	29.4^{ab}
10 DAYS			
Soil/Basin	110.0^{ab}	46.5^{ab}	17.7^{ab}
Sand/Basin	64.6^{a}	39.7^{a}	7.3^{a}
Sand/Collar	53.3^{ab}	46.6^{ab}	6.3^{ab}

* Mean separation, within columns, based on Duncan's Multiple Range Test (59%) of Log transformed Data.

From this and other experiments connected with this study, it appears that a lack of soil aeration in the 3-day basin treatments and insufficient water supply in the 10-day treatments could be the reason for the poorer root growth. However, when only the rootball was rewet in the 3-day sand/collar treatment, adequate water for plant use was provided, yet the soil surrounding the rootball remained well aerated and was a favorable environment for root growth. This suggests that irrigations

confined to the rootball could aid plant establishment under conditions in which the surrounding field soil remains too wet for good root growth between irrigations.

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Ed. Note: Dr. Tsai Ying Cheng, Oregon Graduate Center, Beaverton, Oregon, discussed her work on mass clonal propagation of fruit and shade trees.

A SIMPLIFIED ENTRY INTO TISSUE CULTURE PRODUCTION OF RHODODENDRONS

LYDIANE KYTE and BRUCE BRIGGS

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Some growers are asking if tissue culture is a tool they should try. There is no single answer but with a few guidelines and a modest investment answers are soon evident. In the past two years Briggs Nursery has ventured into rhododendron tissue culture production. This effort is backed up by 10 years of interest and research support. A number of cultivars are now beginning to come out of test tubes and into pots in significant quantities. At this stage of production we feel it appropriate to share some of our beginning experiences including a brief review of starting rhododendrons in tissue culture and some of the systems that have worked for us.

Growers looking for information on how to get started can find help through many sources (5). Among these are agricultural extension agents, colleges, experiment stations, libraries, tissue culture and horticultural organizations, companies that sell tissue culture supplies, and from nurseries engaged in plant tissue culture. Courses in plant tissue culture are available at the W. Alton Jones Cell Science Center in Lake Placid, New York and many universities in the United States. The basic re-

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search for rhododendron tissue culture was accomplished by Anderson (1).

Rhododendrons in tissue culture. Our original cultures were started either by ourselves or other laboratories. There is no particular way to tell when a rhododendron is ready to be cut for starting in tissue culture. Usually the cuttings are taken in a similar state to that for normal propagation by cuttings. Two-inch cuttings are stripped of leaves and terminal bud then washed in water with detergent. They are raised then placed in a 10% solution of household bleach (5% sodium hypochlorite) with a few drops of detergent for 15 minutes. While in this solution they can be agitated by hand, by a magnetic stirrer or in an ultrasonic cleaner. Next they are rinsed in a 1% solution of bleach. Using sterile technique the basal end is trimmed and each cutting is placed in a test tube containing sterile media.

If successful, the cuttings will prove to be uncontaminated and start growing. Growth first takes place by development of one or more axial buds. If it is going to happen at all such growth usually occurs from two to eight weeks after starting. The leaves produced in these breaks are very small. In addition to the nodal breaks a green, granular tissue mass may form. Each granule of this mass is a potential shoot.

The axial shoots are weaned from the original cutting in two or three transfers by removing more of the original stem in each successive transfer. These early transfers may be required every two weeks as determined by the size or the deterioration in color of the explant. As the shoots grow they may be cut into 1 inch sections and laid on fresh agar where they will produce more shoots. Any tissue mass that has grown can also be divided. In this way the multiplication stage is reached in a few months from when the cutting was first taken. Later transfer intervals should be six to eight weeks apart. It was of experimental interest that some cultures which were held in a dimly lighted refrigerator for a year suffered no ill effects.

Rooting. At anytime in the multiplication stage one may wish to remove shoots for rooting and growing on. Shoots are transferred to a sterile root-inducing, agar medium or removed from sterile culture and placed in a growing mix in a covered or misted container. In either case roots appear in about two months. In six months to a year they produce normal size foliage and are ready for gallon cans. The few cultivars we have observed through blooming stage appear true to form. More experience is needed to evaluate genetic stability both in general and on specific cultivars.

To root rhododendrons while still in sterile culture, we maintain the sugar concentrations (30 g/l), eliminate 2IP, IAA, and

KI, reduce the remaining constituents to ⅓ strength, and add activated charcoal (Gibco, 600 mg/l) (2,4). Our work indicates that rooting occurs soon, (one month in some) in agar containing only sugar (30 gm), IBA (5 mg), and activated charcoal (800 mg/l).

Greenhouse rooting of tissue cultured rhododendrons. Anderson has discussed some of the problems of rooting tissue cultured rhododendrons in soil mixes (3). We use peat, perlite, decomposed bark (1-1-1) with a covering of screened sphagnum moss. Flats, trays or 4″ pots are satisfactory for rooting. PLANTCON covers fit over 4″ pots to make a desirable covered container. The constant temperature and light of a controlled growth room are ideal for this demanding stage of development (6). As soon as plants are rooted, then hardened to greenhouse conditions, they are transplanted to individual cells.

Facilities. The first laboratory at Briggs Nursery was an old kitchen adjacent to the office. The first growth room was a back closet with lighted shelves. A homemade transfer chamber with an ultraviolet light and a small (1′ × 2′) HEPA (high efficiency particulate air) filter was satisfactory for transferring (5). This chamber was located in a closed off corner of an existing greenhouse. More lighted shelves for tubes were added in another corner of the same greenhouse. With these simple facilities, we multipled the cultures to about 3000 tubes.

In a few months we outgrew our original facilities. A three room laboratory was built within a new greenhouse with room for expansion. The 15′ × 15′ media preparation room is basically a home kitchen with storage, stove, dishwasher, refrigerator, and sink. A faucet with deionized water leads from a treatment tank in an adjacent restroom. Next to the media preparation room a small corridor has sliding glass doorways which open into the transfer room or the tube room. The 10′ × 10′ transfer room contains an eight foot commercial laminar flow hood (transfer chamber). Air is blown through the HEPA filter providing sterile air in which to work when transferring. The tube room is 12′ × 18′. It has a total of 400 square feet of shelf space which can support approximately 20,000 cultures or 200,000 or more potential plants. The cultures are 18″ from the fluorescent lights and receive 100 to 250 foot candles of light 16 hours a day. Most of the fluorescent tube ballasts have been removed and placed in an adjoining room to eliminate excessive heat in the tube room. Pass-through windows allow material flow between the preparation room and the transfer room and between the transfer room and the tube room. Temperature is controlled between 70° and 80°F with air conditioners and electric wall heaters.

As we expanded, the plastic racks which hold ten test tubes required too much room and handling. An excellent off-the-shelf tube holder was found in the 128 hole, 2½" deep SPEEDLING plastic foam tray commonly used for seedlings. These shallow, square-holed trays hold the tubes on a slant, are lightweight and easily moved. In our search for economy of room we also use 25 mm deep plastic petri dishes and PLANTCONS, a much taller dish we use for rooting.

Media Preparation. The agar media we use are Murashige and Skoog formulae as modified by Anderson (1) as given in Table 1. Nine liters of medium are mixed at one time in an enamel pan. As the chemicals are added to deionized water to mix the formula they are checked off on a list of ingredients. An adequate balance for weighing chemicals can be a major expense. We bought two used balances, a ROLLER SMITH, which weighs up to 500 milligrams, and a HARVARD balance for larger quantities. No weighing is required if a grower buys pre-mixed media. We use an inexpensive pH meter to bring the media to a pH of 4.5. Some commercial mixes have the pH pre-adjusted.

Table 1. Rhododendron medium (Multiplication).

Chemical	Mg/l	Chemical	Mg/l
Sucrose	30000.00	Magnesium sulphate	370.00
Inositol	100.00	Manganous sulphate	16.90
Adenine sulphate	80.00	Zinc sulphate	8.60
Ammonium nitrate	400.00	Copper sulphate	
Potassium nitrate	480.00	EDTA	74.50
Sodium phosphate (monobasic)	380.00	Ferrous sulphate	55.7
Boric acid	6.20	Thiamine hydrochloride	0.40
Sodium Molybdate	0.25	IAA	1.00
Calcium chloride		2IP	5.00
Potassium iodide	0.83	Agar	6000.00
Cobalt chloride	0.03	(pH 4.5)	

The medium must be heated to dissolve the agar (which is a gelatinous extract from seaweed) in it. We heat the medium in three-liter batches in an Erlenmeyer flask on a combination hot plate magnetic stirrer. When heated, the medium is poured from a pitcher into test tubes (18 ml per tube) which are held in 40-hole test tube holders. The test tubes we use are the disposable type made of borosilicate glass. We reuse these tubes indefinitely. For sterilizing we use a household type pressure cooker canner. The canner basket is lined with screen so it will hold the test tubes. Before processing for 15 minutes at 15 lbs pressure the tubes are capped with permeable membrane closures or caps which have been stuffed with a little cotton to help insure against contaminants. After the basket of tubes is processed, it is slanted until the agar is cooled and solidified. The medium is first sterilized in quart jars if it is to be poured into sterile plastic petri dishes or PLANTCONS which cannot be heat sterilized. The dishes are poured with medium inside the transfer

chamber. The medium should be stored in a dust-free area until it is used.

Procedures. Sterile technique is basic to the whole tissue culture operation. It requires an imagination to realize sources of contamination. Particularly in the transfer chamber it is necessary to be aware of what is sterile and what is not. If chamber air flow is obstructed contaminated air may enter the chamber. Tube racks may have contaminants blown from them onto exposed sterile cultures. Solutions of household bleach (10% and 1%) are used for disinfecting gloved hands, implements, petri dishes, and counter tops. Implements must be of stainless steel so they will not corrode in the bleach. Frequent dips into the strong and then the weak solutions are essential. The weaker bleach solution does not harm most cultures. Some laboratories prefer to use alcohol and flame but we find the bleach solutions simple and effective.

General cleanliness is essential but hospital sterility is not practical. No vacuum cleaner or broom should be used in the area due to the dust they may circulate. Floors should be wet mopped every day and counter tops scrubbed. No moldy culture tubes should be opened before sterilizing them. Moldy petri dishes should be handled so as not to disperse the spores into the lab. Good soil catching mats at the door will help keep out nursery soil.

Several housekeeping chores are done in the transfer room. Tubes with freshly divided cultures are labeled with cultivar number, date, and kind of medium. When a transfer is made there is often some dark basal debris which is cut off and discarded. To make this disposal easier we cut up commercial paper toweling into 2½" squares and sterilize them in a covered beaker. A clean paper is placed in a petri dish each time a culture is removed from a tube and placed in the dish for cleaning and dividing. At this time tube caps removed from the used tubes are dropped into a box. The caps are reused later without washing because they are chemically clean and will be sterilized after capping fresh tubes. Plastic petri dishes with cultures are taped shut with PARAFILM to reduce contamination potential, to prevent the extended shoots from forcing the lid off, and to permit easy handling.

The used tubes, still with media but without plants or debris, are returned to the media preparation room. There they are placed in racks which hold 40 upright tubes. Hardware cloth (coarse wire screen) is secured over the tops of the uncapped tubes in the racks. The wire covered racks holding the tubes are inverted and placed in this dishwasher which melts and removes the medium and cleans the tubes. The plastic petri dish-

es are hand washed then dipped in bleach solutions in the transfer chamber before pouring with fresh agar.

Conclusions. At Briggs Nursery we have worked out some of the fine points of getting started in tissue culture. There are several advantages to this method of propagation. From a single cutting there is potential for an infinite number of plants providing no mutations occur. Plants in tissue culture reproduce regardless of season. There is no watering requirement until plants are removed from sterile culture. Thousands of plants can be started in a comparatively small area. We believe we can produce rhododendrons at equal or less cost in the same time frame as by traditional means.

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1. Anderson, W.C. 1975. Propagation of rhododendrons by tissue culture; Part 1. Development of a culture medium for multiplication of shoots. Proc. Int. *Plant Prop. Soc.*, 25:129-135.
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VIRUS ELIMINATION AND RAPID PROPAGATION OF GRAPES *IN VITRO*

ROBERT E. HARRIS and JOHN H. STEVENSON

Agriculture Canada, Saanichton Research Station
Sidney, B.C. V8L 1H3, Canada

Abstract. Heat treatment and *in vitro* culture of shoot tips were used to free *Vitis vinifera* 'Liemberger' of leafroll virus and 'Forta' and 'Auxerrois' ('Cl-21') of fanleaf virus. Rapid propagation of the French hybrid 'Baco' was obtained on full-strength MS medium plus adenine sulfate (80 mg/l), $NaH_2PO_4 \cdot H_2O$ (170 mg/l), i-inositol (100 mg/l), thiamine-HCl (0.4 mg/l), and BAP (3 to 4 mg/l). Rooting of proliferated shoots was most rapid on ¼-strength MS with 0.08 mg/l IBA. The method appears suitable for the rapid propagation of other cultivars.

INTRODUCTION

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transferred to a 1:1 mixture of sterilized peat and vermiculite in high humidity for 3 to 7 days. When the plants from the virus eradication program were well established they were indexed by the PEQ Station.

Unless otherwise stated shoot-tips from the French hybrid Baco 22A were used.

Effect of Medium Strength and Addition of Adenine Sulfate ($AdSO_4$) and Monobasic Sodium Phosphate ($NaH_2PO_4 \cdot H_2O$): Shoot-tips were cultured on full-, ¾-, and ½-strength MS media with 3 mg/l 6-benzylaminopurine BAP, and with or without 80 mg/l $AdSO_4$ and 170 mg/l $NaH_2PO_4 \cdot H_20$. The explants were cultured on agar medium for 56 days followed by 16 days in liquid medium of the same composition. Shoots $\geq$ 2 cm long were removed and counted 82 and 102 days after the start of cultures and 6 shoots from each treatment placed on rooting medium. After 102 days shoots $<$ 2 cm were also counted.

Effect of BAP Concentration in Initial Culture Medium: Shoot-tips were cultured on agar with 0, 1, 2, 3 and 4 mg/l BAP for 27 days, recultured on agar for a further 17 days, and then transferred to liquid media. Sixty days after initial culture, 6 shoots $\geq$ 2 cm in length from each treatment were placed on rooting medium. Two cultures from each treatment were each divided into 3 parts and recultured for a further 45 days on media with the original BAP concentration as the parent cultures.

Effect of BAP Concentration for Continuous Culture: Shoots were removed from the 3 mg/l BAP treatment in the previous experiment. Six shoots 2 to 3 cm long were cultured on 5 ml of liquid medium in 50-ml erlenmeyer flasks with 0, 1, 2, 4 & 5 mg/l BAP. The following procedure was followed:

No. of days after initial culture	
70	Shoots $\geq$ 2 cm removed and counted. Two reps of each treatment were: 1) divided into 3 parts and recultured into 125-ml erlenmeyers. 2) recultured into 455-ml jars containing 30 ml of medium without cytokinin. 3) recultured into jars on media with the same BAP concentration as the parent culture (A).
90	Cultures in 125-ml flasks recultured as after 70 days; 2 each divided and cultured in 125-ml flasks, 2 recultured in jars with, and 2 in jars without BAP (B).
111	Two reps in 125-ml flasks divided and recultured as before, and 4 reps recultured to jars with the same BAP concentration (C). Shoots from A cultures counted in two sizes $\geq$ 2 cm and $<$ 2 cm and 6 shoots $\geq$ 2 cm of each treatment placed on rooting medium.
122	122 shoots from B culture counted as before.

Power Twist lamps providing 2000 lux for 16 hrs/day.

VIRUS ELIMINATION

The medium was made up of the macronutrients of Morel and Muller (8), 0.5 ml/l of Berthelot's (3) micronutrients, and organic supplements (Table 1). After about 14 days when the explants were approximately 1 cm long they were transferred to filter paper bridges in tubes containing 15 ml of liquid medium for rooting. The rooting medium had the same composition as the growth medium but minus potassium chloride (KCl), ammonium sulfate $(NH_4)_2SO_4$ and naphthalene acetic acid (NAA).

Table 1. Nutrient medium used for growing shoot-tips of grapes for virus eradication.

Macronutrients (Morel & Muller)	mg/l	Micronutrient Stock	mg/100 ml
$(NH_4)_2SO_4$	1000	$MnSO_4 \cdot 4H_2O$	161
KCl	1000	KI	50
$Ca(NO_3) \cdot 4H_2O$	500	$NiCl_2 \cdot 6H_2O$	5.6
$MgSO_4 \cdot 7H_2O$	125	$CoCl_2 \cdot H_2O$	6.0
KH_2PO_4	125	$ZnSO_4 \cdot 7H_2O$	10
		$BeSO_4 \cdot 4H_2O$	10
		$CuSO_4 \cdot 5H_2O$	5
		H_3BO_3	5
		$NaMoO_4 \cdot 2H_2O$	0.015
Organics etc.*	mg/100 ml	Organics etc.*	mg/100 ml
Thiamine-HCl	100	Calcium pantothenate	100
Pyrodoxine-HCl	100	Inositol	1000
Nicotinic acid	100	Biotin	1.0

* Add 0.5 ml of micronutrient and 1.0 ml of organic stock to the amount of macronutrients shown and dilute to 1000 ml.

RAPID PROPAGATION

The basic medium contained Murashige & Skoog (9) (MS) salts with 100 mg/l i-inositol, 0.4 mg/l thiamine-HCl, and 30 g/l sucrose. The pH was adjusted to 5.7 for agar and 5.0 for liquid media.

When the proliferating shoot-tips were 20 to 25 mm in diameter they were transferred to 15 ml of liquid medium of the same composition in 125-ml erlenmeyer flasks stoppered with aluminum foil. The flasks were placed upright on a device which tilted the flasks 35° in opposite directions 3 times per minute, thus the explants were alternately exposed and submerged. Agar cultures were recultured every 4 weeks and liquid cultures every 3 weeks.

Proliferated shoots were removed when they were 2 to 3 cm long and placed on filter paper (Whatman #5) bridges in culture tubes containing 15 ml of $^2/_5$-strength MS salts with 0.3 mg/l indoleacetic acid (IAA) and 20 g/l sucrose for rooting.

When the root system was well developed the plants were

transferred to a 1:1 mixture of sterilized peat and vermiculite in high humidity for 3 to 7 days. When the plants from the virus eradication program were well established they were indexed by the PEQ Station.

Unless otherwise stated shoot-tips from the French hybrid Baco 22A were used.

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ROOTING

Effect of Agar vs. Liquid Rooting Media: Six shoots from each of 6 treatments were placed either on agar or on bridges on liquid media; the number rooted were counted every 3 to 4 days.

Effect of Medium Strength and Sucrose Concentration for Rooting: Six proliferated shoots $\geq$ 2 cm were put on each of either normal-, ¾-, ½- or ¼-strength MS medium. The normal strength medium contained 100 mg/l i-inositol, 0.4 mg/l thiamine-HCl, and 0.3 mg/l IAA, and the ¾-, ½-, and ¼-strength a proportional amount of each of the above. Sucrose was added to provide 10, 20, 30 and 40 g/l at all media strengths.

PROLIFERATION OF OTHER GRAPE CULTIVARS

To determine the feasibility of propagating other grape cultivars *in vitro*, 12 virus-free and 2 virus-infected cultivars were established *in vitro* and 6 were included in rooting experiments on either full-, ¾-, ½- and ¼-strength MS with 0 to 2 mg/l IAA.

RESULTS

VIRUS ERADICATION

There was very little difficulty in growing shoot-tips to 1- or 2-cm in length, but rooting was very inconsistent and the ability to root varied considerably among accessions.

Sixty-three plants of 33 accessions were grown and rooted. Of the 63 plants, 28 were not indexed because other sources of virus-free material had become available and another 13 were discarded because the accession was no longer required by the growers.

Eleven plants were indexed, with 5 positive, 3 suspicious, and 3 testing negative. The 11 plants remaining were duplicates of the above and are now entering the indexing program.

The 3 accessions which have tested negative are all *Vitis vinifera*; cvs Liemberger, Forta and Auxerrois (Cl-21). 'Liemberger' was infected with both leafroll and fleck while the other two were infected with fanleaf virus.

RAPID PROPAGATION

Effect of Medium Concentration: Three-quarter strength medium produced about twice as many shoots as full- and ½-strength media when $AdSO_4$ and$NaH_2PO_4 \cdot H_2O$ were omitted (Table 2). With the addition of both compounds there was no difference in the number of shoots produced between full- and ¾-strength media, while shoot production on ½-strength medium was slightly lower.

Rooting of shoots from full-strength medium was more

rapid both with and without the addition of $AdSO_4$ and $NaH_2PO_4 \cdot H_2O$ than from ¾- or ½-strength (Table 3).

Table 2. Effect of strength of medium, with and without $AdSO_4$ and $NaH_2PO_4 \cdot H_2O$ on proliferation of 'Baco' grape *in vitro*.

	Mean No. of shoots $\geq$ 2 cm produced in 102 days[1]	
Medium strength	With	Without
Normal	17.3	6.3
¾	18.8	13.3
½	14.2	7.7

[1] Two cultures of each treatment were divided into 3 parts and recultured after 82 days. To determine total potential production multiply by 3.

Table 3. Effect of strength of medium with and without $AdSO_4$ and $NaH_2PO_4 \cdot H_2O$ in proliferation medium on subsequent rooting of 'Baco' grape.

		No. shoots which rooted[1]			
Medium strength		With		Without	
	No. of days →	11	16	11	16
Full		6	6	4	6
¾		5	5	0	2
½		5	6	0	2

[1] Maximum 6

Effect of the Addition of $AdSO_4$ and $NaH_2PO_4 \cdot H_2O$. The addition of 80 mg/l $AdSO_4$ and 170 m g/l $NaH_2PO_4 \cdot H_2O$ increased shoot production approximately 180% on full strength medium, and 40 and 50% on ¾- and ½-strength media (Table 2). In addition, these compounds either decreased the time to root and/or the percentage of rooted shoots on all media strengths (Table 3). On full strength media 100% rooting was achieved in 11 days with $AdSO_4$ and $NaH_2PO_4 \cdot H_2O$ as compared to 16 days without these compounds.

The Effect of BAP Concentration for Initial Culture of Shoot-tips. The O BAP treatment grew poorly and was discarded after 28 days. After 67 days in culture, explants on media with 4 mg/l BAP had produced an average of 5.5 shoots over 2 cm long as compared to 4.8, 3.2 and 1 for 3, 2 and 1 mg/l BAP respectively (Table 4).

After 11 days, more shoots had rooted from BAP cultures with 2 and 4 mg/l than from the 3 mg/l treatment, but after 17 days the number of rooted shoots were similar to all BAP concentrations (Table 5). Concentration of BAP had no consistent effect on the number or branching of primary roots that developed.

The Effect of BAP Concentration for Continuous Culture. Growth was very slow in the 0 BAP treatment and little or no proliferation of shoots occurred in the 1 mg/l BAP treatment.

Table 4. Effect of BAP concentration in initial culture medium on shoot production of 'Baco' grape.

mg/l BAP	Length of shoots No. of days →	Mean number of shoots produced[1]			
		≥ 2 cm		< 2 cm	Total
		60	105	105	—
1		1.0	2.5	2.5	6.0
2		3.2	9.3	6.0	17.2
3		4.8	14.5	9.3	27.8
4		5.5	6.8	7.7	20.0

[1] Cultures were divided into 3 parts after 60 days. To obtain an estimate of potential production after 105 days multiply by 3.

Table 5. Effect of BAP concentration in proliferating medium on subsequent rooting of proliferated 'Baco' grape shoots.

mg/l BAP in proliferation medium	No. of shoots rooted[1] No. of days on rooting medium	
	11	18
1	1	3
2	3	5
3	0	6
4	3	5

[1] Maximum 6

These treatments were discontinued after 31 and 60 days, respectively. At all harvest intervals up to 122 days, 4 mg/l BAP cultures produced more shoots than other concentrations (Table 6). Explants recultured on a medium without BAP failed to develop shoots.

Shoots from 2 mg/l BAP cultures usually rooted more rapidly than those from other treatments but the concentration had no significant effect on the total number of shoots that rooted (Table 7).

Table 6. Effect of continuous culturing on medium with different amounts of BAP on shoot production of 'Baco' grape.

No. of days cultured	Length of shoots (cm)	No. of shoots produced BAP concentration (mg/l)				Multiplication factor[1]
		2	3	4	5	
90	≥ 2	8.4	6.6	9.4	7.2	3
111	≥ 2	40	25	60	28	9
	< 2	36	27	40	30	9
	Total	76	52	100	58	9
122	≤ 2	22	19	43	28	27
	≥ 2	30	52	93	38	27
	Total	52	71	136	66	27

[1] Cultures were divided into 3 parts at intervals. To obtain an estimate of potential production if all cultures had been retained multiply by the factor shown.

Table 7. Effect of BAP concentration in proliferation medium on subsequent rooting of 'Baco' grape shoots.

Experiment	No. of days to rooting	No. of shoots rooted[1] BAP concentration (mg/l)			
		2	3	4	5
A	12	3	2	2	1
	18	4	5	4	5
B	12	3	1	1	0
	18	3	3	4	1

[1] Maximum 6

ROOTING PROLIFERATED SHOOTS

Agar vs. Bridges on Liquid Medium. After 8 days on rooting medium, 9 out of 18 shoots had rooted on bridges as compared to 2 out of 18 on agar. After 18 days 16 shoots on bridges and only 3 on agar had rooted.

Effect of Medium Strength and Sucrose Concentration: Eight days after culturing on rooting medium more shoots had rooted on all sucrose concentrations on ¼-strength MS than all other medium strengths. Similarly, at all medium concentrations more shoots rooted on 20 g/l sucrose than at all other concentrations (Table 8).

Fourteen days after culturing on rooting media the number of shoots that rooted on ½-strength and ¼-strength media were similar and concentrations of sucrose had no consistent effect. At normal- and ¾-strength media, more shoots rooted with 30 g/l sucrose, at ½-strength medium with 20 and 40 g/l, and at ¼-strength with 20 g/l.

Table 8. Effect of rooting medium strength and sucrose combination on rooting of proliferated shoots of 'Baco' grape.

Medium Strength	Days cultured →	No. of shoots rooted[1]									
		8					14				
	g/l sucrose →	10	20	30	40	Mean	10	20	30	40	Mean
Normal		2	3	2	2	2.2	3	4	5	5	4.2
¾		3	4	3	2	3.0	4	4	5	4	4.2
½		3	5	3	5	4.0	4	5	4	5	4.5
¼		5	5	4	4	4.5	5	6	4	4	4.8
Mean		3.2	4.2	3.0	3.2		4.0	4.8	4.5	4.5	

[1] Maximum 6

PROLIFERATION OF OTHER CULTIVARS

All 14 cultivars were eventually established on proliferating medium. Those that failed to establish on the first attempt established readily on later attempts. 'Foch,' 'Schonberger,' 'Ortega,' 'Reichensteiner,' 'Leon Millot' and 'Oraniensteiner' proliferated readily with 2 to 3 mg/l of BAP, and rooted fairly readily on ¼- and ½-strength MS medium with 0 to 1 mg/l IAA.

The 3 rootstocks ('5BB,' '5C' and 'SO_4') and 'Pinot Noir,' 'Okanagan Riesling' and 'Rotberger' were slow to establish and proliferate. The two virus-infected accessions established, proliferated, and rooted readily.

DISCUSSION

VIRUS ERADICATION

Gifford and Hewitt (7) report that shoot-tips from heat-treated plants grew rapidly *in vitro* but only 2% of them rooted. Galzy & Compan (5) also indicate poor rooting if shoot-tips are taken from the initial culture but report that shoot-tips taken from explants in culture rooted more readily. Many variations of the proliferating and rooting media were tried but with little or no improvement on rooting.

The variation in rooting ability among accessions may have been due to a difference in photoperiod requirements as found by Alleweldt and Radler (1). They found short-day types of grapes in which the shoot-tips growing *in vitro* only rooted if the donor plants had been growing in 13 to 17 hour photoperiods, and long-day types which only rooted profusely if donor plants were grown in 10 hour photoperiods. Determining the photoperiod requirements of each cultivar would be a lengthy process. A better approach might be to grow the shoot-tips of heat-treated plants in a proliferating medium, and maintain them until rooted plants from proliferated shoots are well established in soil. This would reduce the danger of losing the heat-treated shoot-tip if rooting does not take place.

Three virus-free plants out of the 11 indexed is not a high percentage but is higher than that obtained by the shoot grafting method. Also, one of the accessions ('Liemberger') has proven extremely difficult to clean up by other methods and the eradication of leafroll virus by heat treatment and *in vitro* culture is the first reported. Both other accessions were infected with fanleaf virus which had been eliminated in other cultivars by both Gifford and Hewitt (7) and Galzy and Compan (6).

RAPID PROPAGATION

Several preliminary experiments showed that more consistent results were obtained by starting the shoot-tips on agar medium than on liquid medium. However, these tests also showed that after an initial 4 to 6 weeks on agar much more rapid shoot proliferation and growth could be obtained by transferring to liquid medium. Consequently, this procedure was followed.

Results confirmed preliminary experiments that ¾-strength MS salts produced more shoots than full- or ½-strength. How-

ever, the addition of $AdSO_4$ and $NaH_2PO_4 \cdot H_2O$ increased shoot production more on full-strength medium than on either ¾- or ½-strength so that with the additions there was little or no difference between full and ¾-strength. The addition of $AdSO_4$ and $NaH_2PO_4 \cdot H_2O$ also increased rooting, and on full-strength medium initiated the earliest rooting. In future experiments full-strength MS salts with $AdSO_4$ and $NaH_2PO_4 \cdot H_2O$ were used.

Optimum concentration of BAP was 3 mg/l for initial culture of shoot-tips and 4 mg/l for continuous culture. However, the intervals between counts can affect the number of shoots obtained at different levels. At low BAP concentrations relatively few shoots are produced and these grow rapidly, thus enhancing counts taken at short intervals. If longer intervals are used between counts, the larger number of shoots produced by higher concentrations of BAP have a chance to grow and be counted.

Shoots produced with low (2 mg/l) BAP concentrations tended to root slightly earlier than higher concentrations, but transferring proliferating cultures from a medium with BAP to the same medium without any BAP resulted in a nearly complete inhibition of shoot growth. It remains to be determined whether reducing the BAP concentration from 3 or 5 mg/l to 2 mg/l or less on the last reculture will result in equal or better shoot growth and rooting.

It was not practical to continue growing all cultures indefinitely, so after counting the number of shoots produced, 4 of the 6 reps from each treatment were discarded at each reculture interval. The 2 remaining cultures were divided into 3 and recultured. This effectively reduced the potential shoot production by ⅔ each time this was done. The multiplication factor in Table 6 is the amount that each figure should be multiplied by to arrive at the potential yield of each treatment at the date given. The potential yield is, however, even greater since by placing each shoot on proliferating instead of rooting medium, each shoot should produce 540 more shoots in 111 days with 4 mg/l BAP, as can be determined from Table 6.

ROOTING

Throughout the preliminary experiments rooting was very inconsistent. Sometimes 100% rooting could be obtained in 8 days while at other times 100% rooting could not be obtained in 30 days. The results reported here indicate that more rapid rooting occurs in full-strength MS with $AdSO_4$, $NaH_2PO_4 \cdot H_2O$, and 2 mg/l BAP in proliferating medium. Reducing the rooting medium to ¼-strength also increased rooting but it needs to be ascertained whether this is due to the decreased salt

concentration or lower auxin.

Galzy (5) obtained a higher emergence and growth of roots at 35°C than at 20°C, and a higher emergence of roots if $(NH_4)_2SO_4$ was added to the medium and the KNO_3 replaced by KCl. This change in salt composition, however, reduced root growth. Barlass & Skene (2) rooted <3 mm long proliferated shoots of *V. vinifera* L., cv Cabernet Sauvignon on White's (10) medium.

Further work is needed to improve the consistency of rooting.

SUMMARY

The work reported above has shown that both fanleaf and leafroll viruses can be eradicated from grape plants by *in vitro* culture of heat-treated shoot-tips. It has also been shown that grape cultures can be rapidly proliferated *in vitro* on full-strength MS salts with 30 mg/l sucrose, 100 mg/l i-inositol, 0.4 mg/l thiamine-HCl, 80 mg/l $AdSO_4$, 170 mg/l $NaH_2PO_4 \cdot H_2O$ and 3 mg/l BAP, and that proliferated shoots can be rooted on ¼-strength MS salts with 20 g/l sucrose and 0.1 mg/l IAA. Some details of the proliferation procedure merit further study to improve efficiency and better rooting methods need to be developed.

Acknowledgements. The authors would like to acknowledge the assistance of Mr. D. Bertoia, Mrs. C. Winter, and the staff of the Agriculture Canada, Post Entry Quarantine, Sidney, B.C. for providing the heat-treated shoot-tips and indexing the plants in the virus eradication program.

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HOWARD BROWN: Let us take a few minutes now for questions.

VOICE: What is the significance of tilting the tissue cultures in the tubes?

R.E. HARRIS: I don't really know. All we know is that if you don't tilt them they just drown. The alternate exposure from the air and mixing the air with it is beneficial. You can seal the jars up tight and they will still grow well.

JOHN IRELAND: Dr. Cheng, what is the best time of year for the taking of the tissue of the apple plant?

DR. TSAI CHENG: Well, I maintain most of my stock plants in the greenhouse and I take a lush type growth, a very succulent type of new shoots. Another way of doing it; you can place them in tissue culture and force them to produce shoots. Therefore, you will have material from there, too. So this way you don't worry about dormancy if you take materials only in winter time.

VOICE: What happens to the variability in the offspring plants? When you start propagating through tissue culture, you get complete uniformity, and get away from the variation that has given us the kinds of plants that we have today.

DR. TSAI CHENG: We have come long ago to the stage where we must have a custom orchard. We cannot use seedlings or the orchard is not uniform. A uniform orchard is the way we have to go.

CHARLES HESS: Any form of vegetative propagation would do the same thing: cuttings, or grafts on a rootstock, giving a uniform total propulation, so you have the same circumstances with tissue culture. It has not really changed, it is just made more efficient by tissue culture methods.

Your question, though, is a good one; one thing that is being done is to establish a number of germplasm repositories. The University of California at Davis is going to be a center for germplasm repository for a number of fruit and nut species. There is one at Oregon State in Corvallis and another repository is at Geneva, New York. The idea is that there will be places where the genetic material will be preserved. The need for this is, for example, that we might get an outbreak of a particular

disease in a crop and the plant breeders need then to have genetic material to go back to try to get some resistant characteristics bred into commercial cultivars to counteract the disease.

J. MATSUYAMA: In tissue culture propagation you might get good results in a laboratory situation but when you go commercial, when you are talking about a thousand, ten thousand, one hundred thousand plants — are these methods feasible?

DR. TSAI CHENG: As I told you, when we started this project last year, we were commercially oriented. We don't want just to develop the techniques for the laboratory. We want to really use this technique for commercial production. We have been transplanting these materials over and over again in my laboratory and in the nurseries of my sponsors and also by my colleagues at Oregon State University. We all get similar conclusions — it is very easy to transplant the new tissue culture propagated plants. Some of the plants will have a lag period of one week or so and then they will start off and grow rapidly. Now, we are aware of the problems and we are paying attention to conditioning tissue culture plants in such a way that perhaps a less skilled type of person can handle them and know how to transplant them into a soil condition without special skill. We are also working on optimizing growth. We think that under our greenhouse conditions we can produce liners, or saleable ornamental trees in about three months with the right growth conditions and fertilizers, and so forth. Perhaps we can even shorten the growth into less than 3 months. Another step, we are working on acclimitization because we eventually must grow these plants under field conditions. We hope that we can come up with a simple type of cookbook recipes for the nurseries and growers.

J. MATSUYAMA: With a given species, how can you increase the survival rate?

DR. TSAI CHENG: We handle all those species simultaneously. Our commercial laboratory is not yet in production, but by next year they will have experience. Some of my sponsors will perhaps answer your questions; perhaps they will be at next year's IPPS meeting. They will know then more about the commercial end of handling these plants. At this point, I can tell you from my experience and from that of my colleagues' that we speculate that we are not going to have any problems. For actual commercial practice, by next year, when the nursery people have had experience, they will give you a better answer.

CHARLES HESS: What is the number of plants propagated by tissue culture in one particular group? Is it 100 plants, for

example, or more, that you did at one time?

DR. TSAI CHENG: No, we did thousands, tens of thousands.

SOME ASPECTS OF NURSERY PRODUCTION IN QUEENSLAND

MARCUS A. PETERSEN

Danneborg Nurseries Pty. Ltd.

Deagon, Queensland, Australia 4017

Queensland is a very large state of Australia, stretching from New Guinea in the north to approximately 1,500 miles south. So we have very tropical areas in the northern half and sub-tropical in the south. There are, of course, some areas with a temperate climate because of altitude.

We have a dividing range of mountains running north to south. On the eastern side of this range we have a very fertile coastal strip, with rainfalls ranging from 50 inches in the south to over 200 inches in the tropical coastal zone in the north. To the west of the range the rainfall decreases inland and a large area of the western region has less than 10 inches of rain per year and is subject to very bad drought periods at times.

The major part of our population of 2½ million lives along the coastal region, with about one million of these living in the state capitol, Brisbane, which is in the southeast corner of the state. Most of the nursery production takes place in this area. Nurseries in the north of the state produce a wide range of tropical fruit trees, some exotics, bedding plants and house plants, all without any heating costs.

As one moves to the southern part of the state a little heating becomes necessary during a period of about three months during mid-winter, but glasshouses are not used extensively unless for special crops such as ferns, crotons, dieffenbachia and other house plants. Sarlon shade houses are used to a very large extent because of the rather intense sunlight that we experience for most of the year. Most of the better nurseries use the most modern methods of production and disease control available and mechanize operations as much as possible to reduce labor costs, which are quite high in our country.

A Method of Propagating *Lagerstroemia indica* 'Mathewsii.' Traditionally this cultivar and, indeed, all *Lagerstroemia* cultivars have been propagated by hardwood cuttings taken during the dormant period of growth at the end of winter in Queensland. Results were always rather variable and rooting

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percentage averaged about 30% for 'Mathewsii', so we looked for a more reliable method.

Initially the stock plants were pruned back hard in late winter. New growth developed very quickly during early spring after fertilization of the plants. When the new shoots were 2 to 3 feet in length and semi-ripe they were taken off and used as propagating material. We found that the very soft tips, about 3 to 4 inches, did not root very well, but the rest of the new semi-matured wood was ideal, giving an average of 98% rooting.

The method used was as follows: cuttings were made 3 to 4 inches long and with at least three nodes. The bottom cut was made ¼ inch below the bottom node, the lower leaves removed, then the cutting was wounded with a sharp scalpel 1 to 1½ inches in 2 to 3 places around the cutting. The cuttings were dipped in a powder containing 0.1% indolebutyric acid and planted 1 to 1½ inches deep in propagating tubes and placed under automatic mist with a bottom heat of 75°F.

These cuttings commenced to root at 10 days, and at 21 days were gradually weaned off and removed to shade house under 70% shade for 2 weeks prior to potting.

These rooted cuttings were potted into a U.C. type mix containing 4½ lbs 8 to 9 month Osmocote, 3 lbs superphosphate, 1½ lbs GU49, 3 oz fritted trace elements, and 9 lbs dolomite per cubic yard. The plants grew rapidly and 21 days after potting, had shoots 6 to 8 inches in height. These were tip pruned to induce branching; they developed rapidly to saleable size 16 weeks after planting of the cuttings. An added bonus was very good flowering of the plants in the container.

This resultant crop was much superior to any crop of *Lagerstroemia indica* 'Matthewsii,' previously produced by the traditional method.

A Method of Tissue Culturing Nephrolepsis Fern. In our laboratory we use the following method: stolon tips approximately 1 in long are taken from stock plants grown in the greenhouse in hanging baskets. These tips are first placed in a beaker under gauze and placed under running water for one hour. Then the pieces are removed and placed in McCartney bottles of 5% calcium hypochlorite solution for twenty minutes followed by three rinses of sterile water. After the above treatment the pieces are placed onto damp filter paper in petri dish in a laminar flow cabinet and dissected. Only the apical ⅛ to ¼ in is used. These small pieces are planted upright in agar medium in polycarbonate culture tubes which have been autoclaved at 15 pounds pressure for 15 minutes.

The medium used is a modified Murishige fern medium. Culture tubes are placed under Gro-Lux fluorescent tubes in a 16 hours light/8 hours dark regime at 80°F. Originally we used Murishige fern medium, but we found that we were getting too much differentiation during the multiplication stage which made division for subculturing rather tedious. To overcome this, we made adjustments to the auxin and cytokinin balance. In our medium we use 2 mg indoleacetic acid, 0.04 mg kinetin, 1.126 mg N^6-benzyl amino purine (BAP) per litre. We found that, using this balance instead of only 2 mg kinetin per litre, the resultant multiple bud development was rapid and much easier to subdivide for the next two sub-cultures prior to transfer to a pre-transplanting medium. In the pre-transplant stage we delete the kinetin and BAP from the medium. The clumps of multiple buds are divided and planted approximately 30 per jar. These start to differentiate in 2 to 3 weeks and at about 6 weeks we transplant into tubes of sterile U.C. type medium under mist in shaded greenhouse.

The resultant plants develop fairly rapidly and have a very bushy habit which fills the container much better than when traditional propagation methods are used, possibly because of a slight carryover of BAP in the plant system.

Components	mg/Litre	Components	mg/Litre
$CaCl_2$	332.00	NH_4NO_3	1,650.00
$CoCl_26H_2O$	0.025	$MgSO_4$	181.00
$Na_2MoO_42H_2O$	0.25	$MnSO_4H_2O$	16.9
$NaH_2PO_4H_2O$	255.00	$ZnSO_46H_2O$	8.60
$CuSO_4$	0.025	Sucrose	30,000.
KH_2PO_4	170.00	Inositol	100.00
KI	0.83	IAA	2.00
KNO_3	1,900.00	Kinetin	0.04
FeNa EDTA	36.7	BAP	1.126
H_3BO_3	6.20	Thiamine	0.4
Agar	8,000.00		

Note: Delete kinetin and BAP for pre-transplanting.

SPRING COLOR PRODUCTION

DAVID R. ROBERTS
Bailey's Nursery
Lodi, California 95240

Spring has always been a magic time for gardeners, bringing an influx of buyers to nurseries for flower and vegetable plants. Plants providing immediate color play a very important role in spring sales for nurseries and mass merchandisers. In re-

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$NaH_2PO_4H_2O$	255.00	$ZnSO_46H_2O$	8.60
$CuSO_4$	0.025	Sucrose	30,000.
KH_2PO_4	170.00	Inositol	100.00
KI	0.83	IAA	2.00
KNO_3	1,900.00	Kinetin	0.04
FeNa EDTA	36.7	BAP	1.126
H_3BO_3	6.20	Thiamine	0.4
Agar	8,000.00		

Note: Delete kinetin and BAP for pre-transplanting.

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Spring has always been a magic time for gardeners, bringing an influx of buyers to nurseries for flower and vegetable plants. Plants providing immediate color play a very important role in spring sales for nurseries and mass merchandisers. In re-

cent years people have become more and more interested in "instant color" resulting in increasing sales of 3-inch, 4-inch, 6-inch, and 1 gallon color items. For the wholesale operation this means getting an early jump in winter. The name of the game is to pack your greenhouses for the spring explosion.

In Northern California, spring sales generally break loose in early March. For many greenhouse operations this means spring color production must get off to a fast start in December and January. For most growers, this means waiting for poinsettias to clear out and then quickly replanting. It is extremely important to have seedlings, cell paks, bulbs, or pots for shifting ready to fill up emptying greenhouses. These crops can be for finishing in early spring (for example: 4 inch annuals, geraniums, or perennials) or for holidays, such as Valentine's Day or Easter (chrysanthemums or Easter lilies). Having crops that can be shifted or brought in to finish for Valentine's Day can often help get an extra rotation off benches. These benches can then be used to spread spring color (i.e. geraniums) or start late spring crops.

Much of the volume in spring color is from annuals. Popular plants include marigolds, dahlias, petunias, impatiens, begonias, zinnias, cellosia, and vinca, among others. Dwarf cultivars of these plants are most desirable for flowering in pots. Careful attention should be paid to daylength and temperature requirements. Most annuals tend to do well in a wide range of temperatures, depending on how quickly the crop must be brought along. Some crops, such as marigolds and dahlias, can tolerate nights as low as 45°F, but temperatures ranging from 50°F to 60°F are more acceptable. Crops like vinca and celosia will suffer until temperatures become milder, unless they are kept in a warm greenhouse.

While many nurseries in Southern and Coastal California are able to employ outdoor growing year-around, Northern California's Central Valley provides some cool temperatures, often resulting in frosts. Nevertheless, as soon as the weather breaks in spring, outdoor or saran areas are very economical sites to grow color annuals. Petunias and dianthus are excellent for outdoor growing. Later in the season most all popular sun requiring plants can be either moved out or directly planted outside. In the San Joaquin Valley the outdoor area is frequently employed to finish a crop, allowing more plants to be started on the benches. In the very early spring, direct planting outside can be tough on the new seedlings and, later in the season, as the heat begins, seedlings may require some temporary shade.

From seedlings brought up in a well controlled greenhouse, annuals can be transplanted directly to 4-inch pots. Transplant-

ing can be done several ways. One method is to lay out soil filled pots and have planters come along planting them in place on the benches. Pots can also be planted in a central area and then set out on benches or outside. Regardless of what method is employed, efficiency must be used to keep profitability in annual crops. In all stages of production, labor must be kept to a minimum. Sprinkler or automated water systems should be employed to reduce labor. While transplanting can be quickly learned, cultural techniques and quality control in orders is best handled by more experienced greenhouse personnel.

For many years zonal geraniums have been a popular color item throughout the country. Until recent years, cutting-grown cultivars were the only commercially available geraniums. Wtih the introduction of seed geraniums, whole new systems for producing this crop have evolved. Seed geraniums can provide more consistency in crop timing, more consistency in plant size and quality, and elimination of many disease problems associated with propagating and producing cutting-grown cultivars. Some problems that still exist are bloom shattering in shipment, plants that do not self-clean well in the garden and, to date, a lack of double flowered cultivars. The cost of buying cuttings or maintaining motherstock also makes seed geraniums more attractive to greenhouse growers. While the last couple of years have brought large increases of seed geraniums to the marketplace at the expense of cutting types, there will probabely be some shifting back as consumers find that cutting types can be used in different ways. The most popular way to market geraniums in California is in 4-inch pots, with bud or color. Six-inch pots or gallons are also available in the latter part of the season.

There are many perennials that are good spring color. Begonias, such as richmondensis doubles; New Guinea impatiens, with their colorful foliage and bright flowers, ivy geraniums, transvaal daisies, dwarf and standard marguerites, dwarf pinks or carnations, and the ever-popular fuchsias are among some of the many fast growing perennials that can be grown for spring. Often these plants are sold as small liners early in the season, but as spring progresses, they are good items to grow in 4-inch, 6-inch or 1 gallon cans. Most often these plants are started from cuttings and then grown on either in the greenhouse or outside as temperatures warm up.

Profitability is still an important gauge of what plants can be commercially grown for spring color. Annual pots are sold in great volumes but often have a minimum of profit after growing and shipping. Motivated by increasing costs of production and competition in the marketplace, many growers are trying to

produce the maximum amount of plants per square foot of growing space. Also growers need to increase dollar sales per flat when shipping. Two directions are being followed. The first is by pot growers changing from a 4-inch pot to 3¼-inch or 3½-inch pots for items such as annuals which are generally grown pot to pot. The second direction is by growers of green paks moving to slightly larger paks which will allow plants to bloom. Both systems achieve more dollar sales per square foot of greenhouse and truckload. Most important to growers is careful cultivar selection and the use of cultural techniques such as using growth retardants, like B-NINE, or maintaining even growth with cool temperatures.

Either to the small specialized grower or the large diversified grower, spring color production still requires a lot of HUSTLE!

VEGETATIVE PROPAGATION OF TEXAS LIVE OAKS

DAVID L. MORGAN

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Live oaks (*Quercus* spp.) have been grown from acorns commercially for years. Most species of oaks are wind pollinated and are highly heterozygous; as a result, the progeny of a single tree may not resemble its genetic parent. Live oak trees commonly differ in drought hardiness, salt tolerance, height, earliness to leaf, and the presence of insect galls. These characteristics are not reproducible through seed propagation.

Plants propagated asexually (vegetatively) through cuttings reproduce all the genetic information of the parent plant. This is why the unique characteristics of any plant can be perpetuated by establishing a clone. Cuttings taken from a tree genetically resistant to the formation of insect-induced mealy-oak galls, for example, should be expected to grow into gall-free trees.

There may exist further reasons for vegetative propagation of oaks, such as availability of cutting material when acorn crops are poor or out of season; it may prove easier, more rapid, and more economical to take cuttings than to grow trees from seeds. For our purpose clones, because of their uniformity, are unequalled as research material.

Studies at Texas A&M's Research and Extension Center at Dallas during the last five years were designed to determine the feasibility of asexual propagation of live oaks, so that superior

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trees might be produced to study inheritable characteristics, made available to the nursery industry, and offered to the public.

METHODS

Live oak cuttings in full leaf were collected from field-grown trees of different ages at Storm Nursery near Premont in South Texas during the spring-fall growing season. They were moistened, put in plastic bags, placed on ice, and returned to our laboratory where they were quick-dipped in several experimental concentrations of a rooting hormone, indolebutyric acid (K salt), and placed in a greenhouse bench under intermittent mist. The medium was a well-drained 3:1 perlite:peat (v/v).

Cuttings that rooted were transferred into containers of 1:1 peat:perlite, hardened under reduced mist frequency, and allowed to grow in the greenhouse. About 50 rooted cuttings were placed in urban landscapes, on nursery property, and in the tree nursery at the Texas A&M Research Center.

RESULTS

Cuttings treated with IBA hormone concentrations of 10,000 ppm (mg/l) and higher, and those that remained under mist for 12 weeks provided the greatest number of roots.

In general, the younger the plant, the greater the rooting, providing evidence that the phenomenon of juvenility and rooting are closely related in live oak. Cuttings from trees 5 to 8 years old rooted poorly, with the older ones providing the poorest rooting.

The dates during the summer months when cuttings were taken had little effect on rooting. Cuttings taken during the early, warm days of October rooted equally with those taken in the May to August period. Cuttings taken during the colder months of November to March, however, failed to root.

Trees carried an apparent genetic propensity to root, or not to root, an effect observed through several collection dates. Selected seedlings consistently provided cuttings which rooted at higher numbers, while others, equally as consistent, yielded non-rooting cuttings.

Finally, cuttings taken from rooted propagules of a selected tree at Storm Nursery rooted in greater numbers than did cuttings taken directly from the original parent tree itself. Furthermore, these second "vegetative generation" plants provided better root systems than did cuttings taken from the parent tree, still in the field.

DISCUSSION

Because these "second generation" propagules had been maintained year-round in the greenhouse, the dual effects of greater numbers of stronger roots may be attributable to environmental conditions and height control (hedging).

For whatever reasons, an avenue of asexual propagation of live oak may have been opened through this method of successive propagation: cuttings taken from rooted cuttings.

In sum, the following determinations have shown to be consistent:

1. Cuttings taken from young trees root more readily than those from mature, acorn-producing (adult) seedlings.
2. Hormone application is essential; concentrations of 10,000 ppm IBA and higher was most effective.
3. Stem-tip cuttings from the outer branches have rooted well, but non-terminal cuttings (where carbohydrates may accumulate) also have rooted.
4. Cuttings will root if taken at any time during the growing season, but they should be semi-hardwood -- very soft, green cuttings seldom produced roots. Likewise, old, hardened wood is difficult to root. Second-year wood generally is harder and of better quality for rooting.
5. Cuttings should be slightly smaller than pencil size in diameter.
6. Cuttings rooted best under mist; a Wardian case or similar closed propagation chamber may produce heat and desiccate the leaves.
7. Cuttings should remain under mist for 12 weeks. Bottom heat by cables should be provided when greenhouse temperatures drop.
8. Like most mist-propagated woody plants, rooted cuttings of the live oak should be hardened gradually under reduced misting.

Additional investigations are continuing. Clones now growing in the field are being evaluated for growth habit, fertility response, growth rates, and insect gall resistance. These propagules will be further used as sources of cutting material for successive propagation, and compared with cuttings from greenhouse-maintained clones. Selected clones are being employed in fertility (nitrogen) studies in containers.

A LOOK AT FOREIGN AGRICULTURE

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In April, 1978, I had the opportunity to travel to six European countries with Class VII of California's Agriculture Leadership Program.

Before discussing the agriculture that we saw I would like to consider this Leadership Program because I believe it is one of the most important developments that has taken place in agriculture in recent years.

The program was initiated by the Agricultural Education Foundation and is funded entirely by agricultural organizations. It costs $240,000 to run a class of 30 through a two-year program. The objective is to select young people between the ages of 27 and 40 who have demonstrated leadership ability and show the potential for even greater leadership. Working with the Agricultural Education Foundation are the deans of agriculture of four California universities — the two Cal Polys, Fresno State and the University of California at Davis.

Candidates are interviewed by six screening committees, with a requirement that 80% of the class must be from production agriculture. The other 20% may be from agribusiness.

Starting in November the class attends monthly seminars sponsored by the universities or by agriculture businesses. The seminars stress economics, politics, communications, education, and culture such as art, music, drama, etc. Studies in the first year address national issues, with a two-week trip to Washington, D.C., and the Eastern U.S. The second year features international issues, with a three-week trip abroad.

The objective is to provide broadening experience for the class members with the hope and expectation that they will become better spokesmen for agriculture and more effective leaders.

Our trip started in Sweden, where we spent a couple of days with Sweden farm families. In each country we were briefed first at the American Embassy. The Agriculture Attache was our key contact. In most cases he arranged for us to talk with the American Ambassador and to be briefed by specialists in economics, politics, and agriculture. Our next step would be with the country's Ministry of Agriculture and then we would visit farms, factories and cultural activities.

I am going to give you my impression of the countries vis-

ited, based upon only a few days' observation.

Sweden — a very clean and industrious country, people very friendly to the U.S. Farms quite large by European standards, highly mechanized. Tax structure encourages heavy capital investment. Farmers like socialist government. Prices are assured before crop is planted. Heavy subsidies, trained labor. But they hate to pay 50% or more income tax. Environmentally conscious but six nuclear plants operating, with seven more being built.

Russia — Obsessed with the need to be biggest. Still fearful of the threat from the east. Common people in the cities generally non-communicative; somewhat disinterested in Americans. Huge black market flourishing openly. Good technology in agriculture at the high level. Difficulty in transmitting it down to working man's level. Russia is the world's number 1 producer of tractors.

Rumania — *Poorest of East European countries after Russia.* Common people friendly, inquisitive. Have a big movie business. Like American movies — especially westerns. Still very much a police state — no freedom of movement. Farms collectivized, well organized. Managers have a lot of leeway in decisions.

Yugoslavia — Still a socialist, police state. Proud of independence from Russia — consider themselves Western Europe rather than Eastern. Private farms larger, houses better kept. Want more trade with U.S. — involved in several joint ventures. Love sports — rank third in the world in basketball. Hosted Olympics boxing while we were there.

Hungary — Best relationship with U.S. of any Eastern European country. Return of crown of St. Stephen helped. Want "most favored nation" status with U.S. Large collective farms — sell $15 million worth of canned ham per year to U.S. Have a sophisticated pharmaceutical industry. People have more freedom than in past — many families reunited. May travel to Austria without visa. Many may emigrate to the west. Language very difficult. Numerous "Ban the neutron bomb" posters.

Austria — Beautiful, prosperous capitalist country. Prices sky-high, inflation, unfavorable balance of payments. Friendly — like Americans and most others. Open hatred of Russians. Population declining and growing old. Young people moving to Germany and other countries for better jobs. Inefficient agriculture — small farms, one tractor per 27 acres. Agriculture is highly subsidized, since the government pays more for food than they sell it for.

SUMMARY

We saw a diversity of agriculture, much of it unlike our own.

We could see value of collectivizing land or increasing size of farms in regard to management and mechanization.

We could see advantage of managed economy where everyone has a job.

We could see effects of lack of freedom — lack of incentive, absentee planning, inefficient use of farm implements.

Not one of us would have traded our agriculture for the best of theirs.

CUTTING PROPAGATION OF *EUCALYPTUS FICIFOLIA* USING CYTOKININ-INDUCED BASAL TRUNK SHOOTS

ROBERT L. MAZALEWSKI and WESLEY P. HACKETT

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Abstract. The cytokinins, PBA and BA were the most effective treatments tested in inducing buds to break in the lignotuber as well as the upper trunk region of *Eucalyptus ficifolia*. BA at a concentration of 0.8% in water-ethanol (1:1) caused an average of 229 bud breaks per tree. Stem cuttings taken from the PBA-induced shoots exhibited a greater propensity to the root when taken from the area of the lignotuber than when taken from higher on the trunk. Furthermore, cuttings from basal parts of shoots, originating from the lignotuber, rooted better than cuttings taken from the apical portion of these shoots.

REVIEW OF LITERATURE

It is well-known that some species of eucalyptus can be easily propagated by using stem cuttings of shoots arising from lignotubers, whereas cuttings from the periphery of the tree are unrootable (7,10). Chattaway (3) described a lignotuber as a woody swelling in the stem of the eucalypt which contains an abundance of buds with contorted xylem elements. The lignotuber develops in the axils of the cotyledons and in the immediate successive nodes of most of the eucalypts. Carrodus (2) concluded that the primary importance of the lignotuber is the enormous number of buds held in a protected position which have the ability to produce new growth following damage to the tree.

The buds held in the lignotuber are believed to be adventitious in nature; that is, they do not initiate from the apical meristem or axillary buds. The buds of the lignotuber have been

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observed to develop upon the extension of vascular cambium which extends into the swelling of the developing lignotuber (3).

There is clear evidence that the ontogenetic age of the cutting wood is the most critical factor for rooting *Eucalyptus* stem cuttings. It has been shown that stem cuttings taken from young seedlings produce normal roots (1,4,7,8,9). Paton and Willing (9) showed in *E. grandis* that the ability of a stem cutting taken from a seedling to strike roots declined with increasing node number above the 4th node and ceased completely above the 15th node. The ontogenetic aging of *E. grandis* was correlated with an increased level of rooting inhibitors in leaves and stems. These inhibitors were absent in the leaves of easily-rooted stems and present only in adult tissues which rarely form roots in stem cuttings.

The results cited above suggest that cutting material with a high rooting potential could be produced by inducing bud break from the lignotuber and latent buds on the lower trunk of the tree. Derman (5) produced hemispherical intrusions (sphaeroblasts) in the internodal regions of the trunk by completely disbudding headed *Malus* plants. Adventitious buds appeared from the sphaeroblast which developed into shoots. Sachs and Thimann (4), found that kinetin applied directly to the lateral buds of *Pisum* seedlings released the lateral buds from the inhibition of the growing apex. These buds failed to elongate fully as compared to the decapitated apical control. However, an auxin treatment applied locally to the bud would cause normal elongation. Williams (12) working with *Malus* found that cytokinins applied to the axillary buds of apple shoots overcame apical dominance. Axillary buds on actively growing shoots produced spurs and laterals when treated with cytokinins, especially N-benzyl-α-(tetrahydro-2H-pyran-2yl) adenine (PBA).

Other chemicals have been used to induce growth of buds which have had insufficient low temperature chilling for growth. The cytokinin, PBA, was found to stimulate bud break in dormant peaches only when the low temperature chilling requirement had nearly been fulfilled. Erez (6) found in peach, that applications of potassium nitrate and kinetin advanced flower bud formation and thiourea hastened leaf bud opening only when applied towards the end of the growing season.

MATERIALS AND METHODS

In order to investigate the possibility that shoots originating from the base of the trunk would yield cuttings that had a higher rooting potential, it was necessary to induce bud break

from latent buds. Preliminary evidence indicated pruning alone was not a successful method of inducing bud break. Therefore, other methods were investigated.

Induction of Bud Break. Commercially-grown trees approximately three years of age were used in this experiment. The tree which were growing in 17 liter cans, were approximately 2 meters tall when the experiment began. The lower region of the trunk was essentially free of any lateral shoots, especially near the lignotuber. All trees were grown in a greenhouse which was maintained at a day temperature of 80°F (27°C) and a night minimum of 70°F (21°C). The trees were watered with a half-strength Hoagland solution when required.

The experimental design was a complete random design consisting of seven treatments and utilized three trees per treatment. All chemical treatments were applied from the soil level to approximately 30 cm above. Potassium nitrate and thiourea were applied as a 1.0% aqueous solution with Tween 20 R added as a surfactant. Applications were made every three days with a hand atomizer saturating the trunk to the point of run-off. The cytokinin, PBA, was used at concentrations of 0.1% and 0.01% in a paste mixture consisting of PBA and lanolin (1:1, v/v). A thin layer of paste was applied to each trunk by hand once at the beginning of the experiment.

The two mechanical methods utilized to induce bud break consisted of girdling the trunk and the continual disbudding of axillary buds and shoots. Girdling was done by removing a 6 mm wide strip of bark and phloem approximately 30 cm above the surface of the soil. Disbudding of axillary buds continued throughout the course of the experiment; buds were removed whenever any portion of the bud expanded from the axils of the stem and petiole.

In a second experiment the cytokinin benzyl-aminopurine (BA) was used to induce bud break. In this case the cytokinin was applied at 3 concentrations in water-ethanol (1:1) solution using 2 trees per treatment. The lignotuber surface was painted with cytokinin solution twice weekly for 4 weeks. Bud break was determined 1 and 2 weeks after cessation of treatment.

Rooting of Shoots from the Basal Bud Breaks. Basal shoots were removed from two areas of the trunk; the treated area of the lignotuber and the area above the lignotuber. Shoots from the two areas were subdivided in a way to produce apical and basal cuttings, basal cuttings being the section of the stem extending from the trunk of the tree toward the shoot apex for two nodes. The apical cuttings were the section of the stem from the shoot apex towards the base of the shoot for a distance of four leaves. All leaves of the cuttings were left intact. All cuttings

were treated with a 5000 ppm solution of IBA as a quick dip, stuck in vermiculite-perlite mixture (1:1 v/v) and placed under an intermittent mist system.

RESULTS

Bud Break. Fifteen days following the initiation of treatment (October 3), it was evident that applications of PBA at the two concentrations were inducing a great deal of bud activity in comparison to other treatments. Plants treated with thiourea and potassium nitrate show no bud break while girdling and disbudding exhibited only slight activity (Figure 1).

Four months following the initiation of the experiment, the two treatments using PBA continued to develop buds. Shoots from the treatment with 0.01% PBA elongated more than the ones from the 0.1% PBA treatment. A common occurrence with both PBA treatments but more frequently with the higher concentration was the gradual decline in the number of surviving shoots. It appeared as if the concentrations used were causing toxic symptoms in the shoots, followed by death in some instances.

In a second bud-break experiment (Table 1) it was found that BA in a water-ethanol solution was as effective or more effective than PBA in a lanolin paste and caused no phytotoxic symptoms. At a concentration 0.8% BA, an average of 229 bud breaks per tree were produced 2 weeks after cessation of treatment.

Propagation of Basal Trunk Shoots. As reported in the literature, stem cuttings taken from shoots of the lignotuber showed considerable ability to form roots. Although the difference was not significant (at the 5% level), it appeared that the basal cuttings taken from the lignotuber had a greater propensity to initiate roots than those from the apical portion of the same shoot (Table 2). In fact, shoots from the lignotuber rooted similar to stem cuttings taken from very young seedlings.

Table 1. Influence of benzylaminopurine (BA) treatment on bud break from lignotubers 1 and 2 weeks after cessation of treatment.

	Mean Bud Break Per Tree	
Treatment	1 Week	2 Weeks
Control	0	3
0.01% BA	0	13
0.1% BA	0	33
0.8% BA	20	229

In another experiment cuttings taken from shoots initiated above the lignotuber failed to root with the propensity of the cuttings taken from the lignotuber. Neither apical nor basal cut-

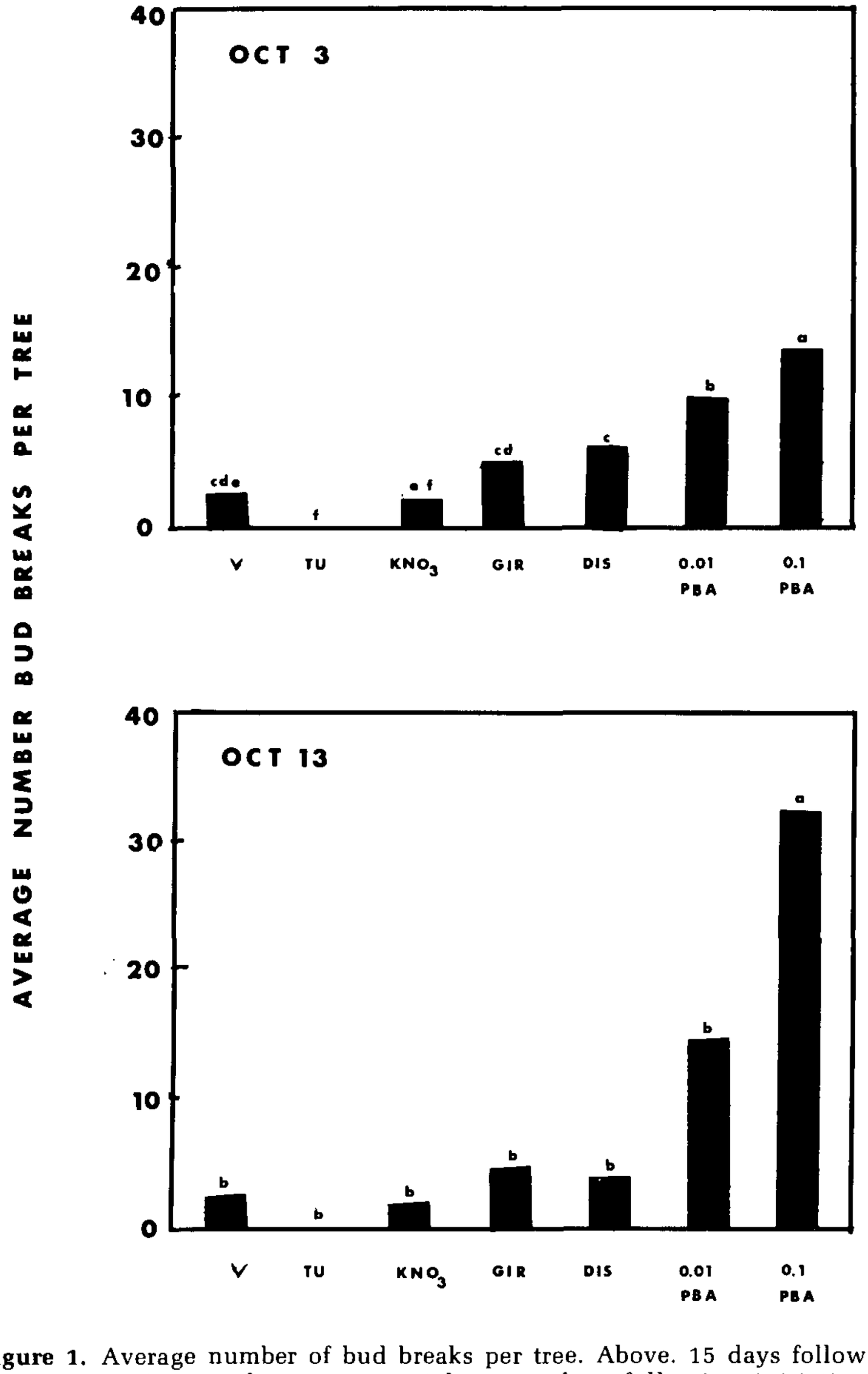

Figure 1. Average number of bud breaks per tree. Above. 15 days following initiation of treatments. Below. 30 days following initiation of treatments. (TU: thiourea; Gir: girdling; Dis: disbudded; V:control) Duncan's new multiple range test, 5% level.

tings from such shoots rooted with any notable success (Table 3).

Table 2. Rooting of cuttings taken from shoots from the area of the lignotuber, following treatment with IBA.

	% Rooting	% Anomalous Roots[1]	% Mortality
Apical Cuttings	20	73	0
Basal Cuttings	70	20	0

[1] Anomalous roots was the name given to protruberances of tissues from the basal cut of the stem cutting which were thought to be callus, but root-like in appearance (8).

Table 3. Rooting of cuttings taken from shoots from the area above the lignotuber following treatment with IBA.

	% Rooting	% Anomalous Roots	% Mortality
Apical Cuttings	6	0	94
Basal Cuttings	0	7	75

DISCUSSION

Bud Break. The cytokinin treatments elicited the quickest and the greatest amount of bud break following application. It appeared that the treatments of PBA in lanolin paste were slightly toxic to the emerging shoots as evidenced by the frequent death of the shoots. Whether the cytokinins, PBA, or the lanolin paste is the toxic element remains unanswered. Concentrations as high as 0.1% PBA in lanolin showed no toxicity symptoms on *Malus* sp. when tested by Williams (12), and 0.8% BA in water-ethanol solution was not toxic in our experiment. Since the activity of different cytokinins varies, further work involving other kinds and concentrations of cytokinins should be implemented. The water-ethanol method of application is a much better and more convenient method of application than the lanolin paste method.

PBA and BA induced bud break from latent buds in the stem as well as from buds in the lignotuber. Shoots from above the lignotuber arose from latent buds rather than from adventitious buds. The greatest profusion of bud release was from the area of the lignotuber; this agrees with the hypothesis that the primary function of the lignotuber is an organ which holds a large number of buds in a protected position.

As reported previously, both potassium nitrate and thiourea are useful primarily to break buds from dormancy (6). The use of these chemicals was probably unsuccessful due to the fact that the genus *Eucalyptus* are evergreen trees without a dormant state. This study supports the theory that potassium nitrate and thiourea act as dormancy breaking substances and do not interfere with apical dominance as do the cytokinins.

Propagation of Shoots. From the results of the propagation of basal shoots induced by PBA, two conclusions can be drawn. First, the shoots, and subsequently cuttings taken from the lignotuber, behave differently from shoots taken above the lignotuber. Shoots taken from the lignotuber were more rootable and possibly more "juvenile" than shoots taken from the latent buds on the stem of the tree. It appeared that buds held in the lignotuber were juvenile in nature and had not undergone the ontogenetic development of the latent auxillary buds found in the adjacent stem.

Secondly, the shoots of the lignotuber behave very much like young seedlings. Work by Mazalewski (8) has shown that the initial node above the cotyledon retains the propensity to root, and cuttings taken from sections of the stem above the cotyledon tend to lose the propensity to root. Similar results were obtained with cuttings taken from the lignotuber. Stem cuttings taken from the lignotuber shoots rooted easily when taken from internodes close to the lignotuber, behaving much like the epicotyl of a young seedling. Above this basal cutting, the potential to root decreased.

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TOPWORKING ESTABLISHED VINIFERA GRAPEVINES

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In California there are approximately 645,000 acres of *Vitis vinifera* grapevines. Of these, 325,000 acres are wine cultivars, 85,000 table cultivars and 235,000 raisin cultivars. The trend in the wine industry has been for an increased demand for white table wines because more people are beginning to consume these with their meals. Table wines are considered to supplement food with the meals.

Most persons beginning to drink wine will choose a sweet to slightly sweet white table wine because it more clearly resembles non-alcoholic beverages to which they are accustomed. Red table wines are more harsh than white wines and the dessert wines, which are higher in alcoholic content, are more difficult to drink. Because of the increased demand for white table wines a shortage in this type of wine is now present along with somewhat of a surplus of many common red wines. Consequently there is a higher premium paid for fruit of the white table wine cultivars than for the reds. In some of the newer grape areas in California, such as Monterey County, temperature data was not accurate when the vines were planted; as a result some wrong cultivars were planted there, Some of these are now being changed over to the more suitable white ones.

Some vineyard managers having red fruited cultivars in their planting are desirous to convert over to whites. In the past the quickest way to accomplish this had been to graft over the vines in the spring at ground level to the desirable white table wine cultivar using the cleft graft (9). This type of grafting requires considerable skill and high percentages of successful takes have been rare. If the grower was to remove the entire vineyard and replant, the expense would be much greater than that of grafting, plus the loss of 3 to 5 years of crops.

Wedge or saw kerf grafting was another method used to change cultivars (2). These methods enabled the grower to change only the head of the vine and save the established trunk. These methods, too, require considerable skill as well as

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the use of black grafting compounds and the use of white latex paint over the grafting compounds to prevent sunburning of plant tissues. The successful take varied from 50 to 90 percent.

T-Budding. More recently T-budding has been used and has given very good success (80 to 95 percent take) (1,3). This method was used by Mr. A. Gargiulo, an Argentine grape breeder, to obtain earlier fruiting of his seedling vines (8). Growers in Mexico saw Mr. Gargiulo's technique and adapted it to change over their own established cultivars at high levels on the vines. They were successful and this method was much easier to perform than any grafting method. Only the head of the vine was changed.

Actually T-budding of grapes was first described in 1901 by Professor Drouhault of Lot, France under the term of Vouzou graft (7). He stated it was one of the easiest and most successful above-ground methods. Mr. Vouzou was a vineyard laborer at Chateau d'Crozes (Lot) who tried this method in 1891 using dormant instead of green budwood, followed by tying with raffia. This method gave him the highest take, over a period of several years (1891 to 1893), including one year of a severe drought which caused failure for all other methods used.

T-budding was tried at Davis and Parlier, California in 1974 with very good results (above 94 percent take). The Greenfield area of Monterey County, which is noted for its severe winds, and where the usual methods of grafting had met with failure was selected for a trial in 1975. A 95 percent take was obtained (5).

Since then many growers have used T-budding to change the cultivar of mature vines. When care and attention to details are observed the success has been high. The method consists in cutting off the tops of the vine just before budding. Starting about one to two inches below the cut-off top, which is 14 to 17 inches below the lower wire of a two-wire vertical trellis, a vertical slit is made about 1″ to 1½″ (Figure 1A) in the bark where the trunk is smooth. The second cut is made at a right angle (90 degrees) to the first cut (forming a T) at the top (Figure 1B). During the second cut the knife blade is inserted at about a 40° angle so that as it goes around the trunk it tends to pull away one of the flaps of the bark. Then, using the quill of the knife or blade, the other flap of bark is opened (Figure 1C). The trunk is now ready for the insertion of the bud. Cutting the bud is done by starting ¾″ to 1″ above the bud, entering at a slight downward angle to about ¾″ below the bud. The bud should be about ⅛″ thick. Starting about ¾″ below the bud the second cut is made at about 25° angle into the budstick until it intersects the first cut and frees the bud from the stick (Figure 1 E,F). The

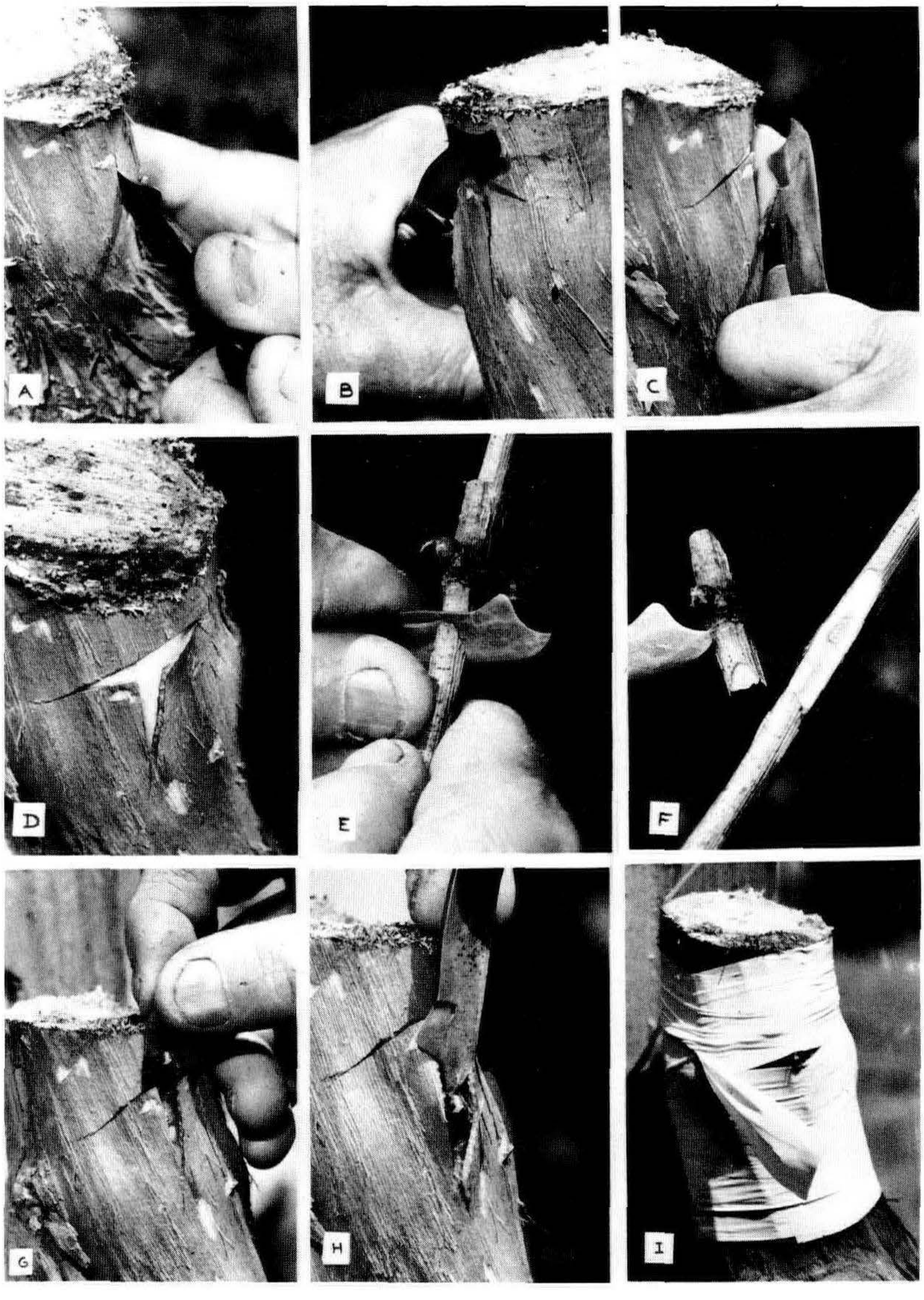

Figure 1. T-Budding. A. First cut-vertical 1-1½ inches long. B. Second cut — horizontal over top of first cut, knife blade pulls open left flap of bark. C. Other flap opened using quill on knife blade. D. Flaps opened ready for insertion of bud. E. Cutting bud — second cut ½ to ¾ inch below bud at 25-30° angle. F. Completed bud. G. Inserting bud under bark. H. Imbedding front of bud more deeply under undisturbed bark. I. Completely wrapped bud.

bud is then inserted under the open flaps on the trunk (Figure 1G) and pushed downward under the bark until the eye of the bud is pushed to the bottom of the cut slit or even lower, splitting more bark (Figure 1H). The top of the bud shield should be ½″ to ¾″ below the horizontal cut. On vine trunks under 1″ in diameter, ½″ wide tape is used. On larger stocks 1″ tape is preferable.

The first wrap is made at the top to hold the two flaps together. Then the tape is moved to below the bud and wrapped upwards overlapping the wraps. Whent he bud is encountered the budder may carefully wrap around the bud leaving only the eye exposed. Or the budder map wrap entirely over the bud being careful to center the eye in the tape. Wrapping is continued upward to about 1½ to 2″ above the horizontal cut (Figure 1I). The last wrap is placed under the next to last wrap pulling the tape tight to stretch it. If the budder wraps over the eye of the bud he must carefully make a vertical slit over the eye cutting only the tape. This method of wrapping is faster and uses less tape then going around the bud but extreme care must be used when slitting the tape so as not to damage the eye.

After the vines have been cut off they frequently bleed. Bleeding retards callusing and may delay bud push by one to three weeks (4). This can be avoided by slashing at the base of the trunk on two sides using a medium-tooth pruning saw to encourage the bleeding well below the bud. If, after slashing, the vine continues to bleed at the decapitated top the slashing cuts should be made deeper.

T-budding is the easiest and most successful way to change over cultivars in an established vineyard. This method works well in May, June, and part of July in the San Joaquin Valley of California. With late budding (even at the end of July) the bud will grow but often the shoot does not mature by the end of summer and may be killed in the winter.

Chip budding. A method is needed to start budding earlier in the spring. Research recently with chip budding indicates that this method is as successful as T-budding (6). However, it requires more skill in that the budder must match cambiums and the cut bud is not of uniform thickness as with T-budding but tapers so that the base is thicker than the top.

The advantage of chip budding is that the grower may start budding in March instead of having to wait until May, as with T-budding. The new head following budding attains a very large size by the end of the growing season (about ⅔ the size of the original head) and the wood becomes well matured to go

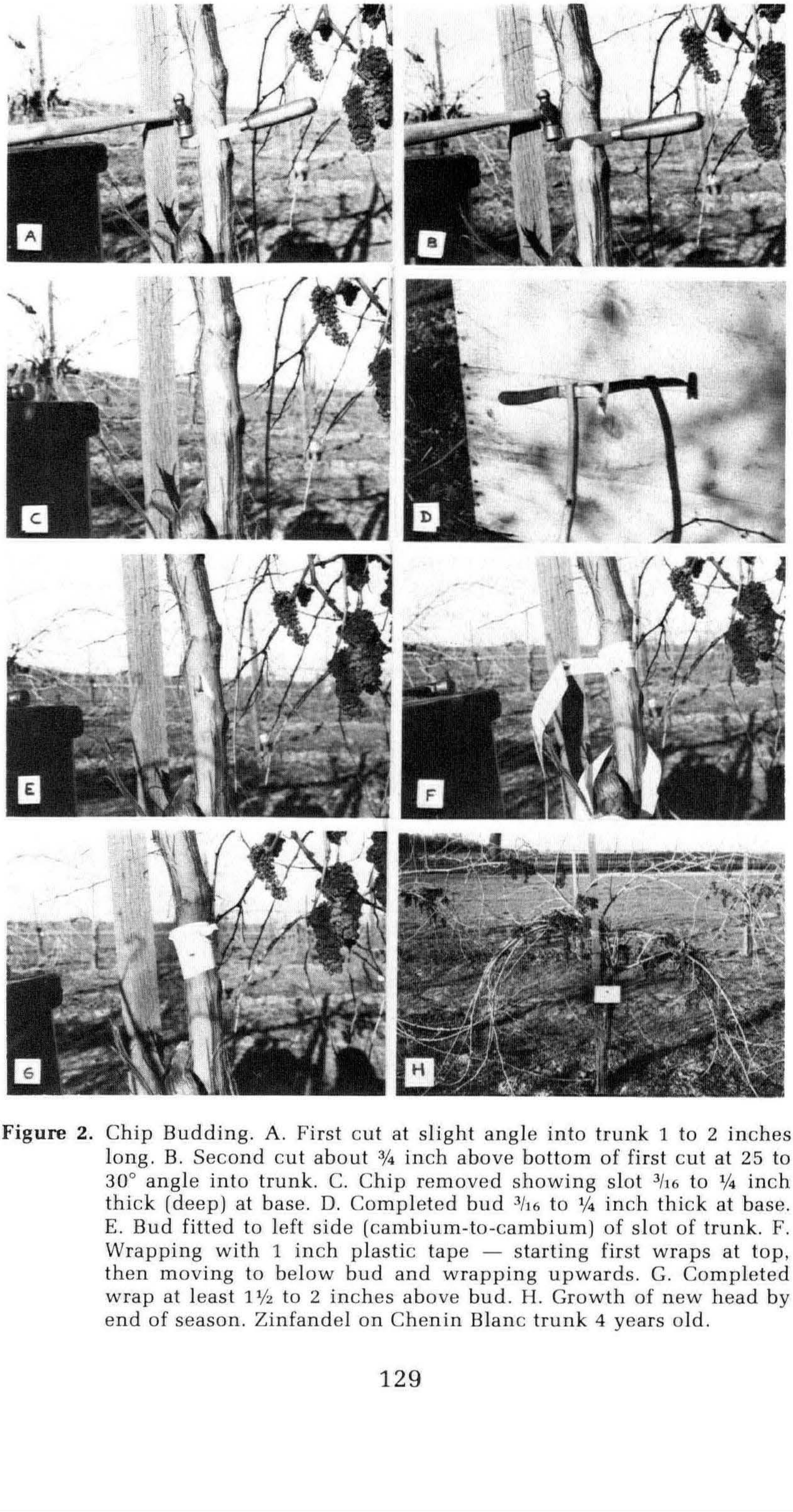

Figure 2. Chip Budding. A. First cut at slight angle into trunk 1 to 2 inches long. B. Second cut about ¾ inch above bottom of first cut at 25 to 30° angle into trunk. C. Chip removed showing slot 3/16 to ¼ inch thick (deep) at base. D. Completed bud 3/16 to ¼ inch thick at base. E. Bud fitted to left side (cambium-to-cambium) of slot of trunk. F. Wrapping with 1 inch plastic tape — starting first wraps at top, then moving to below bud and wrapping upwards. G. Completed wrap at least 1½ to 2 inches above bud. H. Growth of new head by end of season. Zinfandel on Chenin Blanc trunk 4 years old.

through the winter (Figure 2H).

Chip budding offers the advantage of having the inserted bud ready to begin growth shortly later than the time the buds normally push on the vine. By the time the bark slips the grower can rebud those buds that have failed to push using the T-bud method.

Chip budding is accomplished by cutting a slot from the trunk into which the bud will be fitted (14 to 17 inches below the bottom wire) using a light mallet or hammer to tap the knife blade at a slight angle downward into the trunk for 1 to 2 inches depending upon trunk diameter (Figure 2A). The cut cannot be made by hand on vines over 1″ in diameter as the wood is too hard. The second cut is made about ¾″ above the bottom of the first cut into the trunk at about 20° angle intersecting the base of the first cut (Figure 2B). The chip is removed. This leaves an open slot (Figure 2C). It should be as narrow as possible in order that the bud shield will fill the slot completely, or as complete as possible. In order to obtain as narrow a slot as possible the side of the trunk having the greatest curvature should be used. For chip budding the largest budwood is most desirable as the bud shield will then most nearly fill the slot cut into the trunk. The bud is cut slightly different from that for T-budding. The budder starts 1″ to 1½″ above the bud, cutting at a slight angle to about ½″ to ¾″ below the bud. The thickness of the bud increases down to the base about 3/16 to ¼″. The second cut starts just under the bud through the leaf scar at about a 25° angle and meets the first cut at the base. The bud is removed from the stick (Figure 2D) and is fitted (not inserted) into the slot on the trunk making sure that the cambium of the trunk is aligned with the cambium of the bud shield. The bark of the trunk may be 1/16 to ⅛″ thick. A properly fitted bud may show some exposed cut bark surface just on the outside of the bud. Frequently the bud is not wide enough to fill the slot. In these cases the bud is fitted on only one side of the slot, with the cut surfaces of the wood and bark left exposed on the opposite side (Figure 2E). This does not matter although complete bud callusing will be slower. The bud is then wrapped with plastic tape as described above for T-budding (Figures 2F,G). The top of the vine is not cut off at the time of budding. This is not done until the danger of spring frosts are over. Early work on the effect of vine bleeding on chip budding indicates that slashing at the base of the trunk does not effect the bud take or push as it does with T-budding.

The vines will sucker very heavily after the tops are cut off. These must be removed otherwise they will grow while the inserted bud may remain dormant. Generally two buds are in-

serted on vine trunks from 1 to 3 inches in diameter. Over 3 inches in diameter 3 to 4 buds should be used. It is not recommended to bud over old vines which are more than 4″ in diameter.

A word of caution is made for persons starting to use these methods. They should try it on a small scale until they become familiar with what to expect, how the buds grow, how fast the shoots grow and the time that is needed to properly train the shoots during this first year.

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GERMINATION OF HARD-TO-START XEROPHYTE SEEDS

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Problems in germinating the seed of many species of xerophytic plants (representing the Cactaceae and other plant families) have been noted; possible explanations for these include initially low or rapidly declining viability, mechanical resistance of seed coats to imbibition or subsequent emergence of the seedling, or chemically caused dormancies, among which are inhibitors in seed coats or in embryos.

Seeds of 14 species of xerophytic, succulent plants representing the Cactaceae, Euphorbiaceae, Dioscoreaceae, Passif-

[1] Student in Environmental Horticulture.

serted on vine trunks from 1 to 3 inches in diameter. Over 3 inches in diameter 3 to 4 buds should be used. It is not recommended to bud over old vines which are more than 4″ in diameter.

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Seeds of 14 species of xerophytic, succulent plants representing the Cactaceae, Euphorbiaceae, Dioscoreaceae, Passif-

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loraceae and Vitaceae were given combinations of various pre-treatments including the following:

1) 24-hour soak in 200 ppm gibberellic acid solution
2) 3-minute soak in 0.1% thiourea solution
3) hot water soak
4) mechanical scarification
5) leaching for 24-36 hours

Also used was a post-planting treatment, namely complete darkness surrounding the seed flats during the germination period.

The seeds were planted using randomized complete block design and germination was monitored. No significant results were noted for 13 of the 14 species, but darkness significantly promoted germination of *Dioscorea elephantipes* (Dioscoreaceae). No seeds of this species germinated in the light, while 35% were observed to germinate within 13 days in darkness. Of the seeds planted in darkness, a three-minute soak in 0.1% thiourea solution gave significantly better germination at the 5% level than the control or the 24-hour soak in 200 ppm gibberellic acid. Further work must be done to determine optimum concentrations and durations of the thiourea and GA soak. Also, related species should be tested and the possible influence of the phytochrome system in this process evaluated.

NEW ZEALAND NATIVE TREES, SHRUBS AND PLANTS: COLLECTION AND PROPAGATION FROM THE WILD

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Albany, New Zealand

With growing interest in New Zealand plants, both here and overseas, it is time to take a critical look at the New Zealand native plant material currently in production in the nursery trade.

Because of the desire of New Zealand's early settlers to have gardens that reminded them of their home country, great efforts were made to grow and propagate plants from all over the world. Many of those that grew well are, for the most part, on our noxious weeds list today, and a number of those early garden plants have been propagated continuously up until the modern time. While this was going on, New Zealand's natural flora was being destroyed during the process of clearing land for farming and horticulture. A number of New Zealand plant species were taken overseas, and to this day a few of our plants are more widely grown outside the country than they are in New Zealand. There are thousands of gardens in New Zealand that don't contain one indigenous plant. New Zealand gardeners have been slow to recognize the merits of New Zealand flora, and the nursery trade slower still. Many nurseries continue to grow plants which are difficult to propagate and grow, and are often unsuitable for the environment of their average customer. Yet, out the back of the nursery, on the hills, are rare and world-renowned botanical treasures being munched off by the local farmer's cows.

As a result of New Zealand's long botanical isolation, 80% of our flora is indemic — i.e. occurring nowhere else in the world — and of the remaining 20% most are locational variants of the species. Over 350 of our plants are now considered to be endangered, so that the old story about "familiarity breeding contempt" no longer has any relevance as an argument against the growing of New Zealand plants in gardens. New Zealand is a diverse land with thousands of miles of coastline, that varies from a sub-tropical north, to a sub-Antarctic, gale-lashed southwest. We have some of the wettest rain forests, with over 300 inches of rain per annum, freezing mountain slopes, and warm, fertile valleys. This incredible variability has given us diverse and exciting flora, which has suffered badly at the hands of man. We have spent years looking for plants that were once common — and some are on the brink of extinction.

Six years ago we set up a nursery to produce New Zealand native flora. Our entire production is retailed on the property. One of our earliest problems was obtaining quality propagating material of the plants we intended to grow — or, in some cases, finding any material at all. Material obtainable from existing nurseries was, for the most part, deviant cultivars with varieg-

ated leaves or other mutants, which in some cases are an insult to the species. Phormiums with pink and purple stripes are not the way nature would have it. Any seed commercially available usually proved to be of poor viability and, in our opinion, it was probably picked from the most convenient source,re not selected from the best forms available. Some species in the past have been completely overlooked, only because poor types were obtained and proved to be unsuccessful.

We now travel many thousands of kilometres each year around New Zealand, and to some of our off-shore islands, in our quest for propagation material. During these travels, we have noted the tremendous variation of a plant species. It is truly incredible how much a plant can change from one end of the country to the other — the leaf size can vary up to 300%, or the flower have 100% more petal area. Because many kinds are not in seed when we find them, the taking of cuttings from wild plants has proved worthwhile, but not without problems.

Seeds. The most important aspect of seed collection is plant knowledge — i.e. knowing the location of a particular plant in its natural habitat. A diary must be kept with accurate dates of when the seed is ripe each year. Seed yields vary greatly from year to year. Some years are a bonanza, with plenty of good seed available from most species. However, this is more the exception than the rule, and it is general for some species to crop well in one location during one year, and not in another. If you are prepared to travel a few hundred kilometres, seed is nearly always available. Altitude has an influence on the seeding of many species. If you cannot find seed at sea-level, it may have seeded well at 1,000 feet. We have noted a number of species which, in some years, bear in a very narrow altitudinal strata.

Seed collection in itself is not difficult. However, an ability to climb trees is essential. It is important to pick the seed when the first of it is ripening on the tree — pick it too early and it is too green; too late and it may have lost its viability or the birds, wind or rats have beaten you. Before picking any seed, check on the health of a few by cutting in half with a pair of secateurs, and inspect for any obvious problems. It is a waste of time picking a lot of non-viable seed. We only select seeds from trees which have obvious superior character. However, what constitutes "superior character" is very much a matter of definition. One nurseryman might like a species with a small leaf and a dense, bushy habit; another may prefer it tall with pendulous branches. Good health and vigour are most important.

Once back at the nursery, all seed must be cleaned thoroughly. Most seed will not germinate with any flesh present, and we go to considerable lengths to ensure that the seed is properly cleaned. Most of this is achieved with physical clean-

ing methods. We have also found hydrochloric acid to be a very useful chemical aid in seed cleaning and it appears to have good fungicidal properties as a bonus. Fresh seed can be immersed in concentrated hydrochloric acid without any apparent damage. Seed should be planted fresh and we now never bury any seed. It is spread evenly over the top of a propagating tray, containing a mixture of peat, sand, pine-bark and sawdust. We then press the seed firmly into the surface with a flat piece of wood, so that the seed is still clearly visible on the surface, but pushed in level. Germination has improved dramatically since we ceased burying seed and kept propagating trays in a cool, shady place. Once germination commences, a light sprinkling of propagating mix can be used to cover them.

Cuttings. Cuttings from the wild can be a very difficult proposition. However, they are well worth the effort, because of the desirability of bringing specific clones into propagation. Many of the superior plants in the wild may have no seed, or they may be natural hybrids. Many of our plants hybridize freely, and some excellent hybrids exist in the wilds that are going to be very good horticultural subjects. However, one must be careful with hybrids to ensure that only quality hybrids are propagated.

There are two major problems with cuttings from the wild. The first is getting them back to the nursery in good condition. As some of these botanical expeditions take a week, the cuttings are almost compost by the time you get them back to the nursery. The second is plant nutrition. Although a plant may look healthy out on a wind-swept mountainside, it generally is suffering from chronic malnutrition. Therefore, any cutting removed from it often collapses in the nursery before it has time to take root.

We prepare our cuttings, if possible, out in the wilds, and they are packed into plastic bags for easy transport back to the nursery. I like to remove the cuttings from the bags every day and wash in fresh water. Despite all the problems involved in taking wild cuttings, we have found it worthwhile, and some of the improved forms of plants we have obtained are most pleasing. Once we have a few stock plants back at the nursery, propagation is then routine, and rooting percentages jump impressively.

Very little effort has been expended on improving the flowering qualities of New Zealand flora, with the exception of *Leptospermums*. We, as yet, haven't started a breeding programme, but are continually on the lookout for improved flowering forms. Early flowering — i.e. the first year — is promoted by propagation from cuttings. The following species have flowered

for us in the first year — instead of the normal five to eight — and generally display a lower crown and improved form when grown from cuttings:

Ackama rosaefolia
Alseuosmia macrophylla
Clematis paniculata
Hebe species
Hoheria populnea
Leptospermum scoparium
Metrosideros albiflora
M. carminea
M. excelsa
M. fulgens
M. kermadecensis
M. robusta
Olearia cheesemanii
Parsonsia heterophylla
Sophora microphylla
S. tetraptera

Alpine Plants. We have recently extended our range to alpine plants. These flourish outside their alpine environment, even in Auckland's maritime weather. All that is required is to give up any concept of organic gardening and plant your alpines in gravel. We use scoria, and have found those reputedly impossible plants do very well. Any fertilizer used on alpines should be entirely 100% water soluble chemicals, and watered on as a foliar feed.

CONCLUSIONS

In conclusion, I have no doubt that New Zealand native flora has a tremendous future for ornamental, shelter and general amenity planting. In a world so badly plundered of its natural resources, we, as horticulturists, hold the key to man's wealth and prosperity. We can clean up the air by planting great forests that, in turn, will provide us with our fuel, food, building materials, paper, plastics and medicine.

Plants are the future of mankind. We neglect them at our peril. New Zealand trees, shrubs and herbs have their part to play.

Appendices. It is not my intention to outline every New Zealand plant, but you might find the four attached appendices useful.

Appendix 1. New Zealand trees and shrubs with excellent potential.

Ackama rosaefolia
Astelia banksii
A. chathamica
A. fragans
A. grandis
A. nervosa
A. solandri
A. trinervia
Carmichaelia angustata
A. ordorata
C. williamsii
Chordospartium stevensonii
Cordyline indivisa
C. kaspar
Dacrydium colensoi
D. intermedium
D. laxifolium
Dysoxylum spectabile
Elaeocarpus dentatus
E. hookeranus
Elingamita johnsonii
Eugenia maire
Griselinia lucida
Hoheria angustifolia
H. lyallii
H. populnea
H. sexstylosa

Ixerba brexioides
Laurelia novae-zelandiae
Leptospermum ericoides
Libocedrus bidwillii
L. plumosa
Metrosideros carminea
M. fulgens
M. robusta
M. unbellata
Neopanax colensoi (Syn.: *Pseudopanax colensol*)
Nestegis cunninghamii (Syn.: *Gymnelea cunninghamii*)
N. montana (Syn.: *Gymnelea montana*)
Nothofagus fusca
N. menziesii
N. solandri
N. truncata
Notospartium glabrescens
Olearia albida var angulata
O. avicenniaefolia
O. coriacea
O. paniculata
O. traversii
O. virgata
O. virgata var dartonii
Pachystegia insignis
Pittosporum colensoi
P. cornifolium
P. dallii
P. ellipticum
P. fairchildii
P. huttonianum
P. kirkii
P. ralphii
P. umbellatum
P. virgatum
Plagianthus betulinus
Planchonella (Syn.: *P. novo-zelandica costata*)
Podocarpus acutifolius
P. ferrugineus
P. hallii
P. nivalis
Pomaderris apetala
P. kumeraho
P. oraria var novae-zelandiae
P. phylicifolia var polifolia
P. rugosa
Pseudopanax chathamicum
P. discolor
P. edgerleyi
P. ferox
P. lineare
Quintinia acutifolia
Q. serrata
Rhopalostylis cheesemanii (Syn.: *baueria var. cheesemanii*)
R. baueria var cheesemanii
R. sapida
Senecio hectori
S. perdicioides
Many ferns are also excellent subjects

Appendix 2. Plants for indoor pots and planters.

Astelia banksii
A. chathamica
A. fragans
A. grandis
A. nervosa
Arthropedium cirratum
Collospermum hastatum
Cordyline australis
C. kaspar
Corynocarpus laevigatus
Elastostema rugosum
Entelea arborescens
Fuchsia procumbens
Heiliodendron brunonianum and cultivars
Jovellana sinclairii
Libertia peregrinans
Macropiper excelsum var majus
Neopanax colensoi (Syn.: *Pseudopanax colensoi*)
Persoonia toru
Pittosporum cornifolium
P. pimeleoides
Podocarpus ferrugineus
Pratia angulata
P. physaloides
Pseudopanax discolor
P. ferox
P. lessonii
Pseudowintera axillaris
P. colorata
Rhopalostylis cheesmanii (Syn.: *R. baueria var cheesemanii*)
R. sapida
Tecomanthe speciosa
Xeronema callistemon

Appendix 3. Plants for outdoor tubs and planters.

Ackama rosaefolia
Agathis australis
Anthropoedum cirratum
Astelia banksii
A. chathamica
A. fragans
A. grandis
A. nervosa
Cordyline species
Corynocarpus laevigatus
Elingamita johnsonii
Griselinia littoralis
Libertia perigrinans
Melicope ternata
Meryta sinclairii
Metrosideros excelsa and cultirans
M. kermadecensis and cultivars
M. robusta
Neopanax colensoi (Syn.: *Pseudopanax colensoi*)
Phachystegic insignis
Phormium cookignum and cultivars
P. tanax and varieties
Phyllocladus glaucus
Pittosporum cornifolium
P. eugenioides
P. kirkii
P. ralphii
P. tenuifolium
P. umbellatum
Planchonella novo-zelandica (Syn.: *P. costata*)
Pomaderris oraria
Pseudopanax crassifolium
P. discolor
P. ferox
P. laetum
P. lessonii

Appendix 4. Hybrids having a good potential.

Brachyglottis repanda × *Senecio greyi*
Cordyline australis × *C. banksii*
C. australis × *C. indivisa*
C. australis × *C. kaspar*
C. australis × *C. pumilio*
Fuchsia excorticata purp. × *F. procumbens*
Leptospermum ericoides × *L. sinclairii*
Metrosideros excelsa ×*M. robusta*
M. excelsa × *M. umbellata*
M. robusta × *M. umbellata*
Pseudopanax crassifolium × *P. arboreum*
P. crassifolium × *P. lessonii*
P. discolor × *P. crassifolium*
P. lessonii × *P. discolor*
Pittosporum tenuifolium × *P. ralphii*
Sophora microphylla × *S. prostata*

Hebe, Coprosma and Carex hybrids exist in great legions. Many of these natural hybrids have horticultural merit. Both *Astelia* and *Olearia* hybridise and are worth further investigation.

SOME ASPECTS OF *CEDRELA SINENSIS* PROPAGATION

ANDREW D. MALOY
Lyndale Nurseries Limited

Cedrela sinensis, commonly known as the Chinese Toon, is one of the most handsome of spring foliage trees. It's growth habit is straight and erect and it has large, ash like leaves up to 60 cm long, finely divided into ten or more leaflets.

As the leaves unfold and develop they are a beautiful shade

Appendix 3. Plants for outdoor tubs and planters.

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Anthropoedum cirratum
Astelia banksii
A. chathamica
A. fragans
A. grandis
A. nervosa
Cordyline species
Corynocarpus laevigatus
Elingamita johnsonii
Griselinia littoralis
Libertia perigrinans
Melicope ternata
Meryta sinclairii
Metrosideros excelsa and cultirans
M. kermadecensis and cultivars
M. robusta
Neopanax colensoi (Syn.: *Pseudopanax colensoi*)
Phachystegic insignis
Phormium cookignum and cultivars
P. tanax and varieties
Phyllocladus glaucus
Pittosporum cornifolium
P. eugenioides
P. kirkii
P. ralphii
P. tenuifolium
P. umbellatum
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M. excelsa × *M. umbellata*
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P. crassifolium × *P. lessonii*
P. discolor × *P. crassifolium*
P. lessonii × *P. discolor*
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As the leaves unfold and develop they are a beautiful shade

of rich pink which makes a most spectacular display. As the foliage matures it changes to creamy white shades and then to a deep green for the rest of the growing season. It requires warm conditions and shelter from wind which can destroy the tender pink spring foliage.

Cedrela is an extremely popular tree for the home garden and is, therefore, a very worthwhile subject to be grown in the nursery. It grows well in containers and even when young produces the spectacular spring foliage.

Cedrela has a tendency to sucker from adventitious buds on the roots, and given favorable conditions one *Cedrela* plant can become a large cluster of many plants. This gives rise to the main method of propagation — root cuttings.

Root cuttings are made in the winter through to early spring. By digging around the base of a fairly mature tree, roots from 2 to 15 mm in diameter can be obtained. While searching around a parent tree, clusters of suckers can sometimes be found and on digging these up, a mass of twisted and intertwined roots are sometimes to be found. This mass can be up to 10 cm in diameter and on examining it, many adventitious buds can be seen; these roots are particularly good. All roots are washed clean of soil debris and then surface sterilized.

This is done by immersing them in a 1:20 dilution of 0.3% sodium hypochlorite (Janola) and water for 15 minutes. The roots are then cut into pieces 10 to 25 mm in length, trying as much as possible to maintain correct polarity of the cutting. The ends of the cuttings are then dipped in Captan and planted upright in normal cutting medium, ensuring that the upper end is left protruding 2 to 3 mm above the surface. This helps prevent rotting which sometimes occurs if the whole of the cutting is buried. The cuttings are then covered with newspaper, placed in the propagating house at a temperature of around 15°C. Adventitious buds will be stimulated and after a couple of weeks the newspaper can be removed. The resulting plants are then potted up and can produce a saleable plant the following spring.

This brings us to a further method of increasing the stock. When the young plants have been potted about 8 to 10 weeks, a tip cutting can then be taken. This is a very small, 10 to 20 mm cutting and is very soft. All that is required is a leaf and a bud. The leaf is cut back for ease of handling and to reduce transpiration. The cutting is then dipped in Seradix No. 1 and planted in a medium of 100% pumice sand. Given mist and bottom heat the cuttings will be rooted in 4 weeks and can then be potted on. These plants can be held over the winter and potted on the following spring.

NURSERY PLANTS FOR EXPORT MARKETS

BARRIE L. McKENZIE
Topline Nurseries Limited
Oratia, Auckland, New Zealand

Recently we saw the end of a campaign in New Zealand to stimulate the interest in export by manufacturers and producers as well as make people aware that export is vital. Slogans such as — 'The Ship Won't Wait," "Our Jobs Depend on Export," "Take the Plunge," were common advertising. It is without doubt that interest in export has been generated, but little can compare with the interest in horticulture as an export and over a short period we have seen the small grower to the large million dollar company making claims that "moves are being made in the horticultural field" — where does this leave us? We are concerned, in particular, with the field that most here today are familiar, i.e. the growing of live plant material, whether it be for local or export sales.

In ten years we have seen considerable leaps in the value of live plant exports. The following is the F.O.B. value of live plant exports (ref. N.Z. Statistics Department).

1969 — $39,600
1972 — $96,800
1976 — $141,195
1978 — $530,859 (export to 27 countries)
1979 — $1,172,844

In the last 12 months (between July 1, 1978 and June 30, 1979) we have seen a jump of over 100%. Once again I stress that these figures are F.O.B., i.e. not including insurance or freight costs.

Over the past three years I have been fortunate to be able to look at market possibilities in England, France, Japan, Saudi Arabia, U.S.A. and Thailand, and from these trips have been able to formulate definite patterns as to crops to grow and what the customer expects. It is very easy to fix in our minds likes and dislikes to certain plants that are always in demand in New Zealand and, if given sufficient thought, one can almost be certain that this plant would be a seller in a certain country. Careful planning and research of markets must be made before expansion and growing plans are implemented. An example of this is the liking the French have for red colours and any such plant giving a display of red and which can grow in their climate results in interest and sales. This certainly does not mean that interest does not exist for general stock. Comparing two plants (1) *Photinia* and (2) *Cortaderia* 'Gold Band', the first is new but is giving what many ask for — the red colour. The second can be found in large numbers and *Cortaderia* as a plant is

grown not only for colour of plume but for the flowering period. 'Gold Band' is a new form giving yellow variegated foliage; to sell the plant it is not necessary to sell it as an entirely new plant, but market it purely for it's variegations. Still using these two plants as samples, it is necessary to understand what the customer expects as a "liner" so that when delivery is made, disappointment will not occur, which can result in delayed payments. It is also necessary to ensure that the delivery date from New Zealand is acceptable to the buyer — yet delivery times are mainly set by when the plant is suitable for shipping. *Photinia* for delivery in March can be too soft if late growth is experienced, whereas delivery in May/June should be recommended.

Stock Plant and Seed Sources: Mother plants must be selected for even growth and be true-to-type. When volume is required sufficient stock must be available not only to produce the number required but to allow for those which do not make the grade, as well as rejects when packing. Seed sources must be reliable not only for trueness-to-type, but delivery dates as well, so that the grade can be obtained to meet that which has been quoted to the customer as a delivery date:

Cutting and Seed Production: A high standards of hygiene throughout the growing season is essential and this starts from the mother stock through to the work area, the propagation area, and the general liner beds. Consideration must be given to all visible pests and diseases but, equally important, root inspection during the growing period is essential so that root rot diseases can be detected at an early date, and the necessary action applied.

Media for Growing: It is essential to be fully aware of the quarantine requirements of the countries to which you intend to export and, if necessary, grow in a medium acceptable to that country. Recently we have seen the move toward bark in growing media; as this is a wood product and classified the same as sawdust it is not acceptable to ship into countries which currently accept only our peat/sand media on the roots.

Packing Preparations: A clean well-prepared packing shed is necessary which offers adequate shade and light. Preparation benches should be clean and preferably covered with polythene so that cleanliness can be maintained. Plants once shaken out should be carefully examined, trimmed, and prepared for dipping through a fungicide and insecticide dip. Dipping the plants once they are rolled can be acceptable for certain plants, but where large foliage or dense foliage is present, individual dipping is advised. This avoids foliage remaining wet for a long period; if packed in this condition overheating will occur, re-

sulting in damaged plants at the destination.

Inspection by a Ministry of Agriculture Field Officer should be made at this stage and, if necessary, depending upon the size of the shipment, several inspections may be required. Early advice to the M.A.F. is necessary and where weekly consignments are being shipped, a schedule of times and dates for inspection should be made available to the Field Officers as early as possible.

Packing Media: Generally accepted world-wide is sphagnum moss and, in some countries, peat. Whichever medium is used, it must be free of foreign material and be of a very high quality. If countries such as Japan are receiving the goods, it is advisable to fumigate the moss or peat first so that any organism is destroyed. In recent tests large numbers of saprophytic nematodes were found in moss and peat, although we are aware that they cause no harm to the plants, they can be confused with other parasitic nematodes and, if this is the case, the receiving Authorities can and will fumigate without question. It is essential that every factor be considered when shipping as delays can cause losses as well as loss of goodwill. The use of woodwool should be avoided as this is forbidden in many countries; clean shredded newsprint is recommended.

Cartons: Strong waxed boxes with adequate ventilation are recommended. The plants are stood upright and held firmly into position by each other. At no stage should the plants be covered with plastic as this causes overheating and sweating.

What I have covered here are only a few of the important considerations required for exporting. Before involving oneself to any great financial cost a thorough examination should be made covering all aspects from growing to marketing as one weak link can result in losses to all parties. Growing for export can only be considered a challenging and rewarding market.

NITROGEN RESPONSE OF PROTEACEOUS SHRUBS AND OTHER NURSERY PLANTS GROWN IN CONTAINERS

M.B. THOMAS

Department of Horticulture, Lincoln College, Canterbury, New Zealand

Abstract. A range of proteaceous shrubs and other nursery plants were grown in containers with soilless media and various N levels primarily supplied from Osmocote (26 percent N). Plants demonstrated a range of responsiveness. *Grevillea robusta* was the most responsive but required an optimum near to 120g N/m^3/month; two *Eucalyptus* species showed a smaller response than *G. robusta* but required an N optimum of 97g N/m^3/month.

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Camellia japonica and *Erica herbacea* (Syn.: *E. carnea*) 'Springwood White' responded best to the range 57 to 121 g N/m³/month. *G. rosmarinifolia* and *Leucadendron adscendens* were the next most responsive species, then *Hakea laurina* and *Dryandra formosa*. *Leucospermum candicans*, *Protea repens*, *P. scolymocephala* could grow satisfactorily on very low N levels, amounting to just over 5g N/m³/month from Osmocote 18/2.6/10. Optimum N rates for all these species are discussed.

REVIEW OF LITERATURE

Optimum growth of container plants requires a fairly uniform and continuous supply of N but with slightly greater levels in spring (7). Bunt (3) stressed the relatively greater importance of a continuous N supply for pot plants grown in loamless composts compared with crops grown in borders or the open ground. This was because of inherently low levels of available N, roots restricted to a relatively small volume, and the need for frequent watering of plants in containers. Soilless media rich in N would be unsuitable because of difficulties of standardization, and the need to continually monitor N levels to maintain an optimum N supply. The total N requirement and the rate at which it is required depends on the vigour of the species and the manner in which the plant is grown. Temperature, light, water availability, and size of container are the most important factors controlling the rate and amount of growth.

Boyd and Needham (2) discussed different approaches to the interpretation of data from N experiments and emphasized the value of multi-level tests with from 6 to 9, rather than only 2 to 4, N levels. They also stated their preference for the use of linear segments to describe the quadratic N response rather than a smooth curve, since a curve was said to often encourage an over-estimation of crop requirements due to the economic optimum being placed on the crest of the curve rather than on a flat plateau.

Knowledge of the desirable N rate is important. Lack of nitrogen will give rise to plants with low growth rates and often a spindly weak foliage growth, while excessive levels can yield hard stunted plants (3). The use of nitrogen in container mixes was reviewed by Thomas and Spurway (19). It is clearly the single most important factor to consider when examining the nutrition of container grown plants since a continuous supply is required. The rate of supply has a dominant control over plant growth and is influenced by many factors such as fertilizer type, N losses and growing conditions. Furuta (7) indicated that a theoretical requirement of 3g of 14 month Osmocote is required to raise a marketable plant in a one gallon container. In practice this becomes a 9g basal application because of severe N leaching losses over the production time. Immobilization of N and denitrification can also account for poor N re-

covery rates with container-grown plants (8,9).

Potted chrysanthemums were shown to have an N uptake rate, and total N demand, over 10 weeks in summer which greatly exceeded the requirements of cyclamen over one year (3). This illustrates the importance of comparative nutrition and, in previous work (19,20), N requirements have often been shown to contrast strongly among species. The objective of the experiences discussed here is to examine several different species (many in the Proteaceae) and to compare their responses to a range of N levels and, in one case, to compare different fertilizer sources, with other inputs being kept relatively constant.

MATERIALS AND METHODS

Plant Species and Growing Conditions. Six experiments were run with 1 to 5 species in each experiment as follows:

Experiment A.	*Grevillea rosmarinifolia* and *Protea scolymocephala* bagged on 4.10.73 and lifted on 16.9.74.
Experiment B.	*Camellia japonica*, *Erica herbacea* (*E. carnea*) 'Springwood White' and *Hakea laurina* bagged on 8.10.73 and lifted on 2.12.74 and 23.9.74 for latter two.
Experiment C.	*Grevillea* 'Olympic Flame' and *Dryandra formosa* bagged on 9.10.73 and lifted 10.6.76.
Experiment D.	*Grevillea robusta* bagged on 28.1.74 and lifted 12.8.74.
Experiment E.	*Grevillea robusta*, *G. rosmarinifolia*, *Leucadendron adscendens*, *Leucospermum candicans*, *Protea repens* and *P. scolymocephala* bagged on 28.1.74 and lifted on 28.1.75.
Experiment F.	*Eucalyptus nicholii* and *E. notabilis* bagged on 13.6.74 and lifted on 20.11.74.

All plants were seedlings with the exception of *G. rosmarinifolia* (Experiment A), *E. herbacea* Springwood White', *G.* 'Olympic Flame' and *Leucopsermum candicans*, which were propagated by semi-ripe tip cuttings under mist.

Rooted cuttings or young seedlings were potted up individually into tubes containing a medium with little or no nutrients. All experiments (except B) were run in a heated glasshouse equipped with automatic fan ventilation. The minimum glasshouse temperature was 15°C while the maximum was close to 5°C above ambient temperature. Experiment B was carried out in a shadehouse covered with 50% polypropylene shadecloth (Sarlon). Hand watering was done when required and no additional fertilizer application was made following laying-down.

Experimental Design. Experiments A, B, D, E, and F were simple designs based on several levels of nitrogen for a range of species which were mostly in the Proteaceae. Experiment C was the only one with a factorial design and involved 2 N levels × 2 N sources (Uramite and Osmocote 26% N). All were randomized block designs.

Data Collection and Analysis. Visual ratings were used with a score of 0 = dead, to 5 = very vigorous, high quality plants. On completion of each experiment the plants were cut off just above the top of the medium and the foliage was oven dried. All ratings and dry weights were statistically examined using the Teddybear (now Crypto/Teddybear) computer programme for analysis of variance and F test.

Media and Fertilizers. The medium for all experiments was equal parts (1:1, vv) Mataura sphagnum peat and fine grade perlite. The physical and chemical properties of Mataura peat were described by Goh and Haynes (9) and perlite by Morrison *et al.* (16).

The levels of nitrogen in the media varied from 0 to 900g N/m^3 (Tables 2 to 5) and were supplied predominantly from Osmocote (26% N). A basal dressing of 8-9 months Osmocote (18/2.6/10) supplying 45g N/m^3 was used in all experiments except those with nil N treatments. Total N was then made up from 3-4 month Osmocote (26% N) except for half the treatments in Experiment C, where Uramite (38% N) was used. Base dressings of Osmocote 18/2.6/10 supplied 6.5g of P/m^3 and this was supplemented with superphosphate (9% P) to give a total of 30g P/m^3 in Expts. A and B and 60g P/m^3 for F. All other experiments were at the base level of 6.5g P/m^3 from Osmocote 18/2.6/10, or supplied from superphosphate in the nil N treatments. The 8-9 month Osmocote yielded 25g K/m^3 and this was made up to 125g K/m^3 in all trials, except Experiment C, with sulphate of potash (39% K).

The levels of P and K were therefore as follows:

		P	K
Experiments	A & B	30 g/m^3	125 g/m^3
	C	6.5	25
	D & E	6.5	125
	F	60	125

A base dressing of the following was also used in all experiments: 4.5 kg/m^3 dolomite lime, 1.5 kg/m^3 agricultural lime ($CaCO_3$), 75 g/m^3 'Sequestrene' iron chelate (Na EDTA Fe with 12% iron) and 'Sporumix A' (150 g/m^3 containing 1.14% B, 0.62% Zn, 1.27% Cu, 5.46% Mn, 0.06% Mo. 0.05% Co. 9.78% Mg). The media and fertilizers were well mixed and then transferred to PB5 (2½1) 'Plantabags' just prior to potting.

RESULTS

Experiment A. Lack of added N had no unfavorable effect compared with other treatments on the growth of *Grevillea rosmarinifolia* and *Protea scolymocephala* 3 months after bagging of the plants (Figures 1 and 2). However 340-450g N/m^3 appeared to be the upper limit for both species and very severe

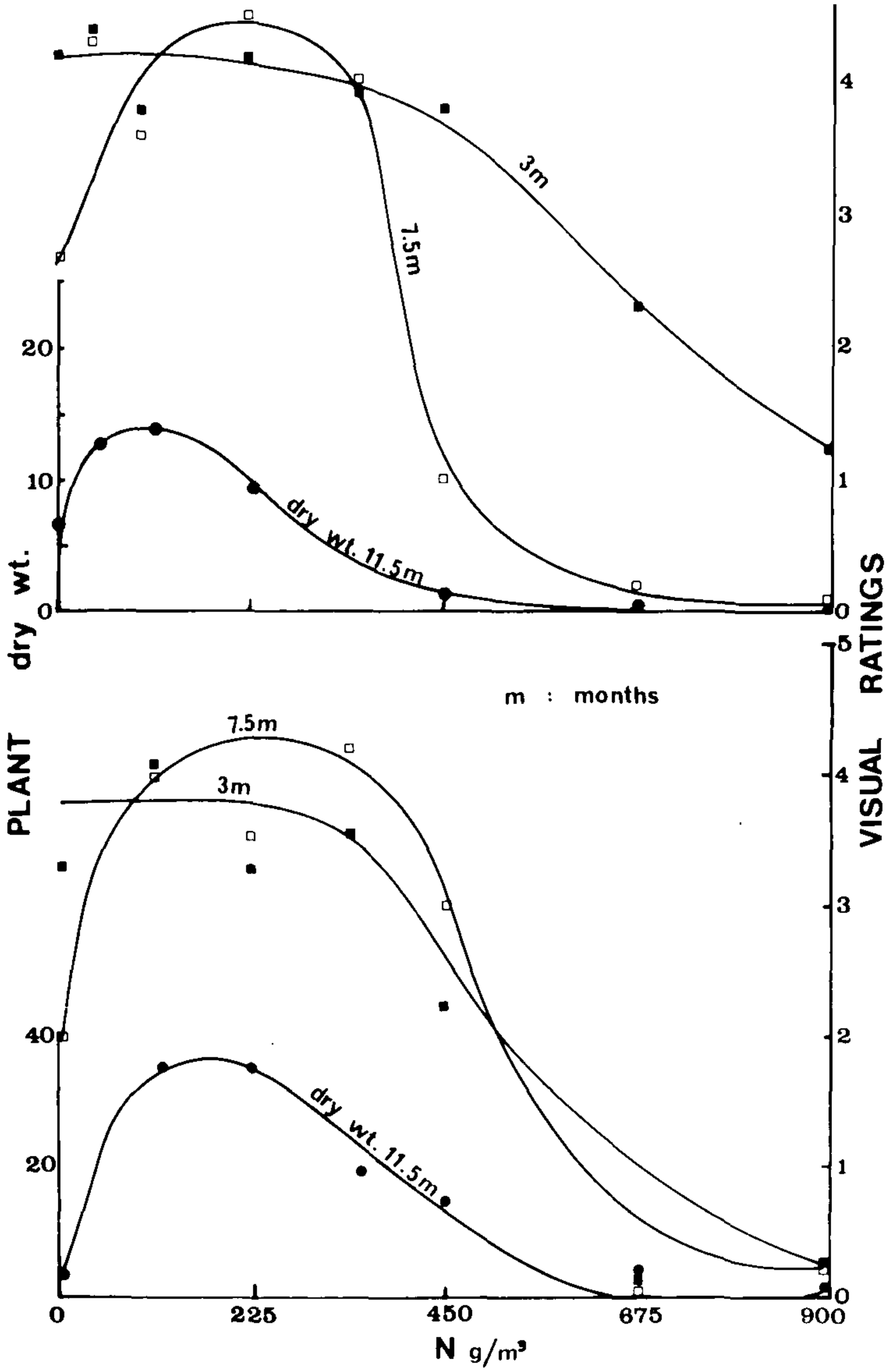

Figure 1. (below): Expt. A. The influence of N levels on foliage growth of *Grevillea rosmarinifolia* plants. Visual ratings and dry weight (g/plt.).

Figure 2. (above): Expt. A. The influence of N levels on foliage growth of *Protea scolymocephala* plants. Visual ratings and dry weight (g/plt.).

Figure 3. Influence of N levels on growth of *Protea scolymocephala* plants. *Left to right:* 0, 225, 450, 675, 900 g N/m^3. Photo taken just before completion of experiment.

damage was evident after 3 months and death of most plants by harvest time in the 2 highest N treatments. Optimum N levels could not be accurately evaluated in these experiments because N was predominantly applied as 3-4 month Osmocote for an experiment which was run for nearly a year. It was noticeable, however, that a total of 225g N/m³ for grevillea and 100g N/m³ for protea appeared to be the optimum N level. These rates would amount to an optimum theoretical release rate of 57 and 24g N/m³ per month respectively with only 5.5 g N/m³/month supplied from the 8-9 month Osmocote after 3½ months. Protea was therefore more sensitive than grevillea to increasing N levels although there was a strong similarity in the response of the 2 species to added N and the onset of toxicity at 3 months. This is shown in a comparison between Figures 1 and 2. Figure 3 illustrates the importance of the correct level of N fertilization, with severe deficiency symptoms at nil N and death of the plant at 900gN/m³.

Experiment B. Foliage of plants in the three species in this experiment was visually rated at approximately 2, 7 and 11 months. There was no apparent response to increasing N levels after 2 months but at 7 months *Camellia japonica* in the nil and 45g N/m³ treatments were showing N deficiency and there was a similar effect in *Erica herbacea* 'Springwood White' and in *Hakea laurina*, but only with nil N. The growth responses for the 3 species are depicted in Figures 4, 5 and 6.

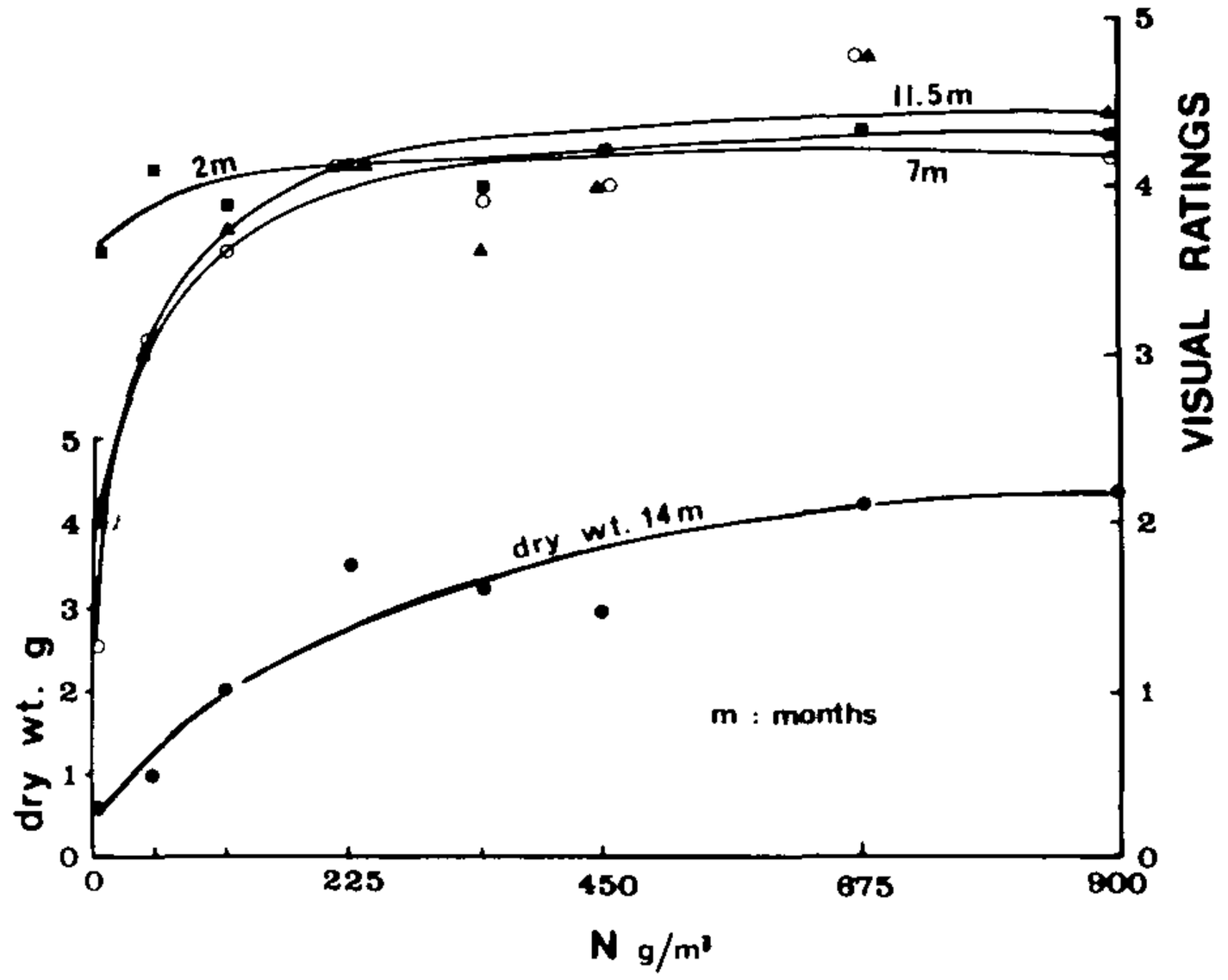

Figure 4. Expt. B. The influence of N levels on foliage growth of *Camellia japonica* plants. Visual ratings and dry weight (g/plt.).

Key to Ratings
■ = 2m
○ = 7m
▲ = 11.5m

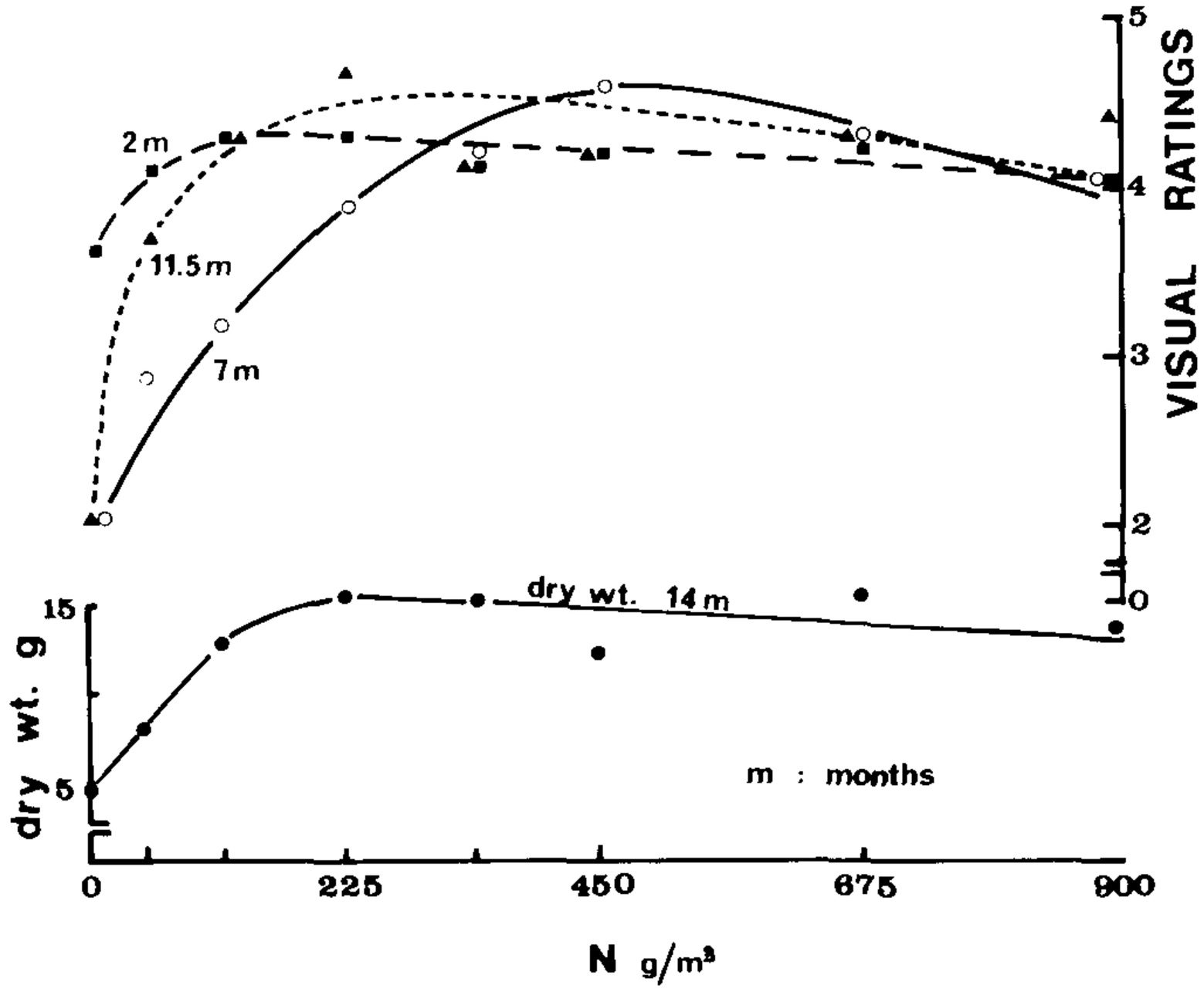

Figure 5. Expt. B. The influence of N levels on foliage growth of *Erica herbacea* 'Springwood White' plants. Visual ratings and dry weight (g/plt.).

Key to Ratings
■ = 2m
○ = 7m
▲ = 11.5m

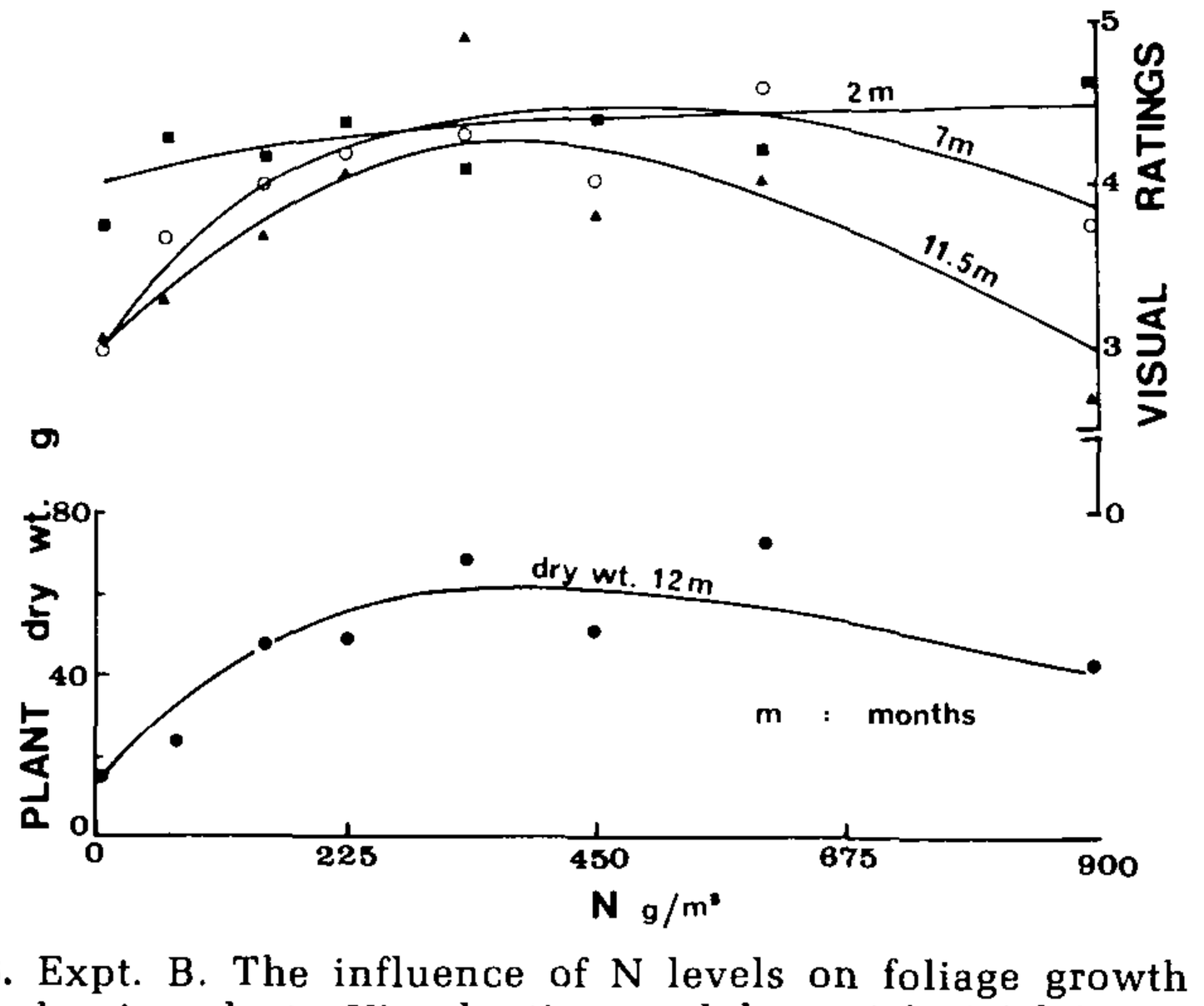

Figure 6. Expt. B. The influence of N levels on foliage growth of *Hakea laurina* plants. Visual ratings and dry weight (g/plt.).

Key to Ratings
■ = 2m
○ = 7m
▲ = 11.5m

There was little N toxicity apparent and in fact the camellias and ericas showed no significant growth depression at any stage even with the highest level of 900 g N/m³ (theoretically amounting to 250g N/m³/month for the first 3½ months). Some growth depression would have been expected for camellia and erica, however hakea showed severe toxicity symptoms at 11½ months. In all 3 species a total level of between 225 to 450g N/m³ appeared to be the most desirable. This would amount to between 57g N/m³/months for hakea and 121g N/m³/month for the other 2 species for the first 3½ months. Figure 7 shows the growth response of *Hakea laurina* to a range of N levels. This plant appeared quite tolerant of very low N rates while growth suppression was apparent at high levels.

Figure 7. Influence of N levels on growth of *Hakea Lurina* plants. *Left to right*: 0, 45, 110, 225, 340, 450, 675, 900 gN/M³. Photo taken just *before completion of experiment.*

Experiment C. This experiment involved *Grevillea* 'Olympic Flame' and *Dryandra formosa* plants supplied with nitrogen at two rates combined in a factorial design with Uramite and Osmocote. The lower rate of nitrogen appeared quite adequate for *Dryandra* (Table 1) and growth of this species in the 225g N/m³ rate was almost significantly (P = 0.07) higher than in 450 g N/m³ when measured by visual ratings. Uramite produced higher dry weight yield than Osmocote for *Dryandra*.

The *Grevillea* plants responded quite strongly to varied N rates and to the type of fertilizer. Osmocote at 450g N/m³ was superior to the lower rate and to both levels of Uramite (Table

Table 1. Experiment C — Effects of N levels and type of fertilizer on the foliage growth (visual ratings and dry weight) of two container-grown nursery plants.

	Dryandra formosa			*Grevillea* 'Olympic Flame'		
N levels (N)	Visual ratings		Dry Wt.	Visual ratings		Dry Wt.
(g/m^3)	2 months	7 months	(g/plt.)	2 months	7 months	(g/plt.)
225	4.0 #	4.0 #	15.1 –	3.8 –	3.9 *	14.4 ***
450	3.7	3.7	14.3	4.0	4.3	22.2
Fertilizer (F)						
Uramite	4.3 ***	4.3 ***	19.6 ***	3.9 –	3.8 ***	15.0 ***
Osmocote	3.4	3.4	9.8	3.9	4.4	21.6
LSD (5%)	0.3	0.3	4.0	0.4	0.4	3.3
(P)			Significant Interactions			
NF	–	–	–	–	–	**
CV (%)	11	11	42	18	14	28

2). This was probably because Uramite can have an N mineralization rate of less than 60% of 3-4 month Osmocote (3) and thus the high N requirements of grevillea compared with *hakea* could not be met with that fertilizer.

Table 2. Experiment C — Interaction of nitrogen rate and type of fertilizer on the foliage growth (dry weights) of *Grevillea* 'Olympic Flame'.

	Uramite	Osmocote
N g/m^3		
225	14.0	14.9
450	16.0	28.3
LSD (5%)	4.6	

Experiment D. The experiment with *Grevillea robusta* was similar to Experiments A, B and F in that it involved several levels of nitrogen. The nil and 45g N/m^3 treatments quickly became inadequate as shown by visual ratings at 3½ months (Figure 8) while the 110g N/m^3 rate was inferior to the highest level of 675g N/m^3 at 3½ months. The optimum rate appeared to be close to 450g N/m^3 or 120g N/m^3 per month.

Experiment E. A very low, plus two medium rates, of N addition were used for six proteaceous shrubs (Table 3). The foliage growth of *Grevillea robusta* plants in the 45g N/m^3 showed the effect of insufficient N after 3½ and 8 months and in final dry weights. *Leucadendron adscendens* was the only other species with a depression in yield with the 45g N/m^3 rate. This occurred only for foliar dry weights and it is noticeable that the other four species showed no ill effects or deficiency symptoms when receiving 0.25 kg/m^3 of 8-9 month Osmocote. A rate of 45g N/m^3 would amount to only slightly over 5g N/m^3/month. The 450g N/m^3 rate appeared toxic on *G. rosmarinifolia* at 3½ months and *Protea scolymocephala* at 8 months while *Leucospermum candicans* and *P. repens* were similarly unaffected by increasing N levels. This indicates that no serious de-

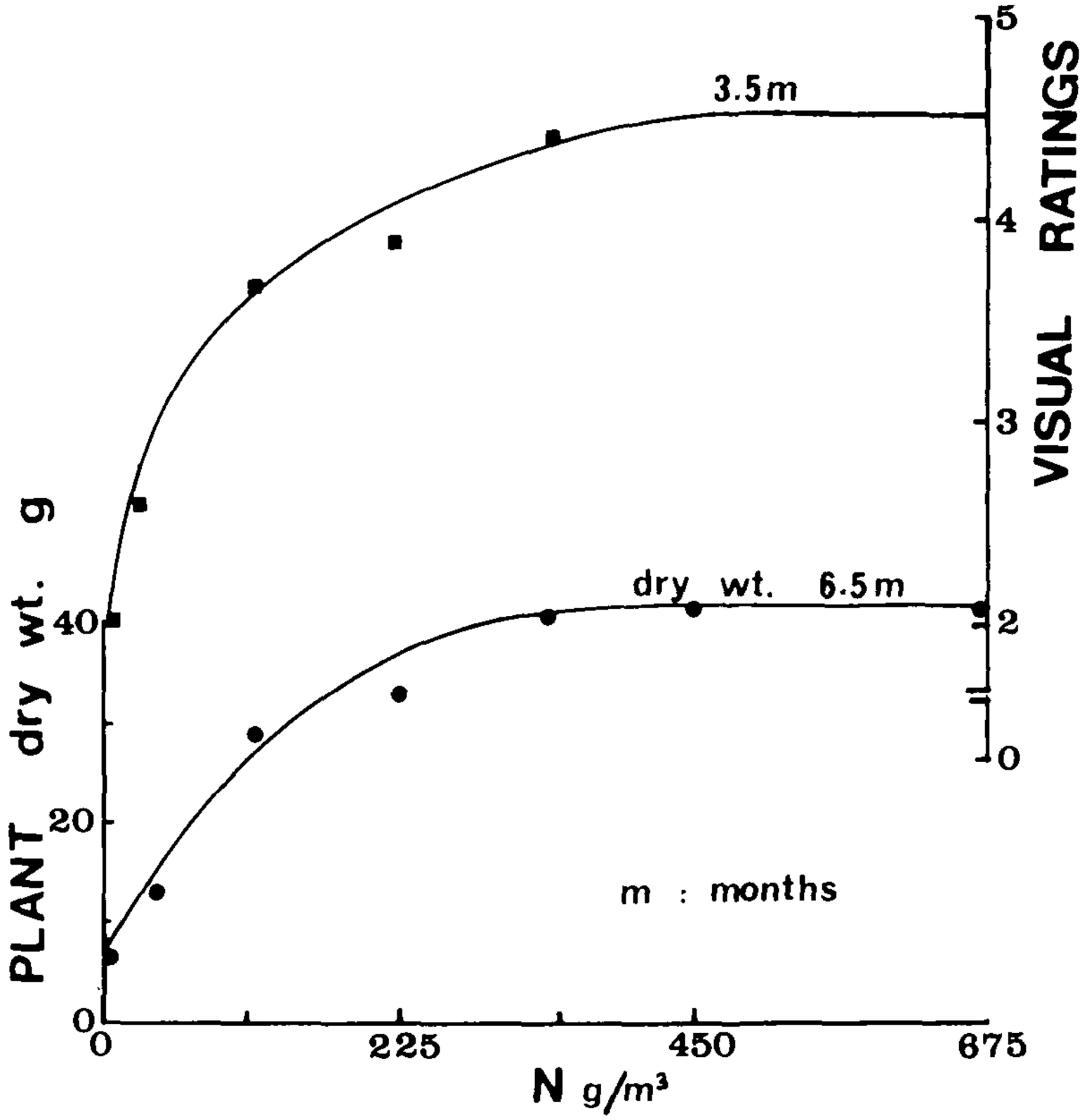

Figure 8. Expt. D. The influence of N levels on foliage growth of *Grevillea robusta* plants. Visual rating and dry weight (g/plt.).

ficiency was occurring. A lack of N response was most apparent with the proteas where the 45g N/m³ treatment for *P. scolymocephala* rated significantly higher than the other treatments after 8 months. In addition, the dry weights for *P. scolymocephala* plants at the very low N treatment were high, although not significantly greater than others probably because of the high variability (CV = 110%).

The optimum levels of N for *G. robusta* and *L. adscendens* appeared higher than those for other species at between 225 and 450g N/m³. The protea species and leucospermum appeared least demanding, requiring only 45g N/m³ (from slow release Osmocote only). *G. rosmarinifolia* from this work and from Experiment A would probably be intermediate between the two groups.

Table 3. Experiment E — Effects of 3 levels of N on the foliage growth (visual ratings and dry weights) of six container grown nursery plants.

Species	N Levels (g/m^3)		Visual ratings 3½ months	Visual ratings 8 months	Dry Wt. (g/plt.)
Grevillea robusta	45		2.8 B b	2.9B b	24.7Bb
	225		4.2 ABa	4.6 A a	61.6Aa
	450		4.6 A a	4.2ABa	55.3Aa
		(P)	*	*	*
		CV(%)	22	17	27
Grevillea rosmarinifolia	45		4.2 A a	4.2a	16.6a
	225		3.8 A a	3.2a	17.8a
	450		3.0 A b	3.4a	18.8a
		(P)	0.10	–	–
		CV(%)	21	22	41
Leucadendron adscendens	45		3.4 a	3.2a	14.6Ab
	225		3.8 a	3.8a	20.2Aab
	450		4.4 a	4.0a	23.2Aa
		(P)	–	–	0.06
		CV(%)	28	42	25
Leucospermum candicans	45		4.0 a	4.6a	31.9a
	225		3.4 a	3.8a	25.2a
	450		4.4 a	4.0a	32.6a
		(P)	–	–	–
		CV (%)	26	33	53
Protea repens	45		3.8a	4.6a	15.1a
	225		3.4a	3.0a	19.5a
	450		3.2a	2.0a	11.5a
		(P)	–	–	–
		CV (%)	37	60	118
Protea scolymocephala	45		4.2a	4.4Aa	23.5a
	225		4.0a	1.0Ab	6.3a
	450		4.0a	0.8Ab	8.1a
		(P)	–	*	–
		CV (%)	19	80	110

Experiment F. Plants of two *eucalyptus* species were grown in media with a range of N levels. There was little difference among plants in all treatments after 2½ months except that plants without added N were noticeably deficient (Table 4). The highest dry weights in plants of both species occurred with the 340 to 675g N/m^3 treatments. The 110g N/m^3 treatment was in-

Table 4. Experiment F — Effects of a range of N levels on the foliage growth (visual ratings and dry weights) of two container grown nursery plants.

	Eucalyptus nicholii		*Eucalyptus notabilis*	
N Levels (g/m^3)	Visual ratings 2½ months	Dry Wt. (g/plt.)	Visual ratings 2½ months	Dry Wt. (g/plt.)
0	2.2Bb	1.8Ac	1.5Bb	0.6Bc
110	3.2ABa	11.4Ab	2.9Aa	11.6Bb
225	3.7A a	17.4Aab	–	–
340	3.7A a	20.8Aa	3.1Aa	30.0Aa
450	3.4ABa	21.4Aa	–	–
675	3.5A a	21.3Aa	2.9Aa	31.5Aa
(P)	*	***	**	***
CV (%)	30	50	40	65

ferior to these. There was no apparent toxicity and the optimum rate appeared to be fairly close to 340g N/m³ for both species. This would be equivalent to 97g N/m³ per month from 3-4 month Osmocote.

DISCUSSION

Higgs (10) noted that *G. rosmarinifolia* could be damaged by high fertilizer rates that did not affect other plants and this was also noted in Experiment A where foliage growth was severely depressed in N additions above 450g N/m³ (Figure 1). A linear response to N rates from split applications of N has been found in other work (20) using a maximum application of 86g N/m³/month. The work reported here indicates that 121g N/m³/month may be too high for *G. rosmarinifolia*. The optimum is therefore about 100g N/m³/month. *G. robusta* responded well up to 450g N/m³ and since this appears to be a robust rapid growing species it is reasonable to assume that the optimum is higher than for *G. rosmarinifolia* and could be placed at 120g N/m³/month.

Proteas can tolerate very low nutrient levels (8) as found in Experiments A and E. These findings indicate that proteas require only low N rates and probably 5 to 60g N/m³/month would be quite adequate, particularly if a soil mix was used. Initial propagation would probably need to be done without added fertilizers and using a mix such as equal parts peat and soil. Experiment E indicated that leucospermums are likely to have a similar treatment.

Leucadendron adscendens (Experiment E) *Dryanda formosa* (Experiment C) and *Hakea laurina* (Experiment B) plants appear to require N levels which are intermediate between proteas and *Grevillea rosmarinifolia* for optimum growth. Hakea was more sensitive to high N levels than *G. rosmarinifolia*, camellia and erica (Experiment B). A rate of 80g N/m³/month is probably the upper limit for plants of the former three species.

Camellias have a relatively slow growth rate and respond unfavorably to moderate salinity levels (6) or high fertilizer rates (17,21). Earlier work (20) indicated that *Camellia* has not more than medium N requirements. In Experiment B, *Camellia* and *Erica* responded similarly and both responded to higher N levels than hakea. Carter (4) stated that ericas only require low liquid feed rates and others have found them subject to chlorosis with certain fertilizers (15) or media (1). Klougart and Bragge Olsen (12) stated that plants in the Ericaceae and Theaceae are very sensitive to salt damage. It appears from Experiment B and earlier work on erica (20) that a level of approx-

imately 80g N/m³/month would appear to be a suitable general optimum for both genera.

Young eucalypts can respond strongly to N and P sidedressings in the open ground (5,13) and these elements are important for their container culture (11). A strong nitrogen response was noted in Experiment F up to a level of 340g N/m³. They were tolerant of 675g N/m³ (185g N/m³/month) and because wide variations in nutrient response have been noted between species (14) broad optimum range of 90 to 130g N/m³/month is suggested to allow for individual species' requirements. In general they respond similarly to *Grevillea robusta* and 120g/Nm³/month should be adequate.

CONCLUSIONS

The differing N requirements of plants in a group of species was demonstrated. The range within the Proteaceae was very wide and native habitat was probably the dominant governing factor influencing the N responses. *Grevillea robusta* showed a high requirement (120g N/m³/month) and *Protea spp.* low N needs (50g N/m³/month).

Nitrogen was supplied from different fertilizer sources and it was concluded that Uramite, which is a relatively poor N source in a soilless mix, was more suitable for *Dryandra formosa* than G. 'Olympic Flame', while Osmocote (26 percent N) was the better fertilizer source for *Grevillea*. This was because *Dryandra* is similar to protea in having a low N requirement and therefore a poor fertilizer source or a low rate of a more efficient fertilizer than Uramite is desirable.

Plants of *Hakea laurina* appeared similar to those of *D. formosa* and had a lower N requirement than camellia and erica. *Leucadendron adscendens* plants had similar N requirements to those of *G. rosmarinifolia* but *Leucospermum candicans* plants would appear to grow best with N levels that are intermediate between the optimum for *G. rosmarinifolia* and *Protea* spp.

Camellia japonica and *Erica herbacea* 'Springwood White' are temperate species which were found to have low to medium N requirements with an optimum of approximately 80g N/m³/month. *Camellia japonica* comes from temperate forests which may not be very fertile and this would partly explain this camellia's low to medium N requirement. Growth rate may also be an important factor influencing the nutritional requirements of camellia and erica. They contrast with eucalypts which have a rapid growth rate and were found to grow strongly in response to 90g N/m³/month. However, habitat is usually implicated and other workers have shown that habitat can influence

N utilization in eucalypts (14).

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THE PRODUCTION OF RHODODENDRONS BY GRAFTING

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Reasons for Grafting. Most rhododendrons today are produced from cuttings but there are, however, still a few cultivars that have defied the plant propagator, making them virtually impossible to root. Grafting is then essential if the cultivar or species is to be propagated.

A second reason for grafting is the widespread problem of *Phytophthora* which causes sudden collapse and the death of the plant. Some rootstocks are less prone to this disease, therefore, scions grafted on these stocks have an advantage when grown under less favorable conditions.

Selection of Rootstocks. The choice of a suitable rootstock is very important and like all root understocks has a definite bearing on the future success of the plants.

The four rootstocks commonly used in this country are:

Rhododendron ponticum
Rhododendron 'Elegans' ('Roseum Elegans'? Bot. Ed.)
Rhododendron 'Sir Robert Peel'
Rhododendron 'Cunningham's White'

R. ponticum. In England and America *R. ponticum* is used extensively but here in New Zealand it has limited use. It is vigorous, has a large root system which develops well in soils varying widely in acidity but the great disadvantage is its susceptibility early in life to *Phytophthora*. This is most evident in areas of high rainfall. In areas where the rainfall is less than 32″ per year, e.g. Hawkes Bay, *R. ponticum* could be considered as a rootstock because of the low rainfall.

Another disadvantage is that it produces an abundance of suckers which, if not removed early, can flourish at the expense of the scion. *R. ponticum* has a distinctive leaf type which makes it easy to detect if it puts forth basal suckers.

R. 'Cunningham's White'. This is a vigorous grower and will tolerate soils which are much less acid than most rhododendrons require thus enabling it to support in vigorous health grafted hybrids which could not otherwise be widely grown due to soil conditions.

R. 'Elegans'. This is not quite as vigorous as *R. ponticum* but is more resistant to *Phytophthora*.

R. 'Sir Robert Peel'. This is a strong vigorous grower and again more resistant than *R. ponticum* to *Phytophthora*.

Other Rootstocks. Briggs Nurseries, Olympia, Washington, U.S.A. is using *Rhododendron* 'County of York' hybrid as an understock. Although I haven't personally used it, 'County of York' cuttings root very easily, it is vigorous and, like its counterpart *R. ponticum*, has a distinctive leaf type which can easily be detected if suckering occurs.

It tends to form thicker plant material than some of the other understocks. This would have the advantage of better cambium contact on cultivars that produce thicker scion material, e.g. *Rhododendron loderi* 'King George'.

When grafting selected forms of the large-leaf rhododendrons, *R. falconerii*, *grande*, and *sinogrande*, understocks should be chosen from within the same species.

One rhododendron grower in New Zealand uses *R.* 'Elegans' rootstock for his large leaf species. Although the grafts appear to callus well, the scions are usually much thicker than the stocks and this may result in incompatibility problems later in the life of the plant. These large-leaf species can be grown from seed, therefore grafting stocks could be available within two or three years.

Scaly-leaved rhododendrons should be grafted onto seedlings of their own types. The "old fashioned" cultivar *R.* 'Fragrantissimum' has given good results on some of the epiphytic rhododendrons, e.g. selected forms of *R. lindleyi*, *R. dalhousiae* and *R. maddenii* series.

Whichever rootstock is chosen it should be well-grown and free of thrips and disease. The health and vigor of the stock is one of the main factors which influences the later success of the grafts.

Preparing and Producing the Understocks.

David Leach states in his book, "Rhododendrons of the World", (1) "The matching of the natural growth periods in rootstock and scion is claimed to produce exceptional vigor in the grafted plants." Although I haven't proved this, I have no reason to disbelieve it.

Rooting of the understocks usually takes place in January, February or early March. Rootstock cuttings, usually 'Elegans' (because of the availability of material) are prepared in the same manner as any other rhododendron cutting. Bases are wounded and dipped in hormone powder to induce formation of roots. They are then set in the mist propagating house in a medium of half peat and half polystyrene beads.

A variation in stem thickness of the stocks is desirable for future selection when grafting, as quite often, scions on some

cultivars produce predominantly thick material, e.g. 'Molly Coker', 'Grand Jury'.

When growing rhododendrons from cuttings they root better if the material is thin and of the current season's wood but in my experience, because of the vigor of the understocks used for grafting, there doesn't appear to be any difference in the rooting ability between thick or thin stocks.

A careful watch over the next 4 to 6 weeks is important. As this is the warmest period of the year strict attention must be given to ensure that water stress does not occur. If this does occur withering of the stem results and the stock becomes useless. As soon as small roots are observed on the stocks grafting can commence.

Incompatibility Problems. Some cultivars are very difficult to grow even when grafted. This could be due to a compatibility problem. *Rhododendron lacteum* and *R. souliei* are both extremely difficult to root or graft and have not given very satisfactory results on stocks of 'Elegans'. However, on other stocks they may give better results. It is a matter of experimentation to determine which stocks are compatible with which scions.

Collecting and Preparing the Scions. Scions are collected early in the morning when the turgidity of the plant is high. They are lightly syringed and placed in sealed plastic bags for preparation later in the day. Scions are prepared in the same manner as cuttings. They are then dipped in a Captan/Benlate solution ready for grafting.

Type of Graft Used. Although there are several types of grafts than can be used, I prefer to use a side graft.

The Grafting Procedures. The grafts should be made as low on the rootstocks as is convenient thus reducing the area from which suckers can later arise. This also encourages the plants to form roots from the scion area.

Stocks are carefully lifted from the pits and placed in trays in preparation for the grafting procedure. All dormant buds on the rootstock, below where the graft is to be made, should be cut out to reduce the number of suckers. Care should be taken to match the cambium on both stock and scion as evenly as possible, particularly the bottom of the graft as it is here that callus formation first begins.

In "Rhododendrons of the World" by David Leach (1), he quotes, "The more quickly the cambium layers of scion and understock can be induced to form calluses which join them the more certain will be the grafting operation." The life of the scion cannot be preserved for any extended period and if it falters for lack of atmospheric moisture there will be no union

with the understock."

As soon as possible after grafting, the grafts are returned to the glasshouse and plunged back into the propagating medium to a depth just covering the graft union. Under no circumstances should the grafts be allowed to dry out. They are then given a drenching of Benlate or Terrozole to guard against attacks from any soil borne diseases.

Aftercare of Grafts. Regular attention to humidity and the amount of moisture given is very important as too much water can be disastrous.

Hygiene in the propagating pits is of the utmost importance and any dead or decaying material should be removed at once. Regular applications of fungicides should be used (e.g. every three weeks). The grafts are left in the pits for approximately two months with bottom heat to help stimulate callus formation. At the end of this period, when a good callus has formed, the grafts are lifted from the medium, stocks cut off and the grafts replunged into the medium for a further three weeks to recover. After this time the grafts should be ready for potting.

Conclusions. Once plants are potted up they are returned to the glasshouse where they are gradually weaned off the mist. They will eventually be transferred to the shade house. One point which is very important is that the new plants are very susceptible to bumps and knocks and so the rubber budding strips which bind the scion to the stock are not cut off at this stage but are left on until planting time. This is usually straight after the first flush of spring growth.

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FEIJOAS: SELECTION AND PROPAGATION

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Abstract. A series of trials in 1978 and 1979 showed that the rooting ability of feijoa cuttings was influenced primarily by the parent tree. Some parent trees produced cuttings which showed high rooting percentages whilst others produced cuttings of very low rooting ability. Other factors, such as the position from which the cuttings were taken from the tree and the size of the container in which the cuttings were grown, also influenced rooting ability. Longer exposure to indolebutyric acid in alcohol as a dip did not increase rooting ability. The taking of cuttings in late winter as opposed to late autumn had less effect than the parent tree on rooting ability.

with the understock."

As soon as possible after grafting, the grafts are returned to the glasshouse and plunged back into the propagating medium to a depth just covering the graft union. Under no circumstances should the grafts be allowed to dry out. They are then given a drenching of Benlate or Terrozole to guard against attacks from any soil borne diseases.

Aftercare of Grafts. Regular attention to humidity and the amount of moisture given is very important as too much water can be disastrous.

Hygiene in the propagating pits is of the utmost importance and any dead or decaying material should be removed at once. Regular applications of fungicides should be used (e.g. every three weeks). The grafts are left in the pits for approximately two months with bottom heat to help stimulate callus formation. At the end of this period, when a good callus has formed, the grafts are lifted from the medium, stocks cut off and the grafts replunged into the medium for a further three weeks to recover. After this time the grafts should be ready for potting.

Conclusions. Once plants are potted up they are returned to the glasshouse where they are gradually weaned off the mist. They will eventually be transferred to the shade house. One point which is very important is that the new plants are very susceptible to bumps and knocks and so the rubber budding strips which bind the scion to the stock are not cut off at this stage but are left on until planting time. This is usually straight after the first flush of spring growth.

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FEIJOAS: SELECTION AND PROPAGATION

IAN D. IVEY

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Abstract. A series of trials in 1978 and 1979 showed that the rooting ability of feijoa cuttings was influenced primarily by the parent tree. Some parent trees produced cuttings which showed high rooting percentages whilst others produced cuttings of very low rooting ability. Other factors, such as the position from which the cuttings were taken from the tree and the size of the container in which the cuttings were grown, also influenced rooting ability. Longer exposure to indolebutyric acid in alcohol as a dip did not increase rooting ability. The taking of cuttings in late winter as opposed to late autumn had less effect than the parent tree on rooting ability.

REVIEW OF LITERATURE

The feijoa (*Feijoa sellowiana*) has attracted interest in recent years as a fruit with export potential. Bailey (1) commented that for successful commercial fruit production all trees planted should bear regular crops of fruit of a size and type desired by the market. Seedling trees produced fruit with a great variation in size and shape and so vegetative propagation was the only way to ensure a consistent type of fruit.

The fruit, to have export potential, must satisfy a number of criteria (Dawes, pers. comm). It must be consistent in shape and size, have a firm skin, and a firm layer of flesh beneath the skin to enable easy handling. The fruit must have an even green colour, large locules, a pale cream to white flesh colour, and a minimum amount of grit cells in the flesh. The fruit must also be capable of a reasonable period of cool storage.

Fruits of both the present commercially important cultivars, 'Mammoth' and 'Triumph' have satisfactory quality factors, but tend to have a short storage life — about 4 to 6 weeks at normal cool storage temperatures.

Feijoas can be propagated by either cuttings or grafting (1). A factor which must be considered in selecting new cultivars is the ease of propagation.

In April 1978, investigations were begun on a number of lines of seedling trees in the Hawke's Bay area to find trees with fruit of a consistent and desirable type. At the same time cuttings of promising selections were tested for ability to root under standard commercial conditions to see if there were any variations among individual parent trees.

MATERIALS AND METHODS

Two sets of propagation trials were carried out: one in 1978, the second in 1979. The first trial in 1978 was to test the ease of propagation of material from 15 different seedlings about ten years old, from two different properties, coded H and F. Approximately 50 cuttings of each selection were stuck on May 26, 1978. Each cutting was of current seasons mature growth taken once the trees had gone dormant. The cuttings were three nodes in length, the basal cut being just below a node. All leaves except the two at the top node were removed. A wound was made from the middle node nearly to the base.

Cuttings were quick-dipped with indolebutyric acid (IBA) at 3000 ppm in 50/50 isopropanol and water. Once prepared, the cuttings were stuck into plastic tubes containing a soil-less medium of equal parts of peat, sawdust, pumice and sand. They were then placed on a heated bed at 20°C in a plastic tunnel

house.

On June 30, 1978 a further trial was laid down with cuttings from several different selected seedlings (from a property coded MD) to test the theory that cuttings from the lower shaded areas of the tree rooted more readily than those from the exposed upper areas. Approximately 50 cuttings were taken from either the upper or the lower areas of the selected trees and treated as described previously.

Cuttings were taken in a further trial on August 8, 1978 from most of the seedlings used in the May trial. Fifty cuttings, approximately, were taken from each tree and treated as above. The numbers of cuttings which were rooted, callused, or dead, were assessed on July 21, November 1, or December 18, 1978 for the various trials.

In 1979, samples of fruits were taken from a further 16 promising seedling trees from six different properties (coded F, H, M, MD, CR and W) and sent to Plant Diseases Division, Department of Scientific and Industrial Research, Auckland, for storage testing. Fifty to 200 cuttings of each of these 16 trees (all 8 to 12 years old) were stuck, as described previously, on May 28, 1979. The type of wood used, i.e. strongly vigorous or weak, was noted.

In addition, two small trials were laid down: firstly, to test the effect of dipping the cuttings in IBA for five seconds, compared to the normal quick dip; secondly to examine the effect of the size of the propagating container on rooting ability. Two containers were used for the latter experiment — plastic tubes of 75cc volume, or "Plexi 100" plastic trays — each receptacle being approximately 25cc volume. Assessments for all 1979 trials were made on August 22 and October 24, 1979.

RESULTS

Influence of Parent Tree on Rooting Ability. *Tables 1 and 2* present the results of the two years trials with the different selected seedlings.

The most obvious results from the data of these two trials is the tremendous variation in rooting capability of cutting material taken from different parent trees. In Table 1 the range is from 76% for H18 down to as low as 4% for H36 and yet all material selected was off trees of similar vigor. The data for the two sampling dates also indicate that after eight weeks from sticking, only about half the cuttings which finally produced roots had actually rooted. A similar pattern emerges in Table 2.

The percentage rooting for cutting material from tree F35 was 81.3% by the final sampling date, approximately five

Table 1. Rooting percentage of feijoa cuttings stuck on May 26, 1978 as determined by parent tree and assessment time.

Tree Number	Assessment Date					
	July 21, 1978 percent			Dec. 18, 1978 percent		
	Rooted	Callused	Dead	Rooted	Callused	Dead
H18	44	52	4	76	0	24
H23	32	47	21	74	0	22
H37	31	46	23	62	0	38
H20	21	48	31	57	0	43
H25	19	59	22	55	7	38
F10	28	56	16	52	0	48
F56	12	72	16	48	0	52
H47	24	45	31	45	0	55
H39	22	45	33	45	0	55
H28	17	52	31	45	12	43
H21	21	53	26	44	0	56
H31	3	86	11	31	0	56
H24	9	35	56	25	0	75
H49	20	17	63	24	0	76
H36	0	36	64	4	0	96

Table 2. Rooting percentage of feijoa cuttings stuck on May 28, 1979 as determined by parent tree and assessment time.

Tree Number	Type* of Wood	Assessment Date					
		Aug. 22, 1979 Percent			Oct. 24, 1979 Percent		
		Rooted	Callused	Dead	Rooted	Callused	Dead
F35	S	57.7	35.8	6.5	81.3	7.2	11.5
H52	W	52.0	12.0	36.0	56.0	2.0	42.0
F11	S	36.1	37.2	26.7	55.0	7.2	37.8
F10	S	33.7	30.8	35.5	51.9	1.9	46.2
F57	M	30.6	36.9	32.4	48.6	2.8	48.6
F56	M	26.5	38.5	35.0	42.4	6.6	51.0
MD	M	27.3	27.3	45.4	42.0	7.3	50.7
W	W	30.9	16.1	53.0	35.3	2.9	61.8
F33	S	9.6	68.5	21.9	33.7	16.9	49.4
CR1	W	20.0	20.0	60.0	27.3	0.7	72.0
M	W	16.1	20.1	63.8	22.8	3.4	73.8
H55	W	19.1	12.4	68.5	21.3	0	78.7
CR2	W	11.8	36.2	52.0	20.5	7.1	72.4
H50	W	11.5	12.5	76.0	15.4	1.0	83.6
H22	W	5.3	15.9	78.8	10.6	0	89.4
H40	W	0	5.1	94.9	1.3	0	98.7

* S denotes cuttings from trees of vigorous growth; M; moderate growth; W, weak growth.

months from sticking, whereas H40 produced only 1.3%. The range in both seasons was remarkably similar. Although most trees selected in 1979 were different than those used in 1978, cuttings from trees F10 and F56, which were tested both years, showed similar rooting ability in both years. For F10 in 1978

the percentage of cuttings rooted was 52% whereas in 1979 it was 51.9%. For F56 it was 48% and 42.4%, respectively.

Effects of Time of Year. In Table 3 the results show that material stuck in August 1978 also showed a wide range of variation in rooting ability — from 10% for the worst up to 81% for the best.

Table 3. Rooting percentage of feijoa cuttings stuck on August 8, 1978.

	Assessment Date					
Tree	Nov. 1, 1978			Dec. 18, 1978		
Number	Rooted	Callused	Dead	Rooted	Callused	Dead
H25	75	14	11	81	3	16
H20	65	15	20	80	0	20
H28	45	33	22	68	7	25
H24	46	17	37	48	2	50
H21	23	26	51	26	3	71
H36	12	44	44	19	15	66
H49	6	35	59	12	6	82
H31	8	72	20	10	68	22

A comparison of data for rooting performance of cuttings from the various trees tested in both May and August, as shown is Table 4, produced a pattern which shows that generally trees producing material of high rooting ability in May also performed well in August. Lower potential material tended also to be poor at both times.

Table 4. Percentage rooting of feijoa cuttings stuck either in May or August as assessed on December 18, 1978.

	Time of Sticking					
	May percent			August percent		
Tree Number	Rooted	Callused	Dead	Rooted	Callused	Dead
H20	57	0	43	80	0	20
H25	55	7	38	81	3	16
H28	45	12	43	68	7	25
H21	44	0	56	26	3	71
H31	31	0	68	10	68	22
H24	25	0	75	48	2	50
H49	24	0	76	12	6	82
H36	4	0	96	19	15	66

Position on the Tree from which Cuttings were Taken. There is an indication in Table 5 that cutting material selected from the lower areas of the trees tends to root more readily than that from the upper areas, even though the overall take was fairly poor. The percentage of cuttings forming roots was over three times greater for trees MD5 and MD2L for wood from the lower areas.

Table 5. Rooting percentage of feijoa cutting stuck on June 30, 1978 as influenced by portion of the tree from which the cuttings were selected.

Tree Number	Position*	Assessed November 1, 1978 Percent		
		Rooted	Callused	Dead
MD5	U	9	7	84
	L	30	10	60
M2L	U	8	8	84
	L	26	33	41
ML	U	13	25	62
	L	20	21	59

* U represents cuttings from the upper portion of the tree, and L the lower.

Time of Exposure to IBA. Results of dipping the feijoa cuttings for five seconds in IBA as opposed to the quick dip are shown in Table 6.

Table 6. The effect of a five-second dip in IBA as opposed to the quick dip or the rooting of feijoa cuttings.

Tree Number	*Dip Time	Assessment Date: August 22, 1979 Percent			October 24, 1979 Percent		
		Rooted	Callused	Dead	Rooted	Callused	Dead
H52	C	52.0	12.0	36.0	56.0	2.0	42.0
	T	40.0	8.0	52.0	48.0	0	52.0
W	C	30.9	16.1	53.0	35.3	2.9	61.8
	T	20.3	18.8	60.9	30.4	0	69.4

* C denotes the quick dip, T the five-second dip.

It appears that there is no advantage in longer dipping in IBA. In fact there is a suggestion of a slight depression in rooting ability if treated longer.

Effect of Rooting Volume. The results in Table 7 show that a higher rooting percentage was attained in the 75cc plastic tube as opposed to the 25cc tray receptacles, even though the overall rooting percentage was low.

Table 7. Percentage rooting of feijoa cuttings as affected by volume of medium.

Tree Number	Container Type*	Assessment Date: August 22, 1979 Percent			October 24, 1979 Percent		
		Rooted	Callused	Dead	Rooted	Callused	Dead
H50	Tu	11.5	12.5	76.0	15.4	1.0	83.6
	Tr	3.7	22.2	74.1	3.7	0	96.3
H55	Tu	19.1	12.4	68.5	21.3	0	78.7
	Tr	5.9	26.5	67.6	5.9	0	94.1

* Tu, denotes plastic tubes; Tr, the "Plexi 100" trays.

The depth to which cuttings could be placed in the medium appeared to be the problem in the plastic trays. The

cuttings tended to be top heavy and move around opening a hole around the base of the cutting. This may have caused some desiccation and subsequent leaf drop on the cuttings, which then resulted in death.

DISCUSSION

Along with the selection of feijoa seedlings for desirable fruit characteristics, it would appear necessary also to examine their ability to reproduce the parent tree from cutting material, if this is to be the desired method of propagation. The results from both seasons trials show a wide range of rooting capabilities for cuttings from various parent trees from extremely low levels up to commercially viable levels. It also appears that there may not be a great difference in rooting ability of cuttings whether taken in May or August, the better rooting selections being satisfactory and the poorer types remaining relatively difficult at either time.

The position from which cutting material is taken on mature trees seems to influence the rooting capability. Material from the lower areas generally appears more satisfactory.

Longer dipping of the cuttings in IBA appears to give no improvement in rooting. On the contrary, it appears to depress root development.

The size of container into which the cuttings are stuck seems to have an important influence on rooting ability. Feijoa cuttings tend to be large and top heavy and need to be deeply set in the propagating mix to prevent movement and to obtain adequate rooting.

Two areas which require further investigation are the time of taking cuttings and also the quality of the wood. It may be that there are times of the year other than May and August when cuttings may root readily. However, observations with the cultivars 'Mammoth' and 'Triumph' suggest that taking cuttings while the tree is in active growth will result in relatively poor rooting percentages.

In Table 2 there is a suggestion that cuttings from trees with vigorous growth may root more readily than those with slow growth. However, all trees in Table 1 were showing weak extension growth and yet the variation in rooting ability was similar. Overall, it appears that the parent tree exerts a marked influence on the ability of cuttings taken from that tree to root. This could have an important bearing on the development of new feijoa cultivars for the future.

Acknowledgements. The assistance of Mr. S. Dawes of Plant Diseases Division, DSIR, Auckland with respect to the desirable fruit characteristics is acknowledged. Also the storage testing and cultivar information provided by

Mr. K. Patterson at the above establishment is acknowledged. The provision of facilities and the encouragement of Mr. R. Ware of Plant Productions Ltd., Napier, is gratefully acknowledged. The interest and provision of plant material by various growers is also acknowledged.

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FASTER BULKING UP NEW INTRODUCTIONS OF FRUIT CROPS

D. McKENZIE

Fruit Research Orchards, D.S.I.R.,
Havelock North, New Zealand

The most pressing problem facing the nursery industry is the need for new methods to speed the bulking up process with new introductions. At present, using ordinary outdoor nursery techniques, it requires at least four years to propagate 1,000 plants from one source plant that is moderately difficult to grow, like most fruit trees. We need to reduce this time to one year — so that we can make faster progress in introducing:

(1) new rootstocks, e.g. BAC 29, 'Colt' cherry, Aotea selections
(2) new cultivars from quarantine, e.g. 'Red Fuji', 'Jonagold', 'Gloster'
(3) new hybrids from breeding
(4) new virus-free selections
(5) new colour sports, e.g. 'Red Delicious', 'Royal Gala', 'Braeburn'
(6) new kinds of fruit, e.g. Nashi pear, persimmon, loquat

The New Zealand Tree Crops Association has recognized the problem in the development of new kinds of walnuts, hazelnuts and chestnuts and, in order to find some solution to this frustrating delay, they have decided to establish a special trust fund that would be used to support research and development of new rapid propagation methods, including laboratory and glasshouse production of meristematic tissue culture, micro-grafting, nurse-root grafting and very small softwood cuttings. The Nurserymen's Association is also studying a similar project and finds the tax-free aspect of trust funds attractive (since individuals may legally invest up to $1,000 and companies 3% of profits).

It is possible that since the fruitgrowing industry is vitally concerned with speeding up the introduction of new material, that the N.Z. Fruitgrower's Federation should consider similar

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action or perhaps the N.Z. Apple and Pear Marketing Board could use some of its Levy Fund and cooperate with these other groups, and perhaps the government would subsidize a concerned effort from the combined forces of horticulture.

It will be necessary to consider some of the existing organisations that may be prepared to undertake propagation studies:

Nursery Research Institute at Massey
Ministry of Works Propagation Unit at Aokoutere
Forest Research Institute at Wakarewarewa
Plant Physiology Division at Palmerston North (research only)
Plant Propagators Ltd. (private firm at Havelock North)
Levin Horticulture Research Division

Each of these entries could undertake research in propagation methods and some could take the process a stage further and produce commercial quantities of plants on a cost basis. Once the methods of propagation had been developed, it would probably be necessary for private specialists to apply them commercially. It may be necessary for the combined nursery trade to support one such firm and regularly place contracts for the rapid bulking up of new introductions. Once established the specialists could also accept contracts from people outside the nursery trade, e.g. government research units, plant breeders and private individuals (e.g. a grower with a new red sport).

We desperately need this sort of fast bulking up service.

PEAT AS A PROPAGATING MEDIUM IN NEW ZEALAND

D.S. ANDERSON

Smith Soil Industries Limited
Mangere, Auckland, New Zealand

Smith Soil Industries of Auckland, New Zealand, began trading as E.R. Smith Ltd. in 1960. It was then an owner-operated business involved mostly with the supply of various grades of metal to the building industry, and screened topsoil to the horticultural trade. The Company operated from a quarry at Mangere.

The move into the topsoil business was the first step towards forging links with the horticultural trade and with the forming of N.Z. Peat Ltd., a wholly owned subsidiary company, whose purpose it was to mine peat at Ngatea on the Hauraki Plains. Following this the step to blending mixes of a U.C. type became apparent.

Using the Hauraki peat and mixing with a suitable grade

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Using the Hauraki peat and mixing with a suitable grade

pumice sand, dredged from the Waikato river at Tuakau the company, which had now changed its name to Smith Soil Industries, began supplying mixes blended to each customer's requirements.

The use of slow-release nutrients became apparent and, with the addition of slow-release trace elements, container plant production expanded dramatically. While originally many mixes were steamed for hygiene reasons, the addition of Terrazole was instrumental in largely eliminating the steaming of nursery growing mixes. Cost was another major factor.

During 1972 Ceramco acquired a 50% shareholding in Smiths and development of the sphagnum rich South Island peat deposits seemed likely. Meanwhile in Auckland the many slight variations of growers' mixes had been evaluated carefully and six standard mixes prepared. These were:

1. A 9 month controlled-release mix for trees and shrubs
2. A steam sterilized seed-raising mix
3. An acid tree and shrub growing mix
4. A 3 month controlled release mix for vegetable and seedling growers
5. A protea mix
6. An orchid mix

These 6 broad categories of mixes enabled Smiths' to have available more or less immediately a growing mix to suit any requirement, and facilitated streamlining of production at the plant.

The company will still blend mixes to individual specification if requested. The using of U.C. type mixes opened the door for some mechanization of the industry — in particular the "potting up" operation and here Smiths' were involved with the Javo potting machine from Holland. This machine enabled many nurseries to boost production and indeed today there are some 32 machines operated in New Zealand. Other machinery followed — all connected in some way with the horticultural trade.

The Baggaley Liquid Feeding Unit, a fully automatic and self adjusting proportioner imported from England followed as well as Olimex machinery from Holland. This range is used by the cut flower trade for deleafing, trimming, sorting, tying and wrapping of flower blooms.

Currently under evaluation is the Dyna Fog chemical insect control sprayer — common in use overseas and now about to be introduced to New Zealand.

During 1976 Ceramco acquired 100% holding of Smith Soil Industries, and development of the privately owned Southland

swamps began in earnest. With the trade name of "Kiwi Peat" (derived from a rare moss called *Sphagnum cristatum*), this Southland peat is light and fibrous with an outstanding capacity for high air and moisture retention, and is ideally suited for horticultural use. "Kiwi Peat" is now being extensively used by leading nurseries throughout New Zealand with particular emphasis toward propagation use. Export potential of the peat is also realized and some export orders have also been filled.

At Ngatea, on the Hauraki Plains, peat is mined from the Porarua dome and is a sphagnum peat but of lower quality than the southland "Kiwi Peat". After the removal of the top cover of vegetation the peat is tined and tilled over the dry summer months and forage harvested and stockpiled for supply during the wet months when access onto the peatlands is impossible. Due to local body problems, mining is restricted but at present Smiths' have adequate resources for the immediate future and mining applications in hand to last some 20 years.

Further peat crown land available for horticulture industries and trade in general will probably come from Kopuatai dome, an area to the south of the present site; however, conservation and flooding studies have to be done to evaluate long term effect in this area.

Smith Soil Industries now employ some 21 people in the North Island and 30 in the South Island. Although still a relatively small company, we are very confident about the future of our industry within New Zealand today and look forward with enquiring minds to the future developments of horticulture in New Zealand.

THE USE OF BARK IN POTTING MIXES

ANDREW D. MALOY

Lyndale Nurseries Limited
Auckland, New Zealand

Two years ago, due to the shortage of peat, we started to look for other materials that we could use as a substitute. Eighteen months ago we started supplementing the peat component in our mix with granulated pine bark. Initial trials were satisfactory and for the past nine months our container mix has been made up of 75% granulated pine bark, 25% pumice.

The mix that we pot our rooted cuttings and seedlings into has 25% peat, 25% bark, 50% pumice. This is because the particle size of the bark is too coarse for the young plants. The source of the bark is *Pinus radiata* from the Thames area and is

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Lyndale Nurseries Limited
Auckland, New Zealand

Two years ago, due to the shortage of peat, we started to look for other materials that we could use as a substitute. Eighteen months ago we started supplementing the peat component in our mix with granulated pine bark. Initial trials were satisfactory and for the past nine months our container mix has been made up of 75% granulated pine bark, 25% pumice.

The mix that we pot our rooted cuttings and seedlings into has 25% peat, 25% bark, 50% pumice. This is because the particle size of the bark is too coarse for the young plants. The source of the bark is *Pinus radiata* from the Thames area and is

processed by Granulated Bark Supplies in Kumeu, Auckland. It is granulated by a hammer milling process and has not been composted or stored for any periods prior to being used in the potting mixes. The pH of the bark as it is delivered to us is 4.2 compared to Hauraki peat 3.75, and Kiwi peat 4.5. The bark and pumice is mixed in a paddle mixer and, during the mixing process, fertilizers are added. Water is also mixed in at this point, the bark being easier to wet while still being mixed.

PROPAGATION OF KOWHAI (*SOPHORA MICROPHYLLA*)

ROBERT BROWNE

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Auckland, New Zealand

The reasons and methods of propagating *Sophora microphylla* 'Fulvida' from seed are discussed in this article.

The main use of this plant for me is as bonsai material. The growth appears naturally stunted and the leaf structure is very fine. It is endemic to the west coast of the Auckland district where it grows in great abundance. This plant does not grow through the normal juvenile stages and will flower after six years from seed planting. The flowers appear in mid-spring and the seed is ready to harvest in late summer. This kowhai has also proved to be very resistant to drought conditions.

Seed Germination. The secret of my quick and even germination of seed is the time of seed collection. The seed must not be allowed to harden at all, but at the same time must be allowed to develop fully. This is difficult to convey, but my simple test seems to be successful. I collect the seed at a time when I can, but with some difficulty, cleanly cut a seed in half with my thumb nail. If the seed squashes it is too soon; if the seed seems soft but you cannot quite cut it, you can still collect it but it will need to be soaked in water for a longer period than the seed that could be cleanly cut.

Having collected the seed pods I immediately remove the seed by hand and soak them in cold water for 12 hours. I have found that any other way of removing the seed from the pods, such as forcing them through a sieve is damaging to the soft seed. The seed is then sown in a 50/50 peat/sand mixture. The seed boxes are placed in a 30% shade house and the box is covered with a sheet of clear glass. Three to four weeks later the seed germinates with about a 90% success rate. In eight to ten weeks the seedlings are ready for tubing up.

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CYCLAMEN PRODUCTION PROBLEMS

R. NOEL McMILLAN

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This article concerns *Cyclamen persicum* 'Giganteum' — a highly bred and large flowered form of cyclamen which has become very popular as a winter flowering pot plant. Unfortunately it is proving a difficult plant to grow of recent years and one is seeing its demise at a steady rate. It is also, unfortunately, an expensive crop to produce with a high input rate of skill, cost and maintenance, and is at the stage of pricing itself beyond consumer acceptance. This is unfortunate because far more goes into the preparation of a good 15 cm cyclamen than a good conifer, and both return the same — so perhaps the problem is one of grower and retailer attitudes, and one of consumer education.

In order to give the problems of production some meaning, I would like to move through the production stages and relate some of the difficulties experienced at these stages.

Planting. Basically there is one rule, "Cleanliness and the avoidance of extremes in all aspects is essential". A standard long-term cyclamen plant commences existence in December. It is essential to get the best seed. A few extra cents at this stage is nothing when compared with the frustration at the other end of the production cycle with a weak and tatty flowering line. The trend of the moment is to short-term cyclamen plants, using selected strains of F_1 hybrids, but we are only using these seriously just this season and cannot really compare results. There is quite a difference in the price being asked for this seed. We have always had difficulty locating good seed, being a small user. We find it impossible to relate the look of seed to the actual crop it produces, but nice plump clean seed does appeal.

For sowing we use a standard U.C. mix with the nitrogen cut to about two-thirds (all mixes are sterilized). We scatter the seed, but with the advent of the Robinson Vacuum Planter, this could be avoided and the planter used to our advantage. With hand sowing, spaced planting in terms of labor and results is not justified. We never soak the seed — fresh seed never needs it, but if you suspect the seed to be old, it would be wiser to soak. Boxes are watered in with thiram and the seed covered with No. 2 vermiculite. Boxes are stacked in the coolest draught free spot you can find in your shed. Weekly hosing down of the stack is enough for boxes to remain moist during germination.

After three weeks one needs to watch the stack carefully as

once the first shoots start to emerge, the boxes need spreading out and re-watering. At times an extra cover with vermiculite is needed to keep the now-forming tubers anchored. By now it is mid-summer and the hottest time of the year — so the coolest house is best.

We plant a second batch of seed in mid-autumn, thus avoiding the hottest months and an even later batch of short term in early winter. Both these later batches receive bottom heat 15 to 18°C for the first six weeks after germination. I read somewhere that this aids early flowering and our trials support this.

Boxing. We have in the past potted to 8 to 10 cm at this stage but unless facilities are available to keep up night temperaures, growth doesn't really come on well until spring. Once plants are big enough to handle they are pricked out into seedling trays (about 20 to a tray). We find it better to use trays from a space point of view, and also the medium is easier to control over the difficult winter period. By eliminating the 10 cm potting stage we eliminate a serious stage of infection. If any old pots are used they are soaked in Mancozeb. Trays are also washed and dipped, but new ones used if possible. Night temperatures below 10°C are best avoided. The mix used for this stage is basically the mix recommended by Massey University, only we reduce Osmocote and use both long term and short term.

Per Mix/m^3: 742 gm short-term Osmocote
1.7 kg long-term Osmocote
1.5 kg superphosphate
3.0 kg dolomite lime
75 gm F.T.E.
250 gm Terrazole
150 gm Benlate

Only seedlings that have germinated regularly and have a good firm leaf are used. It is far cheaper to rogue at this stage than throw out at the 15 cm stage. There are few problems at this stage apart from the regular fungicidal and aphid spray. However, by using the tray method, one loses control of the spacing factor and potting to final pots can be as early as October. With pots, it is November-December. If one is behind schedule, as often happens in the nursery, the plants can become overcrowded and leggy. Humid conditions in the spring encourages mildew to set in. The crowded plants also become difficult to water. We find at whatever stage they are at, three fortnightly drenches with DDT 50% are necessary to eliminate the black vine weevil. This pest can be devastating, particularly in autumn when the plants are budding and being finished.

Summer plantings are ready to pot in early spring and autumn plantings in early summer. It helps from a potting viewpoint to have this barrier behind one for the holiday season. I am not so sure it helps from a plant point of view as the plants go into mid-summer with a full head of stems and it is at this point when trouble can often hit.

Potting. We pot on to 15 cm and sometimes with late plants, 10 cm. Seedlings of 15 cm size produce good-sized plants that should be capable of flowering through to the spring without any additional nutritional needs apart from a sea-based liquid feed. The final mix used is the Standard U.C. (with Mancozeb, Benlate Terrazole additives) (Massey University).

We have trialed many mixes and are still doing so. The price of products, once they gain universal acceptance, mysteriously increases with the result that they often become uneconomic to use. In general one can grow good cyclamen plants in most balanced mixes. The essential requirement is that the mix must be light and spongy with *excellent plus* drainage and remain well-aerated. Our trials with bark mixes have been good. The only plants to really come through last summer well were in bark, peat, soil and pumice mixes. Cyclamen seems to tolerate higher feeding levels than writers indicate, provided the above routines are observed. Cyclamen is a crop that suggests it is not what one puts them in that counts but what one "does and when" that matters.

Once plants are settled and new growth becomes apparent one must be meticulous about spacing. Good sturdy plants can best be produced by full spacing — 450 mm × 450 mm to start with.

Watering becomes a major problem with freshly potted plants. Hot days plus a period (mid-summer) when tropical downpours follow potting, is common. If hygiene has slipped at any previous stage by late summer you will know it. Plants during this stage must not be stressed. They need good light and cool conditions with overhead misting but with the medium not kept too wet.

Soft rot (*Nectria radicicola*) or summer wilt, as I call it, is devastating. A yellowish leaf, usually an older leaf, is the first sign. This usually starts at about the stalk area; if one plucks the leaf out there will be darkening of tissue on the scar of the corm. If present, the plant will often: a) die within two or three days, or b) die within two or three weeks — or it might even hang on for months. The result is inevitable. The plants will certainly not bud up and, if already in bud, will have only one batch of flowers with little or no follow up. A most frustrating disease. The plants have a beautiful intact root system but with

nowhere for the sap to go.

As a means of combating the wilt disease, Massey University suggested concrete floors as a possible solution — I concreted my 450 sq metre house and this proved a disaster — whole rows became infested after the appearance of a few wilted plants. The year before I used raised beds with the plants sitting on black polythene and this was far better, as surplus water drained directly clear of other plants.

Leaf Spot fungi can cause problems under "Sarlon" (shadecloth)-grown stock. It seldom occurs in plants grown under glass or Duralite-grown stock. Ferbam can be useful for control but we try to pick it up at its early stage and destroy infected leaves. Aphids and mites are sometimes a pest, especially aphids Metaxystox/Thioan/Orthene and Pyrox can be used for treatment.

Other problems strike at this stage. *Botrytis* is always waiting to rear it's ugly head, especially if one has not been regular about picking over the natural regeneration of leaves that takes place at intervals. Thiram, Euparen, Saprol, Ronalin, Dithane, Z78 and Benlate can be used in various combinations.

Growing Structures. Cyclamen plants do best under cool conditions. Also they grow best in conditions where extremes are kept to a minimum. Due to their water content they are susceptible to fungus diseases. They are easily upset by sprays and damage to leaves is very easily done. They respond negatively to unusual temperature variations, especially autumn night temperatures. One of the contradictions that I find fascinating is their ability to come through winter frosts, an occurrence best avoided if possible.

As we see it, structures to cater for these needs must have:

1. Floor and air heating with good light (autumn, winter, spring)
2. Light airy situation with controlled night temperatures (shut up) (spring to early summer)
3. Uncovered airy cool "Sarlon" type conditions (60%) with good humidity (early summer to autumn)
4. Controlled light, controlled night temperature (glasshouse) (autumn to late winter)

Ideally one could add to this a capillary or microtube watering system with benched or raised plants coupled with a good preventative spray programme and one cannot help but produce good cyclamen plants.

MICROPROPAGATION METHODS FOR BLUEBERRIES AND TAMARILLOS

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Abstract. Methods are outlined for the micropropagation of high-bush blueberry (*Vaccinium corymbosum*) and tamarillo (tree-tomato) (*Cyphomandra betacea*). These methods should have immediate application for the rapid propagation of new cultivars.

In the case of blueberry, multiplication is achieved by cutting the shoots which develop in culture into single node segments. A multiplication rate of about 5 fold every 6 weeks has been achieved. Small shoots about 2 cm long can be easily rooted in seedling flats under high humidity conditions.

In the case of tamarillo, multiplication is achieved by a combination of enhanced auxiliary bud development and adventitious buds arising from the swollen stem base. A multiplication rate of 6 to 8 fold every 2 weeks has been achieved. Rooting can be carried out either in sterile culture or directly in a seedling flat.

HIGH-BUSH BLUEBERRY (*VACCINIUM CORYMBOSUM*)

Plant material. Stock plants of a number of high-bush blueberry cultivars were grown in a greenhouse with supplementary lighting in winter to extend the daylength to 15 hrs. Shoots were collected at the end of a flush of growth.

Disinfestation. The shoots were cut into 6-node sections and surface sterilized in 0.6% sodium hypochlorite with 0.1% Multifilm X77 (a non-ionic detergent) for 30 min. The tissue was then rinsed three times in sterile distilled water.

Culture medium. For most of this work the culture medium contained ¼ strength Murashige and Skoog materials with full strength Linsmaier and Skoog vitamins (100 mg/l m-inositol, 0.4 mg/l thiamine-HCl), sucrose (30 g/l), NAA (0.02 mg/l) and IPA (isopentenyl adenine, 5 mg/l). The medium was solidified with 6 g/l Davis (NZ) bacteriological agar and sterilized for 15 min at 15 psi (121°C).

Procedures. The surface-sterilized shoots were cut into single-node sections using flame-sterilized secateurs. Four sections were planted in each 100 ml jar containing 25 ml medium. The jars were covered with thin sheets of sterilized, high density polythene held on with a rubber band.

After 4 to 6 weeks the axillary buds on about 50% of the nodes had produced a shoot 2 to 4 cm long with 6 to 10 leaves. These shoots were excised, cut into sections of 1 to 3 nodes and replanted on fresh medium of the same composition in petri dishes. The original cultures were kept and one or two new shoots usually grew from the base of the original shoot. The

new cultures in petri dishes produced axillary shoots which were cut into sections after 6 to 8 weeks. This procedure can be repeated indefinitely giving a proliferation rate of about 5 fold per subculture.

Rooting. *In vitro* proliferated shoots growing in petri dishes could be easily rooted in a peat mix under shaded conditions with high humidity. The basal end of the shoots about 2 cm long were dipped in Seradix 2, (a commercial rooting powder containing 0.3% IBA), planted in a seedling flat containing fine pumice-peat (50:50) and kept under high humidity and two layers of 50% shade cloth. After two weeks about 90 to 95% of the shoots had rooted. The trays were then transferred to intermittent mist for one week after which they were placed on a greenhouse bench.

Subsequent growth. After rooting had taken place the plants were watered twice weekly with a complete nutrient solution (½ strength Hoagland's). When the shoots had attained a height of 7 to 10 cm, the plants were transplanted to propagating tubes.

Comments.

(1) Using these procedures approximately 700 rooted plants can be grown from a single node explant in 9 months.

(2) These procedures have not been successfully used with the following cultivars: Atlantic, Jersey, Dixie, Stanley, Burlington, Berkeley, Blueray, and Ivanhoe.

TAMARILLO (*CYPHOMANDRA BETACEA*)

Plant Material. Stock plants were grown in a greenhouse. Axillary buds with a section of stem attached were cut off with a scalpel.

Disinfestation. The bud segments were surface sterilized as described for blueberry.

Culture Medium. Full strength Murashige and Skoog mineral salts were supplemented with Linsmaier and Skoog vitamins, sucrose (3%), and BA (benzyladenine at either 0.3 or 3.0 mg/l). The media were solidified with 6 g/l Davis (NZ) bacteriological agar and autoclaved for 15 min at 15 psi (121°C).

Procedures. The sterilized bud segments were trimmed under a dissecting microscope to give an explant cube of approximately 2 mm containing the bud. These explants were placed on a medium containing BA at 3 mg/l to induce bud break. This concentration of BA suppresses shoot elongation but axillary buds continue to proliferate. In addition some adventitious buds arise from the swollen base of the explant.

After about 4 to 6 weeks the proliferating bud clusters were cut into segments, each containing several buds, which were replated on to fresh medium. Bud proliferation rates of 6 to 8 fold every two weeks have been recorded.

Transfer of bud segments to 100 ml jars containing 25 ml of a medium with reduced BA concentration (0.3 mg/l) allowed shoot elongation to occur. Shoots of 2 to 3 cm developed over 4 weeks and were suitable for rooting either *in vitro* or directly in peat mix.

Rooting. All shoots formed roots within 8 days on transfer to a medium containing 1 mg/l IBA. After another 2 weeks these shoots were transferred to a seedling flat containing pumice-peat (80:20) and placed under intermittent mist for one week.

Alternatively, the base of the unrooted shoot can be dipped *into Seradix 1, then planted directly into pumice-peat (80:20)*, and placed under intermittent mist. Roots develop within 3 weeks but plant growth lags behind that of plants rooted in sterile culture. However, the advantage of this method is the avoidance of one sterile transfer step.

Subsequent growth. After transfer to the greenhouse bench, the flats were watered twice weekly with a complete nutrient solution (½ strength Hoagland's). Plants rooted in sterile culture attained a height of 10 cm within 4 weeks of transfer to the seedling flat, whereas plants rooted directly in seedling trays took about 10 days longer to reach the same size.

PROSPECTS FOR THE WIDER USE OF CLONAL ROOTSTOCKS FOR DECIDUOUS ORNAMENTAL TREES

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Trees of cultivars whose cuttings cannot be rooted, or which grow poorly on their own roots, are commonly grafted onto seedlings of the same or a related species. This doubtless contributes to the variable bud-take and tree growth experienced in many nurseries.

Sixty years of research into the use of clonal rootstocks for fruit trees has shown how they influence many important tree characters, of which tree size has been studied more than any other. It has been suggested, largely on the basis of observation, that rootstock influence extends to at least 53 genera of woody plants (9). Clonal rootstock attributes of particular interest to nurserymen include the following:

1. Uniform and rapid plant establishment associated with a fibrous root system.
2. High level of bud-take based on specific compatibility tests.
3. Uniform growth because all the stocks are of the same genetic make-up.
4. Known performance in relation to soil-borne diseases.

These important advantages noted for fruit must be considered in the context of raising ornamental trees.

Clonal rootstocks must be propagated vegetatively, preferably by cuttings. Therefore, the nurseryman is faced with a new job because, previously, seedling rootstocks were probably purchased from a specialist raiser. Although many plants are propagated from cuttings in the everyday work of nurseries, the dependence of the future tree nursery on the success of the rootstock raising stage makes it doubly important to carry out this work with technical precision and good management. Most cuttings will need to be grown-on for one season before lining-out, so transferring the requirement for land and management from the seedling raiser to the general nurseryman. These specialized requirements may lead to those specializing in clonal rootstocks supplying other nurserymen in the future.

A good stand of clonal rootstocks growing well when budded will lead to a full crop of uniform trees with maximum return on investment in land, labor, agrochemicals and fuel. In addition to these visible improvements, the selection of clones resistant to important diseases such as verticillium wilt would

remove a serious constraint on land use, and lead to increased productivity. Resistance to the fungus causing specific replant disease in cherries and plums has been found in easy-to-propagate hybrid cherry clones (8).

But will the consumer want trees of identical shape and size, however well grown? In many cases not, especially in the landscaping context, but relatively few grafted trees are used for this purpose. It is in the production of standard trees of named cultivars that quality and uniformity are required especially when precise grades are stipulated in tender documents by public authorities. It is in this area that clonal rootstocks will make their impact.

Fruit-related species. Because of the very specific role projected for clonal rootstocks in ornamental tree production and the limit to available R and D resources it is very important to identify clearly those species most suitable for this approach. Immediate progress can be made with fruit-related species where clonal rootstocks for apple, cherry and plum are available.

Their limited use to date is probably determined by the higher price commanded by clonal stocks compared to seedlings, which is controlled by the closely matched supply and demand situation in fruit tree nurseries. Nurserymen raising flowering cherries and crabapples should reflect that fruit nurserymen justify a cost of about 20p per rootstock against a finished tree price of 120p after a two-year cropping cycle. Such an initial cost would seem more than justified for ornamental trees when the final tree price may be double or triple that of a maiden fruit tree and where the land is occupied for twice the time. The opportunity to clear the land completely rather than to allow the poorer plants to remain for a further year is a significant factor in itself.

Ornamental cherries can now be produced on the freerooting 'Colt' rootstock (*Prunus avium* × *P. pseudocerasus*). A clone (No. 17, now named 'Cob'), almost as easily propagated as 'Colt', has produced trees with particularly thick trunks and good blossom characteristics (Table 1).

It was particularly interesting when comparing a range of interspecific hybrid cherry rootstocks that a statistically significant correlation was obtained between the growth habit of the unworked rootstocks in the nursery and the shape of a common scion worked on them (5). Such influence on tree form might be best exploited in the production of ornamental trees where street or open space planting dictates to a large extent the shapes and hence the cultivars that can be used.

Table 1 Rootstock effects on growth and flowering of Ukon.

Rootstock		Girths (cm) at 15 cm above union		
		Maiden year	Year 2	Year 3
P. avium × *P. pseudocerasus*	No 17	6.0	9.1	13.5
	No 22	5.4	8.0	11.5
	No 38	5.2	7.7	11.9
P. avium × *P. incisa*	No 57	4.8	6.5	9.9
P. avium	1/227	5.0	6.3	9.1
P. avium	4/122	5.0	6.5	9.9
P. avium	F12/1	5.3	6.7	9.6
		Blossom on scale 1 (low) to 9 (high)		
		Year 4	Year 5	Year 6
P. avium × *P. pseudocerasus*	No 17	7.4	7.4	7.4
	No 22	4.8	5.4	5.0
	No 38	5.0	5.8	5.2
P. avium × *P. incisa*	No 57	1.8	3.2	2.8
P. avium	1/227	1.0	2.0	1.8
P. avium	4/122	1.6	3.4	2.6
P. avium	F12/1	2.4	2.6	2.8

Those concerned with the testing and development of hybrid rootstocks derived from *P. pseudocerasus* have always been conscious of the winter cold sensitivity of the species and the fact that this is present in different degrees among hybrids with *P. avium*. While the exceptionally cold weather at the end of January, 1972, (in contrast to an otherwise mild winter) damaged some young nursery plants including these experimental cherry rootstocks (7), experience of a range of winter conditions subsequently suggests that there is little cause for concern.

A valid reason for not using clonal rootstocks in the past was that most ornamental crabs, including *Malus* 'Aldenhamensis', *M. floribunda*, *M.* 'Profusion', *M.* 'Purple Wave', *M. sargentii* and *M. tschonskii* were shown to be sensitive to latent virus infection in the clonal stocks which caused bud failure and poor growth (2), an effect absent in fruiting cultivars of apple.

Fifteen years ago sources free from all known viruses were being produced and these now form the basis of current apple rootstock production. A scheme exists to minimize reinfection (3) involving isolation of stock beds, confirmation of trueness-to-type and occasional monitoring of their health status. Results indicate that natural spread of infection is not a hazard in apple. There is, therefore, no reason why ornamental nurserymen should not exploit the range of vigor control to produce trees suitable for patios, gardens and park situations. Growth of ornamental crabs on a range of clonal rootstocks is now being examined (Preston, pers. comm.) and impressively uniform stands of *Malus* 'Aldenhamensis', *M. floribunda*, *M.* 'Golden Hornet' and *M.* 'Hillieri' on clonal rootstocks can be seen in modern fruit nurseries where they are raised for use as pollinators in orchards.

In plums it is particularly important that clonal rootstocks are obtained from reliable sources in the UK because of the greater likelihood of imported plants originating in Continental Europe carrying the dangerous plum pox virus. Although this aphid-borne virus has been found in the UK, frequent inspection of nurseries linked with a rapid detection technique (1) affords good prospects of containment.

Ornamental species. While advantage can be taken of ongoing fruit work for related ornamentals there is no similar spring-board to facilitate the introduction of clonal rootstocks for the majority of ornamental tree species. Neither is the objective likely to be met by controlled breeding as carried out by the fruit rootstock breeder, because resources are so limited and the task so enormous for ornamentals. Here it is necessary to search for rooting, compatibility, disease resistance and other desirable characters among the natural seedling populations raised for rootstocks, each additional character greatly increasing the work necessary. Preliminary investigations of mixed populations of cuttings suggest that some species will yield worthwhile results readily, while others await improved propagation techniques before progress can be made (Table 2).

Table 2. Rooting percentages of hardwood cuttings bulked from heterogenous seedling populations.

	percentage		percentage
Sorbus intermedia	100	*Alnus cordata*	45
Tilia cordata	95	*Acer platanoides*	31
Acer campestre	90	*Acer pseudoplatanus*	25
Tilia × *vulgaris*		*Sorbus aria*	5
(Syn.: *T. europaea*)	82	*Tilia* × *euchlora*	2
Tilia americana	63	*Quercus rubra*	0
Tilia platyphyllos 'Rubra'	48		

Species which readily form natural hybrids such as *Tilia* × *vulgaris* (*T. cordata* × *T. platyphyllos*) clearly offer the prospects of compatability with a range of important cultivars, such as *T. platyphyllos 'Rubra'* and *T.* × *euchlora* (*T. cordata* × *T. dasystyla*), if rooting can be achieved and clonal rootstocks raised. A species such as *T. cordata* is clearly a source of potential rootstocks for *T.* × *euchlora* which is difficult itself to root (Table 2).

Considerable variation in rooting ability and cutting production has been reported among bushes raised from a small population of seedlings (6). This work has been extended to *T.* × *vulgaris* and rootstocks raised by hardwood cuttings to produce clones of both species. The first budding trials show high levels of bud-take (Table 3) and uniform production of maiden *T.* × *euchlora* trees.

Table 3. Bud-take of *T.* × *euchlora* on clones derived from seedlings of *T.* × *vulgaris* and *T. cordata* (percent).

		Clone	2	3	5	6	7	8	11
T. × *vulgaris*	Maidens growing		13	2	6	20	8	6	4
	Rootstocks budded		14	3	6	23	8	6	4
		Clone	13	16	22	23			
T. cordata	Maidens growing		6	11	11	13			
	Rootstocks budded		6	11	18	13			

No attempt has been made yet to maximize establishment of cuttings by modifying the propagation technique that was developed for fruit rootstocks. Marked year-to-year differences exist which need investigating, but data suggest that there is an inverse relationship between the extent to which cuttings of some clones develop roots while being stimulated in heated bins and their subsequent field establishment (Table 4) in accordance with experience of apple rootstocks (4).

Table 4. Relationship between percent rooting in heated bins (4 year's data arranged in ascending order) and percent establishment of *T.* × *vulgaris*.

Clone 6	Rooting	3	67	96	100
	Establishment	77	62	29	3
Clone 7	Rooting	15	61	90	100
	Establishment	46	44	10	16
Clone 8	Rooting	0	56	97	100
	Establishment	60	39	24	38

CONCLUSION

Opportunity exists to exploit apple and cherry clonal rootstocks to produce uniformly high quality trees of ornamental cultivars. In the interests of maintaining healthy propagation material, rootstocks — particularly of plums — should be produced in the UK. First attempts to raise clonal rootstocks of *Tilia* indicate that high productivity, rooting and compatibility exists within seedling populations of two species. This provides the basis for improving the propagation technique to produce clonal rootstocks reliably.

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COMMERCIAL PROPAGATION OF FRUIT TREE ROOTSTOCKS

NICHOLAS D. DUNN

Frank P. Matthews Ltd.,
Berrington Court, Tenbury Wells, Worcestershire

This discussion considers the production of fruit tree rootstocks, the techniques that are now commercially in use, the reasons for choosing these techniques of production and applying them to individual subjects based on production costs, suitability for site, and the management of our particular nursery.

HISTORY

It has only been in the last ten years that our nursery has started to produce rootstocks. Before this we relied upon imports from the Continent, mainly because they had the ability to produce them fairly cheaply with very suitable soil for stoolbeds or layer production.

With the introduction of the EMLA Virus Free scheme from E. Malling and Long Ashton we had a health status that had never been achieved before for any plant. Realizing the value of such a status we decided to go into production ourselves, firstly to supply our own needs, which was achieved about three years ago, and since then to supply our own trade, and very recently prospects of actually exporting which must be the ultimate reward for a very successful research objective.

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PROPAGATION TECHNIQUES

1) In vitro micropropagation
2) Hardwood cuttings
3) Stoolbeds

In Vitro Micropropagation. This is the most recent of propagation developments and a very exciting one for our trade as a whole. Although a laboratory technique demanding high capital expenditure input and a great deal of skill, care and attention, this must be the future production technique for all plants. As it develops it will no doubt cater for a wider range of plants.

The most useful application at the moment is the bulking up of new plant cultivars where the unit value is obviously high enough to justify the production cost which is an average of 40p per plant at the moment. The market value of fruit rootstocks is between 18 and 25p depending on the quantity and cultivar. Therefore, commercially for rootstocks anyway this is not the most economical method. Also the plants still have to be weaned off into a compost/loam medium under controlled conditions before being introduced to field conditions, possibly requiring a further year before being lined out for budding.

Hardwood Cuttings. Hardwood cuttings have proved very successful with fruit rootstocks but this is only applied to plum rootstocks because they produce few or no roots by the stoolbed or layer method. Apples, although successful by hardwood cuttings, are preferably propagated on the stoolbed, as the production costs are much lower due to mechanization, and there is the advantage that a good proportion of stoolbed rootstocks can be lined out for budding the following spring since they have a more fibrous and hardier root system; hardwood cuttings would need an additional transplanted year to achieve this. There are two hardwood cutting methods open to us for plum rootstock production, depending on the conditions available to the nurseryman.

1) Autumn Insertion.

Cuttings are taken from hedges, prepared and treated with hormone dip in the recommended way and then inserted into the ground in late October, where they manage to form root initials before the winter sets in. This is obviously the most economical way of growing plums but there are few problems involved with this method.

Firstly, defoliation of the hedge plants has to be achieved artificially as we see little natural defoliation in the West Country before the middle of December and we have had little success with chemicals, leaving us, therefore, to do this tiresome

task by hand. Also, depending on one's soil conditions, this time of year can produce very unsuitable soil for planting; and unless very light sandy soil can be found, conditions can often be against us. Very cold winters with frost lifting the cuttings in the ground and general exposure can also result in losses. It was for these reasons and the rather heavy demand of labour for other operations at this time of year, that we chose the second alternative method.

2) Spring Production Through Heated Bins in Coldstore.

This system is far more acceptable to a wider range of subjects because we have total control of the environment in which the bins are situated, and also the ability to give different cultivars variable hormone and temperature treatments to achieve the correct amount of rooting. Although 'St. Julien A' plum rootstock is the main subject for this system we very often use the bins for experimenting with other fruit cultivars. The direct cooled coldstore is maintained at 2°C (36°F) throughout the time of rooting.

In the past, spring production of hardwood cuttings with this method without the use of a coldstore produced problems in a warm early spring where the cuttings would start to grow in the bins before rooting was complete, and also the general loss of carbohydrates in a mild environment would cause large losses after planting out. With a coldstore we are, therefore, able to extend the natural dormancy of the cuttings in a very humid atmosphere, lessening the chance of loss of natural food supplies. Invariably one finds that planting conditions are unsuitable and, therefore, the cuttings can remain in coldstore exactly where they are with bottom heat reduced until such time that the soil is in good condition for planting. They can then be planted into the field in warm conditions facilitating immediate growth to lessen the chance of losses through inactivity; 4 to 5 weeks at a bottom temperature of 18°C (64°F) in a 50/50 sand/peat medium is usually adequate for plums. If we have other cuttings which require more or less time, then they are inserted into the bins at different times to coincide at a common planting time for ease of management.

It is important that following planting, irrigation is available and also a sheltered site be chosen, and I would even recommend the use of some sort of temporary shelter belt to be erected if the site is at all marginal. The time between extraction from the bins and planting must be as short as possible to avoid any unnecessary dessication of the cuttings.

Stoolbed Production. Stoolbed production is used for a range of apple and pear rootstocks and it is the most economical system for us. We have in the last five years been able to

mechanize all the operations and because the root system having been produced in soil is immediately suitable for lining out for budding, whereas the cultured roots from hardwood cuttings requires an extra year in the field before being lined out.

A fine workable soil is required to allow the efficient use of the special earthing equipment. A first grade rootstock of 8 to 10 mm should be planted for the stool establishment but any larger is liable to die after cutting down to ground level in the first year. Annual applications of well-rotted turkey manure at 20 tons/acre we find does aid rooting and helps to maintain a workable soil structure.

For the first two years the stools are harvested with hand pneumatic secateurs and in the third season we introduce an offset tractor-mounted sawblade, as the stool is strong enough to resist the pressure of this machine. It can harvest 1½ hectares a day which, depending on the rootstock, would be between 60 and 80,000 stocks off a mature stoolbed.

The life expectantcy of a stoolbed varies according to the type and is between 12 and 18 years. After this time it produces an ever-reducing quantity and would be uneconomical to keep in production. It is most important to cut as hard as possible into the stoolbed each year, which will maintain its vigor and the grade of rootstock. We generally find, with 'M.M. 106' as an example, that we have a grade-out of 30% each of 5 to 6mm, 7 to 8mm, 9 to 10mm, with 10% spoilage.

Earthing of the stoolbed is mechanical; we have designed our own machinery for this purpose. Herbicides and chemicals for the control of pests and diseases are applied with a tractor-mounted boom sprayer.

Harvesting is generally carried out in December when most leaves have dropped. It is very important to remember that most roots are produced during October and early November so harvesting earlier cannot be recommended.

LEYLAND CYPRESS — ROOTING AND EARLY GROWTH OF SELECTED CLONES

D.N. WHALLEY

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Littlehampton, West Sussex, BN16 3PU.

Abstract. Data are presented for rooting, plant growth rates in containers, and field establishment for Leyland cypress trees of 8 different origins.

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Cuttings taken in February gave best rooting in all cases and those from lateral branches rooted better than those from shoot tips. Growth rates were

measured during a full season in containers. The influences of age of tree, method of staking, and soil type on establishment and growth, when transplanted into the field, were also studied.

Clones superior in rooting and growth to those commercially grown were identified. Staking was beneficial only on a light, sandy soil type.

Leyland cypress (× *Cupressocyparis leylandii*) is one of the most widely grown ornamental conifers in the U.K. It is particularly useful for shelter belt planting as it is resistant to wind and grows well on a wide range of soils. Furthermore, it has the advantage of being tolerant of urban conditions and it is of some interest as a specimen tree or for forest use.

× *Cupressocyparis leylandii* is a bigeneric hybrid of *Cupressus macrocarpa* and *Chamaecyparis nootkatensis*. The trees resulting from the various crosses that occurred over the years have been well documented by Ovens, Blight and Mitchell (15) and more recently by Jobling (10) and by Mitchell (13). There were originally 10 clones, eight arising at Leighton Hall, Montgomery, on two occasions (clones 1-6 in 1888 and clones 10 and 11 in 1911). The other two clones (20 and 21) arose at Stapehill, Dorset, in 1940, or thereabouts.

In addition the Forestry Commission allocated tree identity numbers (relating to the places where they had been planted) to stock-trees of unrecorded origin. They further deduced from historical records, tree dimensions and foliage characteristics, the probable clonal origins of these trees (15). All trees were considered, on this evidence, to have arisen from the Leighton clones. Thus, trees 121, 122 and 123 may have arisen from clone 1 and tree 120 from clone 2.

Specimen trees (clonally derived from either the original clones or numbered trees) were planted by the Forestry Commission at Alice Holt Research Station, Farnham, Surrey. Cuttings obtained from these mature trees were rooted and grown so as to form stock hedges at the Glasshouse Crops Research Institute. These stock plants served as a source of cuttings for subsequent propagation experiments. The selection of material for this study was made following critical examination of the habits of the mature trees and the advice of the research staff at Alice Holt, principally Mr. J. Jobling.

Cuttings from eight individual trees were used in the rooting studies, some of which were true clones and others derived from the numbered trees. Tree numbers are, in general, referred to as clones for simplicity; their probable origins are shown in Table 1. For descriptive detail, see Ovens, Blight and Mitchell (15). Further studies of post-rooting development were then undertaken and this paper presents data for propagation, container growing, and field establishment of eight Leyland cypress clones.

MATERIALS AND METHODS

Rooting. Cuttings approximately 15 cm long were taken from four-year-old stock plants of all 8 clones listed in Table 1 at three monthly intervals, viz: 9 February, 10 May, 9 August and 9 November 1976 and retained in the rooting medium for three months.

Table 1. Leyland cypress — probable origin of eight trees.

Clone[1] or Tree Identity number[2]	Probable origin		Cultivar name
2	Leighton Hall, Montgomery,	1888	'Haggerston Grey'
10	Leighton Hall, Montgomery,	1911	'Naylor's Blue'
11	Leighton Hall, Montgomery,	1911	'Leighton Green'
21	Stapehill, Dorset,	1940	'Stapehill'
120	Cutting from Clone 2, planted in Kyloe Wood,	1906	*
121	Cutting from Clone 1,	1897	*
122	planted in Kyloe Wood,	1897	*
123	Northumberland,	1897	*

* These trees have been loosely known as Kyloe clones.
[1] One or two-digit numbers.
[2] Three-digit numbers.

Cuttings were of two types according to their position on the stock tree, i.e. from either the tips or lateral branches of vigorously growing lateral shoots. For details of this type of comparison see Deen (2). Bases of cuttings were dipped to a depth of 1 cm in a talc-based dust containing 0.3% 4-(3-indolyl) butyric acid (IBA). They were rooted in a medium of equal parts of medium grade Irish moss peat and Chichester grit (of maximum particle size 4.8 mm diameter), under intermittent mist controlled by an electronic leaf. A minimum basal temperature (in the rooting medium at cutting base level) of 20°C (68°F) was maintained, using electronic control units and thermistor sensors (21). Four cuttings were placed per 9 cm² plastic pot (compost depth 6 cm). Pots were randomly arranged across five rooting bays with equal numbers of treatments per bay. Fifty tip and fifty lateral cuttings were taken on each of the 4 dates.

Container growing. Rooted cuttings of all 8 clones were initially potted into 9 cm plastic pots, then into 14 cm black polythene containers (of capacity 2.5 l). The compost used was 75% Irish moss peat, 25% sand with fertilizer additions (per m³) of Osmocote slow-release fertilizer (18:11:10), 3000 g; single superphosphate, 3000 g; magnesium limestone, 2250 g; and fritted trace elements (WM 255), 400 g.

Five gravel-based container beds, irrigated by individual drip lines (Volmatic Ltd) were used. Two plants of each cutting type (tip or lateral) per clone from the February propagation

only were arranged in 5 randomized blocks. There were thus ten plants per cutting type used for assessment of establishment and early growth, giving 160 plants in the experiment. Guard plants were arranged around each block.

Plant height above compost level was measured at two-week intervals between 5 April and 24 November 1977, and growth curves were derived.

Field Establishment. On the basis of their high percentage rooting and apparent vigour in the early stages of container growth, plants of clone 21 and tree 121 were selected for comparison with the clones commonly grown commercially, 2 and 11.

The four staking treatments examined were: (1) unstaked; (2) light temporary cane (90 cm long bamboo); (3) heavy cane (150 cm long bamboo) and, (4) permanent stake (180 cm long metal pipe). Sixteen plants per clone (i.e. 256 plants) were ranked in order of height. These were then planted in a split-plot randomized block design on two different soil sites, the Glasshouse Crops Research Institute (GCRI) brickearth soil and a greensand at Duncton (22 km N.W. of Littlehampton on the South Downs). Within each block there were two paired plants per clone of each staking treatment, i.e., 32 plants per block.

Six blocks were planted on the GCRI site comprising plants from the February, August, and November propagations and two blocks at the Duncton site (plants from the May propagation). Plants were spaced 2 m apart within rows.

Blocks were arranged so that the trees formed long lines at right angles to the prevailing wind. On the flat GCRI site this comprised two rows 100 m apart with one row containing trees ranked 1-8 and the other the smaller trees (ranked 9-16). At Duncton one long row was planted half way down a long windswept hill with one block containing trees ranked 1-8 and the other trees ranked 9-16. Guard trees were planted at the end of each row.

Plant height was measured when in containers before planting (April 1978), in the autumn of the first year of establishment (November 1978) and in the summer of the following year (July 1979).

Angle Measurements. The angle at which the trees had grown was obtained by (1) measuring the divergence from the vertical (angle a1) of approximately 80 cm of 1978 growth (above the level of the stake, excluding the tip) and (2) measuring the angle of lean (angle a2) of the whole tree (Figure 1).

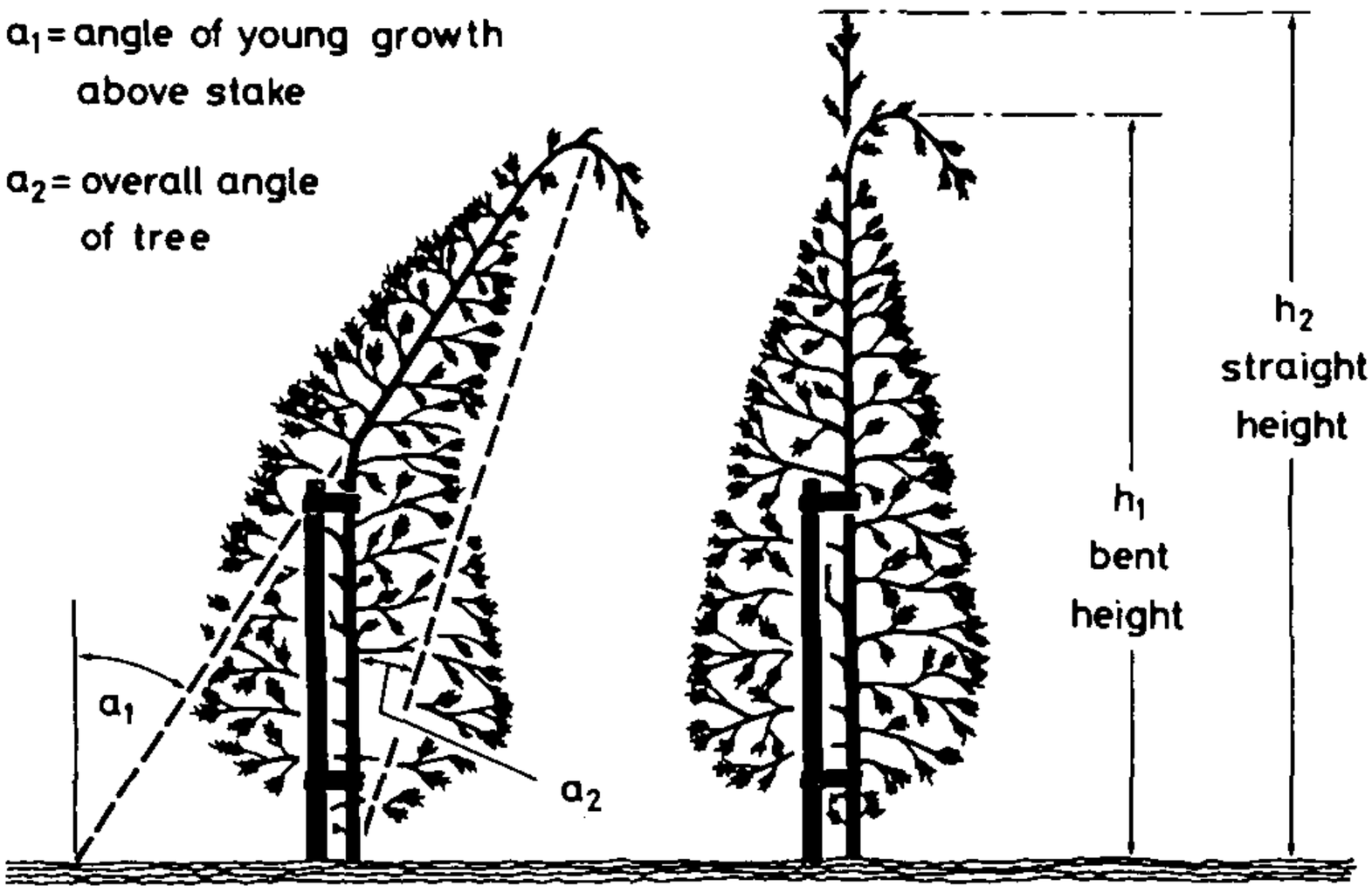

Figure 1. Height and angle measurements made in the field, July 1979.

RESULTS

Propagation. Clear differences were seen for percentage rooting (analyses on angular-transformed data) with respect to the parent tree, position on the stem from which the cutting was taken and time of year. Differences resulting from differing stock plant origins and type of cutting (a positional effect) are shown in Table 2. Clone 21 (Stapehill) and the Kyloe trees (120, 121, 123) rooted well for both cutting types, whilst clones 11 and 10 rooted poorest.

Table 2. Leyland cypress — percentage rooting. Each value is a mean of 200 cuttings.

Clone or tree number	Percent rooted	
	Lateral cuttings	Tip cuttings
21	84 a[1]	63 ab[1]
120	83 a	61 ab
121	80 ab	68 a
123	77 ab	59 ab
122	73 b	51 bc
2	71 b	54 bc
11	57 c	48 c
10	51 c	58 bc

[1] Within each column, values sharing a common letter do not differ significantly at $P < 0.05$.

When the two easy-rooting clones 21 and 121 were compared with clones 2 and 11 (those found commonly in commerce) the effect of different propagation times was clear. Table 3 shows that the best time for taking cuttings of all clones was February; May and August did not differ significantly, whilst November gave the poorest rooting.

Table 3. Leyland cypress — percentage rooting during all propagations from selected trees.[1]

Clone or tree number	Propagation 1 (Feb.)	2 (May)	3 (Aug.)	4 (Nov.)	Overall rooting (percent)
21	99	75	79	38	73
121	96	70	76	54	74
2	87	65	66	32	63
11	70	54	45	39	52
Mean	88	66a	67a	41	

[1] Means for propagation times sharing a common letter do not differ significantly at $P < 0.05$.

These results identify trees superior in rooting ability to clones 2 or 11 and that the usual propagation time (November) gave poorest results.

Container growth. Extension growth in containers for the period April-November 1977 is shown in Figure 2. Data are plotted as growth increments (so reflecting growth rates) rather than as absolute heights. Clone 10 ('Naylor's Blue') was slowest and after initially rapid growth, clone 21 also grew slowly. Clones 2 and 11 exhibited similar growth increases as did those derived from the Kyloe trees (120, 121 and 123). Tree 122 had the fastest rate of growth.

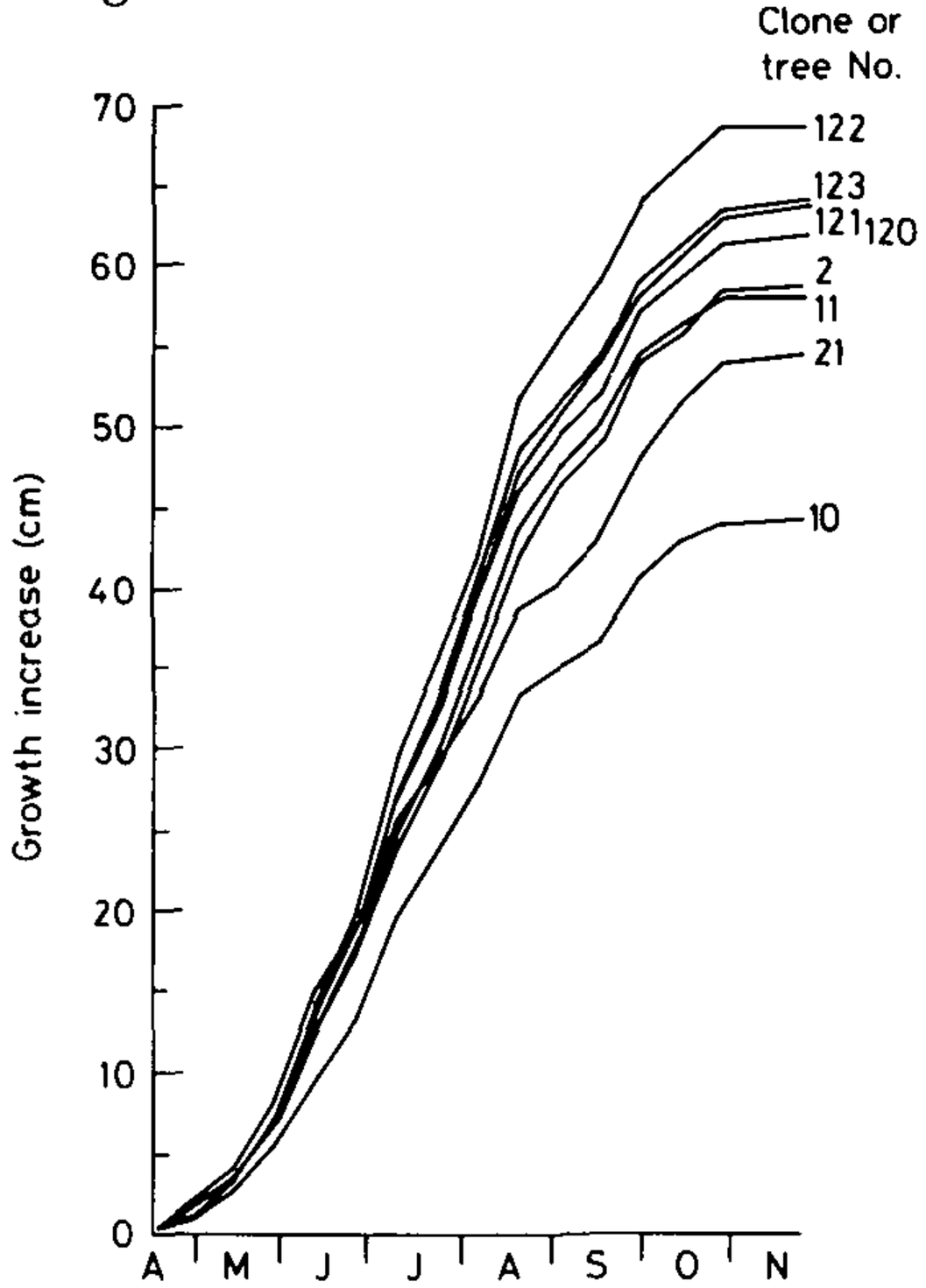

Figure 2. Mean increase in extension growth of plants in containers recorded between April and November 1977.

The duration of the growing period was similar for all trees, although in terms of absolute height the trees performed differently. For example clone 11 was consistently 10 cm taller than clone 2 at each measurement time, although the extension rates were almost identical. This reflects the interaction of a number of variables such as original cutting size, speed and extent of rooting where this occurred, and immediate post rooting growth.

The heights of container plants recorded in April 1978, immediately prior to field planting at the GCRI site, are given in Table 4. There was a considerable difference in height between the plants of the February propagation and the August and November ones, as rooting earlier in the year gave a longer growing period. The later the lifting from the rooting bench the greater was the difference in height between clones 2 and 11, suggesting that clone 11 made earlier and more vigorous flushes of growth in the spring. Had growth rates been derived for the plants of these later propagations the curves might have differed in amplitude and slope from those obtained for the February propagation. Averaging over all propagations the ranking for absolute heights after one season of growth was clone 11 > 121 > 21 > 2.

Table 4. Leyland cypress — height (cm) of container-grown plants after one season's growth (measured in April 1978).

		Clone or tree number			
Propagation		21	2	121	11
1	(Feb)	90.5	96.2	105.3	106.4
3	(Aug)	63.9	56.7	73.5	75.9
4	(Nov)	59.4	53.9	60.5	82.9
	s.e. diff (within rows) ± 4.11 (9 d.f.)				
	s.e. diff (within columns) ± 3.98 (9 d.f.)				
Clone means		71.3	68.9	79.8	88.4

Field Establishment. The effect of plant size on establishment is shown in Table 5. Comparison of plant heights in containers (prior to planting) with later field recordings (November 1978 and July 1979 (straight heights — see Figure 1)) indicated that whilst plants from the February propagation were significantly taller than the others before planting, this difference was substantially reduced, and heights were not significantly different from those plants of other propagation dates. These data suggesting that smaller trees of Leyland cypress establish better than larger ones are in agreement with growers' observations for this and other genera.

Mean plant heights for the various clones during establishment and in the field are presented in Table 6. In all cases, except one, the order of absolute heights was the same as in the

Table 5. Leyland cypress — effect of plant height (cm) on establishment.

	Propagation			
	1 (Feb)	3 (Aug)	4 (Nov)	Significance
Ht. in containers (April, 1978)	99a	67	64	**
Ht. in field (November, 1978)	151	137	135	n.s.
Ht. in field (July, 1979) (bent)	171	157	155	n.s.
(straight)	195	182	178	n.s.

a. Significantly different from other row means at $p < 0.01$.

containers, viz: clone 11 > 121 > 21 > 2. Differences between height in containers in April (when field planted) and in November (after the first summer's growth in the field) and subsequently between November and July showed clone 21, which grew more slowly in the early stages, to have a faster rate of subsequent growth than the others.

Table 6. Leyland cypress — mean plant heights (cm) averaged for plants propagated in February, August and November 1976, during establishment and subsequently in the field.

	Clone or tree No.				
	21	2	121	11	S.E. (diff)
Container grown for one season (Recorded April 1978)	71.3	68.9	79.8	88.4	±2.40 (9 d.f.)
Field growth (Recorded Nov. 1978)	140.5	127.4	144.0	154.3	±1.91 (9 d.f.)
Field growth (Recorded July 1979)	189.1	169.9	185.5	196.2	±1.60 (9 d.f.)
Growth differences April-November	69.1	58.5	64.3	65.9	
November-July	48.7	42.2	41.5	41.9	

Staking. Statistically, only within-site comparisons are valid. Nevertheless, when data are averaged over all clones, it can be seen (Table 7) that during the initial establishment period, unstaked plants in the greensand grew less than any staked plants. Different staking treatments resulted in little difference in plant height.

On the brickearth there were no significant differences between treatments during establishment (Table 7). Subsequent measurements in July 1979 again indicated little difference between treatments on the brickearth, height means for all clones (cm) being: unstaked 42.1, temporary cane 43.7, cane 44.2, stake 44.3. Similarly on the greensand the differences were reduced to non-significant levels, the means being: unstaked 41.3, temporary cane 45.4, cane 44.5, stake 42.7. Except in the initial es-

tablishment stage on a lightly sandy soil, there seems little effect of staking on tree height growth.

Table 7. Leyland cypress — staking treatments on two sites.[1]

Height diff. (cm) between April and November, 1978	Unstaked	Temp. cane	Cane	Stake	Significance
Duncton (Greensand)	45.7 a	59.6	62.0	60.3	*
GCRI (Brickearth)	63.9	64.9	67.3	61.7	n.s.

a. Significantly different from other row means at $p < 0.05$.
[1] Figures are averaged over four clones.

Angle measurements. Data in Table 8 show that, as expected, there were differences in the degree to which the stems were blown over. Least bending occurred in the permanently staked treatment, followed by the heavy cane. There was little effect of a temporary cane; if anything, the latter may have exaggerated wind-rock.

Table 8. Leyland cypress — effect of staking on tree angle.

	Staking treatments				
	Unstaked	Temp. cane	Cane	Stake	S.E. (diff)
Angle of tree above stake ht. (degrees) (a1)	22.2	24.9	17.4	12.6	±1.99 (126 d.f.)
Angle of whole tree (degrees) (a2)	15.1	17.5	9.7	5.7	±0.91 (126 d.f.)

DISCUSSION

For the GCRI site and conditions, propagation of Leyland cypress was optimal under mist from February-taken cuttings (overall mean 88%). Later propagations gave progressively less success. Similar results for rooting have previously been reported for Leyland cypress (9,10,11,16,19). In contrast Van Elk (3,4,5) indicated February to be the poorest rooting time and late autumn the best. Other workers have found the summer or autumn periods to be most conducive to rooting (1,8,14). These differences are difficult to interpret, perhaps reflecting local environmental conditions during propagation. For further discussion see Deen (2).

Differences in rooting behavior among different clones, presented here, indicate that clones exist superior to the commonly grown 2 and 11, in particular clones 21, 120 and 121. As all stock material was of identical chronological age, the observed rooting differences were thought not to reflect differences in stock plant age, although Halliwell (7) has pointed out how important this can be. If tree 120 is derived from clone 2 as Ovens, Blight and Mitchell (15) logically conclude, then it is surprising that it does not root similarly, particularly when trees 121, 122

and 123, all thought to derive from the original clone 1, have reasonably consistent rooting patterns. It is not impossible that during the years as subsequent cuttings have been taken, there has been genetic divergence from the original mother-tree, although the generation times involved here are small. Another explanation could be that relating the final shape and performance of the tree to cutting origin, as cuttings from different positions on the stock tree are known to root differently (17). Furthermore, the ultimate tree shape can be determined by the position from which the cutting was taken and the juvenility of stock material, with juvenile and adult foliage differing markedly in appearance. Welch (20) introduced the term cultivariants (different varieties of the same cultivar resulting merely from differing cutting types) for this phenomenon. It is also possible that whilst clones 120-123 are derived from one of the original six clones they may not have originated from clones 1 or 2 as Ovens, Blight and Mitchell (15) suggest but from others of the group.

Further more detailed rooting studies have been undertaken and are being reported separately. Deen (2) also reviewed other factors responsible for the rooting of cuttings of this bigeneric hybrid.

The extension growth data obtained for the container-grown plants showed that in November, plants from the February-taken cuttings were significantly larger than those from later propagations. This is not unexpected as plants from early cuttings had the summer period in which to grow. Data in Table 4 were for the GCRI site alone and, therefore, included only material propagated in February, August or November. When May-propagated material was included the mean heights (in cm) before planting for each propagation date were: February, 99.6; May, 69.5; August, 67.5; and November 64.2. The growth curves of Fig. 2 reflect growth differences rather than absolute heights, showing that as well as rooting more successfully than clones 2 and 11 cuttings derived from the trees planted in Kyloe Wood also had faster growth rates. In particular tree 122 is outstanding.

Whilst it is extension growth rate that has been examined here, plants having identical growth curves (for example clones 2 and 11) may differ markedly in absolute heights (reflecting different cutting sizes and post-rooting, pre-planting extension growth). Clone 11 grew faster from the cutting stage onwards, producing plants approximately 10 cm taller than those of clone 2 by April 1977. This difference was maintained from April to November during the container growing stage.

Similarly this trend was observed when the trees were

planted out and establishment examined. Clone 11 maintained its superiority over clone 2 (see Table 6). Unfortunately clone 11 rooted poorly in these experiments (in accord with grower observation) but differing from data obtained by the Forestry Commission (9). The only apparent difference in technique is Jobling's use of vermiculite instead of grit in the rooting medium. Apart from poor rooting, clone 11 possesses the desirable characteristics of dense, flattened foliage, and of forming a well-shaped tree. In contrast, clone 2 (which is most widely grown) rooted poorly, has a weak open habit, and forms a poorly shaped tree, which was the smallest of all the clones examined.

Clone 121 possesses many of the desirable characteristics required. It grows strongly (Table 6), roots well, and produces a densely furnished tree, very dissimilar to clone 2.

Young container-grown plants of clone 21 grew more slowly than all except clone 10 (Figure 2) but after field planting, it was the fastest growing of the four clones (21, 2, 121, 11 — see Table 6). This clone is more sparsely furnished than the other clones, with flattened branches and forms a good specimen tree. It does have the advantage of easy rooting.

When the practical problem of necessity of staking is considered, the data indicate that only in a sandy soil early in establishment is there any benefit from support, as assessed from height measurements (Table 7). However, the degree of bending of the 1978 growth and the overall angle from the vertical to which the trees bent was decreased by the more permanent staking treatments (Table 8), temporary canes having little effect.

There were no losses from uprooting (blowing-out) of unstaked trees, although they were blown to a more acute angle than the staked ones (Table 8). A clonal difference was seen, clone 2 responding most. Mean values of unstaked trees on the GCRI site for the top tree angle (a1) were: clone 21, 16.9°; clone 11, 21.3°; clone 121, 22.2°; clone 2, 28.5°. A similar pattern of susceptibility to blowing over was recorded for the whole tree angle (a2), values being: clone 21, 12.8°; clone 11, 13.6°; clone 121, 13.8°; and clone 2, 20.1°.

Height growth was slower in unstaked trees earlier in development (Table 7) but thereafter no significant differences were evident.

Firm staking obviously holds the main stem of the tree upright but this may lead to more crooked trees, bent above the height of the stake and to stems with less taper that are more liable to break on removing the support. This stage has not yet been reached in this experiment nor has the tension to which

the main stem was subjected been measured. However, previous work on deciduous trees has concluded that flexible stakes or supports which allow some main stem movement were optimal for stability, root development and trunk taper formation (6,12,18).

In conclusion, there are available trees superior in rooting, container growth and field establishment, to those most commonly found in commerce. The use of these trees would seem well justified if the maximum potential of this important bigeneric hybrid conifer is to be realized.

Acknowledgments. I wish to thank Mr. J. Jobling for help in the selection of the cutting material, and Mr. T.B. Betts, Mr. P.C. Dolman, Mr. J. Greenfield and Mr. J.K. Davies for very able assistance. Dr. D.O. Chanter and Mrs. A.F. Jarrett provides invaluable advice on statistical design and analysis and Mr. J.L.W. Deen and Dr. K. Loach much helpful discussion.

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PROPAGATION OF *PRUNUS TENELLA* 'FIREHILL'

J.S. WATKINS

Wyevale Nurseries
King's Avenue
Herts, England

The attempts to propagate *Prunus tenella* 'Firehill' by layering and by softwood cuttings in the internal mist unit were failures, mainly because we could not get even the small percentage that rooted to grow on to become saleable plants. I will not tell you how many years we had been trying, but will only go back to 5 years ago when the winter bareroot wax-dipped bench grafting programme was started and *P.* 'Firehill' was one of the subjects tried.

The first problem, and a major one, was trying to find any suitable material for scions. However, by some means or other, about 100 scions were grafted with a take of 20 to 25%. These plants were potted and the subsequent growth was quite good thanks mainly to the understock. It was decided to try budding that summer and strange to relate the success rate was similar, a take of around 25%, and again the growth response the following year was very good. Now we have solved the problem of good quality material for grafting and budding and the routine procedure of using the strong growth from field-budded plants for the winter grafting has established itself. The one thing I must point out is that each year has produced better results and field budding takes are now 90 to 95% and the winter grafting takes 80 to 90%.

To summarize: to be successful with any propagation programme one must, and I cannot emphasize this point too strongly, have the very best quality material to work with.

I am sure some of you must be asking why bud and graft? Well, the answer is this: the budded plants are for sale in winter for bare-root planting some 15 to 18 months after budding. The winter-grafted plants are potted the spring following graft-

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ing and by late summer, after hardening off, are ready for sale to garden centres and, of course, are available for the following summer, if we have not sold them all by then.

Now perhaps I can try to explain the method adopted at Wyevale for grafting. The understock we use is Myrobalan B and is lifted from the cutting bed any time from early November until mid-March and held in cold store until required for grafting. The scion material is cut sometime from mid-December to early January, and again held in cold store until required.

The grafting operation takes place any time from mid-January to mid-March. The type of graft used is one that I can only describe as a modified whip, but I would be very grateful if anyone could give me the correct definition. The understock is prepared, just prior to grafting, by nursery staff (I do not like the term unskilled) by cutting the head off to leave a short stem 3″ to 4″ (2 to 2½cm) and also the root system is trimmed, as this makes it much easier when the plant has to be potted.

At this stage the skilled grafter takes over, and he (or she), trims the top of the stock to leave a slightly sloping cut. The next stage is to make a cut ¾″ to 1″ long from the highest point of the stock and deep enough to reveal the cambium layer. This now leaves the stock with what I can only call a flap of bark.

Next the scion of 4″ to 6″ long (10 to 15cm) is selected to match the width of cut on the understock. The top of the scion is trimmed to a bud if it is found to be necessary.

The next cut is made at the base of the scion to match the ¾″ to 1″ cut on the stock. A second cut is made on the opposite side of base of scion, but not quite so long, and finally a third cut is made at the base of the second cut to form a short wedge shape. This is where the crunch comes: if all the cuts have been correctly judged the scion should now fit snugly into the cuts *on the stock without any cut surfaces showing. The scion is se*curely tied in position with cotton or rubber elastic ties. The completed graft is now handed over to the waxing operator who, using the low melting point candle wax, makes sure that the whole of the scion and union are completely waxed by either dipping scion and union into the wax or by painting the wax on with a brush. When the wax has hardened, the roots and stem up to the waxed portion are dipped in a Benlate solution at normal spraying strength. Now the grafted plants are packed into pallet crates and put into cold store where they are checked weekly and sprayed with Benlate solution.

The grafts remain in cold store until early April when they are potted into 7″ black poly pots (4 litre size) either by machine or hand. The potted grafts are then stood down, pot thick in poly houses or a greenhouse and grown off until late summer

when they are taken outside and hardened off, ready for early autumn sales or for sale the following late spring or early summer.

During the growing period in polyhouses they are checked over and any unsuccessful ones are removed. If necessary they are caned and tied, but this is not usually needed with 'Firehill'.

Finally, I can only put forward the following reasons for the success of this operation: these are, the waxing technique, holding in cold store for 6 to 10 week period and, once again, to emphasize the importance of using the highest quality scion material.

PROPAGATION OF *CORYLOPSIS*

CHRISTOPHER K.A. VERSTAGE

T. Hilling & Co. Ltd. Chobham, Surrey

Corylopsis is a member of the family Hamamelidaceae, cuttings of which, as a family, are difficult to root and hard to get through their first winter. *Corylopsis* is a genus that has high ornamental value at a time of the year when there is little else in the way of flowering plants available in the garden.

There are various means available to the propagator, e.g. seed, layering, and cuttings.

Seed. This is not a commercial method, as good seed is not easily obtained and does tend to have double dormancy.

Layering. This has been the standard practice for producing plants up until recent times when cuttings have taken over as the best method.

Stock plants are lined out about 2 m apart each way, the beds are top dressed with waste cutting compost, which is worked into the soil to give a good medium for the layers to root into. A shoot from the stock plant is pulled down and pegged into the soil surface; where the stem is bent into the ground the stem is wounded to help in the rooting of the layer. The tip of the stem is placed in a vertical postion and staked if required. The bend is covered with soil; this is then left until the following year when it should be well established. It is then severed from the parent plant and containerized and then grown on for 1 to 2 years before being sold.

Cuttings.

Material. This should be obtained from good young plants

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that are true-to-type. These can either be grown in a stock ground or under protection, as the best rooting material comes from actively growing stock. The longer the delay in taking the cuttings, the harder they become to root.

Preparation. The cuttings are made 75 to 100 mm in length and the leaves are trimmed to reduce water loss and to help to get more into a given area. Then they are given a slit wound at the base, which is done by drawing the knife point down the stem on the lower 15 mm when using liquid hormones. Use a slice wound when using powdered hormones. The hormones used depend on the timing of the propagation. For early cuttings taken in June Seradix 2 is ideal. In July/August the material is hardening up so use a liquid hormone (0.5% IBA) allowing it to dry before insertion.

It may be possible to use an acetone dip and then dip into Seradix 2 for the later cuttings as it may be easier to obtain acetone than liquid IBA.

Insertion. This is into a 50/50 peat-sand compost using either seed trays or Japanese paper pots. The latter gave little root disturbance which is good as the cuttings are adversely affected by root disturbance when they are potted on.

Aftercare. The cuttings are placed under mist and are watered in with Benlate solution as this helps to counteract disease problems.

Over wintering. Losses can occur since the cuttings have used up most of its food reserves in rooting and the buds may not be able to break dormancy the following spring. This is a problem with most members of the family Hamamelidaceae, so the aim is to induce 50 to 75 mm of new growth before winter.

If rooted early enough the cuttings can be potted so as to get new growth on them before winter or, if they are late, they are best left in trays until the following spring when they are potted up. The rooted cuttings are housed for the winter. Rooting will be well advanced in 6 to 10 weeks after insertion, with a take of 70 to 90%, on the average.

SUCCESSES AND FAILURES IN STARTING A TREE SEEDLING NURSERY

STEWART ST. JOHN

Kirby Bellars, Melton Mowbray
Leicestershire, England

Reasons for choosing to start a nursery of this type:

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Reasons for choosing to start a nursery of this type:

a) Limited capital required
b) Plenty of scope competing with imports
c) Cheap source of seed — locally collected
d) Working alongside knowledgeable people on the subject
e) Interesting and challenging subject in itself
f) Local outlets

Type of plants to be produced

a) One-year-old lining-out stock
b) Understocks for grafting and budding
c) Hedging material
d) Potted stocks for grafting — birch, beech, *Robinia*, yew.

Choosing a site. One should choose a site with a light to medium well-drained soil. My progress has been stifled by having to start on sites that held these drawbacks:

Half-acre plot right next to the river: subject to flooding and frosts. Soil is fertile but heavy and difficult to work when wet.

Top of a hill: very exposed, cold site. Land is ridge and furrow, causing irregular soil depth; poor drainage and difficult to mechanize.

Seedlings in their first year benefit greatly from warmth. An ideal site would be well sheltered, especially from the southwest, flat or with a gentle, south facing slope. Soil ideally should be on the light to medium side and well drained. Good drainage is imperative as seeds about to germinate will not tolerate waterlogged conditions. The site should also be fenced against rabbits.

Growing system. Starting with 4′6″ beds (135cm), we found them too wide for easy working, weeding, thinning, etc. Now we use 4′ beds (120cm) and also increased path widths to 15″ (37cm) from 9″ (23cm). We prefer slightly raised beds (2″3″) as they are:

a) Marked out ready when raised
b) Drained in a wet spell
c) Less dry at the edges than higher beds
d) Less far to bend to when working

For undercutting it makes little difference if the beds are flat or raised.

Land Preparation. Prepare early where possible, especially for seed sown fresh. It can be difficult to get land cultivations done well on a small scale in an agricultural area. If breaking old pasture, treat for wireworm during pre-sowing cultivations. Sterilize with Basamid or Di Trapex but not too early or there may be reinfestation of weeds. Some seeds are sown straight after collection. These are the bulky to handle species.

Kitting up with tools and equipment. For one acre of seeds beds, one needs:

a) A good selection of hand tools.
b) A reliable sprayer. We started with knapsack, then a motorized knapsack, and now we use a tractor-mounted sprayer with a lance.
c) Gravity roller.
d) Protection material against birds and frost. This is the costliest single item other than land.

My view is that we must use frost protection where necessary as late frosts could wipe out the crop of some species. Frost protection material has a 10 year life and costs 25p per sq. metre over 10 years. It is then used as internal windbreak material, or for shade requiring plants. The area is divided into 6 to 8 bed bays. The natural windbreaks best for the perimeter are *Alnus incana*, *A. cordata* (semi-evergreen), willow, and *Prunus cerasifera*.

Seed collection, pre-treatment and sowing. During the first two years seed was 80% home collected but now we collect only 50% as a wider range of species is grown and many species fail to set seed in this country. Collecting in this country can be time consuming. Home collected seed is relatively cheap and can give better establishment or acclimatization. It can be collected in the right condition — fresh or green. Our business would have failed if we relied on imported seed only. There are problems of unreliable delivery — seed may be too late to treat if we order one year ahead, then the seed is older and less viable. It is expensive and quality is very variable. It is unknown how it was stored and usually there are full dormancy factors to overcome. Foreign seed-houses still do a good job, however, and we couldn't do without them and they offer a very good range of species. It is best to try as many different seed houses as possible. The Forestry Commission now offer a seed service and also gives information on seed treatments. More and more kinds of seeds require source certificate of origin, though not so many ornamentals require certificates.

Record good seed stands during the summer and seek permission to gather whether on private and or county council property. Cherries are gathered in July, rowans in August. The majority of seeds ripen in September or October but those of ash are not ready until November. Check all seed for viability before collecting. This is very important. Fresh seed is usually tested by cutting and examination. Imported seed can be subjected to the tetrazolium test or to a direct germination test. Large seeds can be checked by a flotation test. Collect seeds only from good, healthy well-shaped specimen trees. Don't mix

the progeny of the same species, as they can vary considerably, and keep records of all sources.

Fresh seed is always best; it is more vigorous, has less dormancy factors and a higher germination percentage.

I started by using open stratification bays. I mixed freshly collected seed with peat and grit and placed it in bays straight after collection. I soon ran into problems as seeds of many subjects decayed. Sycamore and Norway maple seed germinate in January after a mild spell, as they only require 4 to 6 weeks chilling. With this method some subjects like *Sorbus* seed gave about 10% germination. The majority had not received sufficient chilling in an English winter. I now only stratify seeds of a few species outside. These are *Acer campestre*, ash and hornbeam, picked green and sown in February or March before the radicle emerges.

I tried to reduce the amount of seed to be sown in spring of cherries, sycamores and Norway maples by sowing in autumn but had disastrous results, including damage done by mice. Only 2000 out of 20,000 cherry seeds germinated. Now I only sow large seeds (oaks and chestnuts) in autumn. If these dry out they quickly die. Norway maple and sycamore seeds are sown in March as there is still time for them to be chilled in the seedbed. I decided to try giving cold temperature treatments in a domestic refrigerator to subjects like *Sorbus intermedia*, *S. aria*, *S. aucuparia*, *Malus*, *Pyrus*, *Amelanchier*, and *Syringa* seeds. I started doing this on a trial and error basis and mixed clean samples of imbibed seed with 2 to 3 times their volume of moist peat or peat/grit, sealed them in polythene bags and placed them in a refrigerator at 2 to 4°C (36° to 39°F). Once per week the bags were opened and the seeds inspected for decay or drying and the mixture turned to allow exchange of air. Inspection will determine when many seed lots are nearing germination time as shown by radicle emergence. I found out how long a stratification time each species required by doing germination tests of 50 seeds each week. These were sown in small trays and the percentage germinated after so many weeks chilling was recorded on a graph. A peak of germination is reached after so many weeks. If a small sample batch is chilled 2 to 3 weeks before the main batch then sufficient time is available to see the length of time the sample batch requires. We then sow the main batch of seed. This system has given consistently good results.

Chilling times for seeds of some species are shown below:

Sorbus intermedia	18 weeks
Sorbus aria	16 weeks
Sorbus aucuparia	20-22 weeks

Malus pumila (Syn.: *M. communis*)	9-11 weeks
Pyrus communis	9-11 weeks
Nothofagus	6 weeks
Prunus avium	10-16 weeks
Tilia platyphyllos	up to 22 weeks

Using this system, a sowing programme can be worked out. Another useful factor, if the equipment is available, is to freeze seed ready for sowing if the sowing conditions aren't suitable or if the seed beds are not prepared. You may ask, why freeze the seed if it is already in a refrigerator. Well, even at 2°C (36°F) the seed, once dormancy has been broken, will start sprouting, but we can freeze down to −5°C (23°F) without detriment to the seed.

In April sow seeds of the cold stored subjects. In April/May sow seeds of birch, and alder, and in May/June, *Ailanthus, Cercis, Hibiscus, Catalpa* and *Robinia*. Seeds of species from temperate climates tend to have lengthy dormancies so that germination does not occur during mild winter spells with the seedlings being killed off by ensuing frosts. In north temperate regions, where winters remain extreme from autumn to spring, cold dormancy temperatures are relatively short because once the cold weather starts, there is no let up. The benefit of prechilling chilling until spring can be seen with coniferous subjects (softwoods), where seeds of some species require no chilling to germinate. However, if seed is pre-chilled, the amount of growth can be doubled in its first year. Try to collect seed before it is fully ripe. This reduces added dormancy factors such as hard seed coats and lengthy cold period requirements. With berried subjects, the longer the flesh is around the seed, the more dormant the seed becomes, so collect on the turn, crush the seed and immerse in water to ferment the flesh. After 3 to 5 days wash through a sieve immersed in water. Run off the water, dry the sample and remove chaff, then a count can be made by weight or volume. Seeds of hard seed-coated subjects require a warm period to break down the hard coat and, in nature, they get this in the summer. It may be necessary to supplement natural warmth in a cold summer by placing the seed in a warm place for a further period, e.g. in thorns and limes. When giving these treatments the seed must be in a moist medium. The use of concentrated H_2SO_4 is suitable for seeds of some hard coated subjects such as *Crataegus crus-galli*, rose achenes and *Hamamelis*. This is supplemented by a warm spell to break through the final stages of the seedcoat, then the chilling can be given. Many subjects just require a cold period. Some show epicotyl dormancy, e.g. *Viburnum lantana*, where the radicle emerges the first summer and the plumule the following one. Other kinds of seed require warm or cold water

soak for up to 24 hours and, with others, boiling water is added, as for *Robinia* and *Gleditsia* seed. When sowing, bulk up small seeds with sand or grit as this facilitates sowing evenly and helps seed to "run." Roll in the seed after sowing and cover with ¼" grit, then roll again.

Ideal germination conditions occur in April during showery weather. One may have to create this during dry spring. Sow too thickly rather than too thinly as one can always thin out, though this depends on the value of the seedlings. For the less hardy seeds, we cover with protection material over wire hoops. This material is later used for windbreaks.

Some seeds show polarity, e.g. sow horse chestnuts so that the brown scar faces downwards. Sown thus they should attain up to 90% straight stems and roots. *Castanea sativa* seed should be sown with the point downwards. Seed density is very important. A number of factors are concerned such as soil type for, if it is heavy, it can produce large plants. Density will also be governed by the quantity and ratio of supplementary feeding and by the type of plant required. For large one-year seedlings, I give 13 × 13cm 60/sq metre. For liner size of good quality I give 8 × 8cm 150/sq metre. It is easy to be greedy and produce dense seedbeds of thin drawn plants. Give a base dressing of 1 to 2oz superphosphate to the seedbed. Seedlings respond well to liquid feeding. We changed from potassium nitrate and urea to a proprietary brand which does not require dissolving in hot water. It is easy to put on too much nitrogen and spoil the crop. Always feed in balance, e.g. 1:2 N:K.

Thinning out is very important for good quality seedling crops. Skilled operators should be able to recognize runt seedlings if the beds are not thinned too early. They have thinner stems or are smaller plants. Spray every 7 to 10 days against usual pests (aphis, caterpillars). For powdery mildew on apples, pears, oaks, field maple, and thorns total coverage by high volume is best and alternate spray materials are used. Much effort should be taken in presentation of a saleable article. The young trees should be neatly bundled and well-graded.

Storage of seeds. Seeds that do not deteriorate when dry can be kept in a cool dry atmosphere. Some seeds heat up if stored too thickly, e.g. beech. These should be stored in not more than 6" layers and should be turned every few days. It is always worth bearing in mind that the larger seeds normally make the biggest plants.

Key to success on a small scale. Don't grow too many lines. It is better to grow a few well and in quantity. Use locally collected seed where possible. Choose a good site with abundant water supplies available.

SOME EXPERIENCES WITH SLOW-RELEASE FERTILIZERS IN CONTAINER-GROWN PLANTS

VOLKER BEHRENS

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Many of our container-grown ornamental shrubs are produced within 15 months from the cutting up to saleable size. Therefore these mass-produced plants are rather cheap and production costs have to be kept at a minimum. One of the main cost factors is a repeated feeding by hand. It is impossible to give all the fertilizer the plant needs during the growing season because of the high salt concentration on the one side and the leaching of nutrients on the other. And liquid fertilizers raise problems too, especially in very wet years. To avoid these problems the fertilizer industry offers various slow-release fertilizers. They are based on two different principles; one is to condense urea with different aldehydes (Ureaform, Crotudor, Isodur); the other is to coat a soluble fertilizer with a material that releases the nutrients slowly.

But up till now only few investigations are published on questions like the following: in which amount should these fertilizers be given to grow containerized plants? Which method is preferable, application on the container or mixing into the potting medium? Is it possible to give the entire quantity at the beginning of cultivation or would two applications be more advantageous? And how do the different fertilizer brands act; are they similar in performance with regard to their effect on the plants?

So to gain more information on these questions two factorial experiments were carried out at the Institut für Obstbau and Baumschule of Hannover University in 1978 and 1979.

MATERIALS AND METHODS

Plant material. As a test-plant *Pyracantha coccinea* 'Orange Charmer' was chosen, since it is an important plant in German nurseries, is vigorously growing, and reacts well to nutrition. It is typical of plants that are usually propagated in summer (late June/July), potted with a little fertilizer in small pots in autumn or early spring, kept under frost protection, and then potted on in the middle of May when frosts are no longer to be expected.

Fertilizers. Five different slow-release fertilizers were chosen, three of them were developed for nurseries, two are lawn-fertilizers (see Table 1).

Container and potting-medium: The plants were potted in

Table 1. Tested fertilizers and their characteristics.

Brand Name	Ratio of Nutrients N:P:K:Mg	Declared Duration	Nitrogen in form of:
Plantosan 4 D (rough granular)	20:10:15:6 + trace elements	10 weeks	85% slow-release, no information about the form by the producer, probably mostly urea form; 15% fastworking
Osmocote	16:10:13 no trace elements	8 to 10 months	resin-coated soluble fertilizer
Triabon (rough granular)	18:8:12:4 + trace elements	10 weeks	75% Crotudor, 25% fastworking
Mannadur Super (lawn-fertilizer)	20:5:8:2 + some trace elements	more than 4 months	50% ureaform, 23% urea, 15% nitrate, 12% ammonium
Rasen Floranid (lawn-fertilizer)	20:5:8:2 + some trace elements	many weeks	70% Isodur, 30% fastworking

pure peat-moss mixed with calcium carbonate (3 g per liter), in 5 liter black plastic bags.

A special trace-element fertilizer was added to the fertilizers which do not contain trace-elements. The containers were placed under an overhead irrigation system.

Treatments and design: Two randomized factorial experiments were carried out in 1978 and one in 1979, with 4 blocks and 5 plants each per plot.

1) Each of the 5 fertilizers was given at an amount of 0.9 and 0.6g nitrogen per liter substrate, either on the container or in the medium (only 1978).
2) The 5 fertilizers were applied in three different ways of application each — in the medium, on the container and a corresponding split application. The amounts were 0.9g N/l (1978) and 0.7g N/l (1979).

At the end of the vegetation period (1978) and at the end of August (1979) the height of growth was recorded, since that is usually the most important criterion for selling pyracantha.

RESULTS

No definite difference — much less a significant difference — was found in height of growth between the amounts of 0.6 and 0.9g N/l, whether given on the container or mixed in the potting-medium. All fertilizers reacted in the same way, there was no significant interaction and, therefore, the means over all fertilizers could be computed and compared (Table 2).

No significant differences could be found between the methods of application in 1978, due to a high variation within the treatments — large differences among the replicates.

Differences among the fertilizers are significant in some cases. Rasen Floranid caused an inferior growth compared with all the others, Triabon was not as good as Plantosan and Man-

Table 2. Effect of 0.6 and 0.9g nitrogen per liter potting-medium on the height growth of *Pyracantha coccinea* 'Orange Charmer'.

Method of Application	Amount (g nitrogen per liter)	Height Growth (cm)+
In the medium	0.6	97.0 n.s.
	0.9	93.5
In the container	0.6	97.0
	0.9	96.5

\+ means of 5 analogous reacting fertilizers
n.s. no significant differences ($\alpha = 0.05$)

nadur Super. Because of the high variation no significant interaction was found and the means over all the methods of application could be computed and compared (Table 3).

Table 3. Influence of different slow-release fertilizers and the method of application on the height of growth (cm) of *Pyracantha coccinea* 'Orange Charmer' (1978).

	Method of application			
Fertilizer	in the medium	in the container	in 2 applications	means
Plantosan	108.0+	102.0	103.0	104.0 a
Mannadur	96.5	100.5	108.5	101.5 a
Osmocote	93.5	96.5	98.5	96.0 ab
Triabon	91.0	97.5	88.5	92.0 b
Rasen Floranid	80.0	86.5	71.0	79.0 c

\+ no significant differences within the fertilizers ($\alpha = 0.05$)
a no significant differences between data with the same letter ($\alpha = 0.05$)

In 1979 the data could not be computed by a factorial analysis of variance, because the treatment "Mannadur in the container" was not comparable, due to irregular growing conditions. The data of each fertilizer and each method of application were analyzed separately.

No significant differences could be proved among the fertilizers, whether they were given in the medium or in the container or in the split application. Differences among the methods of application could only be proved to be significant with Osmocote. Feeding Osmocote in the container is not as good as the two other methods (Table 4).

Table 4. Influence of different slow-release fertilizers and the method of application on the height of growth (cm) of *Pyracantha coccinea* 'Orange Charmer' (August 1979).

	Method of application		
Fertilizer	in the medium	in the container	in 2 applications
Plantosan	102.0+	99.0	104.5
Mannadur	98.5	—	103.5
Osmocote	108.0 a	99.0 b	110.5 a
Triabon	98.5	103.0	105.5

\+ no significant differences within methods of application ($\alpha = 0.05$)
a no significant differences between data with the same letter ($\alpha = 0.05$)

DISCUSSION

The results of these trials were obtained under the climatic

conditions of Hannover, West Germany, and they do not necessarily apply in another situation, but nevertheless they can give some useful indications for plants which are similar to pyracantha in growth and cultivation.

The amount of 0.6g nitrogen per liter given as a slow-release fertilizer (e.g. 3g Plantosan per liter) seems to be sufficient for the whole growing season. This result was supported by accompanying salt concentration measurements. These concentrations were on a sufficient level. A higher amount did not increase the growth in height and did not prolong the period of time in which the plants are sufficiently supplied; it only increased the costs and the risk of salt damage. Therefore in 1979 an amount of 0.7g N per liter was chosen.

Lawn-fertilizers, which are usually much cheaper, might be successful container fertilizers too — like Mandadur Super — or might be of no value for container-grown plants — like Rasen Floranid. The latter caused a growth depression and even necrotic leaves due to temporarily high salt concentration levels. Therefore the fertilizer was not tested again in 1979.

In 1978 the main growing season up to the end of July was rather cold and rainy. Probably that was the reason for the diminished growth of the Osmocote and Triabon treatments in comparison to Plantosan and Mannadur and to the 1979 results. It could be possible that the leaching of nutrients is more severe with fertilizers which have fast dissolving granules, like Triabon. There were no clear and provable differences among the fertilizers within the individual methods of application up to the end of August in 1979. Since the plants had not stopped growing then, changes might be possible, especially with Osmocote. The same applies to the methods of application. There were no differences to be found, excepting Osmocote which should not be given in the container, but there seems to be a tendency that a split application might be of some advantage in comparison to the other methods. This tendency can be seen by the Mannadur treatment in 1978, too.

Probably there are no definite differences among growth in height of plants fed with Plantosan, Mannadur and Triabon. Osmocote might have an advantage.

THE PROPAGATION OF *BERBERIS* BY CUTTINGS

ROGER WASLEY

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Propagation of *Berberis* can be carried out in three ways: seed, division, and cuttings. I shall concentrate on the last of these methods, cutting propagation, which is the main method we use in our nursery. First a word about the stock plants. These are fed with A.I.I.I., N.P.K. + trace elements fertilizer in the spring at which time they are pruned back to encourage vigorous growth.

On our nursery we have most of the stock plants outside but we have some, e.g. *Berberis* 'Harlequin', 'Darts Red Lady', 'Pink Queen', 'Rose Glow', 'Gold Ring' and 'Green Carpet' planted under polythene to produce a large amount of growth fairly quickly. This is the first year I have had this type of stock plant under cover and so far the signs are encouraging as the growth produced is first class.

Now to the mechanics of the operation. There are two types of cuttings taken on the nursery, one type for the mist unit and the other for cold frames. The first method used during the year is the mist unit and such cultivars as *Berberis* 'Harlequin', 'Rose Glow' etc. are taken for the mist, as these produce good soft growth suitable for the environment mentioned. Also with these cultivars being much in demand at the present time one wants the best possible take.

These cuttings are taken during the last two weeks of August. They are of a nodal type and about 4″ long. The lower three sets of leaves and spines are trimmed off and the cuttings are dipped in Seradix No. 1 or No. 2, depending on the maturity of the cuttings. One point to note is that if the cutting is too thin it will not root or, if it does, it will not overwinter satisfactorily.

The cuttings are placed 60 to a seed tray in a mixture of 60% 1/16″ grit and 40% peat, with a ¼″ layer of grit in the bottom of the tray so as to assist drainage. This is because if the mist unit is not working 100% effectively, as often happens, too much water is placed on the cuttings, resulting in basal rotting. The basal temperature in the mist unit is 21°C (70°F). The cuttings are sprayed with Benlate every two weeks so as to try and keep them in a healthy state. As the cuttings are on the mist unit during late August and September there should not be any shading on the glasshouse, as maximum light is required. After six weeks 75% rooting may be expected. They are then taken off the mist bench and overwintered in a heated polythene tunnel.

The second method we use is cold frame production. This is the main method used on the nursery and the species of *Berberis* propagated with this method include: *Berberis* × *stenophylla*, *B. darwinii*, *B.* × *ottawensis* 'Purpurea', *B. thunbergii*, *B. verruculosa* and *B. candidula*.

The rooting medium in the frames consists of an equal mixture by volume of grit, peat and parent soil. This mixture is well forked through and then raked to remove any large lumps of soil.

There are two types of *Berberis* propagated in the frames, deciduous and evergreen. The deciduous types are propagated from mid-September to early October. The type of cuttings are nodal or of a mallet type. Those that lend themselves to a nodal type are the *B. thunbergii* and *B.* × *ottawensis* cultivars. The cuttings are 4 to 5″ long of the current year's growth. The minimum thickness of the cuttings is just below pencil width. The lower three leaf joints and spines are removed and the cutting is then dipped in Seradix No. 3. The cutting is then inserted in the cold frame at a spacing of 1½″ square. These are well watered in and covered with a shaded Dutch light. Rooting of the deciduous types sometimes takes place before the winter, but if not they root by the spring.

Evergreen cultivars are taken next from early October to early November. Mallet cuttings are used with the exception of *Berberis* × *stenophylla* where nodal cuttings are used. The length and treatment of the cuttings are the same as with the deciduous types.

The shading on the Dutch lights is removed during December as maximum light is required. Shading, consisting of emulsion paint and water, is put on again during March so as to reduce scorch on the cuttings. Once rooted the cuttings are potted up in 3″ polythene pots.

MIST PROPAGATION — PAST, PRESENT AND FUTURE

KEITH LOACH

Glasshouse Crops Research Institute

Littlehampton, West Sussex

Past and Present. The International Plant Propagators' Society was founded at a time when mist propagation was in its infancy as a commercial system in the United States, and the founding members played a significant role in its development. The early history of the method has been outlined by Snyder (16). Mist propagation has frequently been viewed as a

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mechanized version of older frame methods which involved manually-applied overhead watering of the cuttings. The most appropriate comparison is with the old "sun-frame" method which used a closed, unshaded frame, with cuttings watered laboriously every half-hour.

The first recorded use of mist (3) by G.E.L. Spencer in 1936 was for propagation of cacao cuttings and was apparently unsuccessful. It attracted little attention at the time but at the end of that decade Rains, Gardner, and Fisher in the United States independently used mist systems for a wide range of species with considerable success. Through the 1940s mist was tried by an increasing number of researchers and nurserymen but its widespread commercial acceptance came in the 1950s in the United States and somewhat later elsewhere.

At the 14th International Horticultural Congress in 1955, papers relating to mist propagation were read by Snyder and Hess (8,17) and by Floor (5) from Holland. These attracted considerable attention and furthered the adoption of the method in many countries. Early developments were comprehensively reviewed by Rowe-Dutton (14) in 1959 and more recently, abstracts of 400 papers dealing with mist have been collected (2).

Initially, mist was applied continuously over the cuttings but the weaknesses of this system were soon apparent. Cuttings were heavily leached and the rooting medium was cold and readily waterlogged. To counter this, mist was applied intermittently, with the aim of maintaining a film of water on the leaf surfaces but applying a minimum amount to the medium. Also, base heat provided by electrical soil-warming cables proved beneficial and the adage, "warm feet and cool heads" was coined as describing the "ideal" conditions for cuttings.

There are, in fact, few direct comparisons of continuous and intermittent mist in the literature. Snyder and Hess's data (17) show that intermittent mist gave appreciably better percentage rooting than continuous mist in only one out of the six species compared, though they remarked that comparisons of root number and length showed intermittent mist to be superior. When Sharpe (15) compared the two systems simultaneously for peach cuttings, he reported that, "neither one appeared to have a clear advantage." However, general experience appeared to confirm the superiority of intermittent mist and brought about a switch from continous application.

Intermittent mist was first controlled by time clocks but more sophisticated alternatives soon appeared. The first "artificial leaf" controller was constructed at Cornell University at the instigation of H. Templeton, a Tennessee nurseryman (19). This

incorporated the now well-known principle of using twin electrodes, separated by insulating material; when wetted a small current flowed between them, when dry the circuit was broken and a relay opened a solenoid valve, restarting mist application. Thus the sensor simulated a real leaf and operated to maintain a film of water over the cuttings. Numerous variations in construction and even in terminology for this sensor have been described (14,20).

A variety of solar control mechanisms have been devised. In these, a light integration mechanism induces misting at a predetermined accumulation of solar radiation by the light sensor. Another controller commonly used is the "sensitive balance" system, first introduced in Britain by H.J. Welch in 1957 and with counterparts in other countries (20). When the mist film evaporates from a screen mounted on one arm of a small balance, the balance tips and so actuates the solenoid. Other controllers were devised (14) though few have survived until today.

In comparing different control systems, attention must be paid to their effectiveness, and their adjustment and maintenance requirements. Ideally, the sensor should match evaporation from the cuttings and integrate all the factors which control this, viz. temperature, humidity and ventilation. With a timer the onus is on the operator to adjust the settings in accordance with the weather, whilst the leaf and balance systems automatically cope with environmental changes. Solar controllers rely on natural correlations between the pertinent factors, e.g. in high light conditions temperatures are high, humidities low and the glasshouse vents open, all of which increase evaporation. Ranking controllers in terms of their theoretical effectiveness, the artificial leaf and balance outperform the solar controller and timer but for trouble-free operation the order is reversed. Each system has its adherents, depending on the individual's relative valuation of efficiency and ease of maintenance.

Physiological Principles. The success of mist propagation relies on its ability to maintain cuttings turgid until roots form. Water loss from a cutting is determined mainly by the vapor pressure gradient between leaf and air. Losses can therefore be reduced by keeping the leaf cool to minimize leaf vapor pressure and/or by ensuring a high ambient vapor pressure in the air. Snyder and Hess (17) clearly differentiated between propagation techniques involving humidification, designed primarily to maintain a high air vapor pressure, and mist, where the main aim is to cool the leaves.

The principles behind mist as outlined by Hess and Snyder

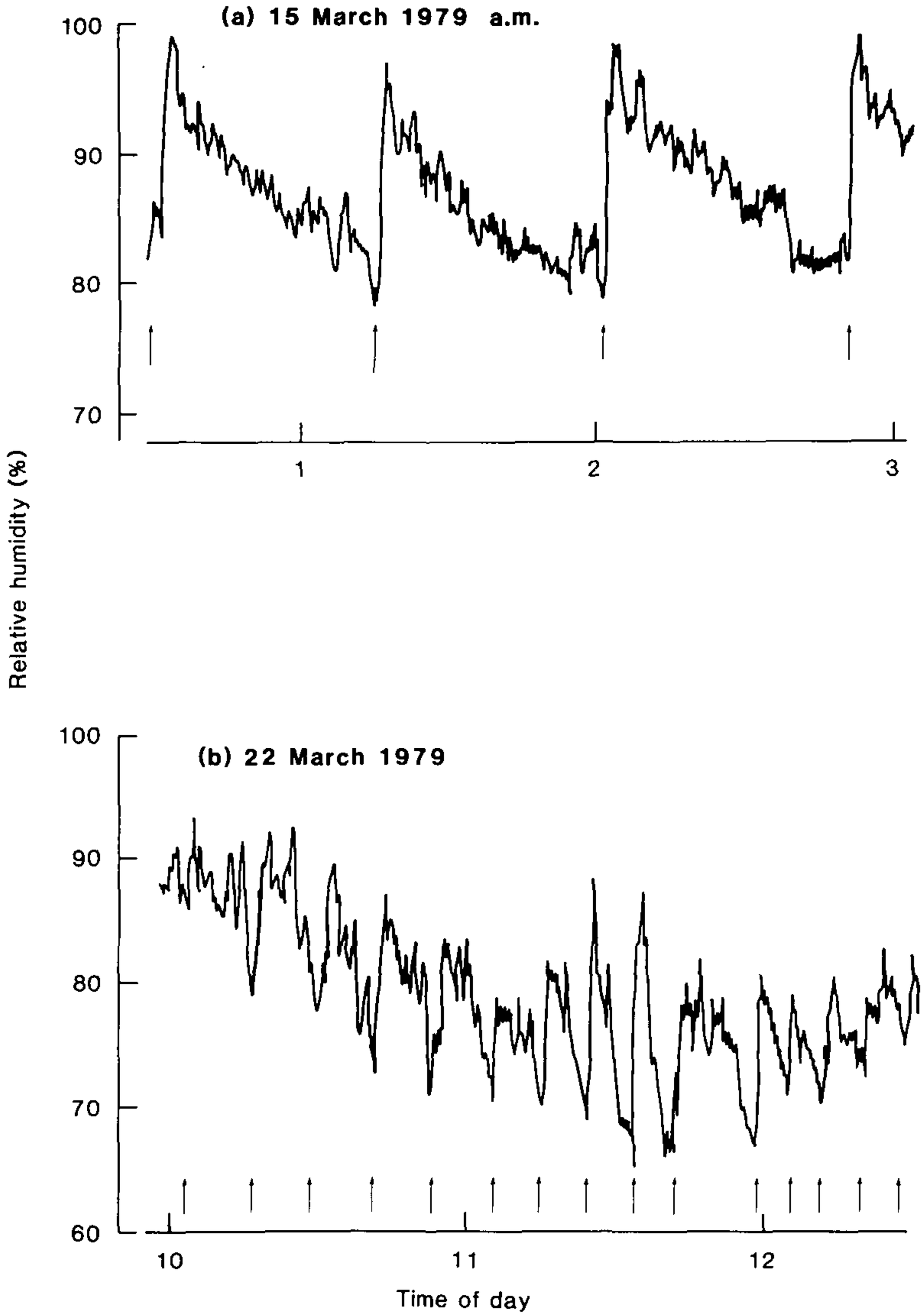

Figure 1. Relative humidity measured on a misted bench using an aspirated thermocouple psychrometer with a fast response time, (a) at night and (b) during the daytime. Arrows indicate mist bursts.

(8) are:

1. Evaporation from the water film covering the leaves cools the leaves and so restricts water vapor loss.
2. Because water losses are small, cuttings can be rooted at high light intensities and this facilitates the photosynthetic accumulation of carbohydrates required for root growth.

Side benefits accrue from controlling the water loss, e.g. more juvenile cuttings, with inherently greater water loss but greater rooting ability can be used.

These principles, based on relatively little data, bear reexamination in the light of subsequent studies. Recent measurements of ambient humidities on a mist bench (Grange and Loach, unpublished) illustrate a problem inherent with mist; between bursts the humidity falls toward ambient glasshouse levels (Figure 1a and 1b) and, if the water film covering the foliar surfaces is less than complete, then water loss must occur from the cuttings. The water cover is inevitably imperfect because falling mist cannot fully reach the leaf undersurfaces where most stomata occur and the cuticle is often thinnest. Increasing the ambient humidity by raising the misting frequency is self-defeating, in the sense that evaporative cooling of the leaves is then reduced and leaf vapor pressure is increased.

Simultaneous measurements of leaf temperatures on misted and non-misted benches showed the effectiveness of mist in cooling the leaves (Figure 2). Leaf temperature of the misted cuttings averaged 7.2°C lower than for non-misted cuttings (Table 1). Air temperatures were also appreciably lower under mist, presumably because the falling droplets cool the air through evaporation. It is clear that, in addition to direct evaporative cooling of the leaves, advective cooling through movement of cooled air over the cuttings on the open bench must make a significant contribution in moderating the leaf temperatures. (Advection is a term describing the transfer of air and air characteristics by horizontal motion.)

Misted cuttings were only 0.3°C cooler than the adjacent air but dry leaves were 2.1°C above adjacent air temperature. The

Table 1. Average temperatures during the day on misted and non-misted benches.[1]

	Mist	No Mist	Difference
Leaf temperature	21.7°C	28.9°C	7.2°C
Air temperature	22.0	26.8	4.8
Leaf/air temp. difference	−0.3	+2.1	+2.4

[1] Measured by 10 differential leaf/air thermocouples and a single aspirated air temperature sensor per bench (1 m^2)

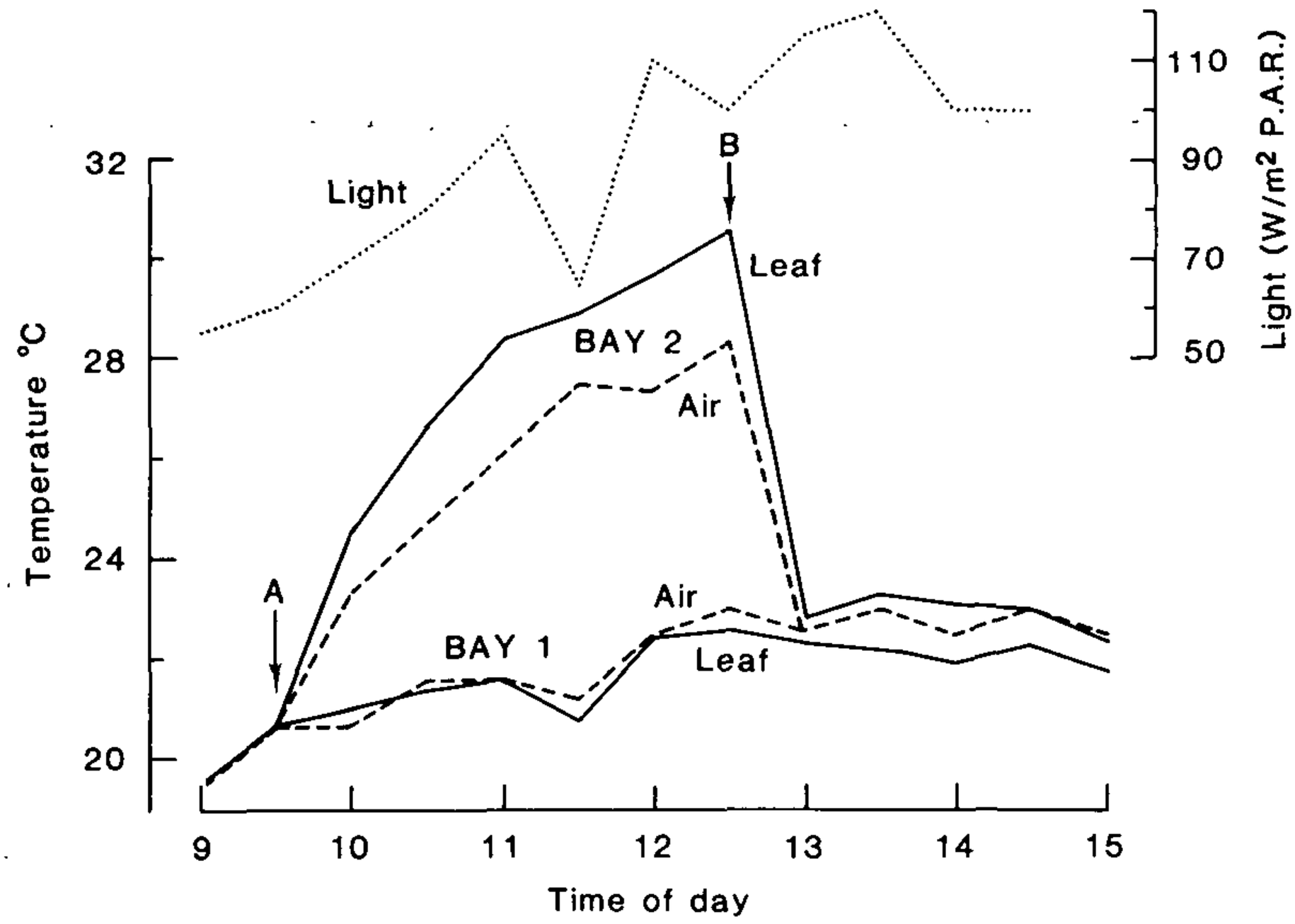

Figure 2. Leaf and air temperatures on misted (Bay 1) and non-misted (Bay 2) propagation benches. The mist on Bay 2 was switched off at time A and on again at B.

consequences in terms of leaf-air vapour pressure gradients are noted in Table 2. Dry cuttings faced three times the leaf-air vapor pressure gradient compared with mist cuttings and would thus lose water three times as fast (assuming leaf resistances to water loss were identical in both cases). Moreover, the water loss from dry cuttings comes from within the leaf, whereas that from misted cuttings is mainly from the externally-deposited water film.

Table 2. Leaf-air vapor pressure gradients during the day for cuttings on misted and non-misted benches.[1]

	Mist	No Mist
Leaf vapor pressure (kPa)	2.6	4.0
Air vapor pressure (kPa)	2.0	2.2
Gradient, leaf to air	0.6	1.8

[1] Assuming internal leaf air is saturated at leaf temperature.

It should be noted that in this experiment, the measurements were made on adjacent bays separated by a polythene divider and shielded above and on the south side to reduce direct sunlight and ensure an even mist spray pattern. Air movement over the bench was, therefore, considerably restricted and in a more open bench situation, the advective cooling would be greater relative to the direct evaporative cooling of the leaves.

In summary, vapor pressure gradients from leaf to air are inevitable even with mist, but the externally-deposited water film constitutes much of the water loss. The importance of advective cooling via mist-cooled air appears to have been overlooked in comparison to direct evaporative cooling of the leaves.

Turning to the second principle; our knowledge of the relationship between light, carbohydrates and rooting has been shown to be inadequate in recent years. While positive relationships between light levels and rooting have been demonstrated (4,9), a number of cases where high light was found to be detrimental to rooting have also been reported (see reviews 1,6,7). Many of the latter examples refer to somewhat artificial circumstances but there is evidence that in routine propagation, high light may be harmful to rooting. For example, when cuttings of *Hebe rakaiensis* were rooted under mist or under polythene sheeting (lightly shaded) in February, the misted cuttings accumulated more dry weight over five weeks but rooted less well, probably because they had a lower water content than those under polythene (Figure 3) — Loach and Whalley, unpublished.

Cuttings under high light usually have a lower water content than those under lower light levels and this frequently confounds interpretation of experiments designed to show the effects of light *per se* on rooting. For this reason we experimented in controlled environmental chambers, where precise temperature control should minimize light-induced leaf temperature (and hence leaf vapor pressure) differences. Propagation of cuttings of *Weigela florida* 'Variegata' and *Forsythia* × *intermedia* 'Lynwood' at 20, 40, 60 and 80 W m^{-2} photosynthetical active radiation (PAR) indicated that an irradiation of about 30 W m^{-2} was optimal for rooting (11). Rooting was negatively related to the sugar content of the cuttings but unfortunately, cuttings at lower light levels again had a higher moisture content (Figures 4a and b), thus preventing interpretation solely in terms of light.

Subsequently, measurements under shaded mist benches showed that leaf temperatures were not greatly influenced by the degree of shading. Presumably the cooling capacity generated by evaporation and advection copes adequately with different radiation loads. Under mist then, light effects can perhaps be examined independently of cutting water status. To test this, we propagated *Viburnum* × *bodnantense* 'Dawn' and *Hibiscus syriacus* 'Blue Bird' under mist at four different levels of shade, and used psychrometric techniques to measure cutting turgor (Grange and Loach, unpublished). Results are shown in

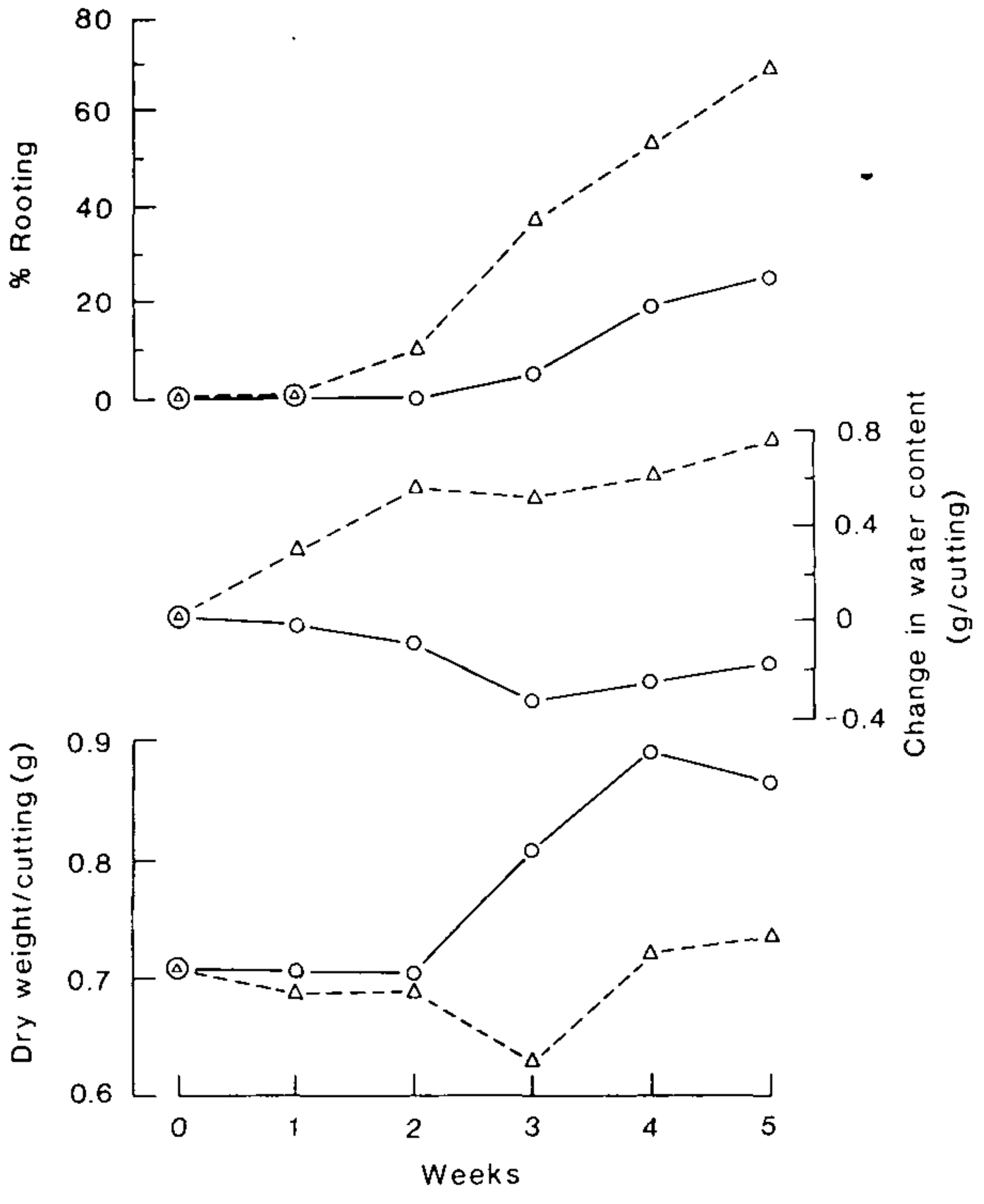

Figure 3. Changes in water content and dry weight during rooting of cuttings of *Hebe rakaiensis* under mist (○—○) and polythene (Δ---Δ).

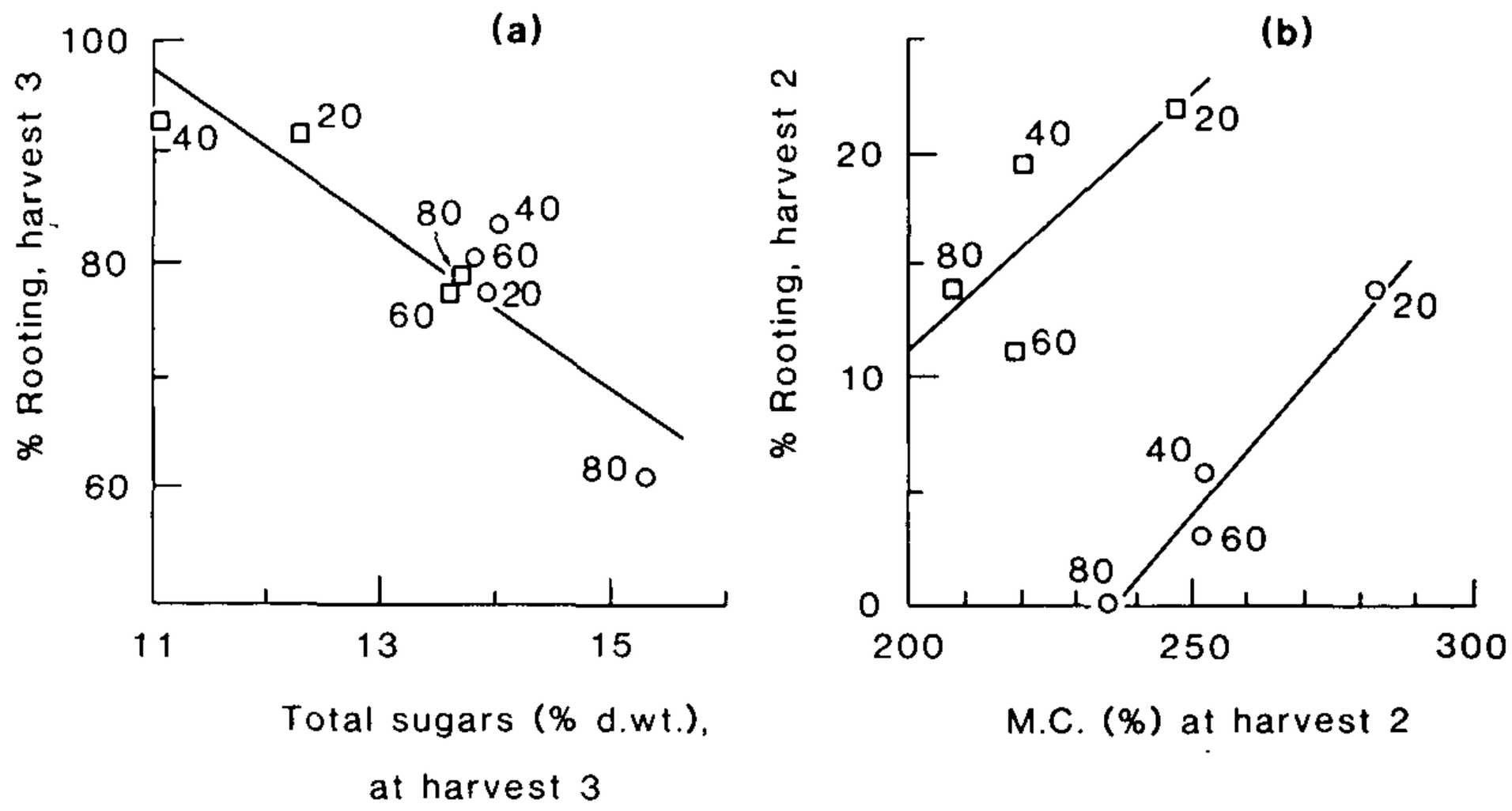

Figure 4. Relationship between percentage rooting after 3 weeks and sugar content (a), and percentage rooting after 2 weeks and moisture content (b) for cuttings of *Weigela florida* 'Variegata' (○) and *Forsythia* × *intermedia* 'Lynwood' (□) propagated at irradiances of 20, 40, 60 and 80 W m^{-2} PAR.

Figures 5 and 6. In general rooting decreased with increasing light but in *Hibiscus*, rooting was less good at the very lowest light level. This corresponds to the "minimum" light requirement observed for a range of hardy ornamentals by Loach and Whalley (12), i.e. 1.5 MJ m^{-2} day^{-1} of total shortwave radiation or 0.7 MJ m^{-2} day^{-1} PAR.

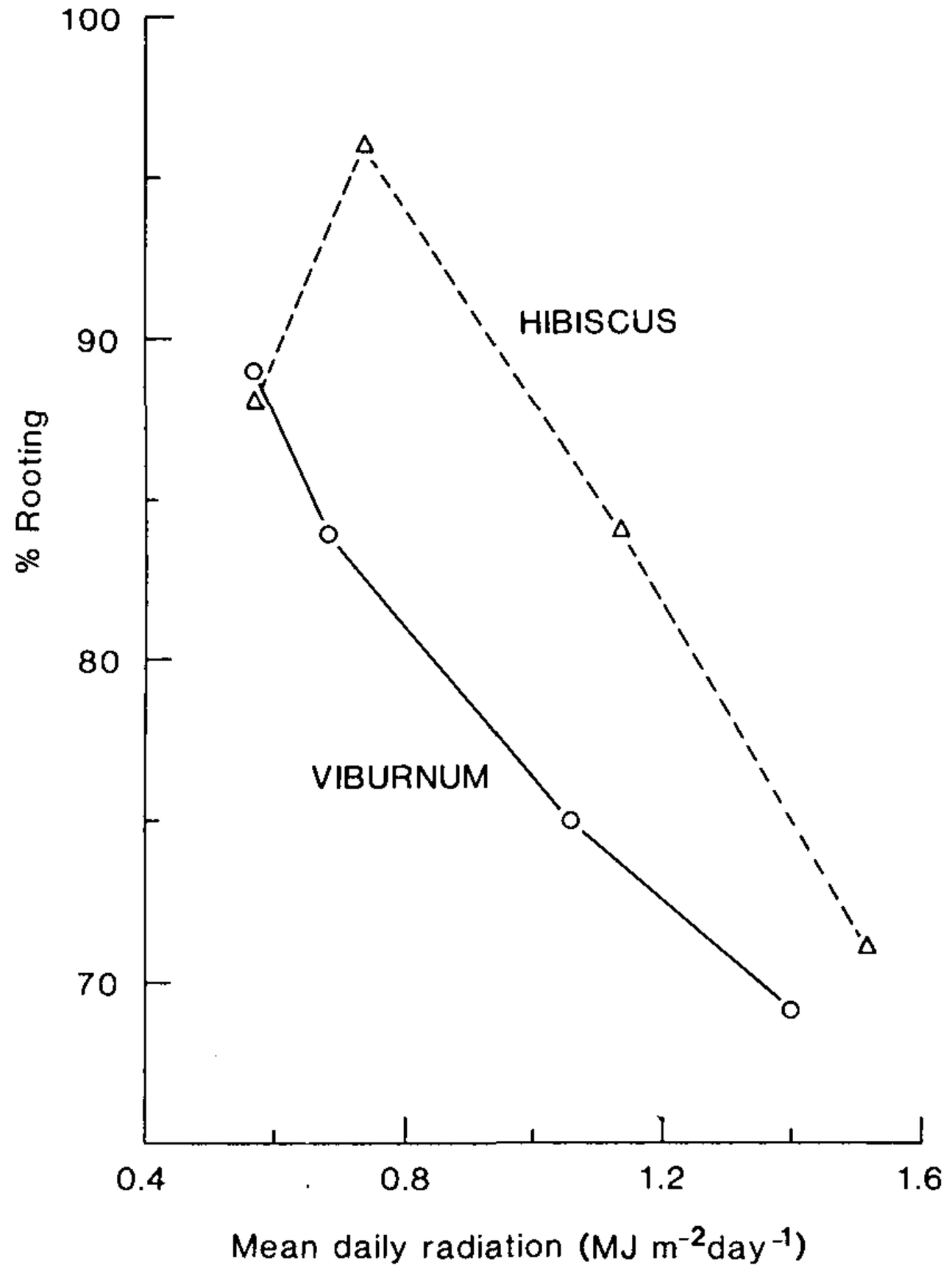

Figure 5. Percentage rooting of *Viburnum* × *bodnantense* 'Dawn' and *Hibiscus syriacus* 'Blue Bird' under mist shaded to give four different radiation regimes.

The osmotic potential of the leaf tissue was measured psychrometrically and as expected, decreased with increasing light, probably because more sugars are produced by photosynthesis at high light (cf. Figure 4a). In *Viburnum*, leaf turgor (estimated as the difference between the measured leaf water potentials and osmotic potentials) was similar in all light treatments, indicating that differences in leaf water status could not have accounted for the poorer rooting at high light. In *Hibiscus*, the leaves curled inwards in the high light treatment and were less effective at intercepting the mist, so that leaf turgor was reduced in this particular treatment (Figure 6). In the other three treatments turgor decreased at low light and again, could not

have determined the order of rooting. A direct negative influence of high light on rooting is indicated.

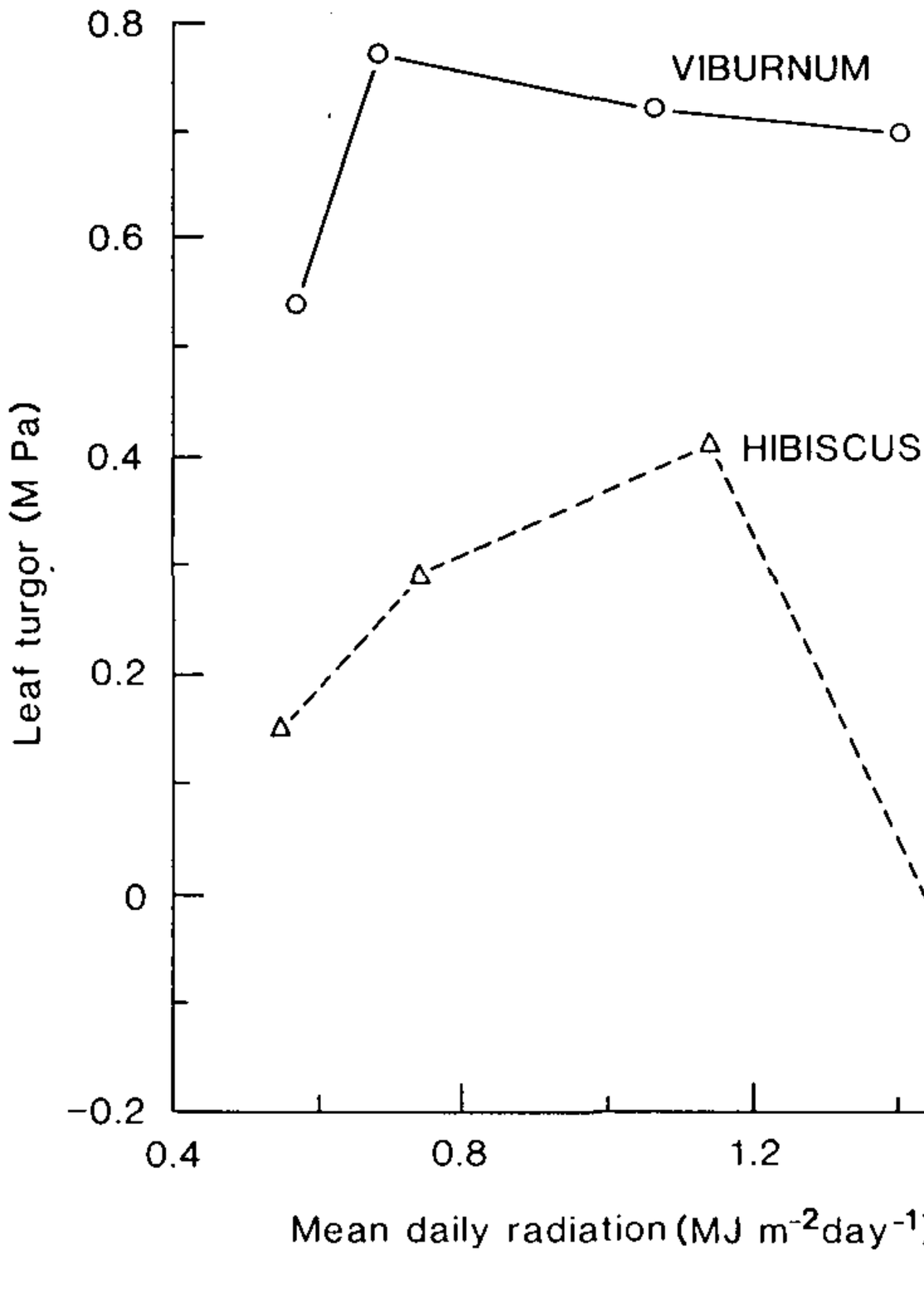

Figure 6. Leaf turgor in relation to radiation for cuttings of *Viburnum* × *bodnantense* 'Dawn' and *Hibiscus syriacus* 'Blue Bird' under mist.

Thus both cabinet and shaded mist experiments support doubts that high light and rapid accumulation of carbohydrates promote rooting in the way suggested by earlier studies. Further experiments to be reported elsewhere have shown that relationship between light and rooting is complex, but the conventional wisdom that mist is successful because it permits maximum photosynthesis, remains suspect.

Future developments. There are four conceivable ways in which mist propagation might be further improved:

1) by improving the distribution of the mist spray,
2) through better leaf cooling to reduce further the internal vapor pressure,
3) by increasing ambient vapor pressure (humidity) to offset the fall that occurs between mist bursts and,
4) through use of "hybrid" systems (see below).

It has already been noted that to minimize water losses (inevitable even under mist) an even spray coverage of all cutting surfaces is desirable. The relative efficiencies of different mis-

ting nozzles have recently been compared (18) but new designs promise further improvements over conventional types. In one of these, the water is broken into very small droplets by an ultrasonic resonator energized by compressed air. Use of compressed air makes the spray very directional, so that an array of these nozzles aimed tangentially into the canopy of cuttings should give better coverage than the conventional downwards-drifting spray. Trial layouts are needed to assess their value.

Conventional mist cools the leaves effectively through evaporation and advection and it is difficult to visualize any simple improvements in this direction. Shading, as we have seen, has little effect and increasing the ambient humidity reduces evaporative cooling and is counterproductive in this sense. However, in dull weather when mist bursts are infrequent and the effects of any imperfections in mist coverage are particularly evident, then humidification may be helpful.

Dutch workers in 1957 (14) trialled a hybrid system combining humidification on dull days with mist at other times (i.e. the humidifier was run more continuously on warm days to ensure that the cutting surfaces were wetted). A plastic-lined glasshouse was used to maintain high humidities but on warm days, air and compost temperatures were excessive. This is an inevitable problem with a sealed, humidified chamber. Ideally a means of sealing the house tightly for humidification, yet allowing occasional ventilation on warm days is required. Continuous ventilation would give uneven distribution of the "mist" from the humidifier. Difficulties were also encountered in devising a suitable controller for the humidifier; presumably this would be less difficult nowadays with the advent of microprocessors. A modified system incorporating ventilation and a superior controller would merit re-examination. Results in 1957 were comparable with conventional mist.

More recently, Milbocker and Wilson (13) have described a humidification system incorporating ventilation. Air is drawn through a ventilated enclosure and humidified at its point of entry. Evaporation of the fine water droplets dispensed by the humidifier, cools the inlet air, so moderating temperatures within the enclosure. In this way, temperatures were maintained below 38°C (100°F) in the enclosure (in Virginia) except on extremely hot, humid days. Provision of sufficient humidification on hot, drier days may present problems. Moreover, even in relative humidities approaching 100%, if leaf temperatures exceed air temperatures, then net loss of water will occur from the leaves. As already noted, where water loss is inevitable then wetted leaf surfaces are advantageous.

Simple outdoor frames, covered with polythene and incor-

porating timer-controlled mist nozzles, were used at Wageningen in the 1950s. Better results were obtained than in conventional glasshouses or with frame propagation but in cool summers it was not always possible to maintain a sufficiently high temperature. Conversely, in the hottest weather, extreme temperatures were again inevitable in these unventilated structures.

Another simple modification of conventional mist that has given improved results in the few test comparisons we have made, is the "mist plus mesh" method (10). Polythene or muslin mesh is placed over the cuttings and holds water droplets to increase the ambient humidity beneath. Some leaves are nevertheless wetted and a degree of advective cooling occurs through the open mesh. Further trials are necessary to test its effectiveness and to determine the best mesh size and material.

To test these various modified and hybrid systems against each other would require extensive experimentation. The first approach should be to make appropriate physical measurements (leaf temperatures and ambient humidities) on a small scale, to determine their relative efficiencies in minimizing leaf-air vapor pressure gradients, in a range of external conditions. Extensive trialling of the best systems should follow.

The polythene alternative. With simplicity in mind, we have tested propagation under polythene sheeting as an alternative to mist. The advantages in terms of capital cost are obvious but the disadvantages of propagating in a sealed enclosure in bright weather have already been noted. Can shading alone provide adequate protection in U.K. conditions? Nurserymen need guidelines to ensure that an appropriate level of shade is used.

Results of experiments to determine the minimum light requirement for propagation in a range of conditions (12) indicated that rooting is not severely curtailed until the daily radiation level falls below about 0.7 MJ m^{-2} PAR. From this and other experiments we devised shading regimes calculated to give an appropriate level of light for each month of the year. Some provision for diurnal light variation is made (insofar as shades are changed twice daily) and for weather variations (with a choice between "dull" and "bright" shade levels as judged appropriate). Experiments covering the period June to August 1979, the most testing time of the year, have given encouraging results (Table 3). In the three species where less than 95% of the cuttings rooted, polythene gave significantly better results than mist. In these cases root quality, as judged from the number of roots per rooted cutting was also superior under polythene. More extensive testing is needed but the possibility

is attractive for satisfactory, year-round propagation under polythene, using a simple, prescribed shading regime.

Table 3. Rooting of cuttings under lightly shaded mist and under shaded polythene[1] in summer.

Species and date	Days in bench	Percent rooting		Root number/ rooted cutting	
		Mist	Poly	Mist	Poly
June/July					
Weigela florida 'Variegata'	19	100	100	41	21
Forsythia × *intermedia* 'Lynwood	20	96	100	16	12
Philadelphus 'Burfordensis'	26	59	95	14	25
Potentilla 'Red Ace'	14	100	100	23	26
July/August					
Callicarpa bodinieri	21	97	95	26	24
Hydrangea 'Altona'	17	95	98	2.6	3.6*
Corylus maxima 'Purpurea'	27	10	25	1.5	3.6*
Cornus alba 'Sibirica'	28	47	73	2.8	3.1*

[1] Polythene was shaded according to the calculated shading regime noted in the text.
* Root numbers scored on a 0 to 5 basis; others are actual counts.

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PLANNING PROPAGATION FACILITIES FOR THE 1980S

DAVID N. CLARK

Notcutts Nurseries Ltd.
Woodbridge, Suffolk

Ivan Dickings, Propagation Manager for Notcutts and myself, have had a once in a lifetime opportunity of planning and constructing a new propagation and liner facility which will take Notcutts into the 80s.

While the time scale for the operation could be simplified into one year planning, one year construction, one year debugging, the decision, in principle, to build a new propagation facility had been made a few years earlier — in fact, at least 28 years ago, according to the oldest member of the propagation staff. In preparation for the new unit, Ivan has been building up a team of staff capable of exploiting the new facilities for the past four years. We had also reappraised the propagation systems we were using including rooting media, direct rooting systems, types of liner pots, etc.

Objectives in planning a new propagation and liner unit:

1. Provide near optimum growing environment facilities for the wide range of plants propagated and techniques used. *Maximize use of space in this controlled environment.*

2. Plan for economical labor utilization, with an integrated materials handling system, including:

a) maximize use of skilled labor on skilled jobs.
b) keep heavy, dirty and monotonous jobs to a minimum.

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a) maximize use of skilled labor on skilled jobs.
b) keep heavy, dirty and monotonous jobs to a minimum.

c) reduce need for unsocial working hours, such as weekend duty.

3. Compromise between initial capital expenditure and future running costs. Plan for efficient use of energy and water.

4. To allow for increased production capacity, including additional space for:

a) "forcing" stock plants for early season propagation.
b) "accelerated" growing of selected liners of summer flowering plants such as fuchsias.

5. The design should be flexible for future changes, allowing for:

a) improvement in propagation techniques and liner production.
b) ever-changing market requirements.
c) installation of gantry materials handling system.
d) expansion.

How we set about the detailed task.

1. Quantified existing facilities and targets (amalgamated two existing propagation units and transferred the remaining production of saleable plants to container unit).

2. Visited other establishments:

a) propagation units abroad and in U.K.
b) other glasshouse nurseries, specializing in pot plants and bedding plant production.
c) glasshouse exhibitions, including B.G.L.A. and N.V.T., Holland.

3. Analyzed main operations involved:

a) preparation and handling of compost
b) box filling
c) cutting and grafting preparation
d) insertion of cuttings
e) movement of cuttings from propagation area to rooting environment
f) movement of rooted cuttings to potting on area and liner area

4. Appointed a company of glasshouse consultants to help with design of the mechanical services, including the glasshouse construction, heating, irrigation and electronics.

The Site. We originally planned to build a propagation unit side by side with our container unit, which we started to construct in 1972. In recent years, it became clear that there would not be room for the two units on one site. Three main factors influenced our final position:

1. *Environment.* The site chosen was reasonably sheltered from wind; although in a frost pocket this was considered less important as the main propagation glasshouse would be heated.

2. *Proximity to services.* Three phase electricity supply within 50 yards. Main Woodbridge sewer within 20 yards. Mains water and borehole water within 200 yards.

3. *Staff accessibility.* The site chosen was in cycling distance from the town of Woodbridge, with its reasonable reservoir of married women, whom we expect will form the nucleus of staff expansion.

The Work Area. *This has been formed from a double span* of 22 ft wide Robinson aluminum glasshouse, double glazed with polystyrene, providing shade and insulation. The area has automatic ventilation. Within this work area we have created three heating regimes, reflecting the type of work to be carried out, including compost mixing, potting on and cutting preparation. The zones have been created by the use of mobile PVC vertical screens/curtains; the fans of the heat exchange unit can also be used to provide further air movement in summer months. Mechanical assistance in this preparation area is provided by a Turner compost mixer and a small Plantarex potting machine.

The Propagation Environment.

1. *Heating Zone.* Four distinct heating zones have also been created by the use of mobile PVC vertical screens/curtains. The use of these mobile screens maximized the possibility of using gantries and other materials handling equipment in the glasshouse area. A medium pressure gas boiler provides the heat for both air and soil heating, although a heat exchange is used to reduce the pressure and temperature of water for soil warming to 38°C (100°F). Automatic ventilation is provided throughout.

2. *Mist.* Overhead mistlines have been installed over the total area to eliminate the need for moving materials within the propagation area; 888 mist nozzles have been used.

3. *Irrigation and Feeding.* A separate irrigation system has been superimposed over the mist unit for the same reason as above, and also to enable soft water to be used for mist and mainswater for irrigation when soft water is scarce.

4. *Water.* Soft water for the mist is collected from the roof of both the glasshouse and the Nico-Poly structure and stored into above-ground tanks with a capacity of 20,000 gallons.

5. *Shade/Thermal Screen.* A dual purpose shade/thermal screen has been installed over the total area. This is controlled by a photoelectric cell during the daytime for shading and a

clock at night for thermal screening. The material utilized is a white woven acrylic, providing 50% shade. I would like to emphasize that the installation requirements of a thermal screen conflicts with the installation requirements of the irrigation system and both of these conflict with the materials handling and heating system and electrical installation.

The Liner Structure.

The cuttings and grafts are rooted and weaned in the controlled environment of the aluminum glasshouse and are transferred to a Nico/Poly structure for hardening off, growing on and overwintering. We consider that the Nico-Poly structure provides ideal liner conditions:

a) cool temperatures in summer
b) drier conditions during winter

The Fordingbridge Linkspan Multi-span house was custom built to include the following features:

a) 22 ft wide bays, rather than the normal 21 ft to facilitate the same materials handling system as used in the glasshouse.
b extra clearance under the gutters to provide extra space required for automatic shading, and allow the use of the battery operated forklift within the house.

Materials Handling/Crop Maintenance.

When we designed our container unit in 1972, materials handling was given the very highest priority. In planning the propagation unit the provision of the growing environment was given first priority but the materials handling came a close second.

In designing the materials handling system, we took into account the following operations:

a) unloading and movement of peat and other bulky sundries
b) movement of boxes, trays and pots from work area to growing area, to liner area
c) loading and dispatch of the finished product (liners)
d) routine maintenance during propagation, i.e. the moving of dead leaves etc.

The materials handling system has three components:

a) A number of narrow, aluminum tiered trolleys which can be picked up by the pallet truck.
b) Battery operated low profile pallet truck designed for glasshouse use.
c) Gantries. We are investigating the use of gantries for two operations: crop inspection and maintenance, and

materials handling.

To enable us to install a gantry we have:

a) installed the heating pipes with extra supports.
b) installed overhead mist and irrigation to keep the floor area clear.
c) planned the glasshouse layout to allow for easy transfer of the gantry across the main access path and also to transfer it transversely from one section to another.

Alarm System. We are currently installing an alarm system which will monitor ten pre-determined criteria including electricity supply, water supply, air temperature. In the event of breakdown, it will automatically ring a predetermined telephone number and report which of the ten criteria is faulty. If no one is home, it automatically dials a second number. This procedure is repeated up to five times and, by changing a casette, the order sequence of the numbers can be changed. We hope this will reduce the amount of weekend duty and reduce the time it takes to get a specialist mechanic to correct the problem.

The Cost. Allowing for grants, various other allowances and a return of 25% on capital, the capital cost will work out about 1p per liner produced.

TAKING STOCK — MANAGEMENT OF STOCK BLOCKS

MARGARET A. SCOTT

Efford Experimental Horticulture Station
Lymington, Hampshire, England

This is a review of the work with stock beds at Efford E.H.S. and deals with why and how they were started, their management, and some data on cutting production, particularly in relation to pruning treatments.

The experimental programme with hardy nursery stock deals mainly with container production plus some work on propagation. Between 1973-78 there was a rapid expansion in the volume of work. In order to have confidence in the accuracy of results from experiments, uniform batches of cuttings were required. This proved virtually impossible to obtain with bought-in material. Often greater differences occurred among plants within the same treatment than among the treatments themselves. Neither could there be firm guarantees of when cuttings would be available and occasionally mixed cultivars occurred which made interpretation of results more difficult. Hence it was decided to propagate our own material for trials.

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At first plants in the grounds (and local gardens) were used as stock plants but this was unsatisfactory due to variability in the material, which was often floral, and unevenness in rooting. Therefore the planning of a stock bed area began in 1972; its main function would be to supply material for the trials but, at the same time, would provide information on stock management and cutting production.

The advantages of a separate stock area include:

1. Ease of management especially in relation to watching when cuttings are ready for taking.
2. The plant health status is known and can be carefully watched.
3. The plant history is known (this is particularly important in experimental work).
4. Growth of the stock plants can be influenced to produce the type of material as and when required, i.e.: nutrition, protection, forcing, pruning, etc.

It was decided to make the Efford stock block clonal by propagating the stock plants from a single parent, with each cultivar selected as being true-to-type. Clonal material was also felt to have several other advantages:

1. Growth would be uniform.
2. It would provide uniform batches of cuttings at any one time.
3. Successive batches of cuttings could be taken with the knowledge that they had exactly the same parentage.
4. Uniformity of the material could induce even rooting within batches.

The correct choice of parent plant material would be very important to ensure that it was:

1. correctly named.
2. of good form.
3. was a good rooting form.

In some instances non-clonal material was planted and ease of rooting monitored to enable the selection of the best form for cloning.

To ensure that stock plants were disease-free they were container-grown for a year. This also allowed adequate time for site preparation. Planting commenced in 1974.

Site. The site selected had natural shelter on all boundaries, either copse or well established *Escallonia* hedges. The field itself was approximately 2 ha; an area of ground 0.5 ha was fenced off against rabbits along the northern boundary. Later, fallow deer became a problem and the fencing was raised to just over 2 metres in height by two additional strands of wire.

The soil type was a fine sandy loam with a pH of approximately 5.5 overlying gravel at 60 to 75 cm which gave reasonable drainage. The surface structure, however, was unstable, easily slaking or capping and in need of building up with organic matter.

Preplanting preparation. The site was down to a grass ley and the first operation was a subsoiling of the area followed by ploughing and an initial cultivation. There was no perennial weed problem and a single application of Paraquat was sufficient to knock down the resulting weed sward. An application of 60 tonne/ha of FYM was then rotavated in. Cultivations were kept to a minimum to prevent excessive structural damage.

The site was divided into three areas for planting which received different base and top dressings to maintain appropriate pH levels. (1) Ericaceae, (2) Calcioles, and (3) Conifers.

The guidelines used for determining base and top dressings were from the Fertilizer Recommendations for Field Grown Nursery Stock published in the M.A.F.F. Bulletin GF 1 (p. 63). This is copied below in Table 1.

Table 1. Recommendations for base and top dressings for field-grown nursery stock.

	P_2O_5	K_2O	Mg*	P_2O_5	K_2O	Mg*
P, K or Mg	Before Planting			Top Dressing (Annual)		
Index	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
0	100	200	75	50	100	25
1	75	150	50	25	50	Nil
2	50	100	25	Nil	25	Nil
3	25	50	Nil	Nil	Nil	Nil
over 3	Nil	Nil	Nil	Nil	Nil	Nil

* At Efford magnesium limestone was used for the Calciole area but Kieserite for the ericaceous and conifer area to limit the rise in pH.

Nitrogen.

Before planting: 50-150 kg/ha N. (ericaceous area: 50 kg/ha in the form of Nitram to maintain a lower pH.)

Top dressing: 50-150 kg/ha N. (rates varied according to species. Ericaceous area limited to 50 kg/ha Nitram.)

Less nitrogen will be required on deep well-structured medium or heavy soils.

The decision as to the number of plants required for a given cutting production after x years was difficult since there was little information available on this subject nor yet on how long stock should be maintained before replanting.

Initially it was planned to keep the stock block for 10 years, but replant after 7 years to ensure there was no break in the continuity of cutting supply. This stage has just been reached

and replanting will begin in 1980, which will also allow comparisons to be made on effects of age of stock plants on rooting.

Spacing. With the exception of the heathers, which were spaced 45 cm^2, all planting was in rows. Spacing depended on the vigor of the species. In general, the slower growing ones were planted 90 cm apart with 1.20 m between rows. Moderately vigorous species were 1.20 m apart and 1.80 m between rows, while the faster growing species were 1.80 m apart with 2.40 to 3.00 m between rows. In certain instances double the number of plants required were planted with alternate ones being removed as growth increased, e.g. hardy hybrid rhododendrons.

Planting. This was done as and when material became available or new species were introduced into the trials. In this way the older plants acted as windbreaks aiding establishment of the newer plantings (Figure 1).

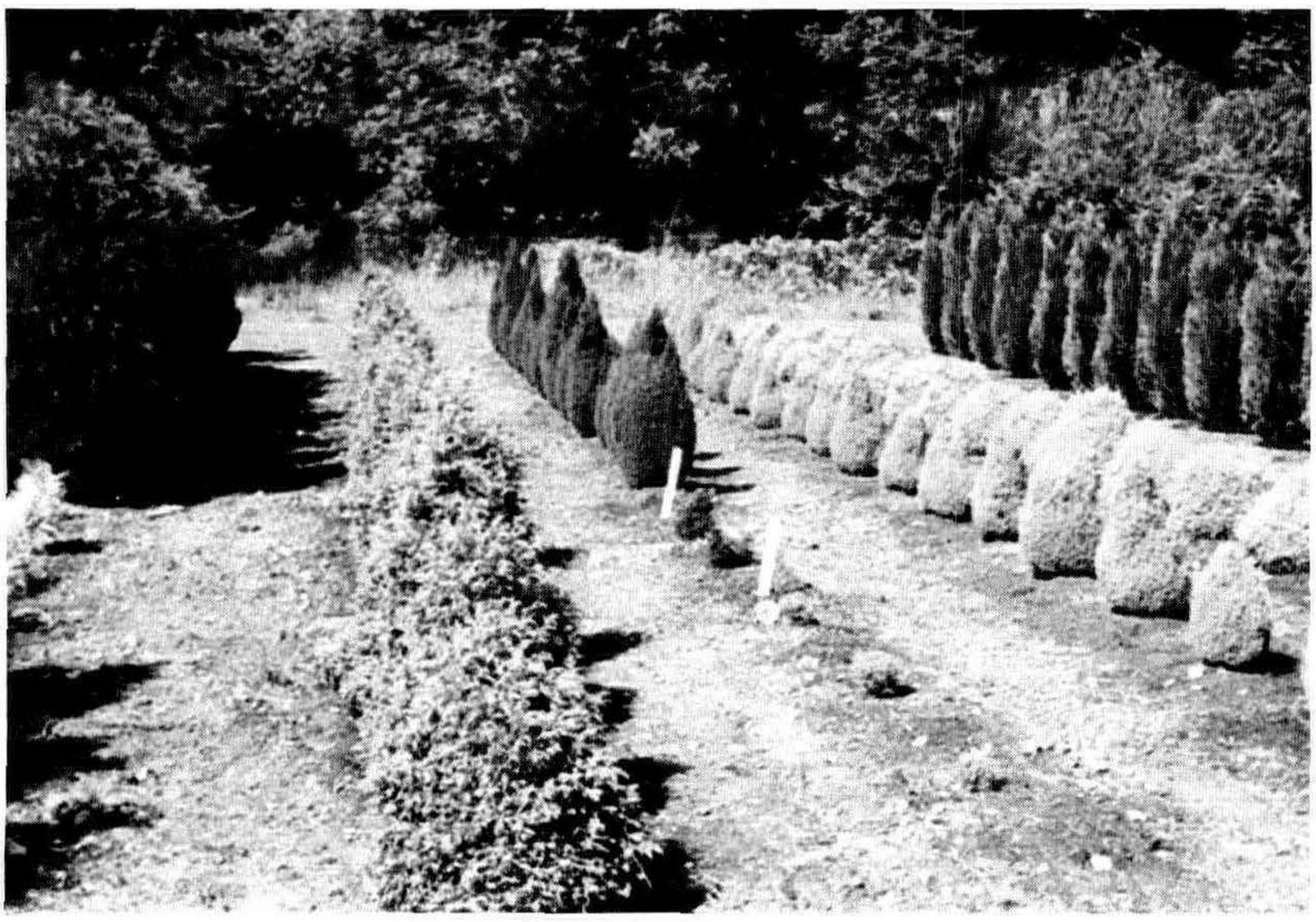

Figure 1. General view of clonal stock in conifer area at Efford Experimental Horticulture Station.

There was little irrigation facility on the stock site until 1978 when a new main was installed. Thus, after an initial "puddling-in" at planting, further irrigation was minimal. During 1975, and especially in 1976, plants suffered severe stress from prolonged periods of dry weather but, despite this, full establishment was achieved of those species already planted and growth in 1977 was excellent.

Weed Control. Weed control, particularly during plant es-

tablishment and early growth, is essential if reduced growth due to weed competition is to be avoided (4). A herbicide programme was preferred but it was decided not to use residuals for up to 3 years after planting to ensure that there was no possibility of their influencing growth or rooting of cuttings. While there have been previous reports at I.P.P.S. meetings that simazine was used on stock beds without adverse effects (1,2,3,5,6,7), there was evidence of some reduction in rooting as a result of simazine application with certain species, e.g. *Calluna* (7), some *Rhododendron* cultivars (1,5), *Juniperus*, and *Ilex* (5).

In the main damage was associated with taking softwood cuttings from treated container-grown plants but, in one instance, rooting of softwood cuttings taken from field-grown *Rhododendron* 'Daviesii' was affected following two successive annual applications of simazine + DCPA (1). Thus it was felt necessary to use simazine with caution and not until plants had become well established, especially as known simazine-sensitive species were included in the area.

Consequently only the contact herbicide, Paraquat was used in the pathways and the area around the plant was kept clean by hand. After 3 years a simazine/paraquat mix was used in the paths, though hand hoeing was continued around the plants. Weed control has been the largest labor input in the stock area and information on herbicide programmes which could safely be used is urgently required.

An alternative method of weed control is to plant through a black polythene mulch (4). This proved very successful when used for a hedge of × *Cupressocyparis leylandii* clones at Efford. In addition to controlling weeds the mulch also aids establishment by improving the moisture status around the root.

Cutting Production. Not all the data collected can be given but a representative sample of species with age and potential cutting production is given in Tables 2 and 3.

These cutting counts were of graded cuttings of the medium size range. The actual potential was looked at in 1979 by taking all available material and grading into large, medium and small, the relative sizes dependent on species.

Pruning. Pruning of stock plants is an important aspect of management in relation to:

a. Maintenance of juvenility to improve rooting.
b. Plant shaping.
c. Timing of flushes of cutting material.
d. Increasing cutting production.

Table 2. Number of cuttings available per plant per annum. Year 1: Plants container grown. Year 2: Planted out in stock field. Year 3: Start of taking cuttings.

Species	Year				
	3	4	5	6	7
Berberis stenophylla	30	140	300	NC	500+
Elaeagnus pungens 'Maculata'	5	30	45		
Rhododendron 'Pink Pearl'	3	8	25		
Ilex aquifolium ('Pyramidalis'; 'Argentea Regina', (Syn.: 'Silver Queen'), 'Handsworth New Silver')	15	35	60	NC	200-250
Viburnum × *bodnantense*	7	20	35		
Viburnum × *burkwoodii*	30	60	100	NC	250+
Chamaecyparis lawsoniana 'Stewartii'	15	60	200		

NC = Not counted.

Table 3. Potential cutting production from stock after 5 to 7 years.

Species and cultivar	Age of stock (from cuttings)	No. of cuttings/plant			Size Grades (cm)		
		Large	Medium	Small	Large	Medium	Small
Ilex aquifolium 'Argenta Regina' (Syn.: 'Silver Queen')	7	108	77	38	10	7-6	6
Chamaecyparis lawsoniana 'Ellwoodii'	6	150	500	200	10-12	7-10	5-7
C. lawsoniana 'Ellwood's Gold'	6	200	300	100	9-10	7-9	5-7
C. lawsoniana 'Allumii'	7	870	370	380	15*	15+	10-15
C. lawsoniana 'Fletcheri'	7	640	1160	200	15+	10-15	5-10
Chamaecyparis pisifera 'Boulevard'	7	300	450	250	7.5+	6-7	5-6
C. pisifera 'Sulphurea' (Syn.: 'Squarrosa Sulphurea')	5	150	400	200	7-9	6-7	5-6
Thuja occidentalis	7	180	600	200	20+	15-20	10-15

* 'Triangular' well-shaped cuttings
+'Narrow' lanceolate-shaped cuttings
} *C. lawsoniana* 'Allumii'

With some species, particularly conifers, the only pruning has been the taking of cuttings each year but with other species a limited amount of work has been started to compare effects of various pruning treatments.

Hydrangea hortensia, Senecio greyii. Stooling the plants back each year produced the best flush of cutting material. With *Senecio* unless the plants were cut back each year growth became predominantly floral.

Deutzia scabra. Three pruning treatments have been compared.

1. Hard prune (Plants stooled to two buds).
2. Medium prune (Half total length of shoots removed).
3. Light prune (Removal of cuttings each year).

The results in Table 4 show that the stooling treatment produced the wrong type of shoot growth for suitable cutting material, better treatments being the medium or light prune, though flowering increased markedly as pruning was reduced.

The following season these plants were either left untouched or sheared back to within 10 cm of new growth in June. While all plants flowered heavily in the second year following the original pruning treatments there was a marked fall-off in cutting production from plants which had only received the light pruning treatment due to the majority of growth being floral. Cutting production was improved by the mid-season prune in the second year.

As a result of these treatments the pruning now adopted for deutzia is the "medium" system of cutting back half the growth each year, early spring if summer cuttings are required, or in June/July if a later batch is needed.

Table 4. *Deutzia scabra:* Effects of pruning treatments on cutting production over two seasons.

	Number of cuttings produced per plant following pruning in April Pruning severity		
	Hard (Stooled)	Medium (½ cut back)	Light (cutting removal)
1st Season			
Good material	11	40	47
Too vigorous	40	25	16
2nd Season			
Light prune	50	30	15
Shearing in June	150	100	50

Berberis × *stenophylla*. With this species, type of pruning, whether hard, moderate or light, did not appear to affect the total number of cuttings available, but timing of production was influenced, as well as ease of taking cuttings in relation to plant size and shape. Hedging with a moderately hard prune in February-March gave a good flush of cuttings for July/August. A second prune in June, cutting back to within 10 cm of the new growth, moved the cutting flush to October/November and this double prune in one season increased total cutting production.

Viburnum × *burkwoodii*. A moderate pruning regime, cutting plants back by half in the spring has produced an even batch of cutting material for early summer. Where only a light prune was given (i.e. removal of cuttings the previous season), growth was more uneven and total number of cuttings reduced. A second prune in June, cutting growth back to within 10 cm of new growth, produced cuttings for September/October and, as well as increasing numbers (Table 5), also produced a cutting with shorter internodes than those of the first flush.

Pyracantha 'Orange Glow'. This has flowered and berried so profusely that cutting material has been reduced and effects of timing of pruning similar to that discussed for *Viburnum*

Table 5. *Viburnum* × *burkwoodii*: Effects of pruning on number of cuttings per plant.

	April prune	
June prune	Light (Cuttings removed)	Medium (½ cut back)
Untouched	100 - 125	150 - 200
Sheared back	150 - 200	200 - 300

were considered. With this particular cultivar the earlier April prune was found best since with the later prune the size of spurs from the extension growth were shorter and much later ripening.

SUMMARY

There has been considerable interest recently in planting specialized stock block areas and there can be no doubt as to the benefits to be gained from having one's own stock plants. A major advantage is to have complete control of growth and all plants within one area so that management, especially in the taking of cuttings, is under the control of the propagator. However, perhaps of greater importance is the flush of uniform material available. The evenness of growth of the stock at Efford was striking due, in the main, to it being clonal in source. There could well be an increase in clonal material in the future when the clonal selection being carried out at Long Ashton Research Station is released back to the trade.

There are a lot of factors involved in obtaining the maximum use out of stock plants and more work is required as to management. In the limited amount of work done on pruning it was obvious that different species are going to need different degrees of pruning to achieve the best results. There are also many techniques to consider for timing of cutting production including forcing, and whether cutting pre-treatment on the stock could improve rooting (i.e. etiolation). The need for more work with herbicides to reduce labor input without adversely affecting rooting has been referred to.

In conclusion, the final quality of plant produced is dependent on many factors but starts right back with the stock and type of cutting taken. Attention to detail and the setting up of the highest standards possible in the stock area will ensure a good start to the production cycle which will be reflected right through the life of the crop in terms of improved quality and uniformity of growth.

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PROPAGATION OF CAMELLIAS

PETER HOWARTH

Winster Select Nursery Stock,
Windermere, Cumbria

We have been attempting to propagate and produce about 5,000 finished camellias for garden centre sales each year. Initially we purchased stock plants from various nurseries on the Continent and in the U.K. Variability in this stock was obvious, therefore the selection of the best plants was made to form the basis of our "mother stock." This material was potted and grown on, some of which was planted outside on a hedgerow system, the remainder grown on in 10" containers in a shaded cold house. In the meantime good specimen plants were located in an area to which we have access and this season it is hoped that up to 5,000 Williamsii hybrids will be produced.

Regrettably in the 1978-1979 winter we lost many of these hybrids growing outdoors, the amazing thing being that many of the Japanese hybrids came through better than say, 'J.C. Williams' or 'Donation'.

Under Rokolene net tunnels a similar situation occurred when the newer Williamsii hybrids stood up to the severe weather whereas 'Donation', etc. died.

Propagation. Shoots are taken from the parent plants using secateurs and placed into polythene bags; these are then placed into a domestic refrigerator overnight or until preparation takes place. We have found that refrigerated cuttings seem to perform extremely well, and this is now a standard practice.

Due to the limited amount of cutting material available and the system we have set up, we always take leaf-bud cuttings in

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Due to the limited amount of cutting material available and the system we have set up, we always take leaf-bud cuttings in

October and November. It could be argued that multi-nodal stem cuttings make big plants quicker than leaf bud cuttings; we would not disagree with this, but the number of stock plants required would be large.

The leaf-bud cuttings have a single leaf and bud, the stem being about 1¼" to 1½" in length. Each cutting is wounded up to half its length. The prepared material is dipped into either a solution of captan or Benlate before dipping into Seradix No. 3. Excess powder is removed, leaving only a minute amount of Seradix on the wounded surfaces. This is very important in order to prevent decay.

A few years ago we used to stick these cuttings into Jiffy 7s, but later changed to 50 cuttings to the normal plastic seed tray. These are just pushed in with the bud almost on the surface and watered well. By this method we are getting a high percentage take. We intend to try the direct rooting cellular system in order to speed up the operation and to reduce root damage when potting on.

The compost used is 3 parts medium grade sphagnum peat with 1 part pink Shap granite chip (neutral pH) 3/16" grist. Rooting is completed in about 6 to 10 weeks according to the cultivar, using a modified Macpenny mist system with a bottom heat of 24°C (75°F) at 15 watts per square foot loading.

After weaning, the rooted cuttings are placed in a cold house and remain there for one year in the trays before potting on into 3½" pots. These, in turn, are grown on for up to one year in a cold structure, then finally potted into 6" pots.

Stopping normally takes place during these periods to stimulate side shoot growth. The compost used throughout consists of 3 parts medium grade sphagnum peat with 1 part pink Shap granite chips. Added to this is half rate Osmocote + frit, half rate ground magnesium limestone, and 4½ lbs of superphosphate, per cubic yard of mixture.

An occasional liquid feed of 26%N and 26% K_2O plus chelated trace elements is given, particularly early in the year.

Our greatest asset for the propagation and growing on of camellias is our natural water supply with a pH of 3.8.

In the early years we used 0.5% Cyclocel (CCC) at 2 fl. ozs per 6" container, but later it has been discontinued since we got yellowing and crinkling of the foliage with little improvement in budding.

Over the years we have grown Williamsii hybrids, e.g. 'J.C. Williams', 'Donation', 'Mary Christian', and 'Bow Bells' along with Japonica types, e.g. 'Adolphe Audusson', 'Chandleri Elegans', 'Lady Clare', 'Rose Emery' ('Fire Ball'), 'Sauterelli' and

'Comte du Gomes'.

These cultivars have proved very successful both at the propagation stage and during subsequent growing on.

In the last two years we introduced the newer Williamsii hybrids 'Anticipation', 'Debbie', 'E.G. Waterhouse', 'Elsie Jury', 'Grand Jury', 'Inspiration', and 'Sayonara', with the cultivar 'Tomorrow' in the *C. japonica* groups. We find that these cultivars are fairly hardy and strong growing. The good solid blooms and color are advantages in the garden centre. But initiation appeared to be better and easier to achieve than in the older cultivars.

It is hoped that we shall continue working on direct rooting into various types of modules and as stock becomes more plentiful, then stem cuttings will be used in order to cut one year in our production system.

HARDY PERENNIALS WORTH PROMOTING

CHRISTOPHER LLOYD

Great Dixter Nurseries,
Northiam, Sussex

Plants that do not readily fit into nursery production systems tend to be dropped. The result is more and more plants of ever fewer cultivars and a general impoverishment to horticulture. Some of the plants mentioned below seem to me to appeal strongly to the public when they are given the chance to see them in a flattering environment.

Rheum australe (*R. emodi*) strikes me as a handsomer rhubarb than the more widely grown *R. palmatum*, because its leaves are more deeply incised and the rich purple coloring on their undersurfaces is long retained. The pure white inflorescence, borne in May, shows up well against a dark background.

The liliaceous *Veratrum album* carries a striking, branched inflorescence whose whiteness shows up more tellingly in a general garden or landscape setting than the better known, dark maroon-flowered *V. nigrum*, which is in more general circulation. *V. album* has a long effective season from July onwards. It produces an abundance of seed, but about 4 years is required to raise flowering-sized plants.

Blechum chilense, sometimes known as *B. tabulare*, is a handsome, tough-leaved evergreen fern that makes excellent ground cover in an open situation. In a sunny site you get a contrast throughout the spring to autumn growing season be-

'Comte du Gomes'.

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tween the copper of young foliage and the dark green of that which has matured. The plant is calcifuge but otherwise of easy cultivation, propagated by division of its mat-forming rhizomes.

The dwarf bamboo, *Arundinaria viridistriata* (*A. auricoma*) grows only 2 ft tall if cut to the ground each April, which is the treatment that obtains the brightest, freshest coloring from its green and yellow striped foliage. This is a clump-forming, non-invasive bamboo, propagating by division when signs of renewed growth have become evident in the late spring.

Next to this, and at the front of a mixed border, I grow a violet from Western Australia that has proved remarkably hardy, *Viola hederacea*. It is deciduous, overwintering as a dense mat of surface rhizomes. The first burst of its upright mauve-and-white blossoms opens in June, a succession being maintained right into autumn. *V. cucculata*, from Labrador, is especially striking in its white form, which has purple pencil marks in the centre. It self-sows abundantly and makes such a striking feature in its April to May season as to sell on sight then. This is a large-flowered violet, deciduous and bone hardy.

Erigeron karvinskianus (Syn. *E. mucronatus*) is hardy only in the milder winter parts of Britain. It has naturalized in many parts of Europe, including the Channel Islands, but originates from Mexico. It is a 9 in-tall daisy with thread-like stems, flowering with unremitting abundance from May till late autumn. The pink and white effect created is owed to the young rays expanding white but changing to pink as they age. Plants self-sow and readily colonize the cracks in walls and paving. An excellent seller when the public can see what it is capable of.

Convolvulus mauritanicus, from Morocco is again hardy only in milder climates but a very beautiful trailing perennial for rock ledges or ornamental pots and tubs with a long succession of clear lavender funnels. Propagated from soft tip cuttings at any time during its growing season.

There is currently a great vogue for herbs, epitomizing a return to the simple, good life as we imagine it once to have been. If herbs can look beautiful rather than weedy, as is so often the case, they have the greater garden appeal and such is the golden marjoram, *Origanum vulgare* 'Aureum'. It does not look much when grown in a container but if there is a flourishing stock plant in the open ground near your selling area, it will do you proud. At its best the color is fresh lime green. In too hot and dry a position it may bake and scorch, as with the majority of yellow-leaved plants.

Crepis incana, in its vegetative state, looks like a grey-leaved dandelion and many visitors tell me, seeing it in that phase, that in their gardens it would quickly be weeded out. In

this they are no doubt correct. When they see it covered, in its July season, with clear pink blossom on a mounded foot-tall plant, they sing a different tune. Propagation, as for the dandelion, is from root cuttings but *C. incana* never makes itself a nuisance.

Epilobium glabellum belongs to a genus of take-over weeds and one is therefore surprised to find that this willow-herb is not entirely hardy. Cuttings of its vegetative, resting shoots should be taken in the autumn and overwintered under cold glass. On neat, 9 in-tall plants the 5 months-long succession of cream-white funnel flowers is borne from May onwards and has a wide appeal.

Yellow daisies are two a penny in the late summer garden scene, but *Grindelia chiloensis* (from the island of Chilo off Chile) has style and distinction and appears to be a good deal hardier than one expected, coming through the last hard winter without protection. It makes a loose, sub-shrubby mat in the manner of *Osteospermum barberae* (Syn.: *Dimorphotheca barberae*) and is increased from soft cuttings. The plant's habit is semi-sprawling, without need of support and the bold daisies are carried singly on long stems. While still in bud they are tacky, with the wetness of a healthy dog's nose.

By its side I have a sub-shrubby ballota that makes a change from the popular grey-leaved labiate, *Ballota pseudodictamnus*. This one, *B. acetabulosa*, is a little greener, more upright in its habit, its inflorescences of interrupted whorls carried in graceful spires, less than 2 ft tall.

Grey-leaved shrubs have a general susceptibility to damage by frost. Thus if gaps tend to appear in low hedging and edgings of santolina or lavender, an excellent and entirely dependable substitute may be found in the South African *Helichrysum splendidum* (which has also been listed as *H. trilieneatum* and its Syn.: *H. alveolatum* in its time). They are a feature of the formal parterre at Drummond Castle in central Scotland, a garden that is situated in a frost hollow. The bushes should be clipped over each spring. The small yellow flowers carried on the young shoot tips are of no significance.

Clematis montana var. *wilsonii*, introduced by Wilson from Central China around 1900, looks like any other white montana when in flower and it has the same vigor, easily climbing to 40 ft on house, castle or tree. But its season, if the right clone is secured, is a full month later than the type-plant and is at its peak in the second half of June — at least in Scotland. Its strong scent, carried on the air, is of hot chocolate.

Another plant I have seen more in Scotland than elsewhere is *Nepeta nervosa* and it is surprising to find that it received

the RHS Award of Merit as long ago as 1930. Unlike the popular catmint, this species has a neat upright habit, a foot tall with dense flower spikes very much on the blue side of mauve. It flowers at midsummer and makes a good edger. It is most easily propagated from seed, which will flower in the year of sowing.

The best stand I have seen of *Thalictrum chelidonii* was at Inverewe in northwest Scotland and the only nursery I know of offering it is Jack Drake's at Inshriach, Aviemore, Inverness-shire. It is not so tall growing as the well-known *T. dipterocarpum*, about 3 ft as against 6, the flowers a little larger, nodding and of an intense shade of mauve.

You also meet *Codonopsis* more in the north than down south and this little grown genus within Campanulaceae is exceptionally hardy. Nevertheless, with me, in Sussex, *Codonopsis convolvulacea* is easier to keep going and multiply when grown in large pots and it makes a fine autumn display feature when grown up brushwood in a 10 in pot. This is a climbing herbaceous perennial that starts growth late in spring. The campanula blue flowers are saucer-shaped, often mistaken by the public for a clematis. It can be increased by its freely produced tubers, or from seed which germinates quickly and flowers in its second year.

Its adaptability to wet places explains why *Senecio smithii* is seen far more in the north of Britain than elsewhere, though it will flourish in any boggy spot. In Orkney it has naturalized in many parts of the Mainland island and it is probable that it was first introduced there by one of the many shepherds who used to do a few years shepherding down in the Falkland Islands where this groundsel is native. It has lush, glossing undivided leaves and a large panicle of daisies with white rays and yellow discs.

The *hippeastrums, often misnamed amaryllis, come from* South America and are mostly tender, but *Hippeastrum pratense* is an easy-going bulbous plant as hardy in Scotland (where I first met it) as elsewhere and not requiring extra heat to make it flower freely. The trumpet-shaped, dazzling red blooms are clustered on foot-tall scapes and open late May or early June. The bulbs increase naturally by division but seed is also freely set and germinates quickly.

Native plants tend to be denigrated by gardeners in their own country, which perhaps explains why the hardy terrestial orchid, long known as *Orchis maculata*, now *Dactylorhiza fuchsii*, a plant distributed in its many sub-species throughout the U.K., is seldom met in cultivation. Get it into a border, however, and it soon builds into fat clumps and makes a showy June display with its mauve spikes above handsomely spotted

foliage. From southwest Europe we have the similar, but even more impressive and equally hardy *D. foliosa*, with rich reddish-purple flower spikes. These species flourish in moist shady conditions and the clumps increase fast enough for division of their tubers in the dormant season to be a reasonable method of propagation.

As plants for border margins, it is interesting to compare *Achillea taygetea* (which I want to push) and *A.* 'Moonshine'. The latter is six inches taller and stronger growing, its foliage more silvery, its corymbs the brighter shade of yellow. It is an easy and deservedly popular plant. *A. taygetea*, at 2 ft, is an even more convenient height and its coloring is a really soft, pale yellow of a shade all too rare in hardy perennials. Though less robust than 'Moonshine', it is still an easy plant, best propagated from soft cuttings in spring.

In a good strain, *Omphalodes cappadocica* makes a striking display of intense blue on 9 in-tall, ground-covering plants for many weeks each spring and is a compulsive self-seller at that season. It is a remarkably versatile plant, flourishing as well in the deep shade of evergreen rhododendrons as out in the open. Clumps can be split and potted in early autumn for sale the next spring, but seed offers another quick means of increase.

Bergenias as a group have been overexposed of recent years, and the fact that many have coarse and leathery foliage, obtrusive for the entire year, has for too long been ignored. The neatness of *Bergenia stracheyi* is a welcome relief. Its warm pink heads of blossom are borne in early spring at a mere 6 in above small stiff leaves that change to reddish purple in cold weather. The white-flowered form is equally attractive.

The attractiveness of the flowering hebes soon makes gardeners forget the losses they sustain in hard winters like 1979, and anyway precautionary cuttings are easily taken in autumn and overwintered in a safe place. *Hebe* 'Watson's Pink', which the RHS gave an Award of Merit when I showed it in 1977, makes a very pretty plant in a 5 in pot within less than a year of being struck. This is more than can be said of clones like 'Midsummer Beauty' and 'Hielan Lassie', which seldom flower in their first year at all. 'Watson's Pink' has numerous short, slender spikes of a clear pink shade, and associates well with grey-leaved plants like *Artemisia ludoviciana*. Its leaves are small and it is considerably hardier than large-leaved cultivars like 'Andersonii Variegata' or 'Simon Delaux'.

The aging joke that spotted aucubas look as though they had been sprayed with Paraquat, has grown very tired. Those who enjoy spotted variegations will agree that the ordinary spotted aucuba is not spotted enough. The splashes of yellow

are too small and indistinct for effect. Nobody should be content with this but should go for a really boldly marked clone like *Aucuba japonica* 'Crotonifolia'. It thrives in shade and any branches that come pure yellow here will be the safer from scorching, to which they are otherwise subject. This is a splendid evergreen shrub both in the garden and when cut for the house.

Another evergreen shrub of astonishing hardiness, considering its Tasmanian provenance, is *Helichrysum ledifolium* (Syn. *Ozothamnus ledifolius*). Nowhere that I have heard of did it suffer in Britain in the 1979 winter. It makes a dense dark green 3 ft. plant, relieved by the pale yellow-green of its shoot tips which show the undersides of their leaves. In May the expanding flower buds are a rich shade of burnt orange, similar in coloring and season to that of *Euphorbia griffithii*. This is their finest moment, before they expand into a white frost of tubular flowers. At all seasons the shrub wafts a strong aroma of stewed prunes. Cuttings are easily rooted, like lavender or rosemary in early autumn, but plants are a little slow to make up.

DISCUSSION GROUP REPORT
DAPHNE PROPAGATION

CHAIRMAN — A.R. CARTER

The difficulties of producing daphnes in commercial quantities attracted quite a number of people to this discussion session chaired by A.R. Carter.

It started with a recommendation of the book, *Daphne*, by C.D. Brickell and B. Mathew, published by the Alpine Garden Society.

SEED

A list of plants that provided a seasonably reliable seed set was given. Although experience was limited among group members, it was stated by one that his *Daphne giraldii* did not crop regularly.

D. acutiloba
D. giraldii
D. laureola
D. longilobata
D. mezereum
D. m. 'Alba'
D. oleoides
D. pontica
D. retusa
D. tangutica

In general, seed should be collected before the berries are fully colored. Birds can be troublesome and greenfinches will take the berries whilst still green.

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Arthur Carter described an experiment with seed of *Daphne mezereum* taken from berries at different stages of ripeness on 15 June 1974. The results expressed as numbers of seed germinated in spring 1975 showed that real differences occurred. The treatments were replicated and germination was expressed as percentages of a possible total of twenty-four.

Seed source	Percent germinated
Red fruits	17
Green fruits	42
Red fruit — seeds soaked in water — 1 hour	29
Red fruit — sees vigorously rubbed	79

When the seeds were extracted from berries, particularly red ones, the testa was coated with dark green, almost black film; a vigorous rubbing with a cloth removed this.

In another season, the effect of gibberellic acid (GA) was investigated on germination of seed of *D. mezereum*. The source of GA was 'Berelex' and seed from green and red fruits was sown untreated and the germination was compared with that from red fruits soaked for twenty-four hours in water, 100 ppm GA or 200 ppm GA.

Seed Source	Treatment	Percent Germination
Red fruits	Nil	23
Green fruits	Nil	30
Red fruits	100 ppm GA	69
Red fruits	200 ppm GA	69
Red fruits	water	69

The need for a grower to use the solvent of any chemical — in this case, water — is amply demonstrated as without it being included in this trial, it might have been assumed that gibberellic acid was doing some good.

It should also be pointed out that the seed for these trials was gathered from a single bush and there is no guarantee that all plants of this species will behave in a similar manner.

Seed of *D. giraldii* germinated readily the first spring after sowing fresh seed. Arthur Carter also reported on two lots of seed of *D. bholua* received indirectly from Sir Peter Smithers in Switzerland. In neither case did germination occur and yet in an earlier instance The Royal Horticultural Society had a batch in late May 1974 and germination occurred in six weeks. It is possible that seed loses viability quickly under unsuitable storage conditions.

It was suggested that seed should be cleaned and sown immediately or stratified, avoiding dry storage where possible.

Daphnes frequently contain virus and seed is less likely to transmit this problem than vegetative propagation.

CUTTINGS

Many daphnes can be propagated by cuttings and root promoting auxins are often used but in many cases are probably not essential.

There seems to have been comparatively little experimental work to guide us, but traditionally quite a range are propagated by soft or half-ripe cuttings.

Soft Cuttings

D. aurantiaca
D. bholua
D. blagayana
D. × burkwoodii
D. cneorum
D. collina
D. genkwa
D. giraldii
D. collina var. neopolitana (Syn.: *D. neopolitana*)
D. odora and forms
D. retusa
D. sericea
D. tangutica

Half-ripe Cuttings

D. acutiloba
D. arbuscula
D. blagayana
D. × burkwoodii
D. cneorum
C. collina
D. genkwa
D. petraea
D. retusa
D. sericea
D. tangutica

One member reported success by splitting the stems and using NAA instead of IBA.

Many species came readily from cuttings and an instance was quoted of a piece of *D. blagayana* being accidentally broken-off during winter and being successfully rooted merely by being pushed into the garden soil.

ROOT CUTTINGS

This is frequently quoted as being a possible method for *D. mezerum* and types and *D. genkwa*. Arthur Carter reported failure and emphasized the natural reluctance to disturb established plants to obtain suitable propagation material. Pot-grown plants were more convenient and generally pieces of root, 2 to 3 cm in length were inserted either vertically or horizontally in sandy compost in December. Not always is success achieved but if two or three shoots emerged from one shoot, it might be worthwhile removing one or two, to try to root the juvenile cuttings.

One member suggested trying inserting the root cuttings at an angle of 45°.

LEAF-BUD CUTTINGS

D. retusa and *D. tangutica* have been recorded as being successfully propagated by leaf-bud cuttings in July to September in a cold-frame. Rooting had occurred by spring but the plants were slower to grow to a saleable size.

GRAFTING

Some daphnes do not regularly produce seed or are difficult to root from cuttings. These are usually grafted and frequently better growth is produced than when the plants have their own root systems. *Daphne petraea* 'Grandiflora' tends to flower at a younger stage when grafted.

The main disadvantage is the increased risk of perpetuating virus when grafting compared with seed propagation.

Rootstocks.

D. mezereum	Widely used but not everyone is happy about its use as a rootstock for evergreen types. Some think they become semi-evergreen.
D. acutiloba	Thought by some not to be reliably hardy.
D. longilobata	Hardy
D. laureola	Evergreen
D. pontica	Evergreen
D. giraldii	Halda states this is better as a rootstock for *D. arbuscula* than *D. alpina*, *D. laureola* and *D. mezereum*.

Grafting method. Grafting seems to have been carried out at most times of the year but probably December to February is favored.

Commercially, stocks of two to three years of age, in good health are used. Scion length varies according to the species and availability but one to two-year old pieces 2.5 to 7 cm long are often used. Side and wedge grafts are employed, tied-in and plunged in a closed propagating case.

For the amateur, less sophisticated methods are successful and Arthur Carter described the simple system he adopts in his small, unheated greenhouse. April to May seemed a good time and for thin-wooded types such as *D. petraea* or *D. genkwa*. Young seedlings of *D. mezereum* one year old or less, were topped and slit down the middle of the hypocotyl. A wedge-shaped scion was then inserted, sealed with Blu-tac and then placed in a shaded plastic covered propagating tray. For anything older or sturdier, the grafted rootstock has its pot enclosed in a polythene bag and the scion is tied in. For vigorously growing subjects, Blu-tac does not hold the joint sufficiently and ugly callus develops.

Root grafts. Brief mention was made of root-grafting where pieces of root 5 to 7 cm long were wedge-grafted with the scion species and plunged in peat.

DISCUSSION GROUP REPORT
DIRECT ROOTING
CHAIRMAN — JOHN STANLEY

The Group discussed the various aspects of "Direct Rooting" but mainly concentrated on what we understood by the term and what types of materials are available.

It was agreed by all that direct rooting was aimed at reducing the movement of newly rooted plants.

Rooting Cells. The discussion followed on to talk about what "cells" or rooting units have been used in the industry in recent years, with comments from the group on their advantages and disadvantages.

The following is a list of the rooting units which are available and have been used commercially or in trials at colleges and experimental stations:

1. SYNTHETIC PREFORMED PROPAGATION BLOCKS.

a. **Foamed Polyurethane.** This type of block is based on flexible foam, which was first marketed in America. Types:

Baystraat. These blocks were produced by Bayer in pre-cut sheets.

Nutri-foam. Developed by Dow Chemicals. These blocks tend to suffer from surface water drainage and saturation at the base of the block due to the pore characteristics of the block. The cell membranes were also difficult to penetrate by the roots.

Rack Substraat. Developed in Germany, based on shredded polyurethane and peat. Experiments have shown this is difficult to wet and leaf wilt occurs rapidly.

b. **Cellulose Pulp Fibres.**

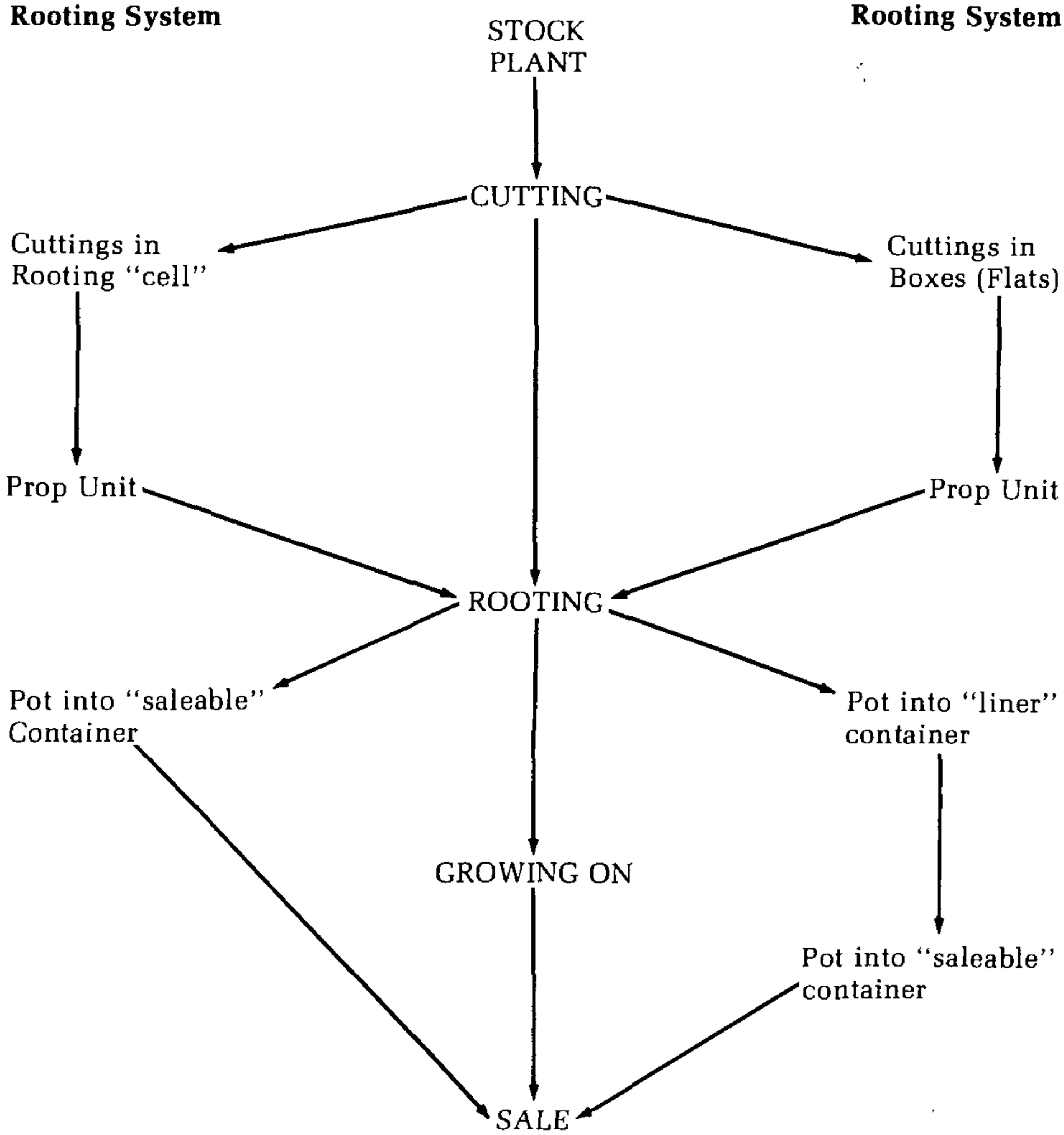
BR8. Developed by the American Can Company. It consists of cellulose pulp fibres held together by synthetic adhesives. These blocks became saturated very easily.

c. **Mineral Wool.** These blocks are manufactured from a fused mixture of sand, carbon and chalk.

Grodan Rockwool. Developed at Hornum Research Station, Denmark. This product consists of ⅓ coal, ⅓ calcium carbonate, and ⅓ basalt; the constituents are placed in a retort which is heated and the strands which are produced are made into blocks with the aid of a wetting agent. The blocks are chemically inactive and a nutrient mixture has to be added if one intends to "grow on"using the blocks. Blocks are produced in 5 cm and 10 cm cubes. Compared with other blocks tried

Direct Rooting System

Traditional Rooting System



Rockwool became easily saturated and growers felt it was only of value to pot plant producers.

Newall's Rockwool. This material is used commercially for thermal insulation of industrial plants. In trials the coarse grade SR4 and the finer grade, Therbloc, were tried. The material arrives in slabs and has to be cut into blocks on the nursery. This material does not seem to be as ridged as Grodan but again tends to become too saturated. The insertion of cuttings into this material is more difficult than insertion into Grodan.

d. **Phenolic Foam.** Urea-formaldehyde foams which, when crushed, are like cottonwool. The blocks release nutrients over a long period once the cutting has become established.

Bloom-Fix. These types are being developed by Silva-Development Ltd. with various pH's and water holding capacities.

e. **Micaceous Mineral Blocks.** These are blocks of minerals composed of silicate of aluminum and other silicates.

Vermipeat Blocks. These are circular vermiculite blocks 54 mm or 38 mm in diameter. The blocks are supplied in plastic coated trays, 90+ blocks to a tray. Before inserting the cuttings, the blocks have to be thoroughly watered. In trials at Merrist Wood we found sand had to be placed in the central hole to support the cuttings.

2. COMPRESSED PEAT BASED BLOCKS. At present these seem to be the more popular blocks being used by growers for tree and shrub propagation.

a. **Commercial Ready-Made Peat Blocks.**

Ky-Kubes. Produced by the Keyes Fibre Company in America, these are cubes tapered towards the top with a ready-made hole for cutting insertion.

Root-o-Blocks. Similar to the above but made in Ireland.

Jiffy Blocks.

b. **Commercial Blocking Composts.** In trials it was found that moss was produced on many of the peat blocks, however this did not seem to detract from the rooting of cuttings.

Fenmere Blocking Compost. Sedge peat.

Levington Blocking Compost. Sphagnum peat.

Caledonian Blocking Compost.

Finnpeat ST 400 Maxi. As with the previous three composts, this product is easy to block and cuttings seem healthy in the blocks.

Humber Blocking Compost. This compost is composed of

90% peat and 10% marl, the marl being used as a grit and binding agent.

Shamrock Blocking Compost.

Alexpeat Block Compost.

c. **Normal Peat Products.**

Irish Peat Moss. Although this is not produced as a blocking compost it blocks easily; whereas the above-mentioned composts contain nutrients, this peat has no added fertilizer. In the early stages of trials cuttings produced have been healthy and, as long as the rooted cuttings are potted up, make a suitable blocking compost.

Levington Blocking Compost. Results in trials have shown little difference between this product and Levington Compost.

3. MISCELLANEOUS CONTAINERS.

Japanese Paper Pots. Growers in the discussion group were most familiar with these pots and favored them for direct rooting. Although used on a wide range of plants some growers mentioned problems with coarse rooted subjects, e.g. pyracantha where roots go to the bottom of the tray and curl under the containers. This meant that at potting the plants were still disturbed.

Objectives. After a review of the materials we discussed the objectives of direct rooting, which were divided into three areas.

1) Many growers were direct rooting as a labor saving technique to produce either cheap ground cover plants by either using a rooting unit or placing the cuttings directly into the saleable container; or to produce plants which do not do well with root disturbance at the early potting stage; for example, *Garrya, Ceanothus, Magnolia,* and *Hamamellis.*

2) Secondly, some growers used direct rooting systems as they felt cuttings have a faster "take-off" and produced better quality plants.

3) Finally, one nurseryman used the technique to alter his timing of potting and sale of plant material. Using the same species, he would grow one batch by direct rooting and another batch by the traditional method. The result was that he could bring forward his selling date for direct-rooted subjects.

It was stressed that these objectives could change, depending on the demands of the industry. At present we are concerned with labor saving, but problems such as peat shortages could alter our priorities as growers in the future.

DISCUSSION GROUP REPORT
PROPAGATION OF HAMAMELIS AND RELATED PLANTS

CHAIRMAN — BRIAN HUMPHREY

The genera within Hamamelidaceae which can be grown in the British Isles were identified as *Hamamelis, Corylopsis, Disanthus, Fothergilla, Liquidambar, Parrotia* and *Sycopsis.* Other genera rarely grown commercially were noted as: *Loropetalum, Parrotiopsis* and *Sinowilsonia.*

SEED

Genera sometimes or normally propagated by seed are: *Liquidambar, Hamamelis, Corylopsis,* and *Fothergilla.*

Hamamelis and Fothergilla. Hamamelis are normally raised from seed to provide rootstocks for grafting. *H. mollis* is sometimes raised from seed but good practice would dictate that the plants are proved by growing to flowering size before sale. *Fothergilla* is occasionally grown from seed.

Source. Some individuals of *H. mollis* and *H.* × *intermedia* (e.g. 'Arnold Promise') regularly set good crops of seed in the U.K. and Ireland and the need for selection for this characteristic was noted. *H. virginiana* and *H. vernalis* are generally less reliable though with these species some individuals are more prolific than others. Seed obtained by purchase from suppliers was often of poor quality generally due to prolonged dry storage. This may lead to deep dormancy or death.

Collection, Extraction and Storage. Early collection (August) of *Hamamelis* seed while still green and extraction from the capsule manually using a knife was said to result in seed which did not show dormancy. The cost of this method of extraction was high.

Collection normally takes place in the September to November period. Once ripened, the capsules slowly dry on the plant. Eventually, the seed is expelled sometimes with considerable force. *Fothergilla* seed is capable of being thrown 15 ft. Collection is normally carried out while the capsules are closed. The seed is extracted by placing the fruits in a covered box and drying them using artificial heat.

Seed is not normally stored. If storage is necessary, refrigeration in sealed containers is recommended to retain viability.

Pre-treatment. After extraction, depleted moisture content can be replenished by soaking the seed for 24 hours.

"Natural" pre-treatment was frequently practiced by stratifying the seed in sand/peat or similar media for up to one year before sowing.,

Hamamelis, and possibly *Fothergilla*, seem to require a warm period of moist storage followed by a long cold period. This can be provided artificially by stratification in a greenhouse for up to 3 months but normally not more than 2 months. This is followed by 3 or more months of cold stratification at 5°C (41°F) in a refrigerator. This procedure delays sowing the seed until May or June. Fresh seed treated in this way germinates well (60 or 70%) but seed which has been dry stored at room temperature before such treatment still performs badly.

In the case of *Hamamelis*, there were no reports of successful chemical dormancy-breaking pre-treatments.

Liquidambar styraciflua. This species is most commonly raised from seed though selection has produced clones vegetatively propagated.

Source. Almost exclusively from imported seed which normally performs well.

Pre-treatment. It was generally agreed that germination was comparatively easy and that the warm period was less important than with *Hamamelis* and, possibly, not required at all. Four weeks warm storage was recommended by one member of the group. A period of 6 to 12 weeks of cold was suggested as necessary to break dormancy. Late arrivals of imported seed should be kept moist under refrigeration at 5°C (41°F) for some weeks before sowing.

Early results with trials using GA_{4-7} indicated that this may be a useful alternative to the cold treatment.

Seedlings of Hamamelidaceae are reasonably vigorous and can be sown in well-drained open beds given some shading until well established. *Liquidambar* seedlings continue in growth well into the autumn and severe damage can occur unless frost protection is provided at the end of the first season.

CUTTINGS

Hamamelidaceae fall into two main groups for the purpose of propagation by cuttings:

Deciduous.

Timing, preparation and treatment. Taking the cuttings early normally gave better results, though one observation indicated that cuttings of *Parrotia* taken as late as September rooted reasonably well (43%). Forcing of mother plants

to produce especially early cuttings was recommended by some members of the group. Cuttings from stock plants in the open were normally taken in June.

Normal current year's shoots including the base, possibly with a heel, were generally used but single leaf cuttings including a portion of stem and bud were suggested for *Hamamelis* by one member.

Hormone treatments were considered important for all Hamamelidaceae. Some noted that Benlate or captan had been recommended as additives to the growth substance. With *Hamamelis*, 0.8% IBA dust in talc was usual but mixtures of IBA + NAA + 2,4,5-T were thought by some to have advantages over IBA alone.

For *Parrotia*, one commercial firm had used IBA in the quick-dip formulation at between ¼% and ½% strength with excellent results (65% +). *Fothergilla* (*F. major* and *F. monticola*) *treated with 0.8% IBA dust gave 78% rooting. Disanthus* responds to similar IBA levels or ¼% to ½% IBA quick-dip, but results are generally less good, 40% to 60% rooting being usual.

Environment during rooting. Most agreed that mist provided a suitable environment, although thin gauge polythene had been used. One member reported a correlation between the rooting medium and rooting percentage of cuttings of *Hamamelis virginiana* as follows:

Rooting medium	Percent rooting
Moss peat	75
2 parts moss peat + 1 part sand	60
2 parts sand + 1 part moss peat	50

Similar results were obtained for *H. mollis*.

Trials have been carried out into the effects of extended photoperiod and CO_2 enrichment during and after rooting. Results to date are inconclusive.

Overwintering and survival. For the deciduous Hamamelidaceae this was recognized as the most significant problem in successful propagation from cuttings.

The ability to overwinter and survive varied among genera (*Disanthus* particularly difficult) and species within the genera. For example, in one trial *Hamamelis virginiana* gave 100% rooting but only 43% survival, whereas *H. vernalis* gave 80% rooting and 80% survival. It was noted that *Corylopsis pauciflora* generally survived less well than most of the other *Corylopsis* species though initial rooting percentages were quite high. A clone of *Liquidambar*

styraciflua, L. styraciflua 'Worplesdon' was noted as rooting and surviving well.

As with rooting, extended daylength and/or CO_2 enrichment had not, so far, produced a consistent improvement in survival.

There was general agreement that overwintering the cuttings in the boxes into which they had been rooted and potting-off the following spring after growth had commenced, was likely to produce a higher percentage of established surviving plants than the alternative of potting off just after rooting.

Rooting cuttings directly into small containers was suggested as a good method of enhancing survival though low rooting percentages make the system questionable on economic grounds.

Evergreen. These are comparatively easily rooted from ripened cuttings taken in the September-October period; 0.5% to 0.8% IBA dust in talc is normally applied and the cuttings are inserted under thin film polythene or mist, the latter preferably in a polythene-lined house.

Survival and overwintering normally present no special problems.

GRAFTING

This technique of propagation is the standard method for *Hamamelis* and *Liquidambar* species other than *L. styraciflua* and the cultivar *L. styraciflua* 'Worplesdon'.

Grafting in the U.K. and Ireland is always carried out under glass.

For *Hamamelis*, three possible systems may be used:

a) Grafting in winter/early spring using a whip graft.
b) Chip grafting (budding) in late spring of dormant (cold stored) buds collected in January.
c) Side veneer or chip graft (bud) in July/September.

It was also noted that a T-budding or rind (bark) grafting technique could be used if the rind (bark) would lift.

Of these methods, the chip graft (identical in method to chip budding except it is carried out in a closed case or polythene tent under glass) was said by one member to produce a better quality plant than the conventional graft using a normal scion.

Summer grafting was said by some members to cause some check to growth the following spring.

Rootstocks. For Hamamelis any species can be used as all

appear compatible with each other. *H. vernalis* was mentioned as being particularly tolerant of heavy alkaline soils.

Distylum racemosum had been suggested as a rootstock but had been shown to produce inferior plants with poor growth.

Quality of the rootstock was stressed, a young, straight, vigorous rootstock producing a stronger union and a higher percentage of "takes".

Liquidambar spp. and selected clones of *L. styraciflua* were grafted onto potted rootstocks (2 yr. seedlings) of *L. styraciflua*. Whip grafting in early spring under glass normally produced a high percentage of successful takes.

Parrotia persica 'Pendula' was grafted onto the type species which was normally produced from cuttings. This pendulous form could either be whip grafted onto a potted rootstock in the early spring or top-worked using a side graft onto a *Parrotia persica* stem "balled up" and brought under glass in the early Spring.

MICROPROPAGATION

It was noted that some work was in progress but so far no results were available.

CONCLUSION

It was felt that propagation of *Hamamelis* by cuttings may assume more importance in the future. Selection of easily-rooting clones for ornamental value and as rootstocks would increase the importance of cuttings as a standard method of production of *Hamamelis*.

DISCUSSION GROUP REPORT
PROPAGATION OF PICEA

DISCUSSION GROUP CHAIRMAN — BRUCE MacDONALD

The genus *Picea* has considerable economic importance, for example, within forestry, where *P. abies* and *P. sitchensis* are grown. *Picea sitchensis* is also used for wind protection of nursery stock in exposed sites. It may be interplanted with *Alnus incana* in order to give initial protection — the latter being removed when the *P. sitchensis* has grown enough to form a "permeable barrier". *Picea* gives some excellent specimen trees, with the species *P. breweriana* and the cultivar, *P. orientalis* 'Aurea'. There are also the slow growing forms which can be included in the design of rockeries and heather beds, for exam-

appear compatible with each other. *H. vernalis* was mentioned as being particularly tolerant of heavy alkaline soils.

Distylum racemosum had been suggested as a rootstock but had been shown to produce inferior plants with poor growth.

Quality of the rootstock was stressed, a young, straight, vigorous rootstock producing a stronger union and a higher percentage of "takes".

Liquidambar spp. and selected clones of *L. styraciflua* were grafted onto potted rootstocks (2 yr. seedlings) of *L. styraciflua*. Whip grafting in early spring under glass normally produced a high percentage of successful takes.

Parrotia persica 'Pendula' was grafted onto the type species which was normally produced from cuttings. This pendulous form could either be whip grafted onto a potted rootstock in the early spring or top-worked using a side graft onto a *Parrotia persica* stem "balled up" and brought under glass in the early Spring.

MICROPROPAGATION

It was noted that some work was in progress but so far no results were available.

CONCLUSION

It was felt that propagation of *Hamamelis* by cuttings may assume more importance in the future. Selection of easily-rooting clones for ornamental value and as rootstocks would increase the importance of cuttings as a standard method of production of *Hamamelis*.

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ple, *P. glauca* 'Conica' and *P. mariana* 'Nana'. Thus *Picea* gives both the nurseryman and private gardener an extreme in habit, form and color — for example the weeping *P. abies* 'Inversa' and the intense glaucous-blue of *P. pungens* 'Hoopsii'.

PROPAGATION BY SEED

The topic first discussed by the group was the importance related to the provenance of seed. It was stated that in Denmark, the Forestry Commission assist the nurseryman by initially procuring seed from a provenance best suited to their country. For example, the seed of *P. omorika* is obtained from Rumania and Finland. It is known that the provenance of *P. omorika* can affect the shape and depth of tree, together with its susceptibility of frost. Similarly with *P. pungens* 'Glauca', where it is important that the provenance gives one as high percentage as possible of the glaucous-blue colored seedlings. The question was raised whether the provenance of *P. abies* had an effect on the percentage success when bench grafting. An answer to this was not possible.

When one is collecting one's own seed, then cones are best removed just before they are ripe. The cones are then placed in a glasshouse after which they will break open to release the seed when shaken. Seed may be stored for up to three years in a sealed container within a refrigerator at 1° to 3°C (34° to 37°F). Sawdust is sometimes used to reduce the shrivelling of seed by placing it into the container with the seed, which is then shakened and stored.

Some species require a pre-sowing treatment of up to six weeks cold-moist stratification to overcome dormancy — for example *P. abies* where a three week period is given. If no cold-moist stratification is given, then all seed prior to sowing may be soaked in water for up to 24 hours in order that it is imbibed to ensure more even germination.

A sowing rate of between 400 and 500 seeds per square metre was given as an optimum sowing rate for *Picea abies*.

The discussion was then orientated towards the aftercare of seed and progeny, after the seed had been covered by a lime-free 3 to 5 mm graded grit. The major points highlighted were as follows:

1) Benefits gained from partial soil sterilization.
2) The susceptibility of new growth to late spring frost. In areas where this occurred, delay of sowing date was advised.
3) Losses incurred by damping-off diseases. A cover of the seed with grit would assist, but fungicidal seed dressings should also be considered.

4) Roguing of the seed bed where one is selecting for color.
5) The importance for controlling red spider mite, green spruce aphid and adelgids.

Finally the raising of seedlings within glass or polythene structures was discussed using either seed trays or paper-pots into which the seed is sown. The uses for this technique were considered to be fourfold: Firstly, to raise forest tree seedlings for subsequent planting for timber, for example *P. sitchensis;* production of a liner within a peat pot for lining out or containerizing; thirdly for the germination of expensive seed, for example *P. breweriana* and; fourthly, to produce a rootstock suitable for bench grafting in two years instead of the traditional three year period, for example, *P. abies*.

BENCH GRAFTING

Propagation by bench grafting provoked a detailed discussion where it was noted that a range of different techniques produced successful results. The discussion was led along the following topics in relation to the grafting of *P. pungens* cultivars — for example, *P. p.* 'Koster', *P. p.* 'Montgomery', *P. p.* 'Compacta' and *P. p.* 'Hoopsii'.

Time of Year. Two periods during the year were used for bench grafting: namely August - September, and January - February. The advantages gained from grafting during August - September were considered to be threefold: Firstly, there was less risk of losses resulting from "flooding of the union" as one was grafting in a period towards the latter part of the growing season, where excessive sap rise would be much less likely to occur.

Secondly, improved scion growth the following year as the vascular tissue would likely to be more united between stock and scion prior to shoot growth, compared with January-February grafting. Thirdly, it relieved pressure on the traditional winter grafting period of January-February for woody plants.

Rootstocks. A three-year pot-grown *P. abies* seedling of "pencil thickness' was the rootstock most used. This could be achieved by growing for two years in an outside seed bed, then potting up into a 7.5 to 10.0 cm. diam. pot for the third year. The system mentioned earlier under "propagation by seed" over a two year period could be considered as an alternative.

Alternative rootstocks mentioned were *P. pungens* and *P. sitchensis*. Another variation mentioned was to lift a three to four year seedling from the field with a ball of soil which, in turn, was root-wrapped with a hessian square. There was one

warning expressed with this method in relation to the final percentage of successful grafts. This was losses due to excessive drying out of the root ball while in the grafting case. An illustration was related where a low percentage was achieved when, on subsequently cutting longitudinally through the rootball, root development had only developed up to 8 cm due to a shallow 'pan' in the soil profile, so when the grafts were watered in the closed case, little benefit was achieved.

Scions. Correct selection of scion material was necessary when grafting *P. pungens* cultivars. The aim should be to select a scion 10 to 15 cm long of terminal or axillary shoots with a well developed terminal bud, and not less than three axillary buds. For the specialist producer, long term planning was necessary for a source of scion wood, using the principles and benefits gained from "hardwood cutting hedges". Three to four year grafted plants lined out in rows in the field and, as from the second year after planting, cut back annually to a framework in order to produce a large number of suitable juvenile shoots for scion wood.

Procedures for Grafting. The basic essential discussed was the importance of having the rootstock dried off before grafting. The stocks should be placed in an optimum temperature of 10°C (50°F) for two to three weeks and, if necessary, the root ball removed for three days and then replaced into the pot to quicken the drying off process.

Excessively high temperatures and humid conditions can cause the rootstock buds to break which, in turn, can lead to subsequent problems related to excessive sap rise. Other details given can be summarized as follows:

1) The base of the rootstocks should be thoroughly 'cleaned-up' with a knife and coarse rag. Some of the rootstocks may require reducing in length so as to facilitate tying-in.

2) Avoid collecting at any one time more than sufficient scion wood to last more than one day.

3) The basal needles of the scion should be removed from where the cuts are to be made.

4) A cloth soaked in white spirit should be at hand to remove resin from the blade of the knife.

5) Length of cuts should be around 4.0 cm in length ensuring they are not made too deep.

6) Four different side grafts are as follows:

a) *Side veneer graft.* This graft probably is the most widely used.

b) *Side veneer graft with an extended lip (1.5 cm).* It was

claimed this helped to avoid the base of the scion from being bruised after tying-in.

c) *Modified side veneer graft.* A flap on the rootstock is made to equal the length of exposed wood. The scion is prepared on both sides so as to form a thin wedge. It was felt that unless the grafts were waxed there was a greater chance of desiccation of the scion.

d) *Oblique side graft.* Here a flap is made into which a scion, cut as for an inlay graft, is tucked inside the flap of rind. This was claimed to be a useful technique when the scion was considerably smaller in diameter than the rootstock.

7) Tie firmly with a rubber strip to give an even tension over the graft; as the strip gives, a gap of the scion, the very base of the graft is left exposed.

8) The importance of correct aftercare was emphasized. For January-February grafting, the grafts can be placed in a grafting case so the base of the pot is standing in moist peat. The grafts are covered by shaded glass or milky polythene.

The grafts are kept very much on the dry side with very limited application of water until after around three weeks when callusing between scion and stock has commenced. The grafts could then be gradually ventilated until, after around six weeks, the glass or polythene could be replaced by a woven *plastic material.*

For August-September grafting, again a grafting case could be used or, alternatively, they could be callused in a cold frame. For the latter, the grafts should be waxed over the union.

Snagging back of the rootstock was normally carried out up to three times for August-September grafting, and twice for January-February grafting. To give greater strength to the union the final snagging back may be carried out so that a 0.5 cm "church window" of exposed scion is obtained, to encourage further callusing between scion and rootstock.

PROPAGATION BY CUTTINGS

Owing to a limitation of time this technique was only briefly discussed. This technique was liked mainly for the slow-growing forms. *Picea glauca* 'Conica' was raised from softwood cuttings in two ways. The first was to bring containerized stock plants into the glasshouse in February. These were placed at a temperature of around 10°C (50°F) to promote early breaking of the dormant buds in order to provide suitable cutting material in late April-early May. Secondly, was to take cutting material in June from outdoor stock plants. However greater success was claimed to occur when semi-hardwood cut-

tings were taken in July and placed within a shaded cold frame. A proprietary rooting hormone applied as a talc at 0.8% IBA was recommended. These cuttings were then left in the cold frame until the following March when they were potted off.

Success achieved with dwarf *Picea* after mid-August seemed to drop when rooted under mist. Due to the tendency of *Picea* cuttings to "damp-off", a fungicidal liquid dip was recommended before the cuttings were placed within the rooting compost. Some success was claimed from rooting *Picea pungens* cvs. in a compost with a high ratio of sand; however the problem is in establishment after potting off and subsequent successful over-wintering.

DISCUSSION GROUP REPORT
OBTAINING AND TREATING SEEDS OF HARDY WOODY PLANTS

CHAIRMAN — P.D.A. McMILLAN BROWSE

Discussion on this subject proved to be somewhat limited as the majority of the group had attended in order to seek information rather than be able to offer experience.

Obtaining Seeds. A list was circulated of commercial seed houses and comments made on the extent of their lists and reliability of supply.

Some discussion took place on the merits of collecting one's own seed where it was possible. It was emphasized that this was not necessarily a cheap alternative as labor requirements were extensive if seed was to be brought to the state of being a clean, well presented sample. It did, however, permit the collector to positively identify his material, to be able to select parent trees for superior, typical, or desirable characteristics and collect at any particular time that was deemed to be advantageous. It was also emphasized that seed bearing, unusual, ornamental woody plants were, more often than not, present in most localities and it was merely a matter of locating such specimens.

Treating Seeds. A brief discussion was held on the two major seed treatments — stratification and acid scarification. It was emphasized that, provided standard techniques were developed and adhered to, there was probably much less variation about a norm in terms of treatment time, than would be expected by reference to revelant literature. It is important to standardize seed condition, treatment technique, real starting point and practical end point.

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COMMERCIAL SOURCES OF TREE AND SHRUB SEEDS

EUROPEAN SEED-HOUSES

1. Principal Seed Officer,
   Seed Branch,
   Forestry Commission,
   Alice Holt Lodge,
   Wrecclesham,
   Farnham,
   Surrey. — G
2. Tree Seeds of Bamber Bridge Ltd.,
   Lower Seed Lee Farm,
   Brindle Road,
   Bamber Bridge,
   Preston,
   Lanc. PR5 6AP — E
3. Mosbacher Gehölz-und Waldsamen,
   Gammelsbach,
   Postfach 1123
   D-6124 Bearfelden,
   West Germany. — E
4. Renz Nachf. GmbH & Co. K.G.
   727 Nagold — Emmingen,
   West Germany. — G
5. Paul Raeyamaekers,
   Turnhoutsebaan 143,
   Mol B-2400,
   Belgium. — E
6. Establissements Versepuy,
   Le Puy — 43000,
   Haute Loire,
   France. — E
7. Vilmorin-Andrieux,
   Service Graine d'Arbres,
   La Menitré,
   49250 Beaufort-en-Vallée,
   Maine et Loire,
   France. — E
8. Søren Levinsen,
   Kollerød Bygade 25,
   3450 - Allerød,
   Denmark. — G
9. A.J. Frost,
   7080 Börkop,
   Denmark. — E
10. H. Den Ouden & Zoon B.V.,
    The Old Farm Nurseries,
    Boskoop,
    Holland. — G
11. B.V. 'Boomwekerij Udenhout',
    Schoorstraat 21,
    Postbus 31,
    Udenhout,
    Holland. — Oaks, Beech, etc.
12. Barilli and Biagi,
    1-40. 100 Bologna,
    Casella Postale 1645-AD,
    Italy. — G
13. Florsilva Ansaloni,
    1-40. 100 Bologna,
    Casella Postale 2100-EL,
    Italy. — G

NORTH AMERICAN SOURCES

14. F.W. Schumacher & Co.,
    Sandwich,
    Mass. 02563
    U.S.A. — E
15. Silvaseed Company,
    P.O. Box 118,
    Roy,
    Washington 98580,
    U.S.A. — Conifers
16. Vans Pines Inc.,
    West Olive,
    Michigan, 49460,
    U.S.A. — Conifers
17. V.B.M. Seeds,
    4607 Wendover Blvd.,
    Alexandria,
    Lousiana 71301,
    U.S.A. — G
18. Laywers Nurseries,
    Plains,
    Montana 59859,
    U.S.A. — E
19. Northplan Seed Producers,
    P.O. Box 9107,
    Moscow,
    Idaho, 83843,
    U.S.A. — Natives
20. Rob Lovelace Seeds,
    Brown Mill Road,
    Elsberry,
    Mo. 63343.
    U.S.A. — Collector
21. Mortensen Landscaping,
    2407 W. Olympic,
    Spokane,
    Washington 99208,
    U.S.A. — *Acers+*
22. Dauber's Nurseries,
    P.O. Box 1746,
    York,
    Pa. 17405,
    U.S.D.A. — Davidia

AUSTRALIAN SEED-HOUSES

23. Nindethana Seed Service,
    Narrikup,
    Western Australia 6326,
    Australia — Natives
24. H.G. Kershaw,
    P.O. Box 88,
    Mona Vale,
    N.S.W. 2103,
    Australia — Natives
25. Flamingo Enterprises,
    P.O. Box 1037,
    East Nowra,
    N.S.W. 2540,
    Australia — Natives

INDIAN SUPPLIERS

26. Chandra,
    Upper Cart Road,
    P.O. Kalimpong 734301,
    India. — Local

27. P. Kohli & Son,
    Park Road,
    Srinagar,
    Kashmir,
    India. — Local

E = Extensive Range
G = General List

DWARF ERICACEOUS PLANTS — A SELECTION WITH SALES POTENTIAL

IVOR STANGER

Nursery Manager, Bournemouth Parks

With my previous experience with ericaceous plants, plus five years in a general retail nursery prior to joining Bournemouth Parks, it might be interesting to evaluate the situation as an outsider to the trade.

During the five years of managership from 1972 to 1977 I became aware, as many others of you must have done, that to build up a new retail nursery with a very wide range of plants specializing in unusual and rare subjects, whilst in a very tight inflationary spiral, was a difficult task.

Now it seems we are off on another round of inflation which will again mean difficulty in budgeting and forecasting with any accuracy.

With this in mind, I think that nurseries, whether wholesale or retail, will have to examine profit margins more closely than before. What has occurred to me is to compare certain plants and their profitability with their relative ease of growing and their popularity with plants in similar groups.

Take, for example, *Rhododendron* 'Princess Anne' (*R. hanceanum* var *nanum* × *R. keiskii*). This plant was raised by Mr. W. Reuthe at Ightham, as a part of a dozen seedlings. We selected this clone, although all twelve seedlings were very good free-flowering plants, each having a fair representation of both parents. This plant was shown at the A.G.S. spring shows three years running and was well received by the public and quickly became in great demand. This is a plant which may be considered as a nurseryman's true friend because it roots very easily from semi-ripe to almost ripe wood cuttings, taken from mid-July through to January. The earlier the cuttings are taken,

INDIAN SUPPLIERS

26. Chandra,
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    P.O. Kalimpong 734301,
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E = Extensive Range
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of course, the better and quicker the rooting. With the use of either polythene or cold glass, a saleable plant 12″ × 9″ can easily be produced in 2½ years. At this age, if exposed to good light the summer before, one can expect 70 to 100% flower bud production, which we all know helps to sell any rhododendron.

Going back two or three years, a plant such as this would have retailed at around £3.50 to £4.00,

a) because it is a new introduction and
b) because it is yellow, compact and very hardy.

If one compares other plants grown on similar production lines, e.g. *R.* 'Blue Tit', *R.* 'Blue Diamond', *R.* 'Remo' and *R.* 'Scarlet Wonder', which at that time retailed for £2.25 to £2.50, it makes economic sense to grow the maximum number of the higher priced cultivar. To this end I never had the luxury of excess stock of *R.* 'Princess Anne' and, in fact, had to refuse several sales in order to build up a good supply of stock and show plants.

Showing plants at local and national level can often be promotionally useful, but many wholesalers and retailers, for one reason or another, completely ignore this side of the business. I feel, however, that it is most important to have one's key moneyspinners prominently displayed in the selling area and/or planted as stock or show plants wherever they have the greatest impact. Another important ploy used in a few nurseries is forcing and retarding plants of these "hot lines" in order to extend the flowering and, therefore, selling season; e.g., *R.* 'Princess Anne' flowers during the last week of April/first week in May and lasts at its best for approximately 3 weeks. It is quite simple to force the plant in gentle heat to flower 2 to 3 weeks earlier and to "hold" a batch in cool, shady conditions for one or two weeks after normal flowering. This effectively gives an extended season from the normal 3 weeks to 6 or even 8 weeks, therefore exposing the plant's sales potential to a wider range of customers.

Having used *R.* 'Princess Anne' as an example of how one type of plant can have an economic advantage over others, I would now like to briefly mention a few more.

R. indicum 'Balsaminaeflorum' (Syn.: *Azalea* 'Rosaeflora'). This plant again has tremendous sales potential, being fully double (not hose-in-hose like most so-called double azaleas). It is again easily propagated by cuttings as with other evergreen azaleas, and although it is more tender than the typical *R. obtusum* × *R. kaempferi* hybrids, under cold glass or polythene during its final pre-sales year, it is still very easy to grow.

It is a very compact and fairly slow growing cultivar, suited

to a slightly sheltered rockery or alpine garden and flowers from mid to the end of May. Because it is that bit different and somewhat exotic in appearance a 20% increase in the retail price can be justified to discerning customers.

R. 'Nakahari'. This is also a suitable alpine type azalea, in that it grows laterally and almost creeps across rocks and soil. It requires virtually identical treatment to *R.* 'Princess Anne' and *R. indicum* 'Balsaminaeflorum'. This plant is good from the economic standpoint, in that it does not flower until mid-June, even into July in some years, thus giving an extension to the rhododendron/azalea flowering period at a time when plant sales generally are declining from their May/early June peak. There is an orange form and red form. Again its novelty value and scarceness can justify up to 20% price increase over typical evergreen azaleas of the same age.

R. yakusimanum – Exbury form. Even with the introduction of many excellent hybrids of this superb species, I feel that from my own experience in the retail field, this plant has not yet been fully potentialized. Even ten years ago this plant was retailing at 4 gns. and I would think that a 3 year old plant will now sell at between £6 and £8.

During my time at Reuthes we had some difficulty in rooting this plant effectively from cuttings and obtaining a good growth response. Layering took 3½ to 4 years for complete establishment. Subsequent growth and flower potential never seemed to match plants grafted onto its near relative, *R. ponticum*. I must admit to having lost touch with results from "quick-dip" high hormone concentration techniques, although two close friends of mine, whom I consider very competent propagators, still insist on grafting onto *R. ponticum*. They both maintain that at the current market price and demand, propagation by saddle grafting is a very favorable economic proposition, as the rate of growth, percentage take, and early bud development yield a saleable plant within 2½ years.

This may also be the place to mention that in this field of the more interesting and much sought after type of plants, such as *R. yakusimanum*, *R.* 'Princess Anne', etc., the demand for the "instant specimen" was, and probably is, on the increase. I feel that growers of vision may well consider planting out batches in multiples of 100 plants or more to grow on for 5 to 10 years. In the field of dwarf rhododendrons their "ground rent" potential is very low, but their realization value, as I found, is extremely high. I remember the stock plants at Reuthes being sought after by various collectors at ridiculous prices, but the stock and show value of the plants alone, apart from their sentimental value, prohibited us from parting with them. Over 12

years ago I was offered in excess of £100 for a single plant on numerous occasions, so I know that semi-mature specimens are really worth considering.

Other ericaceous plants worth considering as relatively easy subjects to grow, with a public appeal and high income for low costs are:

Gautheria procumbens 'Macrocarpa'. This plant has a pronounced "petaloid calyx" and has been exploited well on the continent. It is very compact and free flowering, and produces berries well. It can be rooted from cuttings but one of the easiest methods of growing this subject is to plant it out into stock frames in equal parts peat, sharp sand and pine needles, 10 in apart. If left for 2 to 3 years, the plants will sucker and form a complete mat which can be lifted during the late winter or early spring and carefully divided into small plants, containerized and grown on in gentle heat at first, followed by a netting house or frame for the summer, to flower and berry that autumn for selling. I have found that when potting-on any of these subjects at the young bare root stage, very little or no fertilizer is required in the compost until establishment of the root ball. This has become more noticeable since the introduction of long term, slow release nitrogenous fertilizers which have been proved to release excessive amounts of nitrogen and ammonia during very sunny spells in early spring. This does seem to be more of a problem with ericaceous plants, particularly as the nitrogen is more readily released in high organic potting composts.

Once the root ball has become established, light liquid feeds may be inaugurated and some nitrogenous fertilizers introduced in small quantities in the subsequent potting-on. It has also been my experience that the first potting-on of these rooted cuttings should be into a smaller rather than larger size pot to improve the establishment of a good root ball.

× *Gaulnettya wisleyensis*. This bi-generic hybrid really does flower and berry in profusion and the berries remain on the plant for a long period of time. It roots easily from semi-ripe cuttings from August to November and grows quickly in cool, slightly shady houses and can be hardened off or grown in polythene tunnels during its second and third years. This plant, along with the new and better berried, hybrid pernettyas, is a notable moneyspinner. They are all being sold in greater numbers, particularly when large quantities of berries are present.

Andromeda polifolia. There are two or three worthwhile forms of this charming plant. The typical plant is a soft sugary pink, whilst the rarest form is *Andromeda polifolia* 'Compacta Alba'. A new hybrid, *Andromeda* × *nikko* is soft pink and of

very compact habit. All are very easy to root, grow and flower, and command a good retail price at 2 to 3 years.

Vaccinium glaucalbum. This superb foliage ground cover thrives on the poorest sandy soils and can be propagated either by stem cuttings or plunged in pots allowing suckers to root which are then removed and potted on. This plant is harmed by nitrogen fertilizers and scorches easily.

Other ericaceous subjects worth considering are:

Arctostaphylos uva-ursi, Gaultheria miqueliana, G. cuneata, Cassiope 'Muirhead', *Leucothoe fontanesiana* 'Rainbow', *L. rollisonii. Zenobia pulverulenta* (Syn.: *Z. speciosa*), *Vaccinium vitis-idaea* 'Nana' (*V. vitis-idaea* var *minus*? Bot. Ed.), *Phyllodoce aleutica*, and *R. camtschaticum* (which can easily be grown from seed).

Although not an ericaceous subject, *Cornus canadensis* provides a superb ground cover foil for all rhododendrons and associated plants and if planted amongst the stock beds and/or show areas, will prove itself to be another moneyspinner. It can be propagated by forced softwood cuttings or, as in the case of *Gaultheria procumbens*, be planted out to stock frames and allowed to go rampant prior to division and potting.

GROWTH REGULATORS AND DWARF PLANTS

DENIS McCARTHY

Institut für Obstbau und Baumschule
University of Hannover,
Hannover, West Germany

In the 1950s there were great hopes of an agricultural revolution through the use of hormones in plant production. Gibberellic acid (GA_3) was of particular interest because of many physiological and morphological changes it could cause in the plant. For example, it could increase shoot growth, initiate flower production, break winter dormancy, increase the rate of seed germination and promote cell division. But now, 30 years later, gibberellic acid is being used only in a few cases such as in the production of parthenocarpic fruits in pears and increasing fruit size in grapes. Not all possibilities of its use has been investigated, however. It is known that GA treatment of herbaceous plants such as dwarf peas, tomatoes and maize causes plants to take on the growth pattern of the "normal" plant. With this in mind, it is hoped to cut the production time of woody dwarf plants by applying GA. This should lead to a temporary suppression of the factors that cause dwarfness and

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should result in quicker growth. The cultivation time in the nursery can take up to 10 years, which means that they have to be sold at a price which may turn away potential buyers. This article summarizes the progress of the work which is being carried on in this field in the Institut für Obstbau und Baumschule at Hannover University.

MATERIALS AND METHODS

In 1978 uniform plants of the following species: *Viburnum opulus* 'Nanum', *Salix purpurea* 'Nana', *Lonicera* × *xylosteoides* 'Clavey's Dwarf', *Berberis thunbergii* 'Atropurpurea Nana', *Tsuga canadensis* 'Nana' and *Picea abies* 'Nidiformis' were treated with different concentrations of GA_3. Experimental design was a randomized block trial with four blocks and five plants per plot. Treatment commenced with bud burst and the concentration ranged between 100 and 1000 pm. GA_3 was applied either weekly or biweekly until the end of July. Treatment of *Salix* and *Berberis* had to be discontinued at an earlier stage because the plants were too sensitive even at the lowest concentration.

RESULTS AND DISCUSSION

Every one of the plant species studied reacted to GA. In comparison to the control, *Picea* showed a more upright growth form, longer shoots and a clearly reduced second growth flush in July. Apical dominance was strongly promoted. The plants have been so radically changed in shape that they look like seedlings. They have continued to grow like seedlings in 1979 so that they are no longer recognizable as *P. abies* 'Nidiformis'. Possibly it will take 2 or 3 years before the plants regain their dwarf appearance.

Tsuga reacted strongly to GA. Shoots were up to 100% longer without any damaging side effects. The number of side shoots was reduced, which resulted in plants with an open appearance (Table 1).

Table 1. Influence of GA_3 on shoot growth and number of side shoots in *Tsuga canadensis* 'Nana'.

GA_3	Average shoot growth	Average number of side shoots
0 ppm	12.6 cm	6.2
500	20.3	5.3
1000	21.7	3.5

In 1979 *Tsuga* treated in the previous year maintained their growth lead and have, for the most part, regained their dwarf habit.

Berberis showed a strong reaction to GA even at the lowest

concentration with respect both to shoot length as well as to number of side shoots. GA could possibly be used to produce larger plants quicker but the optimal concentration should be looked for at a rate of less than 100 ppm.

Salix grew almost 100% taller under the influence of GA but the number of side shoots was reduced (Table 2). The higher rates damaged the plants. It should be possible to use it at rates below 100 ppm without any negative side effects, such as susceptibility to winter frosts.

Table 2. Influence of GA_3 on plant height, number of main and side shoots in *Salix purpurea* 'Nana'.

GA_3	Plant height	Average number of main shoots	Average number of side shoots
Applied weekly			
0 ppm	65.6 cm	5.96	5.0
100	103.0	4.96	0.84
250	97.7	3.13	0.61
500	87.0	3.34	0.22
Applied biweekly			
100	109.7	5.33	1.97
200	92.4	4.06	1.42
500	104.0	2.82	1.18
1000	108.7	3.23	0.54

In the case of *Viburnum*, leaf size was increased and internodes were longer, which resulted in larger plants. The number of side shoots was reduced (Table 3).

Table 3. Influence of GA_3 on plant height, shoot number and leaf size in *Viburnum opulus* 'Nanum'.

GA_3	Plant height	Shoot number	Leaf size
0 ppm	18.6 cm	33.5	103.3 cm^2
100	22.6	26.6	117.5
250	25.1	25.6	121.3
500	27.1	25.6	126.7

A few shoots grew stronger than others but this did not seriously affect the shape of the plants.

In *Lonicera*, however, the leaves were reduced in size and, although the plants were larger, the shape was spindly and will probably not retain an acceptable shape (Table 4).

In spite of the severe winter of 1978/79 all treated plants survived undamaged in unheated frames with the exception of *Salix* where the treated plants died back, in some cases, to ground level. The growth of the plants in this season (1979) will be recorded. It is hoped that the treated plants maintain their size advantage and return to their dwarf character.

Table 4. Influence of GA_3 on plant height, shoot number and leaf size in *Lonicera* × *xylosteoides* 'Clavey's Dwarf'.

GA_3	Plant height	Shoot number	Leaf size
Applied weekly			
0 ppm	45.0 cm	20.0	6.75 cm^2
100	66.1	24.4	5.03
250	62.1	24.7	3.08
500	56.9	21.6	3.60
Applied biweekly			
100	62.4	24.8	6.18
200	67.4	25.3	5.30
500	63.4	23.5	4.67
1000	59.9	20.9	3.90

SUMMARY

Six species of dwarf woody plants were treated with gibberellic acid at concentrations between 100 and 1000 ppm. All plants reacted strongly to GA_3. It is hoped that by stimulating growth production, time to produce saleable nursery plants can be reduced.

DESIRABLE AMENITY TREES

ALAN MITCHELL

Forestry Commission
Alice Holt, Farnham, Surrey

Other things being equal an evergreen tree gives twice the value of a deciduous tree visually and more because it provides shelter when most needed. Evergreens are not fully exploited in the U.K. There are few broadleafed evergreen species of rapid growth or large structure. Conifers have been restricted badly by sooty air near towns until recently, but are much used urban trees in other countries.

Flowers or *autumn color* are spectacular but brief and have a low score on their own. *Foliage* is of long duration or is permanent (evergreen) and so has a high score. *Bark* is permanent and is best seen on deciduous trees in winter and therefore scores highly. Any combinations of the above add greatly to value. *Ease of propagation*, and hence (but not necessarily) ease of acquisition, is considered secondary, even if decisive.

Some trees with high general scores.

Arbutus menziesii. Pacific madrone. Evergreen, rich bark colors; prominent flowers, colored fruit; good growth and stature. Tender when grass-high but hard to say whether fully

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hardy as older plant, since few are seen beyond East Anglia and the south.

Ligustrum lucidum. Glossy privet. Evergreen, handsome glossy foliage, densely flowered all summer; open autumn, highly fragrant; shapely crown; moderate ultimate size; proved adaptability to urban, city and street.

Euodia hupehensis. Smooth grey bark; handsome pinnate leaf; abundant flowers in late summer; orange-red fruit. Very vigorous when young; proved adaptability to cities.

Zelkova serrata. Keaki. Bark flecked orange, pink, etc.; elegant leaves held in attractive lines; splendid, rather subtle, autumn colors; vigorous when young; very hardy; easily raised from seed in quantity; proved value in cities.

Acer buergeranum. Trident maple. Bark, flaky orange-brown: Leaves emerge orange; yellow flower-heads with them; foliage dense and pretty; good autumn reds; moderate size; easily raised from seed.

Aesculus flava. Yellow buckeye. Slender leaflets bright glossy green; yellow flowers; brilliant orange and red autumn colors, good growth in city parks; usually seen grafted; home seed not very successful.

Aesculus indica. Leaves emerge orange-brown; slender, shapely and stalked; big flower-heads a month later than horse chestnut; black 'conkers', good growth, used in London Royal Parks.

Aesculus turbinata. Japanese horse chestnut. Smooth grey-pink bark; huge leaves on two-foot stalks; tall flower-heads; good orange autumn colors.

Betula pendula 'Dalecarlica'. Swedish birch. White bark, slender weeping crown; small fancily cut leaves, brief autumn golds; good in towns.

TECHNICAL SESSIONS
Tuesday Morning, December 11, 1979

The twenty-ninth annual meeting of the Eastern Region of the International Plant Propagators' Society convened at 8:30 a.m. in the Ballroom East of the Sheraton St. Louis Hotel, St. Louis, Missouri.

PRESIDENT HALWARD: Welcome to the twenty-ninth annual meeting of the Eastern Region of the International Plant Propagators' Society. It is my great pleasure this morning to welcome you all here. At last count we had 420 registered. This is the twenty-fifth meeting that I have attended since joining and everyone has been a unique experience. I am looking forward to meeting those of you who are attending for the first time and I am sure you will be as excited as I was 25 years ago. This is a unique learning experience for everyone. It is a great opportunity to learn from the top propagators, teachers and authors in the business. Participation has always been the lifeblood of our organization and I hope you will get actively involved. We have a number of guests: Bruce MacDonald and Roger Butler, Great Britain and Ireland Region; Bernard Ferotin, France; Bruce Briggs, Western Region; Robert Ward, Southern Region; and Duane E. Jelinek and Ernest Tosovsky, American Assoiciation of Nurserymen. At this time I would like to recognize Wayne Lovelace who has put the program together. We have a very full program this morning and I will now turn the program over to our first moderator, Dr. John Wott.

CONSTRUCTING A NEW PROPAGATION FACILITY FOR SAFETY AND EFFICIENCY

DON O. SHADOW

Shadow Nursery, Inc.
Winchester, Tennessee 37398

In planning this new propagation facility I tried to incorporate the many ideas which I have seen and thought about for several years.

The outside propagation beds were built from round peeler core posts (8 ft × 5 in). Being the same dimension throughout, they connect well with strapnail fasteners. The beds are 48 feet long by 4 feet wide with 3 feet isles. Future plans call for underground electrical supply of 24 volts in the beds.

The beds are covered with a wire frame made from 6 by 6 in square construction wire, cut every 13 squares, to make a cir-

cular frame without any additional bending. The frame's rough ends are bent, and the whole frame is dipped in a non-fiber asphalt roofing compound diluted with enough gasoline to make it more workable. After drying, the frames are placed on top of the beds and fastened with a long staple at each corner. The staples work much better for me than a bent nail. The above procedure gives a good smooth circular surface on which shade cloth or plastic may be attached.

Our new 80 ft greenhouse was divided and attached to each end of the 40 ft headhouse. This way I can maintain each section at a different temperature. The greenhouse was orientated in a N-S direction to take full advantage of the sun. The headhouse is sufficiently heated each day the sun shines by having a glass house at each end. All side walls of the greenhouse and headhouse are 4 ft underground to take advantage of the earth's warmth. The loft of the headhouse serves for storage of plastic, shadecloth, microfoam, etc. It also has a frosted skylight to furnish natural light when looking for supplies. A trap door allows for easy access when storing or removing supplies.

We have built a cutting keeper which has a mist nozzle in the top. The keeper is 7 ft tall and 4 ft square with 4 levels. The levels are covered with ½ inch hardware cloth. The keeper is covered with plastic and has entry from 3 sides for easy access and to prevent workmen from climbing on the base to obtain cuttings in the back. All excess water drains into a pan rather than onto the floor.

To take better care of our seeds, we made seed drying tables and covered them with ¼ in hardware cloth. This type of construction allows for air movement and proper drying.

The propagation tables are covered with white formica to help maintain a cleaner area for grafting and cutting preparation. I feel we need to improve our sanitation in all areas of propagation.

EVERETT ASJES: Are the posts penta treated?

DON SHADOW: No, copper treated.

PETER VERMEULEN: What type of heat are you using under your grafting benches?

DON SHADOW: Hot water heated with propane.

FRANCIS GOUIN: How are you holding your poles in place? Also do you fumigate and with what?

DON SHADOW: The poles are kept in place just by making a little trench. We fumigate with methyl bromide and we use the same wire structure and clear plastic that we are going to

use during propagation. After fumigation we roll it back for aeration and cutting insertion. This saves on plastic.

ED MEZITT: Do you move the poles to put digging machines under the cuttings?

DON SHADOW: No, but I plan to do this because the poles can be moved easily.

RICK ALLRED: Would you elaborate on your conifer grafting?

DON SHADOW: We use a side graft, lay them on a 45° angle in the bed, and cover with a plastic tent. I am not sure about the temperature. It is between 21° and 27°C (70 and 80°F).

EFFICIENT PRODUCTION IN PROPAGATION

PETER ORUM, JOHN WILDE, DIETER SCHUMACHER
and GARY KNOSHER

Midwest Groundcovers
St. Charles, Illinois 60174

Maybe some propagators have a green thumb or a white root or some other special knack of the art. But efficiency does not come from green thumbs. It comes from analyzing, organizing, developing methods and pushing your crew and facilities to yield their utmost.

What does this mean to us anyway? Making our propagation departments more efficient means that we will produce more plants at a lower cost per plant with the same effort we are already putting into it! And producing more plants at a lower unit costs means more profit. Profit is the lifeblood of business. And that is just as valid for commercial propagators as it is for General Motors. The more profit we propagators make, the more new and better facilities we build, the more propagator meetings we go to, the more plant excursions we go on, the more plants to produce for an expanding market, and the more people we put to work. So the more profit there is, the more life there is. It is high time that we commercial propagators get to look at ourselves as businessmen first and plant lovers second, and that we act accordingly.

We must take a critical look at the various segments of our operation, analyze how they function and figure out what should be done. (In parentheses I should say, that if any of us concludes that all is so well that nothing should be done, I suggest we have somebody else look at it.) A good hard look at our propagation functions (without stubbornness and prejudice)

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will often reveal that some parts of the function can be scrapped all together. An example being artificial wounding of cuttings in most cases or pounding of sticking sand and pounding of soil into the pot. Another part of the function may be done unnecessarily exact, an example being the clean-cutting of the base of cuttings which is usually not necessary. Parts of the function may be altogether missing, such as disinfection of sticking boards and cutting pans. And parts of the function may be done in the wrong sequence. For example, it costs a lot less to transport soil and plants bulk before potting than to transport the same amount of plants already potted.

At this point you may be wondering where the practical details are, that will be useful and meaningful. I have picked three important parts of the propagation and growing process which we shall take a close look at:

1. Making of cuttings.
2. Sticking of cuttings.
3. Potting of plants.

MAKING OF CUTTINGS

We are going to talk about field making of cuttings versus bench making of cuttings and also piecework. Field making of cuttings means to make the cuttings ready to stick right off the plant in the field. Bench making means cutting a branch off the stockplant, bringing the branch inside and there cutting one or several cuttings from the branch.

We feel that field making of cuttings seems to be the best answer for reducing costs by eliminating or reducing many labor wasting operations. Making, stripping, counting, and bunching in the field eliminates the labor of crews gathering plant materials, storage and removal from storage of bulky materials and disposal of waste aftrer bench cutting operations. It made sense to train crews to do the entire operation in the field, since time studies showed an overall reduction of more than 50% in the cost per unit of field made cuttings compared with bench made.

Reduction in labor costs and crew size to perform the necessary operation did not result in significant changes in quality. Making the cuttings more efficiently actually increased the rooting percentage because large volumes of cuttings could be made at the most suitable timing for maximum rooting. Just the savings in storage space and storage handling is significant, and there is less danger of handling diseased material or spreading such diseases as juniper blight.

Crew size is a factor in efficiency, and field making is best adapted to individual contract workers on a piece work basis or

small crews with a good crew chief. If you have a good crew chief and a crew of 5-6 persons you can operate most efficiently as far as travel to stock blocks or production areas. If you have as many as 10 unskilled workers to train in this method you have to use more supervisory help and closer supervision to avoid damage to field production areas or container plants used for cuttings. Cost per unit of production usually goes higher with more crew members and is lowest with individual contract worker in different areas on piece work rates.

The bench making of cuttings, however, can probably not be eliminated completely. Certain plant materials, such as arborvitae and related genera do not lend themselves to efficient field making. These can be made during cold and inclement weather by hauling in, storing and bench making on days or periods when field making is not practical. In winter, if your operation requires the use of deciduous hardwood cuttings, you can bench-make and store cuttings, such as *Ligustrum* and *Lonicera* with good results.

In our nursery we implemented a piecework system several years ago. It has worked extremely well. Without it we would never have been able to achieve the production we have. We have only three cutters and they make over 3 million cuttings in the season from April to October, all field-made. Good piece work operators should earn at least double the average hourly worker's wage.

Well trained individuals on a piece work basis tend to produce a consistent product. There is no evidence that the fast and efficient piece work operator produces significantly poorer cuttings than the slow, careful benchworker on an hourly rate. What is significant is that he produces as much as 5 times the volume.

STICKING OF CUTTINGS

When we receive the cuttings from the field, they are moistened and held in cold storage at 3° to 5°C (37° to 40°F) until we are ready to use them. When the time comes, the cuttings are submersed in a fungicide solution and quick-dipped in a hormone, if necessary. Whether the stickers stick groundcovers in cellpacks, junipers in open flats or deciduous in ground beds, they always do it as piece work.

Close supervision is necessary to keep track of 5 to 6 stickers going at the same time. If a man is not doing a quality job, he must correct his mistake. The second time, though, he would not receive any piece-work or hourly rate. In a 10 hour day, a good sticker can stick 10,000 to 15,000 cuttings. The actual amount would depend on the type and condition of the cut-

tings, whether the cuttings are being stuck in cell packs, open flats, or ground beds, and the sticker's other responsibilities. Some of these other responsibilities may include filling flats with sticking soil, preparing ground beds, watering in the newly stuck cuttings and covering them with saran cloth, and misting the cuttings.

We feel that when an employee is sticking cuttings on an hourly rate, he has little or no personal incentive to push. His wage for one day will be the same whether he sticks 1,000 or 15,000 cuttings. On the other hand, the paycheck of an employee that is in the piece work system is directly proportional to how hard he has worked.

POTTING OF PLANTS

On-site potting is done at Midwest Groundcovers. On-site potting is potting by hand a few feet away from the final growing place. Two men make a potting crew. They have one soil wagon and each a flatbed cart to haul the potted plants to their place. Soil, pots and some plant materials will be supplied by another man who is servicing 3 potting crews and also mixing soil.

On-site potting is more efficient than centralized potting. There are no breakdowns of expensive machines and very little maintenance. Only greasing the tractor loaders and the carts. It is easy to switch from one size container to another. It is not important whether the soil is dry or wet, hands don't get plugged up or stuck. Most motorized equipment used to haul the potted plants is eliminated. On an average we have found that one man in a 10-hour day can pot 2,200 half-gallon or 1,000 2-gallon plants. At this rate our men can usually double their hourly wage.

Before anyone is put on potting piece work, he will have worked with an experienced potter. He has to prove for several weeks that he can work at a constant speed and produce good quality work under all conditions.

We would not want to go back to potting by the hour because we get more done faster by piece work. Our men also absolutely do not want to go back to hourly pay because they like the extra earnings.

BEN DAVIS: How did you establish a piece rate that was equitable for you and your employees?

PETER ORUM: It is very difficult to do and takes time to work out. We started out just potting ourselves and seeing what we could do. Some rates we found out were set too high while others were set too low. We adjusted those in future years.

DWIGHT HUGHES: How are your workers paid when not on piece work?

PETER ORUM: By the hour and this rate depends on the individual.

PETER VERMEULEN: How do you decide who gets the piece work?

PETER ORUM: It is somewhat a seniority question. New people rarely go on piece work. They must prove themselves first.

JOHN SPARMANN: Do you separate cutting preparation, cutting sticking, and potting, in your piece work?

PETER ORUM: Yes.

A SYSTEMATIC APPROACH TO PROPAGATION OF SHRUBS BY SOFTWOOD CUTTINGS

JOHN R. HANNAH

Henry Field Seed and Nursery Co.
Shenandoah, Iowa 51602

Any person growing and propagating plants on a large scale uses a system or a pattern of work flow to accomplish his goal. It has been my observation that many propagators select one system and depend solely on that system to produce their entire output. It seems to me that this leads to the same mistake the army makes when it dresses everybody in olive drab, and then concludes because they all look the same, they are the same. Logically, using one single system of production for a variable input would force a propagator to be inefficient. Therefore, I would like to discuss some of the various systems and techniques of summer softwood shrub propagation and also the way systems can be fitted to the plant rather than fitting the plants to the system as is usually done. The first thing I would like to discuss is the cutting making system. I am going to describe the traditional system and then I am going to suggest some avenues that one might use to simplify a production system.

SYSTEMS FOR MAKING CUTTINGS

Traditional cutting system. A traditional cutting-making system would have at least the following steps:

1. Cutting wood would be removed from a mother plant.
2. The wood would be transported to a holding area.
3. Cuttings would be made to a certain length by a worker sitting at a bench.

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Henry Field Seed and Nursery Co.
Shenandoah, Iowa 51602

Any person growing and propagating plants on a large scale uses a system or a pattern of work flow to accomplish his goal. It has been my observation that many propagators select one system and depend solely on that system to produce their entire output. It seems to me that this leads to the same mistake the army makes when it dresses everybody in olive drab, and then concludes because they all look the same, they are the same. Logically, using one single system of production for a variable input would force a propagator to be inefficient. Therefore, I would like to discuss some of the various systems and techniques of summer softwood shrub propagation and also the way systems can be fitted to the plant rather than fitting the plants to the system as is usually done. The first thing I would like to discuss is the cutting making system. I am going to describe the traditional system and then I am going to suggest some avenues that one might use to simplify a production system.

SYSTEMS FOR MAKING CUTTINGS

Traditional cutting system. A traditional cutting-making system would have at least the following steps:

1. Cutting wood would be removed from a mother plant.
2. The wood would be transported to a holding area.
3. Cuttings would be made to a certain length by a worker sitting at a bench.

4. The bottom leaves would be removed from the cutting.
5. The top leaves might be cropped.
6. The cuttings are stacked in a bundle.
7. Bundles of cuttings are dipped in rooting hormone solution.
8. The cuttings are then stuck in the rooting medium.

There are many steps in this system. Any industrial engineer can tell you that every step results in a cost. Reducing the number of steps automatically reduces costs. At this point we should consider actions one might take to reduce the number of steps in the cutting making process.

Cropping leaves. Cropping leaves is a practice that dates back before the advent of mist systems. At that time it was necessary to reduce the transpiration surface of the cutting in order for it to survive at all. Today it is an unnecessary step with one exception, namely to save room in the propagating bed. If space is not a problem, then cropping is probably detrimental to the plant.

Making cuttings in the field. Rather than bringing wood into the greenhouse to make cuttings on the bench, cuttings can be made right in the field. One cut then results in one cutting. This is not a new idea. It has been done for a number of years by several large Oklahoma nurseries and I am sure many others use the same procedure. At Field's we make our cuttings in the field, bundle them with a rubber band and put the bundles in a plastic bag where they are kept wet with a hand sprayer. They arrive at the greenhouse in great shape and are usually stuck under mist within a couple of hours. This method is fast. I have had one individual make over 11,000 cuttings in one day. Daily counts of 6,000 or 7,000 per individual are not difficult to attain.

Making cuttings without a knife. Cuttings on some plants can be gathered very green before fiber forms and can be popped off the mother plant without a knife. This practice has worked extremely well on *Spiraea* × *bumalda* cultivars, *S. albiflora*, and *Kolkwitzia amabilis*. Perhaps it works on other plants; it is worth investigating. It won't work on everything, but when it does it can save money by eliminating a step.

Leaving bottom leaves. The previous two summers Henry Field's has stuck gooseberry cuttings without the removal of any bottom leaves. They root better than when the bottom leaves are removed. This same thing surely applies on other plants, so this is another step that can be eliminated on occasion.

Making cuttings mechanically. A flat top hedge will often have an abundance of cuttings sticking straight up from it. Mow

them off with electric hedging shears and stick them. It works on some plants. In practice, at Henry Field's we are using a blend of these techniques to meet our propagation goals. We pick the system with the least steps that will give the results we need. Most of our softwood shrub cuttings are made in the field. The only plants we cut on the bench are the various vines we grow. We avoid the use of the knife if we can. We also avoid cropping the leaves unless we absolutely must to give more room in the propagation bed.

SYSTEMS AFFECTING PLANTS AFTER ROOTING

Next we will look at the systems that affect a plant after rooting takes place. The first of these is the traditional liner production system as outlined below.

Traditional liner production system. This system is the one that has been used dating back several generations. The system usually consists of the following procedures:

1. A cutting is stuck in a rooting medium in early summer.
2. As rooting takes place and the cutting is removed from the rooting medium.
3. The rooted cuttings is potted by hand into a clay pot.
4. The clay pot is set into an outdoor cold frame where the plant will overwinter.
5. The following spring the clay pot is removed from the cold frame.
6. The potted liner is removed from the pot, flatted and sent to the field for transplanting.

The primary advantage of this system is its familiarity so when a problem occurs it has usually been seen previously. The disadvantage, of course, is that it has a very high labor cost.

Leafy bare-root liner production system. This is a "bare-bones" sort of system that consists of just the bare necessities. The steps are as follows:

1. The leafy cutting is stuck in a rooting medium.
2. When a considerable amount of roots are formed, the cutting is removed from the medium and sent to the field for transplanting, usually in late July.

This system is most effective when used with species that are vigorous growers and transplant easily, such as *Sambucus, Forsythia, Cornus* (shrub types), *Lonicera, Potentilla* and *Spiraea*. It is very inexpensive which, of course, makes it very attractive. The liners are transplanted to the field in early summer so there is no conflict of labor requirements with the digging and shipping season. In addition, this system can produce a saleable plant in 1½ growing seasons. Unfortunately this is a

rather high risk system. In Iowa the time of planting coincides with our period of highest plant stress from heat and drought. If the planting crew gets careless, the plants can die before they are ever transplanted. The new transplants must have water immediately after planting and repeated waterings until growth commences. The plants take a relatively long time to become established. The net result of the above is that stands from using this system are sometimes not as good as the stands from other systems.

Dormant bare-root liner production system. This is a relatively simple system requiring the following production steps:

1. The cutting is stuck in early summer. It then remains in the bed until it goes dormant in the fall.
2. The following spring, before growth resumes the cutting is moved to the field and transplanted, or the cutting is dug in late fall, roll wrapped and refrigerated through the winter. Transplanting takes place in the early spring (before April 15 if possible).

This system shares an advantage of the leafy bare root system in being relatively inexpensive, especially if the cuttings are spring-dug and winter refrigeration can be avoided. It usually gives good stands. On the negative side, this system can be subject to the vagaries of weather. A wet spring, a late thaw, or a spring drought can all delay transplanting to the fields, thus causing reduced stands. This system also conflicts directly with the shipping and digging seasons, so it adds to the labor crunch that most nurseries experience in the fall and spring.

Tube liner production system. This combines aspects of both bare root systems and the traditional potted liner system. The production steps are as follows:

1. The cutting is stuck in early summer in a tube type container.
2. In 4 to 6 weeks the cuttings are well rooted and are removed from the container for field planting.

This relatively new system offers the following advantages: (1) Planting is done in summer when labor is usually readily available. (2) Cuttings planted in the field become established in a matter of a week. (3) Root penetration into surrounding soil begins in about 4 days. (4) Transplant shock is practically nonexistent. (5) Plants are less subject to drying out in the transplanting process. (6) The whole process seems less influenced by weather than other systems. (7) Cutting sticking and the process of removal from tubes can be done at a work bench in a cool part of the greenhouse. (8) The work itself is much easier on the laborer than sticking cuttings while bent over a bench in a hot greenhouse. (9) Stands and growth seem much

more even than with other systems. (10) Transplanting success of over 97% is common. (11) Saleable plants are produced in 1½ growing seasons.

This system does have some disadvantages: (1) The capital cost is a little bit more than a bare root system, probably about 1.5¢ per plant more. (2) Some plants root so slowly that they are not ready to plant until late summer. The system should not be used to hold plants. When plants are well rooted they should be planted. If not planted, the tube-rooted cutting may not grow properly when it is finally transplanted to the field. (3) Some wide-leaved plants do not tolerate the crowding usually present in tube growing. (4) The system may not produce a large enough plant for sales at the end of two growing seasons for some nurseries. It works great for us since we are mail order and want the $^{12}/_{18}$" and $^{18}/_{24}$" size. If 2/2½' sizes are necessary at the end of two growing seasons, then the system is not satisfactory. There are some adjustments that have to be made in watering schedules, fertilizing and so on; if personnel cannot make the adjustment then problems will result.

Three years ago at Henry Field's a modified traditional system was being used. At that point Field's began to experiment with tubes for growing. Field's experience with tube growing has been extremely successful with the result that slightly over ½ of our softwood shrub production this year was in tubes. We have not gone completely to tubes and will not for the following two reasons:

1. It is a new system and we don't feel we know everything about it yet.
2. We want to diversify our production systems to reduce the risk of a system-induced failure.

Next summer we plan on changing our alignment further. We plan on slightly over half of our production being in tubes, about a fourth by a dormant bare root system, and about a fifth by the traditional system. Up to this point I have treated the cutting making systems and the postrooting handling systems separately. Table 1 illustrates how we fit the systems together and shows the route through the systems that we would prefer to follow in producing a softwood shrub liner from the making of the cutting to the transplanting stage.

In conclusion, I have outlined some systems of production that are presently economically and technically feasible. The propagator must, of economic necessity, continually reexamine all underlying assumptions relating to his or her propagation systems and eliminate any unnecessary steps from the systems.

Table 1. Preference for systems of summer softwood shrub propagation.

Genus or species	Preference for type of cutting system[1]			Preference for type of rooting system[1,2]			
	Make in field	Cut at bench	Use no knife	Traditional	Leafy bare root	Dormant bare root	Tube rooted
Berberis	1	2	No	3	No	2	1
Buddleia	1	2	No	2	No	No	1
Celastrus	No	1	No	4	3	2	1
Chaenomeles	1	2	X	2	No	3	1
Cornus (shrub types)	1	2	X	4	2	3	1
Cotinus	1	2	No	No	No	2	1
Deutzia	1	2	X	2	No	X	1
Euonymus alatus cultivars	1	2	No	3	No	1	2
Forsythia	1	2	X	4	3	2	1
Hydrangea	X	1	X	1	X	X	X
Kolkwitzia	1	2	1	3	No	2	1
Ligustrum	1	2	X	3	No	2	1
Lonicera (shrub types)	1	2	X	4	3	2	1
Lonicera (vine types)	No	1	X	4	2	3	1
Philadelphus	1	2	X	No	No	2	1
Physocarpus	1	2	X	4	2	3	1
Potentilla	1	2	X	No	2	3	1
Prunus	1	2	X	No	No	2	1
Ribes	1	2	X	2	X	3	1
Salix	1	2	X	4	1	2	3
Sambucus	1	2	X	4	1	2	3
Spiraea albiflora	1	2	1	3	2	No	1
Spiraea × *bumalda* cultivars	1	2	1	3	2	X	1
Spiraea × *vanhouttei*	1	2	No	3	2	X	1
Symphoricarpos	1	2	X	2	No	No	1
Syringa (French Hybrids)	1	2	X	3	X	2	1
Syringa persica	1	2	X	4	2	3	1
Syringa patula (Syn.: *S. palibiniana*)	1	2	X	4	2	3	1
Viburnum	1	2	X	1	No	2	No
Weigela	1	2	X	3	No	2	1

[1] Systems marked "No" should be used with caution because problems have appeared with a similar approach in the past. X indicates limited information

[2] 1 is most preferred.

Editor's Note: Joseph Cesarini moderated a group of short presentations on tricks and ideas in propagation and growing. The papers by J.B. Fletcher and J. Peter Vermeulen were part of that session.

GREENLEAF NURSERY'S SHEAR MACHINE

J.B. FLETCHER

Greenleaf Nursery Co.
Park Hill, Oklahoma 14451

In November, 1973, Greenleaf Nursery started working on a faster way to shear containerized nursery stock, other than the conventional hand shearing method. Through the ideas and determination of our division supervisor, Marvin Fuson, and the technical assistance of our maintenance shop supervisor, Luther Taylor, Greenleaf Nursery now has a shear machine that does a quality job and saves many hours of hand labor.

The first shear machine we made used a 1½ horse power electric motor which turned 3450 RPM's. The motor had a double shaft which allowed us to mount a 16″ cutting blade on the bottom and a 12″ fan blade on the top. This machine worked as well as our present machine, however, it required an extra person to control the electrical extension cord and a 12 horse power portable power plant to run the electric motor.

Another version of the shear machine is the lawn mower type. This type did not work well for us on junipers. It left a lot of clippings on top of the plants, the cuts were not smooth and it didn't have enough suction to pull the side branches up to the cutting blade. We had to go over some cultivars two or three times to get an even cut, but on certain shrub and broadleaf cultivars it did work well and it is considerably more economical to construct than the other type of shear machine.

The shear machine that we are using now is powered by a Clinton 503, high performance, 2 cycle gasoline engine. A 26″ × 1″ shaft goes from the motor shaft through the housing to the cutting area. It is connected to the motor shaft by a Falk Brand 20-T-20 coupler and a 20-T blank bore hub drilled to 1″. Mounted in the middle of the 1″ shaft is an Allis Chambers 840 cooling fan blade No. 1005294-2 which creates the suction to draw the lower branches up to the cutting surface and suck the cuttings off the plants. The cutting blade is an 18″ lawn mower blade. There are two Fafnir pillow block 1″ bearings mounted above and below the fan blade. (See Figure 1)

The frame which straddles our 8′ beds is made of 1½″ square tubing. The four tires are 16 × 6.50 – 8 high floatation tires. We roll the shear machine the length of the bed on the outer edge, then we slide the cutting head over about 14″, shear the opposite direction the length of the bed again and continue this process until the bed is completely sheared.

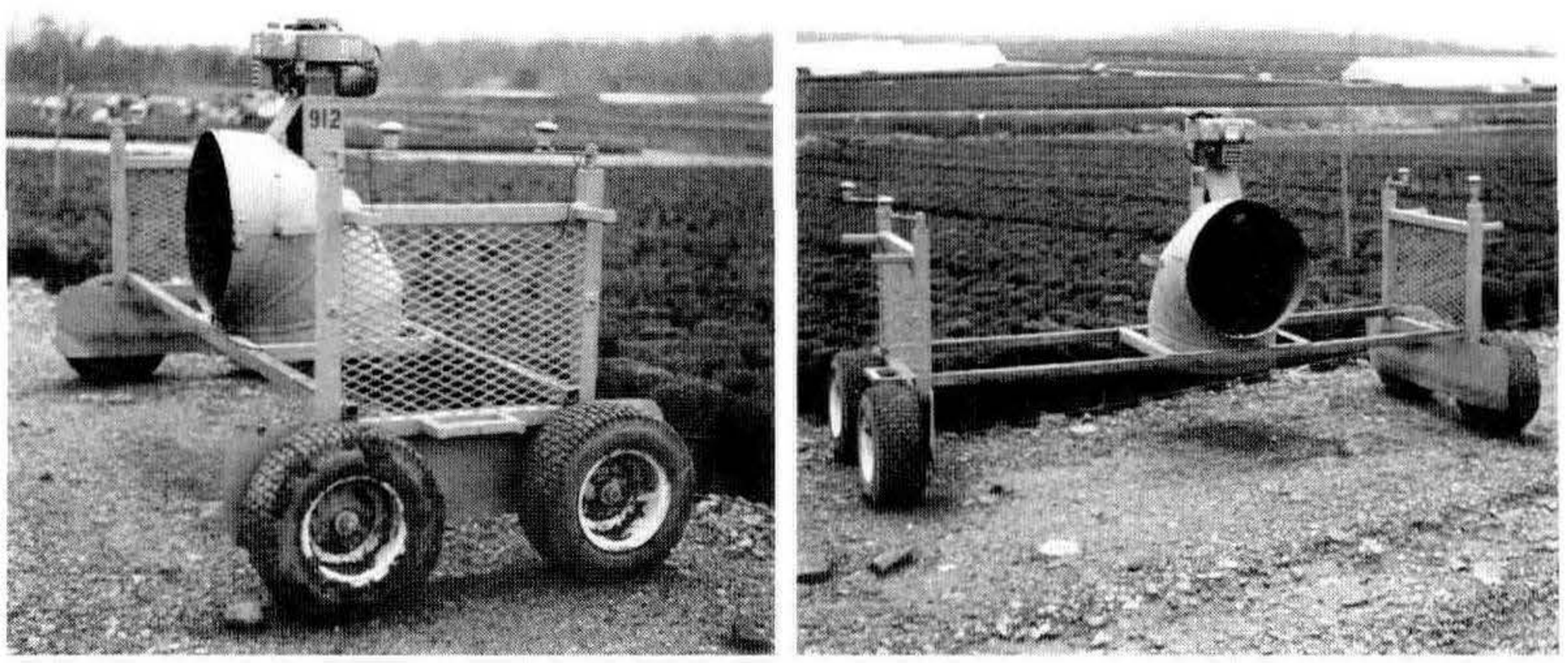
Using the new shear machine, two men can shear about

70,000 one gallon plants, that are can-to-can, in an 8 hour day and about 40,000 one gallon plants after they have been spread, in an 8 hour day.

Some cultivars do require some hand shearing behind the shear machine; however, it is usually less than ½ man hour per 1000 plants.

This type of shear machine will not work on the prostrate juniper cultivars such as Wiltonii (Blue Rug), Bar Harbor and Webberi.

As time goes by and labor continues to be a greater and greater problem, labor saving devices such as this will play an ever increasing role in our related industry. Each of us needs to strive to develop usable labor saving methods and equipment to meet the demands of our growing agricultural businesses.



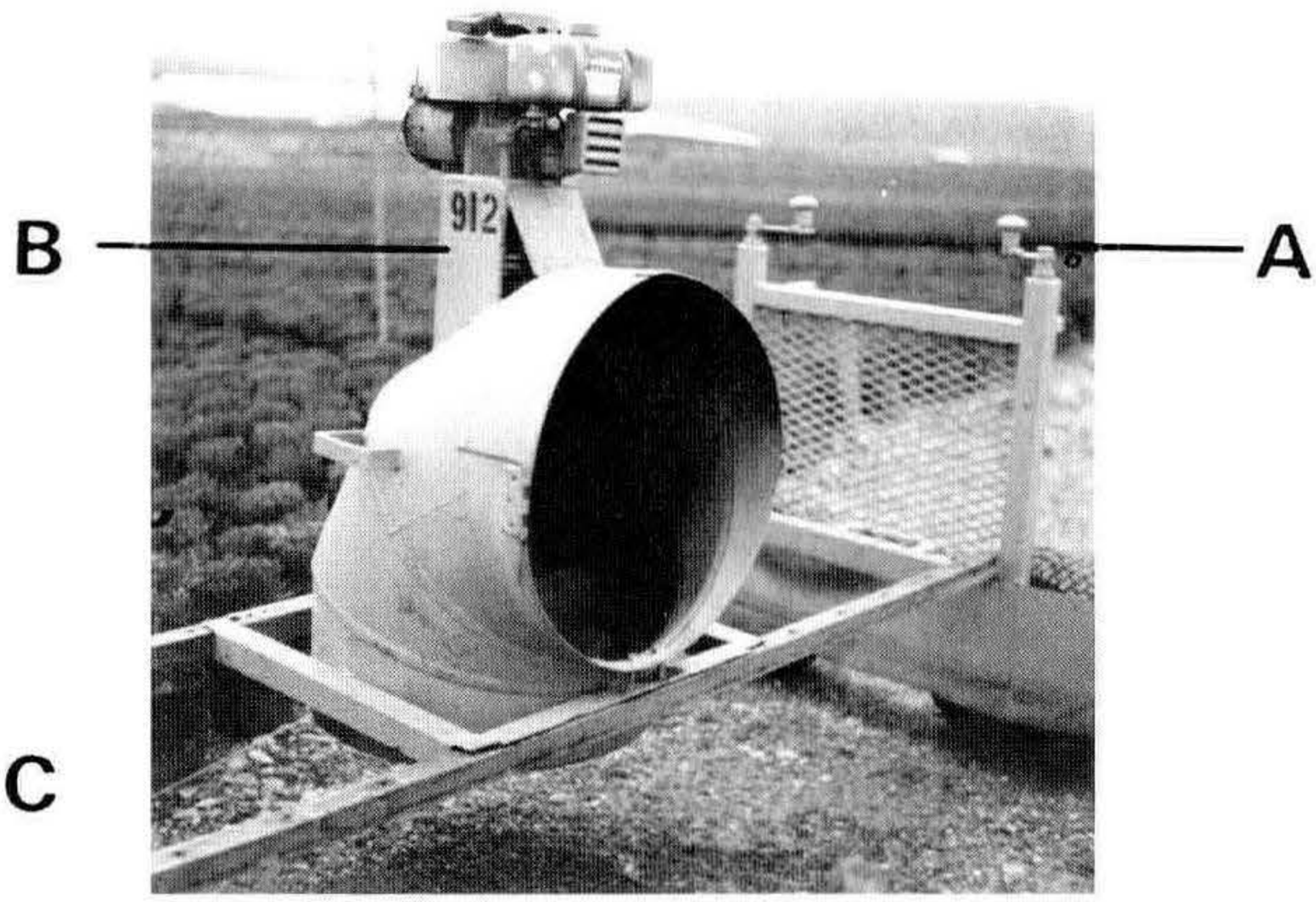


Figure 1. Shear machine. **A.** Height adjuster. **B.** Coupler under motor mount. **C.** Shear machine slides on cross rails.

ON HOUSE STORAGE AND REPEAT USE OF POLYETHYLENE FILM FOR COVERING GROWING STRUCTURES

J. PETER VERMEULEN

John Vermeulen & Son, Inc.
Neshanic Station, New Jersey 08853

Our nursery is situated in the fertile Raritan River Valley in Somerset County, New Jersey. We are in USDA climate Zone 6a, but because of the low elevation and valley position, our microclimate is that of Zone 5a. Frost-free days range from 142 to 196, spring to fall. Our average mean temperature is 10°C (51.2°F) with a maximum of 36.5°C (98°F).

Poly-covered overwintering structures for our container-grown nursery stock, which consists of woody ornamentals ranging from *Abies* to *Zelkova*, are a costly requirement for the production of top quality stock.

Our structures are variations of the quonset (hoop) style houses quite common in the trade. Because of the consistency of our soil, a silt loam, we have problems with our houses moving up and down from the heaving effect of frost. Initially we had problems with wind entering the houses and drying the containerized stock inside. We solved this by using a double layer of poly stapled to a 2″ × 4″ wooden stringer running the length of the house about 15 inches above ground level. Sand, lying at the bottom of the U created by the poly extending down from the stringer to the ground and back up again to the stringer, weighs the poly, keeping it pressed against the ground as it moves up and down throughout the fall to spring seasons.

For many years we covered the houses in mid-fall and kept them covered until after the last frost, which varies from late April to late May. To keep the air temperature within the houses at a more uniform low level we covered with white poly, the least expensive we could buy, provided it had a good percentage of pigment. Nevertheless, high inside temperatures into the 80's on warm late winter days sometimes forced early growth which then was susceptible to frost injury. To overcome this the poly was slashed, which allowed the heat to escape and also let in more light and yet still afforded protection from light frosts. This, however, spoiled the poly and prevented its further use. Poly was relatively cheap then, approximate ½¢ per square foot, thus the waste was an acceptable cost.

The 1973-74 oil embargo (our first warning of things to come, incidently) set the stage for a poly resin shortage which prompted the extruders to increase prices, much to our dismay,

beyond that warranted. The old Dutch nettle was aroused and that, when coupled with the austerity lessons left over from the Great Depression, caused us to take a closer look at our procedures.

For a few years we had been saving the clear poly which covered our heated houses by rolling it up tightly along the length of the houses towards the ridge rafter and tying the rolls in place there after covering them with black poly to block the damaging ultra-violet rays. We were, and still are, getting two winter seasons from the poly which is UV inhibitor-treated (Monsanto's 602). Perhaps we could get 3 or even 4 seasons of use from this grade; however, we have been too timid to try on these houses in which there is a disaster potential if the poly broke down, shattered or crumbled in mid-winter. Here I would like to suggest some applied research, perhaps the USDA, Horticultural Research Institute, or the Agricultural Extension Services.

With this experience we reasoned that our white poly on the unheated houses could be similarly saved and so, in 1974, we covered 15 houses with UV inhibitor-treated white poly (also Monsanto). We had to use 6 mil, as 4 mil was not then available. Using the technique I will describe, this poly is still on and is looking good going into its 6th season. In 1976, 4 mil 602 white poly became available and the remaining 18 unheated houses are now covered with it.

Some of you have seen this firsthand at the nursery, and the information has been published previously by Francis Gouin in Maryland Cooperative Extension Services, "Nurseryman's Notes", Sept.-Oct. 1976, based on observations made on the tour by this Society during our 1976 meeting.

I mentioned previously that we have 2″ × 4″ wooden stringers running the length of some of our houses. Some of these are bolted to the pipes driven into the ground into which the bow-ends are placed, thus supporting the arch. Some serve as a plate resting on top of posts and lag bolts are screwed into this plate. On other houses the bolts are screwed into railroad ties. In all cases we have wood to nail into that runs the length of the house. This is important to us because we fasten the poly to these stringers after rolling it first onto 1″ × 2″ wooden lath strips which then are nailed to the stringers (plate or tie). We use an 8 penny double-headed nail about every 1′ to 2′ depending on the condition of the wood being nailed into.

One side of the house is fastened first, the poly first being draped over the house. It is recommended safety practice to tack the other side to keep the poly secure while it is being permanently fastened on the first side. After that is accom-

plished the other side is secured. We try to cover with the poly on warm days without wind as the poly is more elastic then and permits a really good pull-down when rolled on the lath and nailed on the second side. All hands and often feet are urged constantly to muscle it down to get it drum tight. We don't want that poly to move and chafe against the bows. Later, when it gets colder and the poly shrinks, the house actually *sounds* like a drum when tapped.

The many advantages of this technique are as follows:

(1) First and foremost is that of economics. The poly now going into its 6th year was put on at a material cost of 0.96¢ per sq ft Today's cost is 3.21¢ per sq ft. Labor cost to pull off, dispose of and reapply the poly annually is about 0.0012¢ per sq ft. The labor to roll and cover is about 0.0064¢ per sq ft. We have a total annual saving of approximately $3357 on the unheated houses covered with white poly using a 6 year use factor and of $1207 on the heated houses covered with clear poly using a 2 year use factor (in both instances using an inflation factor of 10%). This totals about $4500 per year saved. In our installation this comes to about .0276¢ per sq ft (white .0329¢, clear .0205¢).

(2) Second is our contribution toward savings of energy in both the raw mineral product and the energy used for production and distribution.

(3) We have a capability of rapid recovering of the houses in the event of needed frost protection.

(4) We have greatly diminished our disposal problem.

(5) Additional saving of wood laths, productivity, supervisory time, overhead, etc.

We see no reason why, with some minor modifications, this technique cannot be adapted to almost any structure or method of poly sheet covering.

HADLOW COLLEGE — THE AIMS OF THE NURSERY STOCK DIPLOMA EDUCATIONAL PROGRAMME

A. BRUCE MacDONALD
Hadlow College of Agriculture & Horticulture
Hadlow, Tonbridge, Kent, England

BACKGROUND INFORMATION

Hadlow College is situated in Kent, some 30 miles south of London. The village of Hadlow lies between the towns of Maidstone and Tonbridge. As horticultural and agricultural col-

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leges function, Hadlow is relatively new in that it was founded in 1967. It was formed with the amalgamation of two Farm Institutes in Kent — Swanley, which was devoted to horticulture, and Sittingbourne — where the bias was agriculture and fruit growing.

The structure of the college is basically as follows: Firstly, there is the College Principal, K.E. Garner, and he is backed up by Adam Sommerville, who is both Vice-Principal and Head of Horticulture. Within the Horticulture Department there are the college lecturers, the great majority of whom teach and instruct in specialist subjects. Working closely with them are the technical instructors, whose involvement is teaching students the practical skills. If one takes the nursery stock section, then Chris Lane as senior instructor is very much responsible for the planning and day-to-day running of the nursery, besides instructional involvement.

The college now has some 170 full time students, out of which usually just over 90 specialize in horticulture. In addition, there are 250 part-time horticultural students who attend on a daily or weekly basis on a wide variety of short courses. The college farm is made up of 450 acres, while the horticulture department consists of 135 acres. The latter acreage is made up of 90 acres for fruit growing, 3 acres for glasshouse crop production, 20 acres for vegetable production and 20 acres for nursery stock production, which includes 2 acres of glasshouses and tunnels.

As with other sections of horticulture at the college, the nursery stock section is managed along commercial lines with full student involvement. A major philosophy of Adam Sommerville is that students must have the opportunity of working with the full-time nursery staff in order that they are better equipped for the industry after they leave the college.

The nursery can be categorized into two divisions: firstly, field-grown stock where a 10 acre site produces annually some 10,000 to 12,000 trees and 5,000 bush roses. Other items grown here are seed-raised crops, conifers, and a considerable area devoted to stock plants. The container plant division now produces annually over 100,000 saleable plants. One area is devoted to larger quantities of a basic range of material, for example × *Cupressocyparis leylandii*, *Elaeagnus pungens* 'Maculata', *Skimmia japonica* and *Mahonia japonica*. Another area is devoted to ericaceous and high value crops — for example *Rhododendron*, *Magnolia*, *Hamamelis* and Japanese maples. Over the last three years the range of plants grown has greatly increased, for example 92 cultivars of azalea, 110 species/cultivars of dwarf rhododendron, 11 cultivars of *Hamamelis*,

together with well over 300 unusual and rare plants. The college is constantly checking new plants for both field and container work. These are bought or exchanged with many specialist nurseries, both within Britain and abroad. One can assess the propagation and growing on of many of these plants while at the same time ensuring that the student leaves with an up-to-date knowledge of a broad range of plants. The most recent development is the introduction of a container liner production unit.

A major national event at Hadlow is the Biennial Conference devoted to nursery stock production. The morning is spent listening to specialist speeches invited from the trade, advisory and research services, while the afternoon is devoted to viewing the college production units where a number of practical demonstrations based on the morning program are carried out. These demonstrations involve the industry, students and nursery staff.

To summarize, the major points to stress are as follows:

1. All staff work as a team to produce well-trained students for the industry and to manage an up-to-date commercial unit.
2. Lecturing, technical instructors and nursery staff are all involved in teaching practical skills by demonstrating and working with the students.
3. Strong links with industry are absolutely vital for two-way communication. The college is very fortunate to have nurserymen on the college governing body, advisory committees, for course assessment, participation at college conferences and also willing to receive and guide students, when visits to their nurseries are arranged.
4. A student is trained so he or she can carry out a range of practical skills and, depending on ability, will be able to subsequently take a level of responsibility.

In order to be a full time student and study at the college, four basic requirements must be met:

(1) That a full 12 months practical work has been completed.
(2) That he or she is 18 years of age.
(3) That the necessary academic entry qualifications are obtained. This will depend on the type of course selected.
(4) That an interview and outside references indicate that he or she is keen, reliable and will benefit from a full-time training period.

THREE YEAR COURSE — ORDINARY NATIONAL DIPLOMA IN HORTICULTURE

To qualify for this course the proposed student must have four slected "O" levels or equivalent, together with the necessary 12 months of practical work.

This course is termed a "sandwich course", in that a person spends one year at the college, during which time he can choose one of three commercial options — fruit, glass, or nursery stock production. The second year is spent on a selected nursery holding, and the third year is spent at the college specializing in-depth his chosen option.

The course is designed so the student can be assessed regularly over the year period — for example, when he(she) is on practical operations, weekly tests, projects, plant identification and sandwich year work. In addition to this, they will have exams in February and June, both in the first and third year.

My colleague, Ken Turner, oversees the basic organization of the three year program and acts as course tutor in the first and second year. During the third year the course tutor is the specialist crop production lecturer in either fruit, glass or nursery stock production. The course has two outside assessors, one who is industry based and one who is an experienced educator.

Year 1. Here the aim is to give the student a broad insight of the horticulture industry in Britain. Besides botany, soils science, crop protection, machinery and management, the student has one lecture a week on nursery stock, landscape, fruit, vegetable and glasshouse production. This general year is felt extremely important in that it gives the student a background knowledge which may be useful if he or she enters retail sales or, at a later date, should they wish to change from nursery stock production into fruit growing.

The student's practical work is varied in that complete mornings are spent on the nursery while, in addition, time is spent on machinery and estate maintenance.

During May of this first year a week's study tour is arranged to visit different nursery holdings, gardens, research and experimental stations. The college mini-buses were used for this and each night is spent at one of the many youth hotels situated within Britain. This study tour is most important in that it firstly gives the student the opportunity of seeing modern horticultural production, it teaches him to get alone with other people in a close proximity, and thirdly it tells the staff member with them a great deal more about each particular student.

Year 2. At a half-way stage during the first year the student is encouraged to select one of 3 options — glasshouse, fruit, or nursery stock production. In conjunction with the industry, a nursery is selected on mutual agreement with the nurseryman, the college, and the student. He or she is then finally selected on condition that the nurseryman will employ the student for a full 12 months.

Before the student departs for his sandwich year he or she is briefed on its objectives by the industry assessor (currently Tom Wood, of Oakover Nurseries, Ashford, Kent) and also the course tutor on the necessary project work to be carried out. This project work is divided into 4 sections:

1. Monthly diary of operations — these are returned monthly to the course tutor.
2. Prepare a map(s) and written material on the nursery resources. This includes labor, buildings and machinery.
3. Detailed account on crop production techniques of the major items grown.
4. An assessment of the student's contribution to the nursery.

The employer submits to the college a bi-monthly report on the student — in particular relating to work output and interest shown in his work. The course tutor visits each student twice a year and may hear problems relating to the student's performance. These can be discussed with the employer in addition to any personal problem the student may have. During February of the sandwich year all the students are invited back to the college for an afternoon and evening where he or she relates to their fellow students and college staff information about their work. During this period the students are informed about college developments and they are asked for topics which they may wish to study for their third year project work.

An observation made by many staff is how many students quickly adapt and mature during this practical year and how they both improve in character, interest, and work outputs.

Year 3. The third year, again commencing in September, is where the student studies his chosen option in depth. Nursery stock teaching is dealt with on the production of named crops, also the principles of production — for example, irrigation, cold storage, mechanization and quality control, operation of a garden centre, and plant identification. Along with this is landscape construction, management, soil science, crop protection and botany.

Built into the course are 4 other important contributions:

1. Practical work dealing with a wide range of nursery op-

erations.

2. Project work in both management and crop culture. Two management projects are implemented by the management lecturer, Paul Truscott.

Firstly, one relating to legislation in horticulture, while the second is formulating a financial development program for a nursery. Local nurseries are used and the owners give great assistance by providing realistic financial background. Last year this took place at Walmeston Nurseries, owned by Roger Butler, where they had to financially plan, with technical back-up, an extension to a current container area with a market outlet, mainly to local authorities. Later they present their case to the owner of the nursery and a bank manager.

There is a cultural project where the student, course tutor and a member of staff, with a particular specialist knowledge, agree on a topic. Advice is also sought from industry, experimental and research establishments, for example East Malling Research Station. A number of these are devoted to propagation; projects which have been particularly interesting include the following:

A. Bench grafting of trees for container tree production.
B. Incision wounding of cutting, for heated bins (Garner bins).
C. The value of an "acetone dip" to improve the performance of commercial talcs — for example with hollies.
D. Intensive seed raising techniques for deciduous trees.
E. Pre-sowing treatments to improve seed germination of trees, e.g. *Aceraceae*, *Rosaceae* and *Oleaceae*.

There is also a group project where 4 to 6 students work together to produce a crop using their own ideas and making their own decisions. Last year one group studied the bench grafting of trees within *Fagaceae* while the other studied *Pinaceae*. The aim of this project is investigational in that it helps the student to develop a skill and specialist knowledge in addition to observe, reason and conclude.

3. Visits are arranged to a wide range of nurseries through the year. This would be equivalent to 5 to 6 half days per term.

4. A 10 day overseas study tour to nurseries in France, Belgium, Holland and West Germany is organized. Both the college and students contribute financially to this. The college mini-buses are used and accommodation arranged at youth hotels. This tour is most valuable as it firstly enables the students to meet first-hand nurserymen from competing countries, secondly, to study their production techniques and, thirdly, to experience life in

different countries. A detailed report of the study tour is written up by the students.

The final exams are taken in mid-June and the students' performance is judged alongside their course assessment and project work over the full 3 years. They may pass at 3 levels — distinction, credit, or pass.

The college then hopes that the students, after a further 2 to 3 years practical work in the industry, will progress to a responsible managerial position. Some students naturally take responsibility earlier than others, while a number start into business in their own right.

The college O.N.D. course is regarded as a team effort by all staff, but it is realized that it could not achieve the desired result if there was not the close two-way relationship which exists with growers within the horticultural industry.

Finally, the college also provides a one-year course in nursery-stock production called the National Certificate in Horticulture. The basic entry requirement is 12 months practical work in the industry, backed up by good references. During this 12 months the student may have been released by his employer to attend day or block courses. This course is very much a practically based course on craft skills and does not contain such a high level of academic content as the Diploma course. Many students from this type of course within the country provide the "backbone" to nurseries.

Recently it has been college policy to involve itself more with short (block) courses. These courses cater to garden center and nursery personnel. The student normally attends for 3 one-week blocks over 1, 2 or 3 years.

The college is now looking to the future where it is trying to evaluate the type of courses it should be holding for the 1980's. How to provide for this future is difficult. It may be that greater emphasis should be placed on courses of a higher academic level or, alternatively, of a more practical nature. The college has to assess from its own experience, and the growers in Britain what type of trained student the industry requires and whether there are sufficient openings for them at that particular level.

PETER VERMEULEN: You mentioned cold grafting to keep your temperature down. Could you elaborate on your findings?

BRUCE MacDONALD: With bare rootstocks we use a splice graft and dip the scion and union in grafting wax. The grafts are placed in a box half-filled with peat. The box is filled with peat to above the graft union and placed in the cold for 2

months. We are getting an 80% success rate. We have had mixed results with pot-grown containers. Only the graft union is waxed with conifers and the grafts are placed on the floor at 7° (45°F). Shading is important for success during the 6-week callusing period.

Tuesday Afternoon, December 11, 1979

The afternoon session was convened at 1:30 p.m. with Dr. Roy A. Mecklenburg serving as Moderator.

APPLIED PLANT PHOTOGRAPHY

JOSEPH A. BOWERS

The John J. Tyler Arboretum
Lima, Pennsylvania 19037

Slides are frequently used as visual aids for presentations on many subjects. Certain techniques can be applied to plant photography which will greatly improve the quality of your presentation. Rather than listing specific formulas for good picture-taking, general techniques for improved photography with a 35 mm camera will be discussed. Purchased 5 years ago, my camera cost about $200 with a few accessories. Comparatively, it is an inexpensive single-lens reflex camera.

Therefore get to know your camera, its assets and limitations. The proper way to hold the camera is with your left hand under the lens, with your thumb and index finger manipulating the focusing ring and other settings. Use your right hand to hold the camera body and to depress the shutter release. Keep your elbows close to your body to minimize camera movement. For low light conditions requiring a long exposure, use a tripod and cable release. Other alternatives are to lean against a tree or building, or rest the camera on a solid object. Use the following formula to determine the slowest shutter speed that you can use for a given lens. If the lens' focal length is 50 mm, use the closest shutter speed to that number, in this case 1/60 of a second.

Different types of film produce different results. For comparison, I have chosen Ektachrome and Kodachrome. The packaging colors will show the predominant color of the film. Ektachrome has strong blues and cool colors, while Kodachrome shows up reds and warm tones. Other films have similar color

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dominance; Fujichrome is strong in greens and Agfachrome in oranges.

The ASA or film speed is a rating of the film's sensitivity to light. Low ASA members, such as 25 and 64, are designed for bright light conditions, yielding brighter colors and a finer grain. Higher ASA numbers like 200, 400, or 500 are for lower light conditions, and the colors are muted and more grainy.

Proper metering is the most important key to good quality photography. The meter in your camera measures your subject for a correct exposure of 18% reflected light, which is a neutral gray. This "correct" figure is derived from the following formula: white reflects 90% of the light, and black reflects 3.5% of light. The square root of the product of 90 and 3.5 equals 18. For accurate metering use an 18% gray card. Place the card on your subject, meter it, and shoot, using that setting.

Special situations require compensation because the meter reading will give an unsatisfactory result. When your subject is against a bright background, a metered exposure of the whole scene will result in a dark subject. Instead, meter on your subject closely, back away and shoot. Another effective way to deal with a bright background is to fill the dark areas with light from your flash unit. When photographing whites, meter readings will be inaccurate. Your meter will tell you to photograph those whites as grays. This would include white backgrounds, close-ups of white flowers, and snow. To correct the exposure, meter from a gray card or open your camera up 2 or 3 f-stops. The opposite is true for pictures of dark or black subjects, including bark or black backgrounds. Under-expose your picture by 1 or 2 stops. There are some new cameras which are advertised as fully automatic. The meter selects the correct exposure, and you take the picture. However, the meter cannot be overridden, and you cannot compensate for special situations.

When you want the best possible exposure for important pictures, bracket your exposures. Take a picture at the correct setting, then over-expose by one stop, then under-expose by one stop. This will give you a choice of which you think is best.

Color saturation will give you richer, more brilliant slides. By setting the ASA on your camera ⅓ of a stop under the film's rating, you will slightly underexpose your color slides. For example, set 64 ASA film at 80 on the camera. This is most effective in bright light conditions with strong color.

The way in which a slide is focused is important to the viewer. The eye is drawn to the sharpest portion of the image. If the subject is blurred, and another part is in sharp focus, the viewer's eye will be distracted. A bright spot in the slide will

also detract from the center of interest.

Depth of field is the in-focus part of the photograph. Many cameras have a depth of field preview button, which allows you to see exactly what is in focus. The lens has a depth-of-field scale which shows how many feet or meters are in focus. A wide lens opening will show shallow depth of field, and a small opening will have a large area in focus. One third of the focused area will be in front of your focal point and ⅔ behind. When taking pictures of a nursery row, choose a small lens opening to keep the whole row in sharp focus. If you are shooting an individual plant, it shows up best against a blurred background, so choose a wide aperture. The reverse may be true in specific situations. A fuzzy dandelion plume may be enhanced by a sharply focused background.

Many filters are available for special effects and color correction. A flourescent filter will correct the greenish-blue tinge resulting from using daylight film under flourescent light. To correct the yellowishness of incandescent light when using daylight film, use a flash. Close-up filters or extension tubes are available for close-up pictures. The filters are quick and easy to use, compact and light. Extension tubes taken longer to set up, but give a sharper picture with more depth of field. The tubes also provide more magnification than filters.

An appropriate background is vital to a good photograph. The background should never distract from the subject. A building, cars, or people might distract the viewer from what you want to say about your slide. If you can, move to a different angle to shoot, or use a wide lens opening to blur out the background. When doing close-up work, put your subject on a piece of glass. Raise it 8″ to 12″ off the ground, and shoot with a wide aperture. This will blur the background and give the subject a floating appearance.

Don't put horizon lines or other dominant lines in the center of the photography. Move them to the upper or lower third of the viewfinder. Fill the frame with your subject. The less background, the better, in most cases. You pay for your film and processing, so make the most of it, and use all the film for what you want most.

PRACTICAL REQUIREMENTS FOR CONTROLLED ENVIRONMENT NURSERY STOCK PRODUCTION

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Over the last 10 or 20 years, a revolution has been taking place in the nursery industry. Retail nurseries deal almost exclusively with containerized plants which can be handled, transported and planted at almost any time. Conifer seedling produces are adding greenhouse complexes to provide container or "plug" seedlings to help avoid the availability, mortality and planting shock problems associated with field-grown stock. Methods are being investigated which will allow the grower to eliminate inclement weather losses, such as those caused by unexpected frosts and dry spells, and provide a system of production not dependent upon the traditional spring labor forces required to compress huge quantities of work into several weeks. New propagation processes will enable the nurseryman to reproduce, for himself, sufficient quantities of best selling ornamental cultivars and thereby avoid the supply problems faced by other retailers.

At Michigan State University, research has been progressing and experience has been gained in this field of controlled environment nursery stock production; we would like to share some of our results with other growers.

SPECIES AND SIZE REQUIREMENTS

To effectively prescribe controlled growing conditions for plant material, it is important to specify whether hardwoods or conifers are to be produced and stock should be grouped accordingly. Lighting, heating, watering and essentially all other provisions may vary significantly when growing one type or the other. Producing forest tree seedlings for large scale plantings will require substantially different production facilities than necessary for retail potting stock. One must decide what target quantity and size is required in order to efficiently utilize a controlled environment.

MATCH CONTAINER TO SIZE GOALS AND PRODUCTION PHILOSOPHIES

In keeping with the basic goal of trying to completely regulate plant growth for optimum benefit, containerization is generally considered of paramount importance. This will allow each individual tree its own root environment free from competition by adjacent seedlings and results in maximum uniformity

for a given crop. In addition, containers allow the transfer of seedlings from the shadehouse to the field without severing large number of feeder roots thereby reducing transplant shock.

There are probably almost as many container systems as growers themselves and certainly each container has corresponding advantages and disadvantages. The Leach tubes are hard plastic bullets which fit into a receptacle and are easily rearranged for consolidating filled cavities or grading for shipping purposes. The soft plastic styroblock and hard plastic multipot have extruded cavities which are not removable but provide a plug plant without the inconveniences of handling many individual tubes. The styroblock can be reused 3 or 4 times and the multipot 8 to 10 times. The Japanese paper pot and Kys peat sticks are containers which can be planted with the seedling. This allows very little of the accompanying soil to be lost in transit so root disturbance is kept to a minimum.

The paper pot must be filled with soil as all the others; however, the peat stick is made of a compressed medium which is ready for wetting and sowing. To aid in plug extraction the book planters, such as Rootrainers, were designed. These units lay flat in storage but when closed form cells which can be filled with a soil medium. When the seedlings reach the desired size, the "books" are opened up and the plants extracted with little soil ball disturbance.

Probably the most flexible container system is the plant band system used in the Forestry Department at Michigan State University. Paperboard containers are inserted into polyethylene (high density) receptacles one foot square. Their square shape controls root curling and the open bottom design encourages air pruning of roots. Different size plant bands can be substituted to generate seedlings ranging in size from 6″ blue spruce, (*Picea pungens*), to 3′ black walnut, (*Juglans nigra*), using the same basic components.

One key consideration which should be focused upon at the beginning is the degree of production system mechanization desired. Using highly mechanized facilities, it is possible to produce a million forest tree seedlings with only two employees. The styroblock and multipot are probably the best suited for mechanized filling and sowing equipment. One problem, however, is that it is not feasible to produce 3′ English oaks, (*Quercus robur*), or sugar maples, (*Acer saccharum*), with the block sizes available.

MATCH SOIL MEDIUM TO CONTAINER

Once a container is chosen, the next step is to determine the growing medium. A mixture of peat, topsoil and sand has

been a longtime favorite for potted plants, but with rising greenhouse overhead costs, many growers have switched to soilless media. Mixtures free from pathogens, herbicides and weed seeds, and which vary little from year to year provide perfect substrates for total growth control and maximum yield. Shipping costs are lower for the finished plant due to the lighter weight soil mix. The most common mixes contain approximately 50% milled Canadian peat moss and various percentages of vermiculite, perlite, sand, or bark.

The goal is to develop a mixture which works best with a specific container and growing system. It is important to employ a mix which, when compacted, will maintain the proper balance between moisture and aeration and permit a firm soil plug to be extracted at harvest time. Coarse mixtures with perlite score the inside of small styrofoam cavities, thereby reducing reuse life, but may be required in deeper containers to prevent waterlogging. When using a commercially prepared mix containing 50-50 peat-vermiculite, we found it necessary to keep the soil almost bone dry to avoid yellowing from excess water on jack pine (*Pinus banksiana*), and western white pine (*Pinus monticola*). Since then we have used a mixture of equal parts of Canadian peat, #3 vermiculite, and perlite; this works well with over 50 species. The only problem we have encountered with this mix is a lack of firmness in the soil plug. This problem has been resolved in two ways — by slightly greater compaction at the time of filling and by increasing the vermiculite fraction in the mix.

THE CONTROLLED ENVIRONMENT

One must next choose a suitable facility in which to control the environment to achieve the highest yields for given crops. This can vary from a large greenhouse complex to a growth chamber. Excellent results have been attained with plants grown on a growth frame in an enclosed room with exclusively artificial light. Still another possibility which shows promise is a hybrid of these two extremes and consists of multiple layers in a standard greenhouse. The chief benefits of a 2-layered production scheme is the ability to produce twice the number of plants without investing in and heating another structure and at the same time use solar energy rather than electricity for most of the lighting.

Whatever construction is chosen, the temperature should generally average 21° to 29°C (70° to 75°F) with extremes not lower than 10°C (50°F) or higher than 30°C (85°). In many climates cooling pads are mandatory for adequate cooling during summer days. With poly greenhouses, the humidities are usu-

ally high enough to make additional humidification unnecessary. In an air conditioned growth room, however, humidifiers are desirable.

Other than the obvious temperature considerations, the single most important environmental factor to be regulated for nursery stock production indoors is photoperiod. Night lighting is essential for most species to keep the plants in an actively growing phase. The result is that 3 or 4 years of growing time can be telescoped into one continuous production phase of 4 to 9 month duration. To effect this physiological control, red light (650-700nm) must be used continuously or for short periods at properly spaced intervals during the dark hours. Cool-white fluorescent lighting at approximately 40 foot candles is effective if continued at night to provide at least an 18 hour day. This would amount to roughly forty 4-foot 40-watt, 2-bulb cool-white fluorescent fixtures in a 30′ × 96′ house. At our greenhouses we use fluorescent lights which are switched on in the evening and remain on long enough to extend the photoperiod to 20 hours. Incandescent sources provide light rich in the red wavelengths, and can be cycled in short intervals and be, therefore, less costly. The Colorado State Forest Service at Fort Collins, Colorado schedules their lights to run for 25 seconds every six minutes and this is enough to "trigger" the plants for continuous growth.

If only artificial light is used in a growth room, cool-white fluorescent high-output lamps @ 900 ft. c are very effective in providing blue, yellow, orange, and some red wavelengths for good growth response. An even better spectrum is achieved when incandescent lamps are included at the ratio of 1 incandescent for every 3 fluorescent units to provide a better red-blue balance.

SEEDING

It is of paramount importance to grow a crop from genetically superior seed, that is, seed with proven qualities of high germination, superior color, growth rate or any other desired characteristic. Pretreatment of seeds is required in some species. Black walnut, and sugar maple need moist stratification at 4° (38°F) for 3 months while others such as white birch, (*Betula papyrifera*), blue spruce and Douglas fir, (*Pseudotsuga menziesii*) need little or no stratification. At MSU we sow seed at a density of 3 to 5 seeds per cell depending on germination test results and cover lightly with medium to a depth of 1½ times seed thickness.

After misting several times daily to prevent surface drying, the seedling hypocotyl should emerge in about 1½ weeks. A few days after sowing we treat the surface with a light application

of benomyl to control damping-off fungi and repeat the procedure at 2 weeks. At 4 weeks, seedlings from overfull cells are transplanted into empties and at 6 or 8 weeks excess seedlings are thinned so that each cell contains only 1 tree. Barber shears work well for snipping unwanted germinants.

FERTILIZING AND WATERING

Prior to sowing, the soil medium should be fertilized several times with a fertilizer complete with trace elements such as Peters 15-16-17 or 20-19-18. The medium should also be watered with clear water to thoroughly moisten it for sowing. The seedlings should be fertilized once per week for approximately 6 weeks with a full strength solution with one such application containing STEM micronutrient mix. After 6 weeks, a switch to 25-0-25 is necessary to keep phosphorus buildup from occurring and upsetting other nutrient balances.

Occasionally, additional amendments are required. Calcium sulfate (gypsum) can be blended in with the soil at time of mixing or "salted" on the surface and rinsed in at a rate of 15 to 20 lbs per 100 sq ft. Chelates of zinc, iron, manganese, or copper may be necessary to correct deficiencies. Magnesium sulfate (Epsom salts) at 10 lbs/100 gal is effective as a foliar spray to green up chlorotic, magnesium deficient leaves. Soil samples taken from each species at 3 or 4 week intervals should be analyzed by a reliable soils lab. Posting the results indicating present nutrient status will insure that deficiencies are corrected promptly and toxicities will be avoided before they occur.

For most species, the quantities listed in Table 1 have proven to be generally sufficient and safe to guide our fertilizer program. These figures are based on a saturated paste extract method of soil analysis.

Table 1. Fertilizer salt mix.

Parameter	Level or Concentration
pH	4.5-5.5
Nitrate nitrogen	80-150 ppm
Phosphorus	10-20 ppm
Potassium	120-200 ppm
Calcium	150 ppm
Magnesium	>60<120 ppm
Soluble salts	150-250 mhos $\times 10^{-5}$
(mhos $\times 10^{-5}$ mult. by 6.4 gives ppm of sol. salt)	

Enhanced carbon dioxide levels up to 2000 ppm can double the growth rate of some plants and are easily provided by a gas-fired CO_2 generator.

PEST PROBLEMS

Once a crop is sown, optimum conditions provided for such rapid growth that it is critical to maintain control over pests and other cultural problems. Overwatering could easily have been the cause of at least 50% of the crop failures we have studied, so some method of evaluation and monitoring soil moisture is desirable.

For insect threats there are methods available for adequate control. We have tried to maintain predator mites to control two-spot spider mites (*Tetranychus telarimus*). We have released tiny wasps, (*Incartia formosa*) to parasitize white fly eggs and provided ladybugs and praying mantis to help moderate populations of some other harmful species. When an outbreak occurs, however, all ideals of biological control are shoved aside and judicious use of pesticides is essential.

For sucking insects such as aphids, lindane or malathion is good for immediate control, but a systemic such as Orthene is more thorough. Control for two-spot mites can be achieved with Plictran. Sevin works well on chewing insects such as caterpillars and leaf beetles. For light infestations of white flies or fungus gnats, yellow boards covered with tanglefoot provide some control, but with heavy populations, closing the house and releasing an aerosol bomb containing Resmethrin is more effective. For soil insects such as fungus gnat larvae or root weevils a dilute malathion, chlordane, or diazinon soak can be used.

Mechanical traps and treated bait such as Ramik are sufficient to avoid rodent damage. We have had countless nuts of English oak dug up, assorted spruce seeds buried in larch (*Larix* sp.) experiments, and various hardwoods chewed off at the base by these unseen "visitors of the night".

It becomes evident that a highly artificial environment devoid of most natural buffers, is very sensitive and must be monitored closely. Under ideal conditions for plants, we often find ideal conditions for pests and pathogens. The so called "salad bar" of greenhouse crops must be constantly monitored to avoid massive outbreaks and the infected plants removed if nothing else. Here containerization allows the flexibility of efficient mobility not found in other systems.

RECORD SYSTEM

Another technique to insure the highest crop success from one year to the next is the employment of a comprehensive record system. This begins with a stroll through the greenhouse facility every couple of hours and up each aisle at least once per day. Look for tears in the poly, holes, cracks, broken fan belts, water lines off, pumps or nozzles plugged, and so forth.

Jot down any observations relating to the condition of the stock such as leaf wilting, curling, or chlorosis, insects, etc. The minimum and maximum temperature should be recorded daily and preferably graphed by a hygrothermograph to indicate fluctuations. Every watering, fungicide, and insecticide application should be logged and described as to concentration, dosage, method of application and time applied.

In addition, a sample of plants should be measured weekly and their height graphed to indicate whether or not the crop is progressing satisfactorily. Using well-recorded growing techniques, one can not only help ensure himself greater crop uniformity but he can also describe his past actions in a form that is easily understood by future employees or other growers from whom he is seeking advice.

GROWING TIPS

We are continually screening various species' response to controlled environmental production and several recommendations can be made. When sowing conifer seeds in the cloudy winter months in a dark, humid greenhouse, a fungicide such as benomyl should be applied soon after sowing and continued weekly for 4 weeks to avoid damping-off. It is very important to follow this schedule for 6 to 8 weeks with Douglas-fir seed, or grey mold (*Botrytis cinerea*), will claim numerous seedlings.

It has been our experience that trembling aspen, (*Populus tremuloides*) and sycamore, (*Platanus occidentalis*), generally need foliar applications of magnesium to reverse chlorosis. Green ash, (*Fraxinus pennsylvanica*), has required applications of iron chelate to ensure proper leaf color. Jack pine needs high iron concentrations in combination with low (4 to 4.5) pH to provide healthy green stock. If full strength fertilizer solutions are used on warm or sunny days, slight burning and leaf cupping might occur on hardwoods.

In our greenhouses, aspen, fruit trees, and willow species invariably are infested by two-spot spider mites in about the 3rd month. Sycamore, honeylocust, (*Gleditsia triacanthos*), northern white cedar, (*Thuja occidentalis*), and green ash will probably get mites, especially if they are in the same greenhouse as the other hardwoods just mentioned. Sycamore often gets large aphid populations also. English oak is likely to harbor aphids and occasionally a few mites.

Avoid spraying pesticides on warm or sunny days. Cloudy days or evenings are ideal times to spray. Care should be used when spraying malathion on European black alder, (*Alnus glutinosa*), as it has caused complete defoliation subsequent to

an application.

We would not recommend the constant injection of fungicides into the watering system. In fact, they should be used only for direct control of specific problems. By accidentally eliminating the wrong population of fungi it is conceivable that another more damaging population might become even more extensive. One should always experiment on a number of plants before subjecting a whole crop to an unfamiliar fungicide. We almost totally ruined a section of blue spruce seedlings several years ago by applying a toxic level of the fungicide, Dexon.

When applying water, avoid heavy sprays which cause the seedlings to bend over, or irreversible stem curvature may result. Watering should not be done in the heat of the day as the temperature shock to the plants can be damaging. Partial warming of the irrigation water will help to reduce shock to the plants.

HARDENING OFF

When a crop of seedlings approaches the desired height the supplemental lighting should be discontinued and hardening off procedures started. A normal photoperiod will permit cessation of growth and, on conifers, one should expect to see bud development beginning after 3 weeks. During the months of June through August in Michigan, the seedlings can be taken directly from the greenhouse to a shadehouse. Actively growing seedlings of larch might turn yellow and defoliate if no protection is provided from the summer sun. Birch will have some scorching and leaf curl.

For those seedlings needing overwintering, good success has resulted from placing units tightly together directly on the ground, covering containers completely with sawdust and thoroughly soaking with water in the fall. Fencing and poison bait are needed to avoid rabbit and mice damage.

To harden seedlings off in the winter months, the greenhouse temperature should be adjusted to a maximum of 13° (55°F) during budset. Approximately 3 or 4 weeks after beginning short days, the temperature can be lowered to 10°C (50°F), a week later to 7°C (45°F) and so on down to 3°C (37°F). Most conifers require 4 to 6 weeks of chilling at less than 5°C (40°F) to permit reflushing when the temperature is increased. If a crop of blue spruce or English oak reaches the targeted size and is actively growing at the end of February, one should not expect those seedlings to reflush in May or June after hardening, shipping and planting.

OPERATING PHILOSOPHY

One rather blunt recommendation can be offered for those

interested in controlled environment nursery stock production and that is "don't be cheap". Hire a good manager who is a dedicated jack-of-all-trades type of person and don't let him go. Put financial incentives on obtaining successful crops and allow him the authority to direct the operations. One large company employed a staff of six people individually trained in pathology, ecology, physiology or a related specialty. There must be, however, final one-point responsibility on the part of the grower and he must have a reliable staff who can handle the program in his absence.

The greenhouse should have safe, automatic temperature regulating devices rather than manual vents or doors. If at all possible, one should have backup systems for water, electricity, and heat as it is not hard to lose an entire crop of a million seedlings in one day during an unexpected power failure.

LOOKING AHEAD

The future of controlled environment agriculture is going to be filled with challenging opportunities. New greenhouse design, perhaps sunken below ground level, will probably incorporate passive heat storage and thermal blanket systems. We might see Christmas tree growers and high value hardwood producers planting large containerized trees for rapid plantation establishment. We will see various combinations of tissue culture, vegetative reproduction and controlled environment greenhouse growing being employed to generate new and traditional exotics in fractions of the usual time. Species with high unit values can be cultivated from a seed to a saleable potted plant within 1 year. This will enable those growers with indoor production facilities greater independence than their competitors who must depend on shipping in bareroot stock from other states.

Controlled environment production offers a flexibility which does not exist with outdoor facilities. Research is being done continually to locate the best seed sources, determine optimum growing conditions and discover potential production practices for each species of interest to commercial nurserymen. Conventions and meetings are vitally important to having an effective program of controlled environment production in order to share and discuss our successes and failures. These will provide encouragement and knowledge to enable us all to make dramatic advances in this new and exciting method of nursery stock production.

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GERALD KLINGAMAN: We have tried some plants in plant bands and obtained nice whips. I am worried about the rooting after we plant them in the field. Do you have any thoughts on whether the roots will continue to concentrate at the bottom or will branching occur further up?

JOHN HART: That has been a problem. A few years ago our plant band did not have any holes in it and it was deep. Perhaps with things that are going to be balled and burlaped after a few years it may be better to use a shorter band so you will not have a concentration of the roots coming out of the bottom.

GERALD KLINGAMAN: Have you done any work with mycorrhizal fungi?

JOHN HART: We tried it once but could not keep it going. In a greenhouse with optimal fertilization practices we feel that the mycorrhizal influence will not be that strong.

VOICE: What do you use to control green algae?

JOHN HART: We do not get much algae unless we overwater. The surface usually dries out quickly.

BRUCE MacDONALD: We have a problem in England with algae and use Algofen and Gloquat.

DON SHADOW: What fungicides do you use to control damping-off?

JOHN HART: We use benomyl. We also use Canadian peat which helps to control damping-off.

BRUCE BRIGGS: Have you worked with the "bug light" on growth acceleration?

JOHN HART: Most of our work is done with cool-white fluorescent tubes. One can use incandescent lamps to obtain red light.

AUTUMN COLOR FROM UNUSUAL WOODY PLANTS

GARY L. KOLLER

Arnold Arboretum
Jamaica Plain, Massachusetts 02130

Autumn in New England and across parts of North America is a special time, for the countryside blazes with color from a wide array of trees, shrubs, and vines. While horticulturists and homeowners are familiar with colorful standards such as sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), winged euonymus (*Euonymus alata*) and bradford pear (*Pyrus calleryana* 'Bradford'), there are plants just as colorful which remain virtually unknown. The plants which follow are spectacular autumn performers at the Arnold Arboretum and ones which I believe deserve review and testing by professional plants people.

TREES

Acer heldreichii — Balkan maple

Autumn color: clear to golden yellow
Size: 30-50 feet tall, 30-50 feet wide
Hardy to −25°C (−10°F) (perhaps lower if more widely tested)

Balkan maple is native to Albania, northern Greece nd southeast Yugoslavia. It has a deeply-lobed leaf which is visually attractive throughout the growing season. Branching structure is strong. This species of maple has proven successful enough at the Arnold Arboretum for numerous spontaneous seedlings to be occurring. Seeds germinate following 3 months cold stratification at 50°C (40°F).

Acer maximowiczianum (Syn.: *A. nikoense*) — Nikko maple

Autumn color: orange to orange-red to reddish-purple
Size: 25-40 feet tall, 25-40 feet wide
Hardy to −33°C (−30°F)

Nikko maple is small in stature, structurally strong and of easy culture. It remains little known outside of its Japanese and central China homelands because of a lack of viable seeds and a double dormancy which slows germination of the sound seeds. Seeds are available commercially from Fujita Seed Co., Ltd., P.O. Box 211, Osaka Central, Osaka, Japan.

Acer pseudo-sieboldianum — purplebloom maple

Autumn color: yellow to red-orange
Size: 10-20 feet tall, 10-20 feet wide
Hardy to approximately −36°C (−30°F).

Purplebloom maple which is native to Korea and Northeastern China is *almost unknown to North America. It is noteworthy because it possesses* desirable landscape traits similar to Japanese maple (*Acer palmatum*) and full moon maple (*Acer japonicum*). While normally a large shrub, one specimen at the Arnold Arboretum approximately 65 years old is 18 feet tall and 25 feet wide. The serrated leaves possess 9-11 lobes, have a rich green summer color and an appearance similar to several cultivars of *Acer palmatum*. Flowering occurs in April with hanging clusters of purplish flowers which are ornamen-

tal when viewed against the unfolding spring foliage.

Arboretum taxonomist Richard Weaver describes *Acer pseudosieboldianum* as having the most spectacular autumn color of any plant he observed during a 1977 trip to Korea. He further states that this maple fills an ecological niche almost identical to *A. palmatum*.

Limited testing indicates that this tree may prove to be hardy in areas with low winter temperatures of −31°C (−25°F) to −36°C (−30°F) and this would make the species useful in locations where *Acer palmatum* and *Acer japonicum* cannot survive.

Propagation using cuttings has been attempted at the Arnold Arboretum. A 40% success rate was achieved, in limited testing, using a rooting hormone of 1% IBA and taking the cuttings in mid-June.

Acer tegmentosum Manchurian striped maple

Autumn color: clear yellow
Size: 20-30 feet tall, 15-25 feet wide
Hardy to approximately −36°C (−30°F) (perhaps lower if more widely tested)

Acer tegmentosum belongs to the striped-bark group of maples and bears stems and twigs which display white stripes on a green or brown background. The landscape combination of the attractive bark, rich yellow autumn color and preference for a lightly-shaded growing situation indicates that this tree may be useful in specialized urban landscape such as courtyards. Manchurian striped maple is native to Korea and Northeast China and is closely related to our native moosewood (*Acer pensylvanicum*).

Propagation experiments conducted at the Arnold Arboretum indicate that 75 cuttings were taken on August 15 from a parent tree which was 31 years old. Cuttings were treated with Hormodin No. 3, inserted into coarse sand and placed within a closed case. By September 17, 67 cuttings had rooted and were potted up.

Acer triflorum three-flowered maple

Autumn color: orange to scarlet
Size: 25-40 feet tall, 25-40 feet wide
Hardy to −33°C (−30°F)

Brilliant is the only term to describe the autumn foliage of the three-flowered maple whose fall coloration is a serious rival for the display put forth by sugar maple (*Acer saccharum*). An additional landscape feature is showy bark color which ranges from tan-brown to brownish-white. This tree is closely related to paperbark maple (*Acer griseum*) but grows twice as fast. The largest specimen of this Korean tree at the Arnold Arboretum is 56 years old and is 35 feet tall with a 35-feet spread.

Seeds of *Acer triflorum* have a double dormancy and require two years in outdoor seed beds to germinate. A 50% success rate was achieved by taking cuttings from forced-stock plants in February. The cuttings were not treated with rooting hormone; they were inserted in a medium of sand and placed within a closed case.

Pseudolarix kaempferi golden larch

Autumn color: golden yellow
Size: 40-60 feet tall, 30-40 feet wide
Hardy to −29°C (−20°F)

This magnificent deciduous conifer is native to but rare in China. Growth is irregular from tree to tree and the general impression is one of asymmetry. Foliage is fine in texture. Cones are highly ornamental and resemble tan ar-

tichokes. Upon ripening, the cones shatter and disperse the seeds. Plants at the Arnold Arboretum are distinctly alternate in cone production; there was a prolific crop in 1978 and almost none in autumn 1977 or 1979. A small grove of trees at the Arnold Arboretum produces abundant viable seeds which germinate best with a pretreatment of 60 days at 5°C (40°F).

Sorbus aucuparia F. Beissneri — Beissner European mountain ash

Autumn color: golden yellow with pink tints
Size: 20-25 feet tall, 10-15 feet wide
Hardy to −37°C (−33°F).

Autumn color is one of several features which make this plant worth review. It bears white flowers in May followed by clusters of yellowish fruit in autumn. The most significant trait is the stem color which is copper to orange and is bright enough to be visible and distinct from a quarter-mile away. The habit of Beissner European mountain ash is upright, making it useful in narrow spaces.

This cultivar originated as a single individual found in the mountains in Germany in the late 1800s. It can be maintained by grafting it onto *Sorbus aucuparia* understock.

Sorbus rufoferruginea — flameberry mountain ash

Autumn color: brilliant red to purple red
Size: 15-20 feet tall, 8-12 feet wide
Hardy to −23° (−10°F) (perhaps lower if more widely tested)

Flameberry mountain ash is native to the mountains of Honshu, Shikoku and Kyushu in Japan. It bears terminal clusters of white flowers in May, followed by small reddish fruit in October. It needs to be evaluated for resistance to borers.

This plant falls within the *Aucuparia* section of mountain ash which indicates that it could be grafted or budded onto *S. aucuparia* understock. Seeds germinate after 3 months of cold at 5°C (40°F).

Sorbus esserteauiana — Chinese mountain ash

Autumn color: yellow, orange, red and bronze are determined by the amount of sunlight
Size: 20-30 feet tall, 15-20 feet wide
Hardy to −36°C (−30°F) (perhaps lower if more widely tested)

In May the tree bears large terminal clusters of white flowers followed by orange-yellow fruits in the autumn. Upon ripening, the fruits are quickly eaten by birds. This species of mountain ash shows no sign of borer damage at the Arnold Arboretum.

According to E.H. Wilson in *Plantae Wilsonianae*, he found this plant growing in Western Szechuan, China on cliffs and in woods, describing it as "rare".

Seeds of this species germinate after being stratified for 3 months at 5°C (40°F). Scions can be grated onto *Sorbus aucuparia*.

Sorbus serotina

Autumn color: brilliant red
Size: 15-20 feet tall, 10-12 feet wide
Hardy to −29°C (−20°F) (perhaps lower if more widely tested)

A large shrub or small tree native to Korea, *Sorbus serotina* has a delicately-textured leaf composed of 15-17 sharply-toothed leaflets. The plant has terminal clusters of small white flowers followed by clusters of yellow-

orange fruit in autumn. The fruit color contrasts ornamentally against the autumn foliage.

S. serotina should bud or graft successfully onto *S. aucuparia* understock. Seeds germinate after 3 months of cold at 5°C (40°F).

SHRUBS

Aesculus parviflora — bottlebrush buckeye

Autumn color: clear yellow
Size: 8-12 feet tall, 6-18 feet wide
Hardy to −36°C (−30°F)

A large, multi-stemmed, spreading shrub which bears 8- to 12-inch tapering clusters of white flowers in July. It is native to Georgia and Alabama where bottlebrush buckeye grows as an understory plant in wooded areas; it also thrives in full sun.

Because of the toughness of the plant and adaptability to a wide range of growing situations, this plant might be ideal for colonizing areas along superhighways and as a foundation plant for large institutional buildings.

Seeds germinate without pretreatment but they must be gathered quickly for they are a favorite food for squirrels. The plant can also be stock-increased by division and cuttings.

Aronia arbutifolia 'Brilliantissima' — red chokeberry

Autumn color: crimson red
Size: 6-10 feet tall, 4-8 feet wide
Hardy to −29°C (−20°F).

Brilliant is the only term to describe this native plant which inhabits bogs and low pinelands from Florida and Louisiana, north to Minnesota and Nova Scotia. This shrub bears clusters of small white flowers in May flowered by bright purple-red fruits which provide a distinct contrast against the colorful autumn foliage. Fruits persist into the winter.

Aronia arbutifolia 'Brilliantissima' is easily propagated by greenwood cuttings taken in July.

Enkianthus perulatus — white enkianthus

Autumn color: yellow to scarlet
Size: 3-6 feet tall, 3-8 feet wide
Hardy to −23°C (−10°F).

This Japanese shrub bears a multitude of tiny white urn-shaped flowers in May. The bark on stems and branches is smooth and gray. A slow growth rate may be viewed as a disadvantage by nurserymen, but in the home landscape this slow growth rate can be used to advantage to create low maintenance landscapes.

Propagation success has been achieved by taking softwood cuttings in mid-June. The heel cuttings are treated with Hormodin No. 2, placed in equal parts of peat and perlite and placed under mist. Once rooted, the cuttings must be allowed to remain undisturbed through the first winter and potted only after they have resumed new season growth.

Euonymus hamiltoniana var. *yedoensis*
(Syn.: *E. yedoensis, E. sieboldianus*) — Yeddo euonymus

Autumn color: pink
Size: 8-12 feet tall, 8-15 feet wide
Hardy to −29°C (−20°F)

Yeddo euonymus bears fruit which is highly ornamental for weeks after the leaves have fallen. Capsules are rose-pink and upon ripening, open to display a shiny orange aril. This plant is high resistant to aerial salts; in Rhode Island mature plants thrive within a few hundred feet of the Atlantic Ocean. One disadvantage is that this Japanese shrub is susceptible to scale insects.

Propagation is easily accomplished through seed which results in plants displaying variation in form, autumn color and fruit productivity. Greenwood cuttings taken in July or August provide a means of perpetuating clonal material.

Fothergilla gardenii dwarf fothergilla

Autumn color: yellow-orange to scarlet
Size: 2-3 feet tall; 2-4 feet wide
Hardy to −29°C (−20°F)

A compact, multi-stemmed shrub which bears white flowers in May, dwarf fothergilla is native from Virginia to Georgia, but like so many worthwhile native plants, it has been neglected as a landscape plant. This small shrub tolerates an exposure of sun or shade, adapts to a wide range of varying soil types. As a result, it appears to be a perfect candidates for extensive use by landscape architects, since it can be used as an understory plant in groups or masses. It is being grown and marketed in containers by Herman Losely and Son, Inc. of Perry, Ohio.

Propagation records at the Arboretum indicate that cuttings rooted 100% when taken the 26th of July, treated with Hormodin No. 3, placed in a medium of equal parts peat and perlite and placed under mist. This is a plant which should be overwintered in the propagation container and transplanted only after new season growth resumes in the spring.

Itea virginiana Virginia sweetspire

Autumn color: red to reddish purple
Size: 6-10 feet tall, 6-8 feet wide
Hardy to −29°C (−20°F).

Another neglected American native shrub which ranges from New Jersey southward to Florida and west to Louisiana, *Itea virginiana* forms a large, multi-stemmed mass which normally grows along streams in moist, poorly-drained soils. It also occurs in wooded areas, but where it does not receive sufficient light, the plant becomes thin and straggly. Flowering occurs in July when terminal clusters of fragrant white flowers appear. In autumn, the tan seed capsules are handsomely displayed among the reddish-purple autumn foliage.

This plant is being grown by Losely Nursery in Perry, Ohio and they report that the plant is sometimes subject to winter damage when temperatures reach −29°C (−20°F) and where the plant is in low wet soils.

Itea virginiana is easily propagated by stem cuttings. High percentages of rooting occur using a five-second quick dip of 8000 ppm of IBA in 50% alcohol. The cuttings are inserted in equal parts of peat and perlite and placed under mist. Cuttings will root in high percentages any time of the year.

Lindera angustifolia narrowleaf spicebush

Autumn color: dull but attractive rose-red
Size: 8-12 feet tall, 8-10 feet wide
Hardy to approximately −27°C (−17°F).

This rare Chinese shrub was brought to our attention by Bill Collins, Horticulturist for American Garden Cole in Circleville, Ohio. The autumn foliage

is rose-red and then the leaves turn brown and persist throughout the winter providing the shrub with an evergreen-like effect when viewed from a distance. Branching is multistemmed and the total effect is that of a rounded mass. Mr. Collins reported that their plants suffered stem damage when winter temperatures hit −17°F but they recovered the following summer.

Seeds of *Lindera angustifolia* germinated after being stratified 3 months at 40°F. We have not been successful in rooting cuttings.

Lindera obtusiloba — Japanese spicebush

Autumn color: butter yellow
Size: 15-20 feet tall, 12-18 feet wide
Hardy to approximately −29°C (−20°F).

A large, multistemmed, rounded shrub valued for its early-season flowering period, female plants of *Lindera obtusifolia* are said to bear attractive small yellowish flowers which have a slightly lemony fragrance. E.H. Wilson in *Plantae Wilsonianae* describes this plant as being common in the woods of Western Hupeh, China and in spring, "very conspicuous on account of the brilliant colour of the young leaves".

Preliminary tests conducted at the Arnold Arboretum indicate that cuttings taken in early June can be rooted using a five-second quick dip of 8000 ppm IBA in 50% alcohol. Cuttings are placed in a medium of equal parts sand and perlite, under mist.

VINES

Vitis amurensis — Amur grape

Autumn color: crimson to purple
Habit: vigorous climber
Hardy to −29°C (−20°F)

This grape is native to northeast China and adjacent areas in the Soviet Union. In addition to purplish autumn color, the vine bears small grapes about ⅓ inch across, containing 2 to 3 seeds.

While grapes are not often considered as landscape plants, this species could be used to create quick shade on a trellis or arbor, or it could be used to dress up some of the drab fencing used in urban areas.

Seeds germinate readily after 3 months of stratification at 5°C (40°F). Both hardwood and greenwood cuttings root easily.

Vitis davidii — Briar grape

Autumn color: brilliant red
Habit: vigorous climber
Hardy to −23°C (−10°F)

Briar Grape bears large heart-shaped leaves and old branches have prickles. Fruit is about one-half inch in diameter, black and is said to be edible and sweet.

Seeds and cuttings are treated as for *Vitis amurensis*.

Descriptive information and details concerning propagation is sparse for each of the plants described and any plant could make an interesting project for an enterprising student of horticulture or botany. All of the foregoing plants are presently growing at the Arnold Arboretum in Jamaica Plain, Massachusetts. Climatic data for this site is as follows:

Maximum temperature	27°C (100°F)
Minimum temperature	−22.7°C (−9°F)
Average length of growing season	165 days
Average rainfall	(109.2 cm) 43 inches

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RALPH SHUGERT: Question for Jack Alexander. How are you propagating *Lindera obtusiloba*?

JACK ALEXANDER: We have had some success with softwood cuttings when treated with 8,000 ppm IBA in 50% alcohol.

HENRY KOCK: Are *Acer pseudo-sieboldianum* and *A. sieboldianum* synonymous?

GARY KOLLER: In *A. sieboldianum* the leaves have 7-9 lobes while *A. pseudo-sieboldianum* has 9-11 lobes. *A. pseudo-sieboldianum* is about 20°F more cold hardy.

BOB McNIEL: The plants of *Acer tegmentosum* I have seen have not been growing well when exposed to full sun. Can you comment on this?

GARY KOLLER: Our most successful plants are growing under light shade. This plant may therefore have an advantage in city conditions where shade is viewed as a problem. The plant also declines rather fast if the bark is injured.

ED MEZITT: *Sorbus americana* has always been a rather weak shrubby plant for us. Are there stronger plants available?

VOICE: We growth nothing but S. *americana* in the Chicago area. It is native to Lake County, Illinois and generally grows as a clump. It lives longer, gets less borers and has no fireblight. It also has better fall color than *Sorbus aucuparia*.

INTRODUCTION, TESTING, AND EVALUATION OF ORNAMENTAL PLANTS[1,2]

H.S. BHELLA[3]

North Central Regional Plant Introduction Station
USDA-SEA-AR, Iowa State University
Ames, Iowa 50011

Plant introduction, in its broadest sense, is the introduction of wild plants into cultivation. Throughout the development of civilization, wherever man has gone, he has always taken along seeds of the plants with which he was familiar. The search for new or better plants was often an underlying reason for many of his explorations into unknown parts of the world.

THE HISTORY OF PLANT INTRODUCTION

Plant introduction in North America existed long before the colonial period. Only a few plants, from which the United States derives the major portion of its food and fiber, are native to North America north of Mexico. Some of the most important native plants, in terms of economic worth to U.S. agriculture, are sunflower, cranberries, blueberries, strawberries, conifers, and hardwoods. All of our major crops and most of our important fruits and ornamental plants have been introduced from foreign lands.

Although numerous valuable crop and plant species had been previously introduced, it was not until 1812 that the government of the new nation turned to any official consideration of agriculture and its development. Much progress was made through efforts of various individuals such as Benjamin Franklin and Thomas Jefferson. The latter was especially active

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[1] Joint contribution from the U.S. Department of Agriculture, Science and Education Administration, Agricultural Research, in cooperation with the Iowa Agriculture and Home Economics Experiment Station, Ames, IA 50011.
[2] Journal Paper No. J-9765 of the Iowa Agriculture and Home Economics Experiment Station. Project No. 1018.
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while Minister to France, sending back seeds of many grasses, cereals, and vegetables and cuttings of olive and other fruit trees.

The U.S. Government early recognized the need for a continuing search for more adaptable crops. In 1819, the Secretary of the Treasury instructed all U.S. consuls to send useful plants back to the United States. This is the first official record of U.S. Governmental activity in the interest of foreign plant introduction. In 1827, President John Quincy Adams issued another circular instructing all U.S. consuls to "collect, and transmit seeds and plants, with information regarding climate, soil, propagation, cultivation, insect pests, and uses and agricultural literature." Several consuls participated and sent plant introductions to the United States. One of the consuls, Dr. Henry Perrine, in Campeche, Mexico, sent back many economic plants, and urged expansion of this program.

From 1836 to 1862, the Patent Office, U.S. Department of State, handled plant introduction activities. In 1836, the Patent Office was reorganized, and Henry L. Ellsworth was appointed Commissioner. Through his efforts, he secured in 1839, the first U.S. Government appropriation of $1,000 for the collection and introduction of seeds and plants and the gathering and publishing of agricultural statistics. Ellsworth established the Federal Free Seed Program. By 1877, more than 2,000 packets of seed plus 150,000 packages of plants for cuttings were dispersed free of charge by the U.S. Government under this program.

In 1849, the Patent Office was transferred from the State Department to the Department of Interior, and a Commissioner of Agriculture was appointed to take charge of plant introduction activities. These events eventually led to the establishment of the U.S. Department of Agriculture in 1862. The new department did not receive cabinet rank at first and continued to be headed by a commissioner. Finally in 1899, because the department had developed and expanded so much, and the pressure from agricultural interests was so great, the position of Commissioner was raised to the cabinet rank of Secretary of Agriculture.

James Wilson, Director of the Iowa Agricultural Experiment Station, became Secretary of Agriculture in 1897, a position he held through three administrations. He was a man of broad agricultural interests and played a far-reaching role in the development of the U.S. plant exploration and introduction system.

Wilson brought together the scattered efforts of various divisions and established a new Section of Seed and Plant Introduction in 1898. The Secretary appointed David Fairchild, a dedicated plantsman, to head this new section with an appro-

priation of $2,000. Since then, all seeds and plants introduced by the U.S. Department of Agriculture have been given a PI (Plant Introduction) number. Plant Inventories are published annually by the U.S. Department of Agriculture.

This development was the first landmark in the evolution of the U.S. Plant Introduction System as we know it today, but there was one significant weakness. There were no centralized facilities available for permanent maintenance and preservation of the seed once it was introduced and used. Consequently, much valuable germplasm was lost during the first 48-year period of the new system.

The passage of the Research and Marketing Act of 1946 is a second landmark in the evolution of the plant introduction system. It presented the opportunity for establishing Regional and Interregional Plant Introduction Stations with funding and staff provided by both the federal and state governments.

THE NATIONAL PLANT GERMPLASM SYSTEM

The National Plant Germplasm System (NPGS) is a coordinated network of institutions, agencies, and research units in the United States, which works cooperatively to introduce, maintain, evaluate, catalog, and distribute all types of germplasm. The principal elements of the NPGS are (Figure 1):

Figure 1. The principal elements of the National Plant Germplasm System.

1) The SEA-AR Germplasm Resources Laboratory at Beltsville, MD;
2) SEA-AR Plant Introduction Stations at Glenn Dale, MD, and Miami, FL;
3) State-Federal Regional Plant Introduction Stations at Ames, IA, Experiment, GA, Geneva, NY, and Pullman, WA;
4) The State-Federal Potato Introduction Station at Sturgeon Bay, WI;
5) The SEA-AR National Seed Storage Laboratory at Fort Collins, CO;
6) The Interregional Virus Free Deciduous Tree Fruit Laboratory at Prosser, WA; and
7) A large group of federal, state, and private plant germplasm curators. For example, the U.S. National Arboretum, Washington, DC, is a principal curator of germplasm of woody ornamentals.

Coordination of the research and service functions of these elements is achieved at the state, regional, and national levels. Each state agricultural experiment station (SAES) and participating federal agency is represented directly or indirectly on technical committees related to regional or interregional sta-

tions. Scientists who serve as technical committee members on these projects, not only collaborate in the evaluation of plant introductions but also formally represent the NPGS and provide liaison among other scientists at their respective locations.

Some of the representatives of each technical committee are members of the USDA-SEA-AR Plant Germplasm Coordinating Committee, which is internally advisory to SEA-AR. Several representatives of each technical committee also are members of the National Plant Germplasm Committee (NPGC). The NPGC also includes representation from the National Council of Commercial Plant Breeders and Cooperative Research.

These cooperative units, which comprise the NPGS, have the general mission of providing plant scientists with the germplasm needed to carry out their research. The research programs supported in this way vary widely and include the breeding of new varieties for such purposes as resistance to diseases, insects, air pollution, temperature, moisture, salinity, and other environmental stresses; for increased yield and improved quality; for ease of harvesting, better processing, and longer storage; for beautification, noise abatement, erosion control, and resistance to fire; and as sources of anticancer medicinals, analgesics, and industrial chemicals.

The NPGS is well established and is functioning to fulfill the germplasm needs for minimizing the genetic vulnerability of major crops. An advisory group to the NPGS, the NPGC, continually reviews, makes funding recommendations, and advises administrators of the USDA and SAES on needs and goals of the NPGS.

PLANT EXPLORATIONS

Introduction of plant materials is accomplished through planned foreign and domestic explorations. Planned explorations result from requests initiated by breeders, plant scientists, commodity groups, etc. Proposals for plant explorations can be submitted by any of these persons or groups to the Coordinator of the Regional Plant Introduction Station in their region for review and possible funding by USDA-SEA-AR.

Plant germplasm collected through USDA-financed plant explorations becomes a part of the NPGS. The Plant Introduction Officer, Germplasm Resources Laboratory, Beltsville, MD, catalogs all incoming accessions, assigns PI numbers, makes taxonomic identifications, and distributes PI materials to the Reginal Plant Introduction Stations.

Germplasm also is entered into the NPGS from domestic research programs. This germplasm includes induced and natural mutations; cytological stock such as monosomes, trisomes, and

translocations; marker genes; species hybrids, breeding material with valuable combinations of characters; pest-resistant stocks; and obsolete commercial varieties that may have genes useful in the future. Research personnel who develop such material are obligated to call it to the attention of the appropriate Regional Plant Introduction Stations for inclusion into the NPGS.

Since 1898, some 434,000 plant introductions have entered into the NPGS. Over 190 foreign and domestic plant explorations have been funded by the USDA, more than 50 to collect ornamental plants.

Ornamental Plant Explorations. Many of our ornamental plants were brought originally from foreign lands by professional plant explorers who went on long and often hazardous journeys to collect ornamental plants. A few of the outstanding and dedicated plant explorers who made the USDA's plant exploration program truly successful are as follows:

NIELS E. HANSEN (1897-1906). Professor Hansen, Horticulturist at the Agricultural College of South Dakota, became the USDA's first plant explorer. The USDA's PI number 1 started with Hansen's collection from Moscow, Russia. His expedition was funded by the USDA and lasted from June, 1897, to March, 1898. The itinerary included eastern European Russian, Turkestan, Western China, and Siberia. Hansen made his second exploration trip to Russia in 1906.

Hansen sent thousands of seeds and plants to the U.S. Plant Introduction Office. Although the main objective of Hansen's trips was to collect alfalfa and forages, he sent several ornamental PI's of barberry, *Caragena*, crabapples, *Crataegus*, *Elaeagnus*, *Euonymus*, *Lonicera*, *Potentilla*, *Rhamnus*, and roses.

DAVID FAIRCHILD (1899-1933). Fairchild, the pioneer USDA plant explorer and first Head of the USDA's Seed and Plant Introduction Section, was one of the most successful and outstanding of the early 20th century U.S. plant explorers. He was highly competent, and many of his ornamental introductions from the Orient succeeded in the United States. He made eight plant exploration trips during 1899-1933. During his 1899-1903 trip to Japan, he brought back the first of the famous flowering cherry trees planted in Washington, D.C.

FRANK N. MEYER (1905-1918). Frank Meyer made four trips to Asia between 1905 and 1918 and brought several new species of *Euonymus*, Chinese elm, lilac, wild roses, *Viburnum*, and ornamental willows. Meyer found a dwarf lilac species on the high Wu-tai-shan mountain in northeastern China; the species was later named after him. This small lilac species, *Syringa meyeri*, blossoms as a very young plant and is especially treasured in modern landscape.

Meyer also collected pear seeds for rootstock purposes, which later resulted in the release of the Bradford ornamental pear. *Pyrus calleryana* 'Bradford', PI 209840 (a selection from PI 47261), is a beautiful, thornless, symmetrical, and upright-growing tree. It is loaded with white flowers during spring, occasionally followed by small brown fruits that are not edible. During the summer, it has dark green foliage which turns to gold-orange or red-mahogany during the fall.

JOSEPH F. ROCK (1911-1923). Joseph Rock, an Austrian plant collector, was first sent to Burma by the USDA in 1911 to search for the chaulmoogra tree (*Hydnocarpus kurzii*), the oil of which was used to treat leprosy. From Burma, he proceeded to China, India, and Siam, where he remained intermittently until 1923. Rock introduced many new species of lilies, azaleas, and rhododendrons to the United States.

JOHN L. CREECH (1955-present). John Creech, Director, U.S. National Arboretum, USDA-SEA-AR, Washington, D.C., is among the most active of modern-day leaders in the field of ornamental plant explorations. In 1956, he co-authored the USDA/Longwood Gardens (Kennett Square, PA) Joint Ornamental Plant Exploration Program, which resulted in 11 exploration trips in Asia, Europe, South America, and Australia.

Creech made eight plant exploration trips from 1955 to 1978 in northern India, Nepal, Japan, Hong Kong, Taiwan, Siberia, and the USSR and brought back a wealth of ornamental plant materials. The introductions collected by Dr. Creech are notable, not only for their immediate horticultural value, but also for their potential in plant breeding, such as disease resistance, ornamental characteristics, etc. The introductions of *Betula platyphylla* var. *japonica (PI 235128) and B. maximowicziana* (National Arboretum No. 39811) represent authentic material for the nursery trade and arboreta of two outstanding ornamental birches that had been represented by incorrectly identified or hybrid material.

In addition, Dr. Creech has introduced several hundred cultivars and wild species representing major plant groups such as *Abies, Acer, Adonis, Ardisia, Aucuba, Camellia, Chrysanthemum, Cotoneaster, Cryptomeria, Elaeagnus, Eurya, Hedera, Hemerocallis, Ilex, Lagerstroemia, Nandina, Pieris, Rhododendron,* and *Wisteria.*

New cultivars developed through breeding by Dr. Creech or selections made by him and others from his PI are as follows:

Chrysanthemum 'Montana' and 'Tokyo'
Cotoneaster microphylla 'Emerald Spray'
Euonymus fortunei 'Longwood'
Eurya japonica 'Winter Wine'

Hedera helix 'Yalta'
Ilex 'Albert Close', 'William Cowgill', 'Howard Dorsett, 'Edward Goucher', and 'Harry Gunning'
Juniperus conferta 'Emerald Sea'
Sedum spurium 'Royal Pink'
Rhododendron 'Bayou', 'Ben Morrison', 'Green Mist', 'Mrs. L.B.J.', 'Petite', 'Pink Ice', and 'Whitehouse'

NC-7 REGIONAL ORNAMENTAL PROGRAM

The members of the NC-7 Technical Committee, during their annual meeting in Brookings, SD, in January 1954, recognized that there was a lack of ornamental plants capable of withstanding the extreme weather conditions in the North Central Region. The committee approved an ornamental evaluation project, which led to the organization of the NC-7 Ornamental Subcommittee.

The NC-7 Ornamental Subcommittee, consisting of one representative from each SAES and one from the NC Regional Plant Introduction Station, organized a program of uniform testing and evaluation of ornamental plants in the North Central Region. The subcommittee meets every other year and prepares a list of ornamental plant materials desired for future testing and evaluation. Foreign and domestic ornamental PI also are added to this list as they become available.

The horticulturist at the NC Regional Plant Introduction Station assembles the desired plant materials. The plants are either propagated at the Regional Plant Introduction Station or obtained from other sources such as nurseries, botanic gardens, arboreta, experiment stations, etc. Plants are either distributed without increase or are grown at the Regional Station until they attain adequate size and number and then are distributed to the NC-7 trial cooperators, as well as to arboreta and botanic gardens (Table 1). The average annual minimum temperature at the planting sites vary from −40°C (−40°F) to −18°C (0°F) (U.S. Department of Agriculture Plant Hardiness Zone 3-6).

Table 1. List of North Central Regional Ornamental Trial Cooperators.

Alaska	Alaska Agri. Exp. Sta., Fairbanks
	Alaska Plant Materials Center, State of Alaska, Palmer
	Washburn Farm and Nursery, Palmer
Colorado[z]	Dept. of Horticulture, Colorado St. Univ., Fort Collins
Illinois	Dept. of Horticulure, Univ. of Illinois, Urbana
	Dept. of Plant and Soil Science, Southern Illinois Univ., Carbondale
	Dept. of Horticulture, Kishwaukee College, Malta
	Morton Arboretum, Lisle
	Chicago Botanic Garden, Glencoe
Indiana	Dept. of Horticulture, Purdue Univ., West Lafayette

Iowa	Dept. of Horticulture, Iowa St. Univ., Ames
	Iowa Arboretum, Beaver
	Bickelhaupt Arboretum, Clinton
Kansas	Dept. of Horticulture, Kansas Sta. Univ., Manhattan
	Kansas St. Univ., Colby Branch St., Colby
	Kansas St. Univ., Hort. Exp. Field, Wichita
	Plant Materials Center, USDA-SCS, Manhattan
	Kansas Landscape Arboretum, Washington
Kentucky[y]	Dept. of Horticulture, Univ. of Kentucky, Lexington
Maine[x]	Dept. of Plant and Soil Sciences, Univ. of Maine, Orono
Michigan	Dept. of Horticulture, Michigan St. Univ., East Lansing
	Division of Campus Parks and Planning, Michigan St. Univ., East Lansing
	Michigan St. Univ., Hidden Lake Gardens, Tipton
	Rose Lake Plant Materials Center, USDA-SCS, East Lansing
	Matthaei Botanical Garden, Univ. of Michigan, Ann Arbor
Minnesota	Landscape Arboretum, Univ. of Minnesota, Chaska
	Univ. of Minnesota, Southern Exp. Sta., Waseca
	Univ. of Minnesota, West Central Exp. Sta., Morris
	Univ. of Minnesota, North Central Exp. Sta., Grand Rapids
	Paul Bunyan Arboretum, Brainerd
Missouri	Dept. of Horticulture, Univ. of Missouri, Columbia
	Plant Materials Center, USDA-SCS, Elsberry
	Missouri Botanical Garden, St. Louis
Nebraska	Dept. of Horticulture, Univ. of Nebraska, Lincoln
	Univ. of Nebraska, North Platte Sta., North Platte
	District Conservationist, USDA-SCS, Blair
	Kearney St. College, Kearney
	Forestry Division, City of Omaha, Omaha
	Parks and Rec. Dept., City of Scottsbluff, Scottsbluff
North Dakota	Dept. of Horticulture, North Dakota St. Univ., Fargo
	Dept. of Horticulture, North Dakota St. Univ., Carrington
	North Dakota St. Univ., Dickinson
	North Dakota St. Univ., Bottineau Branch, Institute of Forestry, Bottineau
	Plant Materials Center, USDA-SCS, Bismarck
Ohio	Dept. of Horticulture, Ohio Agri. Res. and Dev. Center, Wooster
	Secrest Arboretum, Ohio Agri. Res. and Dev. Center, Wooster
	Nursery Crops Research, USDA-SEA-AR, Delaware
	Mt. Airy Forest Arboretum, Cincinnati
	Holden Arboretum, Mentor
	Cox Arboretum, Dayton
South Dakota	Dept. of Horticulture, South Dakota St. Univ., Brookings
	Dept. of Horticulture, South Dakota St. Univ., Highmore
	Dept. of Horticulture, South Dakota St. Univ., Yankton
Wisconsin	Dept. of Horticulture, Univ. of Wisconsin, Madison
	Univ. of Wisconsin Arboretum, Madison
	Boerner Botanical Gardens, Hales Corners
	Paine Arboretum, Oshkosh

[z] Western Region
[y] Southern Region
[x] Northeastern Region

Since the start of this program, about 350 ornamental plant introductions have been distributed in the NC Region. Once a cooperator receives plants, he/she sends a report of planting, and 1-, 5-, and 10-year performance reports. Information on per-

formance is compiled, and 5- and 10-year evaluation summaries are prepared and distributed to the cooperators, plant scientists, nurseries, etc. Research findings of significant horticultural interest are published in professional, semiprofessional, or popular journals and magazines.

The results of these regional ornamental trials have provided plant scientists, nurserymen, and homeowners with useful information on the potential of new ornamental plants.

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Tuesday Evening, December 11, 1979

The twenty-ninth annual banquet was held in the Ballroom West of the Sheraton St. Louis Hotel, St. Louis, Missouri.

On behalf of the Society, awards were presented to Mr. William Mertens, Department of Horticulture, Virginia Polytechnic Institute and State University, for the best graduate student award paper and to Dr. Robert D. Wright who was the advisor for the work presented in the paper by Mr. Mertens.

The award for the best undergraduate paper was presented to Mr. David Eichholz, Department of Horticulture, Purdue University, and Drs. Henry Robitaille and Paul Hasegawa, advisors for Mr. Eichholtz's paper.

Mr. Peter Vermeulen made the following presentation:

AWARD OF MERIT

Presented by Peter Vermeulen

This evening we are privileged to recognize by suitable award a person who has, in the eyes of this Society, made noteworthy contributions to the art and science of plant propagation — a person who has a keen interest in plants — their selection, propagation, production and their use in the beautification of home grounds and public areas.

The recognition is that of his/her fellow members by nomination, which only makes the granting of the award that much more esteemed. The award committee functions only to solicit, screen and make final determination, completely separate and apart from opinions or desires of the officers other than the exercise of their privilege to nominate, the same privilege accorded to every member. The award is made only, when in the opinion of the committee, it is warranted. The 1979 committee is immensely pleased to say that it has so determined and is much warranted.

Our Award of Merit recipient was born in Providence, R.I., November 13, 1923. With one notable exception his childhood could be considered normal. It seems there existed in the young heart a seeking of the unusual excitement, not normally found or available, for whenever he was late coming home, his family would look for a carnival, and there would find him.

Much to his credit he completed high school, and went off to New London, Connecticut to work for the Electric Boat Company as a pipe fitter on submarines. This was but a step into the navy in which he served two years.

After Leaving the Navy — In 1948 he fell in love — twice — at the same time. He found a wife and his second love, plants. He became a husband and assistant in agronomy and horticulture research at the University of Rhode Island, attaining his B.S. in 1951.

So onto Cornell for graduate studies and research, earning his M.S. in 1954; his thesis was — "The Effects of the Level of *Oxygen, Growth Regulator, Temperature and Position on Storage* of Hardwood Cuttings".

There his authorship budded with his paper to this Society in 1957, "The Effects of Daylength on Germination of *Sciadopitys verticillata*". He has since authored others to the Society, dealing with original works on the photoperiodic effects on propagation and growth of woody ornamental plants; the devel-

opment of the "flashlighting techniques to increase growth of seedlings; the vegetative propagation of *Sciadopitys verticillata*, the rooting of blueberry cuttings under fluorescent light; the relationship of flower bud development to the survival of the 'Cornell Pink' azalea; the propagation of cuttings of white pine witches'-brooms, clonal and seasonal differences in resin production and its relationship to the rooting of umbrella pine.

He has presented papers at the 16th International Horticultural Congress in Brussels, Belgium in 1962; the International Conference on Electromagnetic Radiation in 1965; the Symposium on Propagation in Krogerup, Denmark in 1975, etc., etc.

He was awarded the Jackson Dawson Gold Medal by the Massachusetts Horticultural Society, and the Award of Merit by the Connecticut Nurserymen's Association.

He was conferred a Ph.D degree at Cornell in 1957 and, in the same year, was appointed Assistant Professor at the University of Connecticut where he became Associate Professor in 1962 and Professor in 1978.

Notwithstanding all of these accomplishments he found time to assume the duties of Secretary-Treasurer of this Society in 1962-1965. Personal testimony of this speaker to his keen ability, pleasant manner, and total dedication stems from working with the recipient as Program Chairman, at which time one soon learns the priceless value of a good Secretary.

Our recipient's professional societies are many including: The American Society for Horticultural Science; American Society of Plant Physiologists; International Plant Propagator's Society; American Association of Botanic Gardens and Arboreta; International Association for Plant Tissue Culture; Pi Alpha Xi, Sigma Xi; Phi Kappa Phi; Alpha Zeta; International Society for Horticultural Science; Tissue Culture Association; International Association of Tissue Culturists.

I could go on and on to list reports published in various other media; institutional, organizational, and public.

This is only one portrait of our recipient. On the other face we find a compassionate servant of his fellowman which can be understood in the pen of Edwin Markham who wrote:

"There is a destiny that makes us brothers, none lives to self alone; all that we bring to the lives of others comes back into our own."

He is now teaching Plant Propagation to approximately 80 students in the spring semester, and Advanced Plant Propagation, at the University of Connecticut.

He is continuing his work on witches'-brooms and has recently named and introduced four eastern white pine witches'-

broom progeny — 'Green Shadow', 'Blue Shag', 'Sea Urchin' and 'UConn'. He is also carrying on his work with rooting of Japanese umbrella pine, *Sciadopitys verticillata*.

Probably by now many of you know who our recipient is. He is a person with a sense: A sense of purpose, A sense of dedication, A sense of service, And yes, A sense of humor, but chiefly, A sense of humility.

Friends I am deeply honored to present, in your behalf, the 1979 Award of Merit to — Sidney Waxman.

Thursday Morning, December 13, 1979

The Thursday morning session convened at 8:15 a.m. with Andrew T. Klapis, Jr. serving as moderator.

CURRENT DEVELOPMENTS IN THE HARDY NURSERY STOCK INDUSTRY WITHIN THE UNITED KINGDOM

A BRUCE MacDONALD

Hadlow College of Agriculture & Horticulture,
Hadlow, Tombridge, Kent, England

The aim of this paper is to highlight some of the current trends and developments that have taken place within the nursery stock industry in the United Kingdom. It will be related under three main sections:

1. Contributions by the nurseryman.
2. Contributions by the research stations.
3. Contributions by the advisory (extension) service of the Ministry of Agriculture.

However, one cannot in reality look at them as isolated compartments, as many ideas have been join efforts within two, or all three sections.

CONTRIBUTIONS BY THE NURSERYMAN

Specialization and marketing. A major trend has been the movement of nurseries to specialize in a particular crop or production system. This was very much accelerated when the pound sterling was considerably devalued against other currencies as imports of plant material became considerably more expensive from countries such as West Germany, Denmark, France, Belgium and Holland. This encouraged the industry to become more self sufficient.

Today there are nurseries specializing in pot grown liners (young plants), producing for example, conifers, evergreen

broom progeny — 'Green Shadow', 'Blue Shag', 'Sea Urchin' and 'UConn'. He is also carrying on his work with rooting of Japanese umbrella pine, *Sciadopitys verticillata*.

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Today there are nurseries specializing in pot grown liners (young plants), producing for example, conifers, evergreen

shrubs, and clematis. This type of enterprise has been particularly attractive for young people beginning their own business. Other specialist crops include advanced nursery trees, seed raised rootstocks and amenity plants of broadleaved trees, rose rootstocks and ground cover plants. Along with this specialization has meant an overall improvement of the quality of plants being sold. Thus many items being offered for sale by the wholesale trade are both competitive in price and quality against our continental competitors.

Marketing. The nurseryman is now becoming much more conscious of the importance of plant promotion, good presentation and efficient marketing. The Anglia Group, a major marketing co-operative made up of five well known nurseries in East Anglia, has been the pioneer of many ideas — in particular in the promotion of sales of plants for garden centre sales. Good management, a well designed catalogue, a central marketing office and quality plants have all been important factors for their success. Other marketing co-operatives have followed suit such as the Midland Group, Fargro in West Sussex, and Greenleaf Nurseries in Northern Ireland.

National schemes for selling plants have increased with National Tree Planting Week, Horticultural Trade Association (H.T.A.) Gift Vouchers, "Buy British Trees" and "Plant of the Month", the latter organized by the Garden Centre Group of the H.T.A.

Nurserymen are employing more people to act as salesmen for selling plants. They travel in different areas of the country visiting, in particular, garden centres and local authorities.

A major outlet over the last few years for plants has been local authorities and government departments — for example the Department of the Environment. Whether these outlets will be as successful in view of the current government financial cut backs is causing concern. The publication of a "reader document" agreed with local authorities is a major step forward.

Distribution of Nurseries. The current size of the industry is about 16,600 acres, growing annually some 50 million container plants. The nurseries are now becoming much more diverse in their location over the country. The major increase has taken place mainly in the West Midlands and East Anglia. Kent is also a county which has increased in percentage area and contains nurseries with a great range of differing enterprises. One or two small nurseries have arisen in Western Argyll in Scotland where some financial backing has come from the Highland & Island Development Board.

Within different counties, for example Kent, Surrey, Hampshire and West Midlands, there have now formed active Nurse-

rymans' Discussion Groups which meet monthly in autumn and winter to discuss in detail many aspects of nursery production. During the summer months they meet to visit nurseries, research and experimental establishments. This, in turn, has assisted in the formation of Training Groups under the auspices of the Agricultural Training Board (A.T.B.). The A.T.B. has carried out excellent work in organizing proficiency tests and a wide range of short courses for employers and employees.

Plant Introductions. The British climate, although very unpredictable, does enable gardeners to grow a very wide range of plants. Many of the nurserymen are extremely good plantsmen and have a great specialist knowledge on different groups of plants — for example rhododendrons, alpines, dwarf conifers, trees, and clematis. The nursery industry is going through a phase of introducing "new plants" to the public. Some of these plants have been grown for many years but given little publicity of their potential; however, others are new in that they have been bred within the United Kingdom or imported from abroad.

Groups of plants which have been imported and given considerable publicity for retail sales by Blooms Nurseries, Diss, Norfolk, are the ornamental *Phormium* from New Zealand, and the prostrate forms of *Juniperus* from North America. Greenleaf Nurseries have widely promoted the golden forms of *Cupressocyparis* × *leylandii* bred in Northern Ireland and the fire-blight resistant *Pyracantha* from North America. Some famous nursery names have introduced plants in England to the trade; for example, Hilliers near Winchester with *Sorbus* 'Sunshine', *Hamamelis vernalis* 'Sandra' and *Daphle bholua* 'Ghurka'.

At nurserymans' conferences more lectures are being given by curators of famous British Gardens, such as the Royal Horticultural Society's Gardens at Wisley and Savill Gardens near Windsor, and the Hillier Arboretum near Romsey.

Stock Plants. Nurserymen have now become strongly aware of the importance of correctly named, well-maintained stock plants of the best clones. Greater attention is being given to pruning techniques and replacement programmes to obtain benefits from disease-free juvenile material.

One particular aspect which has interested Hadlow College is the techniques of growing stock plants under the protection of polyethylene and woven plastic. This is used for high value deciduous plants such as *Acer*, azalea, *Hamamelis* and *Magnolia* because cutting material is available earlier in the season and over a longer period in the correct condition, and to achieve greater success in percentage take. This, in turn, gives a much greater chance for successful overwintering of the subsequent young plants.

Propagation facilities. Facilities for propagation have undergone the following changes:

1. Simplification
2. Reduction of energy inputs — for example, insulation
3. Intensification of number of cuttings being rooted
4. Sophistication with automated controls
5. Reduction of handling by nursery operators
6. Direct rooting.

I would now like to take three recent innovations for discussion.

Temperature controllers for basal heat. A very accurate system for temperature control is now available from Nobel Engineering Ltd. Worthing, Sussex. This is basically an on/off proportional controller with 4 or 6 thermocouple sensors. One sets the desired temperature for the cuttings or grafts on a dial. The sensors then record on a dial the average temperature over the bed. It also quickly ensures a response should the temperature drop below the desired level. This system gives greater efficiency compared with the traditional rod thermostats.

Sonar Mist. Standing misting equipment gives a water droplet of a relatively large size, often giving an excess of water. Nozzles are closely spaced often causing overlap of misting spray patterns in addition to a drip problem underneath the nozzle itself.

A misting nozzle (sonicore nozzle) made to suppress dust in the asbestos and fibreglass industry has been modified in Sweden for use in plant propagation, and is now creating considerable interest. The principle is that compressed air energizes an ultrasonic resonator which, in turn, breaks up water into very small droplets to give a "hanging effect". Amongst the advantages include a smaller head of water, very uniform cover and a reduced number of nozzles. Also the air supply operates a spring-loaded valve so after each misting burst, there is no drip. The system, available from Ultrasonics Ltd., Shipley, Yorkshire, is currently being installed in two English nurseries.

Panels for Providing Basal Heat. A very modern half-acre propagation unit has just recently been constructed at Notcutts Nurseries, Woodbridge, Suffolk. It was designed by the consulting firm of Sheard & Fawcett in conjunction with the management team at Notcutts. The basal heat is provided by hollow extruded polypropylene panels developed by Robinsons of Winchester and I.C.I. Plastics Division. These panels were initially developed for heating swimming pools to circulate water heated by solar energy. In the propagation unit they are joined together with a heater at either end to cover the floor. The materials used for the floor base are 2″ thick polystryene sheets which are

laid on polyethylene. On top of the polystryene is placed the panels over which is placed capillary matting. The cutting trays are then placed onto the matting. The water in this case is heated by a gas boiler.

Mechanization. Nurseries are becoming strongly aware of the need for mechanization. Specialist machinery is being obtained in two ways — firstly, importation of machines from France, Holland, West Germany, Denmark and Belgium through agents within the United Kingdom and, secondly, by nurserymen adapting and constructing their own.

Imported Machinery. Standard models of planting and undercutting machinery has now been imported over a number of years from Egedal in Denmark. However, an interesting development has been the formation of a firm in Surrey named M.J. Farthing. This company specializes in potting machines (Meyer) from West Germany, in addition to a very wide range of items from Holland. Two machines are worthy of further comment.

Firstly, the Damcon Lifter from Opheusden in Holland has become popular since its introduction in 1978. It is a hydraulically operated lifter with the aim of selecting individual trees within the row. The frame is laid with a horizontal position and twin hydraulic rams move the 'U' shaped undercutting blade into the soil beneath the tree selected for lifting. There is also a depth adjuster and the blade may be vibrated by a hydraulic motor. There is a clamp which holds the tree and a shaker to remove excess soil.

Another example is the Amtac root balling and wrapping machine. This is powered by a tractor power takeoff or a single phase electric motor. The principle is that the operator holds a balled plant in the machine and an elastic netting is wrapped tightly around it.

A machine widely used on some continental nurseries is the B.45 tractor from Bobard S.A. in France. During 1979 two of these tractors were purchased by English nurserymen. It was initially designed for vineyard work. It has an 8 ft clearance and can straddle 2 rows of trees. The tractor is extremely versatile with its 2 drive wheels independently steered. Implements are rear, mid or front mounted. It can work on slopes by altering its clearance height on one side to give stability. In addition, one may adjust the width of the straddle in order to accommodate varying row widths and it has a turning circle of 360° within its own length. The attchments include levelling blades, disc harrows, lifters, root pruners, spraying and fertilizer distributors. There is an electronic sensor which can direct hoeblades so weeds may be removed right up to the tree stem.

British Machinery. A potting machine designed and built

by Dorrell Bros. at Bransford, Worcester has created considerable interest. The machine achieves a rate of 1,400 per hour on 2½" pots using 3 operators. One advantage of this machine is that blockages are nearly eliminated as an upper horizontal conveyor completes a closed circuit of moving compost.

The specialist fruit tree rootstock producer, J. Savage of Marden, Kent, has designed two interesting items. One is a machine for automatically removing layers from stool beds. After the soil has been removed from the stools by an offset plough, a power takeoff driven machine with a revolving saw blade severs the layers at the desired height. A second machine is designed to incorporate liquid soil sterilants to a considerable depth using a plow to open up the depth of soil.

Another machine is now available called the Pepler Reelmaster which automatically winds up the polyethylene used for field sterilization. It is powered by an hydraulic motor powered by the tractor.

DEVELOPMENTS WITHIN RESEARCH

East Malling Research Station — East Malling, Kent. Recommendations for research are made by the Joint Consultative Organization. This is a joint committee made up of growers, and research and extension officers. This has resulted in an increase in government support for nurserymen and amongst these priorities, propagation is foremost. Evidence of the weight given to this is the formation of a Plant Propagation Department at East Malling Research Station, headed by Dr. B.H. Howard. There propagation problems of fruit and ornamental trees are tackled in a three point program, as follows:

(1) *Physiological Aspects of Rooting.* Attempts are made to understand the internal mechanisms of plants which are responsible for marked improvements or failures of rooting. Information gained in this way provides the basis for establishing the general principles which are so necessary when dealing with large numbers of species. Examples of their work include studies on how to precondition shoots, while still on the stock plant to root more readily when subsequently taken as cuttings. At present, they are exploiting the well known etiolation effect by covering hedges before bud burst with black polythene tents and finding that the resulting cuttings root much more readily than when they grow normally.

Investigations of differences in rooting due to the position of the shoot on the stock plant also provides the basis for physiological studies and indicates how stock plants should be managed.

Seasonal changes in rooting of cuttings are well known to nurserymen and their cause often investigated. A study by an American postgraduate student working in the Plant Propagation Department at East Malling has given some very convincing evidence of the involvement of cofactors in the sap which increase in spring and which further supports the view, that rooting in winter cuttings is not determined by the increase in spring bud activity, as has often been argued.

(2) *The Need to Select for Rooting Ability*. The attitude at East Malling is to put selections for good rootability high on their priority list because it overcomes the need to develop detailed and costly propagation procedures. One is convinced of the merits of this approach on seeing such products of their breeding program as the cherry rootstock, 'Colt', which produces pre-formed roots while still on the stock plant and hence needs no further inputs. Selections within this hybrid family between *Prunus avium* and *Prunus pseudocerasus* have been shown to be particularly suitable for raising good quality flowering cherry trees with thick trunks.

The principle of selection is also applied to seedling populations of ornamental species in order to find plants with the capacity to root and so forms the basis of producing clones. In this way clonal rootstocks, as tree on their own roots, can be produced to give more uniform stocks of plants that at present are produced on seedlings. An example is the selection of clones of *Tilia* × *europaea* and *Tilia cordata* on the basis of their rooting ability by winter cuttings. This work has now reached the stage of raising maiden linden trees on clonal rootstocks for the first time, emulating East Malling's work over many years with clonal apple rootstocks — a development of considerable interest to the nurseryman.

(3) *Technical Improvements to Produce Simple Propagation Methods*. Dr. B.H. Howard has fully reported at previous IPPS Conferences the techniques of chip budding. This is now an accepted and well used technique in Britain for the production of high quality fruit and ornamental trees.

Wounding of winter hardwood cuttings for the heated bin (callus or Garner bin) has been studied recently using the M.27 apple rootstock. Different wounding techniques were used at the base of the cutting with the aim of increasing root number and improve subsequent establishment in the field. Two incision wounds, some 2.0 cm in length proved superior. Anatomical studies of the stem base showed that within the additional callus, a cambium formed. It was observed that the developing roots were formed in association with a typical cambial growth which forms in the wound callus.

Cutting source, time of collection, IBA response and compost conditions are all considered under the heading of "techniques" and evidence of how reliable techniques can be developed when the correct inputs are brought together can be seen from the regular stands of cherry, plum quince and apple cuttings.

Long Ashton Research Station — Bristol. Mainly as a result of pressure from the nursery stock industry a clonal selection scheme for ornamental trees and shrubs is now under way. This scheme is centered at Long Ashton Research Station. With the increasing number of plant introductions, nurserymen are very much aware of the confusion of correct nomenclature of plants sold, but it is intended to involve educational colleges such as Hadlow, Merrist Wood, and Pershore for plant collections of different genera.

The aim of the scheme is that clonal selection will increase the uniformity, compatability, and overall attractiveness of plants. Where feasible it is planned to develop virus-free material. The initial plants selected for the scheme have come from 8 to 12 different sources and these have been planted for assessment at Long Ashton. Plants included so far are: *Malus floribunda*, *Potentilla fruticosa* 'Tangerine', *Daphne* × *burkwoodii* 'Somerset', *Ceanothus* × *veitchianus* and *Forsythia* × *intermedia* 'Lynwood'.

The variation of material supplied can be illustrated with *Cornus alba* 'Spaethii', where only one source was correctly named, the remaining being the more vigorous *Cornus alba* 'Gouchaultii'. It is planned to release early next year the best clones of 4 different plants. These may be identified by having the letters L.S. followed by a number, after the latin name.

Nurserymen are now much more aware of the benefits to both crop quality and fuel costs, by providing windbreaks. Long Ashton, with its renowned collection of *Salix*, has been a major source of reference and ideas. The publication of K.G. Scott entitled, "Living Windbreaks — their Establishment, Maintenance and Effectiveness", together with the Ministry of Agriculture booklet on "Windbreaks" provides valuable information to the nurseryman on living and artificial windbreak material. Three widely planted windbreaks in Britain are now *Alnus cordata*, *Salix* 'Bowles Hybrid' and × *Cupressocyparis leylandii*. Also Long Ashton has found *Nothofagus procera* promising with a growth rate twice as fast as *Fagus sylvatica*.

Glasshouse Crops Research Institute — Rustington. Recently a new nursery stock laboratory has been built where work is now headed by Dr. K. Loach. Work has been directed toward fundamental research on the relationship between water

stress of the cutting and its ability to root using different propagation systems. Results have shown the benefits for rooting cuttings during the winter months under polyethylene, while mist is preferable during the summer.

The ease of rooting and initial growth rates using 8 clones of × Cupressocyparis *leylandii* are being studied. Early results showed that the widely grown 'Clone 2' within the nursery trade is not the best for ease of rooting, speed of growth and attractiveness.

The Pathology Department has been studying the control during the propagation stages of *Phytophthora sp.* on conifers and rhododendrons. This soil-borne organism is still very much a problem within Britain. Control has been directed to dips or drenches of cuttings. Two promising fungicides are Furaxyl (Fongarid) and a May & Baker compound, numbered LS 74-783. As zoospores have been found in the irrigation tanks, a control using chlorination and ultra violet irradiation has been effective.

A further line of work is the effects of photoperiodic lighting and gibberellin sprays on *Rhododendron* and *Picea* plants to extend the natural growing season and reduce the period of dormancy between flushes of growth.

CONTRIBUTIONS BY THE MINISTRY OF AGRICULTURE ADVISORY SERVICE (A.D.A.S)

Recent developments carried out by A.D.A.S. — Ministry of Agriculture/Extension service is centered at their Experimental Horticultural Stations (E.H.S.), but there is also a considerable amount of work done on nurserymans' holdings. This work is largely based at Efford E.H.S. by Miss M. Scott, while nationally by A.R. Carter and B.J.W. Morgan. The major topics for review are as follows:

Reduction of Heating Costs. Three techniques were found to reduce heating costs during propagation:

1. A reduction of up to 25% could be achieved by insulating the propagation beds. The technique is to use expanded 2.5 cm thick polystyrene sheets which are wrapped in polyethylene, then placed along the sides and back of the bed.
2. The installation of a secondhand boiler and pipework to heat water, instead of heating by electricity. The beds could also be insulated as previously described.
3. The application of basal heat during daylight hours only. Although the rate of rooting of cuttings was slightly slower with some plants, only about ⅓ of the amount of electricity was used.

Rose Rootstock Production. Each year a large number of rose rootstocks are imported into Britain from West Germany, Denmark and Holland. The major rootstock used is *Rosa dumetorum* — 5 to 8 mm grade. Research by Dr. Blundel at the University of North Wales, experimentation by A.D.A.S., combined with strong nurseryman involvement has now combined to give British raised rootstocks sold under the name of "Bristocks Limited." Meticulous studies into hip collection, seed extraction, pre-sowing treatment to the seed, soil sterilization, precision mechanical sowing, weed, pest and disease control, mechanical harvesting and finally grading-out, have lead to provide high quality stocks for sale to rose growers.

A vital operation is the presowing treatment based on acid digestion followed by two different temperature regimes. The seed is soaked for approximately 50 minutes in 95% concentrated sulphuric acid. The seed is then given a warm, moist stratification for 30 days at 24°C (75°F) followed by cold moist stratification for 12 weeks at 4° to 5°C (39° to 41° F).

Rose Propagaiton by Budding. A mechanical aid designed initially for bench-budding rose rootstocks using unskilled labor was developed by L. Pettifer at the University of North Wales. It is called a "budding gun", and operates on the principle that the bud is removed from the scion wood as a "core" containing the bud and a sliver of wood, and is then retained in the gun. The bark is next cut and lifted by blades at the end of the gun with the final stage being when the bud is released between the two flaps of bark. One then ties in as for conventional budding.

Capillary Irrigation. Overhead irrigation is the major technique on both the continent and North America but, in Britain, capillary irrigation is widely used. A standard design formulated by the A.D.A.S. for an outdoor constant stock is available for nurserymen. The aim is to provide an adequate water reserve in the summer combined with adequate drainage during the winter. Basically a 5 cm depth of sand is placed over 500 gauge black polyethylene attached to side boards on the perimeter of the bed. Facilities are also constructed to allow for drainage of excess water. Water is applied to the sand by either bi-wall tubing, seephose, drip nozzles or micro-tubes.

Synthetic matting materials as an alternative to sand have created considerable interest. Their advantage is that they give a more flexible system, are lighter in weight, more effective on slopes, and cleaner for retail sale. Work at Efford E.H.S. has been to evaluate the performance of the different synthetic materials. They are made from different materials, for example, compressed wool shoddy, acrylic waste fibres, polyester and nylon fabric; the material found suitable for outdoor container

stock was Lantor 4.H — made from waste wool, nylon and acrylic fibres as non-woven felts.

To prove accuracy of water control an instrument called the "Water Bug" may be used. This was invented by F. Richardson, Flowering Plants Limited, Buckingham. This reacts to changes in moisture content of the substance so one can operate it either on a dry or wet regime.

A problem with capillary irrigation is the rooting through from the container into the sand or matting and the formation of algae, moss, and liverworts on the surface. The material, Gloquot, manufactured by Wykamol of Winchester, may be sprayed at 5½ fluid oz/sq ft of bed to overcome this. Investigations are currently being carried out with this and other materials to prevent rooting through from cutting trays (flats) into the propagation bench.

Weed Control in Container-Grown Plants. Annual weeds such as *Cardamine hirsuta*, *Epilobum*, and *Poa annua* are a major problem for the nurseryman. Experimentation has lead to chemicals being used on a routine basis. The problem area is with young stock grown under glass or polyethylene. The two major chemicals used are chloroxuron (Tenoran) and simazine. Chloroxuron is applied at the rate of 1½ oz. in 6 gallons of water per 1000 sq ft of bed surface every 6 to 8 weeks, ensuring the foliage is washed off immediately with pure water after spraying to reduce the risk of leaf scorch. This chemical also controls algae, moss, and liverworts, but is not very effective against *Poa annua*. Simazine is applied every 9 to 10 weeks at the rate of 1 oz in 6 gallons of water per 1000 sq ft of bed surface. There is less risk of leaf scorch, and it controls *Poa annua*, but has the disadvantage in that more plants are susceptible to it and its failure to control moss, algae, and liverworts.

Currently trials are in progress using "herbicide cocktails", one aim being to give control of a wider weed spectrum. Mixtures include chloroxuron and diphenamid (Enid) and chloroxuron with simazine. A prototype herbicide applicator is currently being developed by A.D.A.S. at Winchester, where one is able to adjust the boom for the height and width of a growing structure.

Chemicals to Regulate Plant Growth. Following the work using chlormequat (Cycocel) to assist bud initiation on camellia, work has been extended to investigate dikegulac-sodium (Atrinal). Here the aim is to compare the number of axillary shoots as well as bud initiation. For camellia best results seem to be with 0.1% Atrinal applied at the "rabbit ear" stage of new growth. Studies have been extended to *Ilex*, *Rhododendron*, *Clematis*, *Erica*, and *Berberis*. At Hadlow College we have

found it effective on quick growing deciduous plants under glass such as *Spiraea* and *Ceratostigma*. The correct application rate and stage of plant development are vital when using dikegulac-sodium. Investigations using this chemical have been reported in past issues of the IPPS Proceedings.

Other items of importance include comparisons of different polyethylene and woven plastics for container plant production. Also the formulation of standard peat and sand growing media using slow release fertilizers; this has been one of the most important items of work over the last decade. The nurseryman is now very interested in bark as an alternative to peat, the latter now being difficult to obtain.

APPENDIX

RESEARCH STATIONS.

Dr. Brian H. Howard,
Head of Plant Propagation Department,
East Malling Research Station,
East Malling, Kent.

The Director,
Long Ashton Research Station,
University of Bristol,
Long Ashton, Bristol,
Gloucestershire

Dr. Keith Loach,
Glasshouse Crops Research Institute,
Worthing Road, Rustington,
Littlehampton, Sussex.

The Director,
The National Institute of Agricultural Engineering,
Silsoe, Bedfordshire.

MINISTRY OF AGRICULTURE ADVISORY/EXTENSION SERVICE — EXPERIMENTAL HORTICULTURE STATIONS AND ADVISORS.

Miss Margaret Scott,
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Miss Pat Cooper,
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Luddington, Stratford-on-Avon.

The Director,
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The Director,
National Fruit Trials,
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Arthur R. Carter,
National Nursery Stock Advisor,
Ministry of Agriculture,
Coley Park, Reading, Berkshire.

Brian J.W. Morgan,
South East National Stock Advisor,
Ministry of Agriculture,
Coley Park, Reading, Berkshire.

PROPAGATION FACILITIES.

George E. Sheard,
Fawcett & Sheard Ltd.,
Engineering and Horticultural Committee,
35, Broad Street, Wokingham,
Berkshire. RG11 1AN.

S.R. Freeman,
Nobel Engineering Ltd.,
Clare Works, Woods Way,
Mulberry Industrial Estate,
Goring-by-Sea, Worthing, SUSSEX.
BN12 4QY.

Managing Director,
Robinsons Developments Ltd.,
Solar Heating Engineers,
Robinson House,
Winnall Industrial Estate,
Winchester SO23 8LH.

Ultrasonics Ltd.,
Sonimist,
Otley Road, Shipley, Yorkshire, BD18 2BN.

GROWING STRUCTURES AND CLADDING MATERIAL.

Michael Rochs,
Clovis Lande Associates Ltd.,
Gaza Trading Estate,
Hildenborough,
Tonbridge, Kent. TN11 8PL.

PARTIAL SOIL STERILANTS — 'BASAMID'.

B.A.S.F. United Kingdom Ltd.,
Agrochemical Division,
Lady Lane, Hadleigh, Ipswich,
Suffolk, IP7 66Q.

Available in Canada from:
Plant Products,
Bramalea, Ontario.

MACHINERY.

Potting Machines, undercutting, lifting and spraying equipment.

John B. Edmonds (Valeford Potter)
Dorrell Bros.
Bransford, Worcestershire.

Undercutting and Lifting Equipment from the Netherlands.

J. Van Dam B.V.
Damcon and Van Dam Lifters,
Postbus 15, Opheusden, Netherlands

Polybob Tractor from France.

Bobard S.A.
17, Rue de Reon,
21200 Beaune, FRANCE.

(United Kingdom Agent:)
Heygates Machinery Ltd.,
Bugbrouke Mills,
Northampton.

SPECIALIST UNITED KINGDOM MANUFACTURER and importer of machinery for nursery stock.

M.J. Farthing,
M.J.F. Ltd.,
2, Summers Road,
Farncombe, Godalming,
Surrey, GU7 3BA.

SPECIALIST DANISH NURSERY STOCK MACHINERY.

Egedal Maskinfabrik,
Egebjerg,
8,700, Horsens, Demnark.

(United Kingdom Agent)
Ernest Parsons,
E.P. Nursery Machines,
Station Road,
Plumtree, Nottingham.

GUS MEHLQUIST: What was the role of the acetone you mentioned in your first paper?

BRUCE MacDONALD: The idea came from East Malling and we have found it very successful with hollies. The acetone disolves the IBA in the talc rooting powder and promotes better rooting. This has only been an observation with us.

DAVID SHAFER: You mention Blazamid in your talk. Would you comment on the relative merits of it versus methyl bromide.

BRUCE MacDONALD: Blazamid is cheaper, half the price of methyl bromide. Because it is a granular material we do not

need a contractor for application as with methyl bromide. Blazamid, however, does not provide the same degree of disease control and turn around time is 3 to 4 weeks.

PETER VERMEULEN: Would you comment on the use of encapsulated fertilizers in combination with capillary watering?

BRUCE MacDONALD: There is certainly less chance of salt buildup with overhead watering than with capillary watering. Rain should help to remove excess salts if they do build up, or overhead watering can be used to remove the salts. Top dressing with fertilizer, however, is generally useless with capillary watering because the top soil layer is often dry.

HUGH STEAVENSON: What is the trend in England on the use of the polythene bag as a growing container?

BRUCE MacDONALD: The trend is back to rigid pots. Transport factors, labor and handling costs, and potting machines have influenced the trend.

JIM WELLS: Blazamid is not available in the U.S.; however, Vapam is very similar and equal to it.

JIM WELLS: Do you see any trends occurring in the size of plants being grown in containers?

BRUCE MacDONALD: We are seeing a development to larger containers for trees and large conifers. At the same time there is also a trend towards smaller containers for young plants and the mass market outlets.

PROPAGATION OF *ACER CAMPESTRE, A. PLATANOIDES, A. RUBRUM,* AND *A. GINNALA* BY CUTTINGS

DOUGLAS J. CHAPMAN

The Dow Gardens
Midland, Michigan 48640

This survey-study was initiated to determine if *Acer campestre, A. platanoides, A. rubrum,* and *A. ginnala* could be propagated by cuttings and grown using accelerated growth techniques, as developed by Hanover et al (7), to produce a 3 to 4 foot plant in one season. During the past decade Davidson (3), Schwab (9), and others have noted continual graft incompatability within the cultivars of *A. rubrum*. Presently, it hasn't been determined if this incompatibility is pathologically or physiologically induced or is due to a provenance response of the stock (personal conversation with Davidson (3)).

Softwood cuttings were used in this study so that the plants could be grown on using accelerated growth techniques after propagation (6,7,8,10). It was felt that juvenility moves ac-

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ropetally in plants, and juvenile plants (seedlings) are more photoperiodic responsive than mature plants (7,10). If this hypothesis held up, one could maximize growth. Softwood cuttings of the aforementioned *Acer* species were taken at 2-week intervals to determine the optimal time to take cuttings. Brown and Dirr (1) and Burd and Dirr (2) suggested there was an optimal time for taking selected *Malus* cultivar cuttings. Further, they suggested that softwood cuttings were superior to hardwood cuttings when continued growth was desired.

METHODS AND MATERIALS

The cuttings of *A. campestre* and *A. platanoides* were taken at two-week intervals commencing on May 23, 1979. Cuttings of *A. rubrum* were taken at 2-week intervals commencing with May 30, 1979. All cuttings were approximately 8 cm long with two nodes and dipped in a 10% sodium hypochloride solution for 20 minutes to disinfest the surface of the cuttings. Subsequently, the cuttings were dipped in Hormodin #3 and placed under intermittant mist with bottom heat. The mist was set to come on for 10 seconds every 7½ minutes. The media temperature was adjusted to 24°C (75°F). The cuttings were checked every 2 weeks to determine if they were rotting, callus formation was evident, or if the plants had rooted.

RESULTS AND DISCUSSION

A. campestre proved to be a relatively easy plant to work with. Most plants callused heavily with good rooting on cuttings taken on or around June 4. These profusely rooted plants established rapidly. As the summer progressed, rooting percentages decreased significantly. When working with *A. platanoides*, although the plants started activity earlier in the season (broke dormancy), they showed a clear tendency to rot, with 12 of the 20 plants rotting and only 5 showing callus on the early cuttings. But by June 18, rot was no longer evident and profuse callusing was common, with 17 of the 20 cuttings rooted. *A. rubrum*, also, showed tendency to rot early in the season with heavy callusing after the initial terminal elongation stopped, but with good rooting of cuttings taken in mid-June. *A. ginnala* cuttings taken any time throughout the study showed little tendency to rot. As summer progressed from May 30 through June 26, callusing and rooting percentages increased dramatically with 18 of the 21 cuttings rooting as late as June 26. Additional study is needed to correlate high rooting with some morphological characteristics. In reference to *A. campestre*, *A. platanoides*, and *A. rubrum*, there is little question that cuttings taken very early in the season usually show tendencies toward rotting while cuttings taken in mid-June rooted

in commercially accepted percentages. In contrast, *A. ginnala*, continued to show increased rooting and may, in fact, allow taking cuttings over longer periods of time, therefore, more efficiently utilizing propagating facilities. The rooted cuttings grown under accelerated growth techniques, showed a positive response but additional study is needed. Some of the plants doubled in size every 2 weeks but cultural practices, such as fertilizer, water, and storage must still be worked out.

Table 1. Propagation response of cuttings of *Acer campestre*, *A. platanoides*, *A. rubrum*, and *A. ginnala*. 1979.

Species and dates stuck	Number of Cuttings			
	Stuck	Rotted	Callused	Rooted
A. campestre				
May 23	20	7	12	8
June 4	20	—	19	15
June 18	20	—	15	1
July 2	21	—	16	5
A. platanoides				
May 23	20	12	5	0
June 4	25	5	10	1
June 18	20	—	19	17
July 2	20	—	17	5
A. rubrum				
May 30	20	13	6	4
June 16	20	—	20	18
June 26	20	2	18	12
A. ginnala				
May 30	20	2	10	7
June 16	20	—	16	9
June 26	21	—	20	18

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RAY MALEIKE: How old were the trees that the cuttings came from?

DOUGLAS CHAPMAN: They were mature and cuttings were taken throughout the plant.

RALPH SHUGERT: Would you comment on your accelerated growth technique and the use of supplementary light?

DOUGLAS CHAPMAN: Harold Davidson and I believe that the production techniques could be significantly different. There is no reason why we could not root the cuttings, develop a good root system, put them in cold storage, and bring them back into a greenhouse in March. By doing this you would be back into an acceptable daylength and good light quality. We have looked at leaving the rooted cuttings under lights; however, we did not get any response until fertility levels were acceptable.

BILL CUNNINGHAM: You mentioned disinfecting the cuttings. What did you use for this purpose?

DOUGLAS CHAPMAN: We use 10% Clorox and it did reduce the amount of rot we encountered.

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CUTTINGS FROM HERBICIDE-TREATED NURSERY STOCK — WHAT CAN WE EXPECT?

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Abstract. Fourteen herbicides were tested on cultivars of *Taxus*, *Juniperus*, *Rhododendron*, *Leucothoe* and *Pieris* from 1970 to 1979. Mature tip cuttings were harvested from 2 container and 6 field experiments following herbicide applications. None of 11 soil-applied (preemergence) herbicides and only one of the 3 postemergence herbicides caused significant reductions in rooting of cuttings. Some herbicides were applied at 2 to 4 times normal rates and reapplied 4 to 5 times in containers, or 2 to 3 times in the field before cuttings were taken. The only significant effects on rooting of cuttings from treated plants were obtained when glyphosate was sprayed over *Taxus* in

10. Vaartaja, O. 1959. Evidence of photoperiodic ecotypes in trees. *Ecol. Monogr.* 29:19-111.

RAY MALEIKE: How old were the trees that the cuttings came from?

DOUGLAS CHAPMAN: They were mature and cuttings were taken throughout the plant.

RALPH SHUGERT: Would you comment on your accelerated growth technique and the use of supplementary light?

DOUGLAS CHAPMAN: Harold Davidson and I believe that the production techniques could be significantly different. There is no reason why we could not root the cuttings, develop a good root system, put them in cold storage, and bring them back into a greenhouse in March. By doing this you would be back into an acceptable daylength and good light quality. We have looked at leaving the rooted cuttings under lights; however, we did not get any response until fertility levels were acceptable.

BILL CUNNINGHAM: You mentioned disinfecting the cuttings. What did you use for this purpose?

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May, August or November, and cuttings were taken in December, January, or March. Glyphosate caused less foliar injury to *Juniperus horizontalis* 'Plumosa' than to *Taxus cuspidata* during any season of application and did not affect rooting of cuttings from the treated junipers.

About a decade ago we became aware of the need to evaluate effects of herbicides on rooting as another criterion for herbicide safety in nursery stock. From then on, whenever possible, we have rooted cuttings from our herbicide treated plots and evaluated the results. In 1972, we reported experimental results obtained with 16 herbicides (1,2). We found that most herbicides either caused no significant effects on rooting of cuttings or did so only when applied at excessive dosages which often caused plant injury. McGuire and Pearson (7) applied simazine (Princep) and diphenamid (Dymid and Enide) on container-grown ornamentals. Simazine, but not diphenamid, injured *Ilex* and *Rhododendron* cultivars and reduced the rooting quality of softwood cuttings taken 30 days after treatment. 'San Jose' juniper was less affected. Fretz (6) also applied several herbicides at normal and excessive dosages on container-grown azaleas and evaluated the rooting response of softwood cuttings. Diphenamid (Dymid), trifluralin (Treflan), and chlorpropham (Chloro IPC) caused no effects on rooting, but 3 to 4 times normal dosages of EPTC (Eptam), simazine, and dichlobenil (Casoron) reduced rooting response.

This report summarizes the results of 8 field and container experiments conducted since 1972 as they relate to herbicidal effects on rooting potential.

MATERIALS AND METHODS

Herbicide evaluation experiments were conducted at the Valley Laboratory of the Connecticut Agricultural Experiment Station and in commercial nurseries. Uniform samples of cuttings were taken from replicated plots of herbicide treated plants and rooted in the greenhouse. Cuttings from randomized field plots also were randomized and replicated in the rooting benches. The techniques and conditions varied greatly from one test to another, but were uniform within each experiment.

When the cuttings were lifted, rooting of each was evaluated on a scale of 1 to 6 as follows:

1 = dead
2 = callused, but no roots
3 = poor (one or more very small roots)
4 = fair (roots developed on part of cutting)
5 = good (roots on all but one side of cutting)
6 = excellent (roots all around cutting)

Percentage rooting was based on the percentage of cuttings

Table 1. Herbicides tested for effects on rooting of cuttings from treated plants.

Common name	Trade name and formulations	Chemical name
alachlor	Lasso 10G, 15G, 4 EC	2-chloro-2′,6′diethyl-N-(methoxymethyl)acetanilide
asulam	Asulox, liquid	methyl sulfanilylcarbamate
bentazon	Basagran, liquid	3-isopropyl-1H-2,1,3-benzothiadiazin-4(3H)-one 2,2-dioxide
bifenox	Mowdown 80W	methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate
glyphosate	Roundup, liquid	N-(phosphonomethyl)glycine
methazole	Probe WP and 5G	2-(3,4-dichlorophenyl)-4-methyl-1,2,4-oxadiazolidine-3,5-dione
napropamide	Devrinol 10G and 50W	2-(α-naphthoxy)-N,N-diethylpropionamide
oryzalin	Surflan 75W and 5G	3,5-dinitro-N^4,N^4-dipropylsulfanilamide
oxadiazon	Ronstar 75W, 2G, 4G	2-tert-butyl-4-(2,4-dichloro-5-isopropoxyphenyl)-Δ^2-1,3,4-oxadiazolin-5-one
oxyfluorfen	Goal 2G	2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene
perfluidone	Destun 50W	1,1,1-trifluoro-N-[2-methyl-4-(phenylsulfonyl)phenyl]methane-sulfonamide
pronamide	Kerb 50W	3,5-dichloro(N-1,1-dimethyl-2-propynyl)benzamide
simazine	Princep 80W and 4G	2-chloro-4,6-bis(ethylamino)-s-triazine
trifluralin	Treflan 5G	α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine

ranking fair (Class 4) or better. Cuttings judged fair or better were considered fit for transplanting with an excellent chance for survival. Rooting scores were calculated by summarizing these ranks and dividing this by the total number of cuttings within each group. Rooting scores represent the average root quality of a group of cuttings. For analysis of variance, rooting percentages usually were transferred into angles and rooting scores were analyzed directly.

The herbicides evaluated for potential effects on rooting are given in Table 1. All dosages of herbicides are given in pounds of active ingredient (ai) or acid equivalent (ae) per acre (lb/A).

RESULTS

Container-grown plants. Data presented in Tables 2 and 3 are from an experiment in which 7 herbicides are applied 4 or 5 times over 2 seasons. Mature tip cuttings were taken 2 to 4 months after the final applications in July and August 1978 and rooted under mist.

Table 2. Percentage reduction in weeding time and fresh weights of *Juniperus horizontalis* 'Plumosa Compacta', and rooting of cuttings from plants receiving 4 or 5 applications of herbicides in containers over a 2-year period.[1]

Herbicide	Rate (ai, lb/A)	Percent reduction in weeding 2nd year[2] July	Aug	Juniper top weights (grams)	Rooting Percentage	Rooting score
untreated controls,	0	0	0	63	92	5.1
periodically weeded	0	0	0	108	90	4.6
napropamide 10G	4	55	41	132	92	4.8
	16	47	20	87	82	4.7
oryzalin 5G	4	99	80	156	62	4.1
	16	100	97	166	50	3.4
oxadiazon 2G	4	94	80	142	70	4.3
	16	99	91	124	75	4.2
alachlor	4	36	70	104	92	4.6
	16	78	96	127	75	4.1
oxyfluorfen 2G	2	95	97	170	78	4.3
	8	99	97	170	78	4.3
trifluralin 5G	4	78	64	111	87	5.0
	16	95	82	168	72	4.3
methazole	4	94	74	139	67	3.8
	8	99	82	172	77	4.8
oxadiazon+ oryzalin	2+2	92	80	144	85	4.7
alachlor +	4+0.8	78	91	156	75	4.2
simazine	8+1.6	99	99	120	72	4.2
L.S.D. p = .05				47	N.S.	N.S.
p .01				62	N.S.	N.S.

N.S. difference not significantly different at p = .05.

[1] Alachlor and alachlor plus simazine were applied in June, Aug. and Oct. 1977, and May and July 1978. The other herbicides were applied in June and Sept. 1977, and May and Aug. 1978. Cuttings were taken Nov. 2, 1978 and rooted under mist.

[2] Weeding of the untreated controls cost an estimated $1407 per acre for the 2-month period.

Table 3. Rooting percentage of cuttings taken following four applications of herbicides in containers over a 2-year period.[1]

Herbicide	Rate (ai, lb/A)	*Leucothoe fontanesiana*	*Rhododendron* 'Chinoides'	*Pieris japonica*	*Rhododendron* 'Louise'
controls, weeded		75	100	84	22
periodically		87	100	90	41
napropamide 10G	4	95	88	83	30
	16	82[2]	100	79	50
oryzalin	4	82[2]	92	80	38
	16	76[2]	92	82[2]	22[2]
oxadiazon 2G	4	82	100	78	42
	16	72[2]	100	77[2]	21
		N.S.	N.S.	N.S.	N.S.

N.S. difference not statistically significant at p = .05

[1]The herbicides were applied in June and Sept. 1977, and May and August, 1978. Cuttings were taken Oct. 3, 1978 and rooted under mist.

[2] Plants showing foliar injury or reductions in vigor from the herbicide treatment.

The time required to weed the untreated containers during July and August of the second season was 0.71 minutes per gallon container. Based on 40,000 gallon containers per acre and a labor cost of $3.00/hr this translates to weeding costs of $1,407 per acre for that 2 month period. As seen in Table 2, most herbicides at the low rate (normal rate) markedly reduced weeding times and therefore weeding costs. Weeding times were higher than expected with napropamide because of the predominance of creeping woodsorrel (*Oxalis corniculata*) that is resistant to napropamide. The higher weeding times for alachlor relative to the other herbicides are due in part because alachlor was last applies in May, whereas the other herbicides were applied in June. Reapplication of alachlor in July following weeding gave improved weed control in August.

The rooting results with cuttings from *Juniperus horizontalis* 'Plumosa Compacta' (Table 2) show apparent reductions in rooting from oryzalin at normal rates (X) and 4 times normal (4X) rates and trends in reduced rooting with other herbicides. Because of variability, however, the differences in rooting were not statistically significant at the 5% probability level. However, most treatments sharply reduced weed populations and many produced significantly more growth than the untreated controls. Increased vigor may have been a factor in apparent reduced rooting percentages of cuttings.

The rooting percentages of *Leucothoe*, *Rhododendron* 'Chinoides', *Pieris japonica* and *Rhododendron* 'Louise' following 4 applications of napropamide, oryzalin, and oxadiazon in this experiment are given in Table 3. None of these herbicides, even at 4X dosages, significantly affected rooting of cuttings taken 6 weeks after the final application. This was true even though some treatments reduced the vigor of either foliage or roots, or both.

In a second two-year container trial conducted at another commercial nursery during 1977 and 1978, neither alachlor nor alachlor plus simazine at extreme dosages significantly affected the rooting of cu and sand, for example.

Table 4. *Rooting of cuttings of Rhododendron catawbiense* 'Nova Zembla' following 5 applications of alachlor alone or with simazine in 1-gallon containers.[1]

Herbicide	Rate (ai, lb/A)	Rooting Percentage	Rooting score
untreated		63	4.0
alachlor 15G	4	74	4.5
	8	68	4.3
	16	57	4.1
alachlor 15G+ simazine	4+0.8	57	4.1
	8+1.6	61	4.2
	16+3.2	69	4.6
		N.S.	N.S.

N.S. difference not statistically significant at p = .05.

[1] The rhododendrons were planted on June 9, 1977 and treated June 14, 1977, Aug. 1977, Oct. 1977, May 1978, and July 1978. Cuttings were taken Oct. 4, 1978, rooted under mist, and evaluated Feb. 28, 1979.

Field-grown Taxus and junipers. *Taxus* and junipers are widely grown in wholesale nursery production in Connecticut. Almost annually since 1970 an experiment has been started in which newly planted *T. cuspidata* and Juniperus horizontalis 'Plumosa' (Andorra juniper) were treated in May or June with experimental and standard herbicides and retreated a year later. The soil is a sandy loam with an organic matter content of 2 to 3%. Cuttings were taken in December or January following the second herbicide application, as in normal nursery practice. The cuttings were rooted in sand with bottom heat and intermittent mist and evaluated about 3 months after sticking. As shown in Table 5, a number of herbicides, even at 2X and 4X rates failed significantly to affect rooting of cuttings from the treated plants. Perfluidone injured both the *Taxus* and junipers, but did not affect rooting of cuttings. Bentazon caused slight injury on *Taxus* at 2 lb/A, but also had no effect on rooting of cuttings.

In a trial started in May, 1977, napropamide was applied before planting and oryzalin plus simazine after planting six *Taxus* cultivars. All treatments were reapplied on the soil surface the following spring. Cuttings were taken in January, 1978. None of the treatments significantly affected rooting of the cuttings (Table 6).

Table 5. Herbicide treatments (lb, ai/A) causing no significant effects on rooting of cuttings from *Taxus cuspidata* or *Juniperus horizontalis* 'Plumosa' as compared with untreated periodically weeded controls.

Years in which cuttings were taken		
1973[1]	1976[2]	1978[3]
napropamide WP or G3 or 6	perfluidone WP 3 or 6[4,5]	napropamide G or WP 4 or 8
pronamide WP 2 or 4	bifenox WP 3 or 6	oxyfluorfen 2G, 4 or 8
methazole WP or G3 or 6	oxadiazon WP 2 or 4	oryzalin WP, G or AS 2,4 or 8
alachlor G, 4 or 8		alachlor G, 4, 8 or 16
alachlor G + simazine G 4 to 6 + 1.5 to 3	alachlor EC + simazine WP, 5 or 10 + 1.5	oxadiazon G, 4 or 8
		bentazon 1 or 2[5,6]
simazine G, 3	simazine WP 1.5	oryzalin WP + simazine WP 2 + 1.5
trifluralin G 2	oryzalin WP 2 or 4	
trifluralin G + simazine G 2 + 1.5	oryzalin WP + simazine WP 1.5 + 2	
	asulam 3 or 6	
	asulam + oxadiazon WP 3 or 6 + 2 or 4	

[1] The herbicides were applied May 8, 1970, May 12, 1971, and May 13, 1972. Cuttings were taken in January, 1973.
[2] The herbicides were applied June 11, 1975 and May 26, 1976. Cuttings were taken in December 1976.
[3] The herbicides except bentazon were applied May 18, 1977 and May 19, 1978. Cuttings were taken in December 1978. Bentazon was applied in June and August of 1977 and 1978.
[4] Treatments that injured *Taxus*.
[5] Treatments that injured juniper.
[6] Bentazon severely injured juniper and no juniper cuttings were taken.

Table 6. Effects of napropamide and simazine plus oryzalin in the field on rooting percentage of cuttings from treated *Taxus* cultivars.[1]

Herbicide	Rate (ai, lb/A)	*T. cuspidata*	*T.* 'Brownii'	*T.* 'densiformis'	*T.* 'Hicksii'	*T.* 'Hatfieldii'	*T.* 'Greenwave'
untreated		100	96	79	87	96	79
simazine+ oryzalin	1.5+2	95	100	71	92	100	96
napropamide	4	100	96	79	67	87	96
	8	100	100	75	96	100	83
		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

N.S. difference not statistically significant at p = .05
[1] Treatments were applied in May, 1977 and again in April, 1978. Cuttings were taken in January, 1979 and rooted in sand under mist.

The effects of asulam and glyphosate sprays applied at 4 different times of the year over established plants of *T. cuspidata* and *Juniperus horizontalis* 'Plumosa' were evaluated in 1973 and 1974 (Table 7). Asulam at 3 or 6 lb/A at any date of application caused no plant injury and had no effect on rooting of cuttings.

Glyphosate caused only slight injury to the junipers during active growth, but did not affect rooting of cuttings. However, glyphosate killed shoot tips of *Taxus*, especially at 1.5 lb/A during May or August (3). As shown in Table 7, August and November applications on *Taxus* markedly reduced the rooting percentages of cuttings taken in December or January. These results were confirmed in another experiment with glyphosate in a commercial nursery during 1975 (Table 8). Glyphosate at 0.75 lb/A (1 qt Roundup per acre) in August 1975, killed established

annual grasses with little or no observable injury to *T. media* 'Densiformis' or 'Greenwave'. However, cuttings taken from treated *T.* 'Greenwave' the following March failed to root as well as cuttings from adjacent untreated plants. Cuttings from treated *T. media* 'Densiformis' were slightly affected.

Table 7. Effects of asulam and glyphosate applied at different times on the rooting percentage of cuttings of *Taxus cuspidata* and *Juniperus horizontalis* 'Plumosa'.[1]

Herbicide	Rate, lb/A[2]	Time of application	Taxus 1973	Taxus 1974	Juniper 1973	Juniper 1974
untreated controls	0	—	96	99	82	96
asulam	3	Apr. 18-19	88	95	90	98
	6		98	98	81	95
	3	May 30-31	92	93	73	95
	6		96	97	85	100
	3	Aug. 8-9	92	100	88	98
	6		92	100	75	97
	3	Nov. 5-7	92	100	63	100
	6		96	98	83	95
glyphosate	0.5	Apr. 18-19	92	100	83	98
	1.5		98	98	60	100
	0.5	May 30-31	100	100	85	98
	1.5		96	80	81	85
	0.5	Aug. 8-9	90	98	77	95
	1.5		56	85	79	97
	0.5	Nov. 5-7	79	97	85	93
	1.5		4	20	79	98
L.S.D. p = .05			18	12	N.S.	N.S.
p = .01			24	16		

N.S. differences not statistically significant at p = .05.

[1] The herbicides were sprayed over the plants in 50 gal solution/A once each year at the specified time. Cuttings were taken from the plants in Dec or Jan, rooted in sand under mist and evaluated in the spring. Each figure represents an average of 60 cuttings.

[2] lb/A active ingredient for asulam and lb/A acid equivalent for glyphosate.

Table 8. Effect of August application of glyphosate on rooting of *Taxus* cuttings.[1]

	Taxus media 'Densiformis'		*Taxus* 'Greenwave'	
Treatment	Percent rooted	Rooting score	Percent rooted	Rooting score
untreated	96	4.9	72	3.9
glyphosate 0.75 lb/A[2]	88	4.9	22	3.2

[1] glyphosate was sprayed over the Taxus in Aug. 1975. Cuttings were taken on March 10, 1976, rooted in sand, and evaluated July 20, 1976. Each figure represents an average of 100 cuttings sampled from 4 different areas of the treated plots.

[2] acid equivalent.

DISCUSSION

Of the 14 herbicides applied alone or in combination in 8 field and container experiments, only one caused significant reductions in rooting of cuttings. The herbicide was glyphosate, a systemic growth regulator type herbicide with apparently long residual effects in woody plants. Glyphosate is registered for preplant and directed applications in nursery plantings, but not for broadcast spraying over nursery plants such as was done in our experiments. Since glyphosate is adsorbed and inactivated on the soil it is unlikely that directed sprays of glyphosate would affect rooting of cuttings from treated plants.

A number of the herbicides that were included in these experiments are not yet registered for use in ornamental plantings. These included asulam, bentazon, bifenox, methazole, oxyfluorfen, and perfluidone. Asulam has been effective in postemergence control of annual grasses and certain broadleafed weeds in narrow-leafed evergreens, whereas bentazon has given late season postemergence control of yellow nutsedge in *Taxus* (5). Oxyfluorfen and bifenox are preemergence herbicides that may eventually become available for use in ornamental plantings. None of these herbicides appear to affect rooting of cuttings from *Taxus* or juniper in the field.

Herbicides that have become registered for nursery use and hence available to growers since our earlier reports (1,2) include oxadiazon (Ronstar), napropamide (Devrinol), oryzalin (Surflan), and alachlor (Lasso). There has been no indication from these or previous studies that normal rates of oxadiazon, alachlor or oryzalin affect rooting of cuttings from treated plants. Further, despite their wide use by nurserymen, we have not heard of any problems in rooting of cuttings that might be related to use of these herbicides.

Napropamide has become available to nurserymen more recently than the other materials. In 1972, we reported reducing rooting of softwood cuttings of *Rhododendron* 'Daviesi' and 'PJM', but not *Rhododendron* 'Tunis' or 'Purple Gem' (2). One grower also reported to us that napropamide appeared to have reduced rooting of cuttings from treated *Taxus*. In the work reported here, where all of the cuttings were from mature shoots, we saw no evidence of rooting reduction from napropamide on 6 *Taxus* cultivars in the field and 5 species including 2 *Rhododendron* cultivars in containers.

The herbicide simazine has been used by nurserymen for almost 2 decades. Previous reports (2,7) have indicated that simazine can affect rooting potential of cuttings from certain plants, but in those instances simazine was tested on plants of marginal tolerance and under conditions for which no label reg-

istration has been granted. Simazine currently is registered for use on certain established ornamentals grown in the field, but not in containers. Nevertheless, most of our results with low rates of simazine (1 lb/A) in containers have shown no significant effects on rooting response. Stock plants grown in containers are more vulnerable to adverse effects of herbicides because a greater number of applications are required and with leachable soil mixes and heavy irrigation, herbicides can move into root zones.

CONCLUSIONS

These studies and those reported previously permit several conclusions about the effects of soil-applied herbicides on rooting of cuttings from treated plants. No herbicide has consistently reduced rooting of cuttings and most observed effects have occurred under one or more of the following conditions: (1) at higher than normal herbicide dosages which often caused plant injury, (2) on plants with marginal tolerance to the herbicide, (3) at short time intervals following herbicide application, or (4) on softwood cuttings rather than mature cuttings. Precise herbicide applications at dosages and on plants specified on the herbicide label are not likely to cause problems in rooting of cuttings. However, it is wise to use all new herbicides on a trial basis, leaving comparable untreated plants, so that tolerance and rooting response can be observed under the growers' conditions. This is particularly true in container plant culture. We must continue to evaluate potential effects of herbicides on rooting of cuttings from stock plants. At this time, however, the bulk of the evidence suggests that properly applied, herbicides do not post a threat to plant propagation.

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Thursday Afternoon, December 13, 1979

The Thursday afternoon session convened at 2:15 p.m. with Dr. Philip Carpenter serving as moderator.

WINTER STORAGE OF BAREROOT LINERS AT SUBFREEZING TEMPERATURES

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Why do we store plants at subfreezing temperatures? Primarily because dormancy is guaranteed, it is closer to nature, diseases are nonexistant or easy to control, and low temperature give high relative humidity. Additionally, plants grow faster initially; this is very important when hot, dry summers follow short springs. Storage at subfreezing temperatures does have some limitations. Shipping during midwinter at a moments notice is hard to do unless stock is packed accordingly and humidity must be replenished every 5 to 6 weeks.

We use the following procedures: Plants are dug in the fall or early spring when they are dormant. Sometimes the foliage is "sweated off", as with rose bushes. Botran spray is applied on roots as well as canes. Plants are then graded and bundled for storage in bins. The bins are made out of 2″ × 4″ lumber and placed on pallets so that cold air can pass under the bin as well as over the top since the floor gives off some heat. Plants are placed root to root and a layer of paper waste (called clarifier), obtained from a paper company, is placed between the roots. It is light-weight and nontoxic. Most important, it is not a disease carrier. This medium is wet until water can be squeezed out of it. Bundles must be limited in size so that the roots will not dry out. With roses there are 5 bushes to a bundle, while with seedlings the diameter at the root neck should be no larger than 4 to 5 inches.

We dig dwarf Alberta spruce, nested spruce, and Colorado spruce early in the spring when plants are still dormant. Extra care must be taken when packing these conifers. Plenty of space must be left between the layers. Branches should be free from packing material because they may rot at the point of freezing.

After the plants are packed they are washed down with Botran to prevent *Botrytis*. Captan and Ferbam do not seem to work too well at low temperatures. We do not use Terrachlor as it inhibits growth the following spring.

A good thermostat with a 1°F differential is a must. The temperature is set at −1.5°C (29°F) and will fluctuate between −2° and −1°C (28 and 30°F). This will hold the plants dormant. It is important to reach freezing temperatures within a few days.

Every 5 to 6 weeks, preferably on a mild day in winter, the thermostat is turned up for 24 hours so the air temperature goes to 4.5° to 10°C (40 to 50°F). At this time, plants are sprayed with Botran to replenish humidity in the air and moisture inside the branches. The temperature is then again dropped to −1.5°C (28°F).

Three to 5 days before shipping and/or planting, the temperature is raised by opening the doors or bringing in a portable heater for 24 hours to thaw out the packing medium. As soon as the medium is thawed out the temperature is dropped to 0.5° to 1°C (33° to 34°F). If plants are not immediately shipped or planted they are given a final spray with Botran. Small quantities of plants can be packed in bushels, boxes or pallet boxes so small quantities can be removed without thawing the whole cold storage.

Care must be taken to maintain humidity as high as possible. However, plants frozen in ice can become waterlogged. This is not detrimental to the plant but can be if the roots are waterlogged. This waterlogging is also bad for cuttings or scions.

In order to winter store plants at subfreezing temperatures there are certain basic requirements one must have:

1. *Air-tight insulation.* We have sprayed 2 inches of polyurethane on cement block walls.

2. *Cooling coils with automatic defrost heaters.* Defrost water is run outside until plant medium is frozen. Defrost water is then run onto storage floor. If needed, additional water is poured on the floor every 2 weeks.

3. *Thermostat with 1°F differential.* This is to insure that the temperature does not drop too low at any point. It is presumed that plants start to solidify at approximately −2°C (28°F). Lower temperatures may result in dehydration. Our storage is run by air conditioners. Circulation fans are going all the time except when automatic defrosting takes place.

We have made two observations about storage at subfreezing temperatures.

1. Arizona or California grown rosebushes, subjected to a 60 day freezing period, started much more vigorously and rapidly than others coming out of regular storage.
2. Junipers do not store well this way.

In conclusion, most nurseries should have cold storage

facilities. Plants stored at subfreezing temperatures start growth rapidly in the spring. It is the most natural, healthful way to store plants.

CONTAINER PRODUCTION OF EUONYMUS ALATA 'COMPACTA'

CLAYTON W. FULLER

Bigelow Nurseries, Inc.
Northborough, Massachusetts 01532

Five years ago, when we decided to grow some of our *Euonymous alata* 'Compacta' in containers, we were not aware of the various problems that would arise from growing this species in containers. This report outlines some of these problems and our solutions.

We always gather our cuttings from the best growing stock in the nursery. In our area, cuttings are taken the 4th week of June. They are taken only from the most vigorously growing plants. The cuttings we make are 6 to 7 inches in length and about the diameter of a lead pencil. They are put in bundles of 25 in the field as they are made, and held together with an elastic band. They then are brought into the propagating work area where the bottom 2 or 3 sets of leaves are removed. We do not recut the cuttings; thus reducing the labor in the work area. We never remove any part on the terminal growth, because we feel that natural self-branching is sufficient. We also find that it checks the growth of the plant later on in its growth cycle. The cuttings are then placed 100 to a flat in coarse perlite. We use no hormone or fungicide dip on our cuttings. We have tried auxins in the past and found no beneficial effect from them. The cuttings are placed in our propagating frames using Mist 100 nozzles and a Mist-O-Matic scale.

As soon as a sufficient root system has developed (8 to 9 weeks) the cuttings are removed from the propagating frame. Around the first week of September they are potted into a Nu-pot with a soilless potting mix. We are presently using Pro-Mix BX. The potted cuttings are grown on in the fall until freeze-up time. The plants are fed with Peters 20-19-18 every 10 to 14 days at 3 ppm until they defoliate, when they are put in a minimum −2°C (28°F) cold storage house.

Around the first of April the following year, the plants are removed from cold storage and set outside before any bud development occurs. Sometimes, because of weather conditions, we do see some bud swell, but this seems to have no effect when the plant is placed outside.

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As soon as weather permits in April our canning operation begins. Feeding is done every 7 days at 3 ppm until the plants are containerized. The plant is upgraded from the Nu-pot to a 4 quart container. It should be explained here that because of different measurement sizes in our industry the 4 quart container mentioned here is actually larger than a standard 1 gallon container. We were using a 1 gallon container, but found it was too small to sustain the plant growth for the 2 years we like to grow this plant without trans-canning. This was one of our early mistakes. We did not size our container large enough to maintain optimum growth of the plant.

The potting mix we are using at present consists of equal parts of coarse sand and well-rotted softwood bark with 7 lbs dolomite limestone and 7 lbs Surge (a commercially formulated fertilizer made for container growing) per cubic yard.

Because of the tremendous ability of *E. alata* 'Compacta' to absorb nutrients for optimum growth, strict attention must be given to the feeding schedule. Our present feeding schedule after first year canning is 3 times a week with 20-19-18 (Peters) at 3.5 ppm through the overhead irrigation system. This is injected into the system by a GEWA injector for 20 minutes each feeding. We continue this schedule through to the first of September when it is cut to once a week for 3 weeks, then discontinued for the year to allow the plants to become winter hardy. The only other fertilizer our first year containers receive is a broadcast of 15-15-15 pelletized fertilizer the third week of June at the rate of 150 lbs per acre. Because of this fertilization program we feel that after the initial growth in the spring we can induce the plant to flush a second growth cycle around the second week of July. Therefore we have a plant with branches at the bottom and hopefully 15″ to 18″ on the single leader. Because we are looking for this extended growth in the terminal leader in the first year, no nipping is done in the container. Our second year plants start with this growth, and due to its self-branching qualities it will give us, hopefully, a well branched, saleable 15″ to 18″ plant (with a few 18″ to 24″) at the end of the second growing season.

Our fertilization program for second year plants includes one feeding in the spring, when the growth is active, with Osmocote (fast start) 18-6-12 at the rate recommended on the label. Although this formulation normally should sustain a plant for the growing season, we find with *E. alata* 'Compacta' that a second feeding the second or third week of July at half the recommended rate is needed to sustain the growth and quality of the plant. No other fertilizers are applied except the slow release on our second year plants, although this year we are seriously considering using liquid fertilizer instead of the second

feeding of Osmocote.

Overwintering of the plants and winter injury have not been a problem with us until this past winter. The third week of December we tip our containers in place, then cover them with micro-foam, then 4 mil plastic over the micro-foam, to protect the foam. We always irrigate the plants before tipping to insure proper moisture for the plant during the time they are under the micro-foam. This is where we had considerable damage to our plants last winter. Although we know a dry plant will not survive the winter months, our experience last winter indicates waterlogged root systems do not survive either. In January we had 3.2 inches of rain, which completely inundated one area of our growing pad. The micro-foam and plastic did a fine job of trapping the water as the temperature fell rapidly, thus leaving the containers half in ice. When these plants were uncovered in the spring they appeared at first to have survived. but upon close examination injury was found in the root system and at the cambium layer. There were no survivors in this block of plants.

The micro-foam is removed the first week of April and the plants are spaced 18 inches on center. We feel this spacing allows the plant to develop all the lower branches, thus ensuring a quality plant.

At the present time the only herbicide used on our *E. alata* 'Compacta' is Treflan granular at recommended rates applied immediately after canning, or when the older plants are uncovered in the spring. A second application is applied 8 weeks into the growing season. A walk-through hand weeding is needed to control weeds that may have been carried into the container area. We have used Ronstar 2G on our containers; while it does not appear to cause permanent injury to the plants, we feel that it does inhibit growth.

In conclusion, I would like to say that *E. alata* 'Compacta' is a plant that adapts very well to container growing if close attention to cutting size, no nipping, container size, fertilization, spacing, and overwintering procedures are observed.

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WOODY NON-LEGUME NITROGEN FIXING PLANTS[1]

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Nitrogen is an essential inorganic element for all forms of life and, with the exception of water, is the most frequently encountered limiting factor in crop production. Organisms capable of using atmospheric nitrogen ordinarily require no other source, but those lacking this capability are dependent upon nitrogen from fertilizer or soil reserves. Biological nitrogen fixation of atmospheric nitrogen not only supplies the element to the fixing organism, but is a source of nitrogen for other plants. This occurs through leakage and plant decomposition in a variety of habitats that are important in food production, prevention of erosion and maintenance of ecological balances.

Nitrogen fixation by legumes has long been recognized and has become an important part of modern agriculture. The occurrence of nodules and nitrogen fixation by non-legume angiosperms is less noted but offers many potential uses.

The first occurrence of nodules on nonlegumes was recorded early in the nineteenth century (25). The latest widely-accepted compilation reports 157 species in 13 genera as possessing nodules (8), including *Alnus*, *Arctostaphylos*, *Casuarina*, *Cercocarpus*, *Coriaria*, *Discaria*, *Dryas*, *Elaeagnus*, *Hippophae*, *Myrica*, *Purshia* and *Shepherdia*. *Comptonia peregrina* (L.) Coult. var., *asplenifolia* (L.) Fern, reported as a nodulating genus in some earlier lists, has also been called *Myrica asplenifolia* L.

Several changes have appeared in the literature since the compilation of this listing. *Arctostaphylos uva-ursi* was reported to possess *Alnus*-type root nodules apparently solely on external inspection of nodular structures (1). Under microscopic examination the "nodules" were found to be aggregates of latent buds and sprouting was induced.

Farnsworth and Hammond (14) observed nodules on the roots of *Artemisia ludoviciana*, family Compositae, and reported the endophyte to be bacterial. Reduction of acetylene to ethylene, a test of nitrogen-fixing activity, was recorded. Apparently nodulation also occurred on prickly pear cactus (*Opuntia fragilis*, family Cactaceae) (14), but acetylene reduction has not been reported. Nodulation and acetylene reduction by *Datisca cannabina* and *D. glomerata*, family Datiscaceae, has been recorded (12).

Isolation of the nitrogen-fixing organism associated with non-legume plants has been attempted by a number of investigators with varying amounts of success.

Callahan, et al. (9) successfully isolated the actinomycete symbiont from nodules of *Comptonia peregrina* var. *asplenifolia* (Syn.: *M. asplenifolia*) after incubation and enzyme maceration. Reinfection of sterile seedlings was achieved repeatedly and the same actinomycete reisolated from these seedling nodules. The induced nodules actively reduced acetylene to ethylene. The isolate has also successfully induced root nodules with high acetylene reduction activity in seedlings of *M. gale, M. cerifera, Alnus crispa,* and *A. glutinosa* (14,23). However, attempts to nodulate *Elaeagnus umbellata* were unsuccessful (5).

The taxonomic status of actinomycete root nodule endophytes has not been duly defined (14,23). Becking (2) applied the generic name *Frankenia,* in the single family Frankeniaceae, to the endophytes of nonleguminous nodules and designated specific epithets referable to the host species or to the original designations. With the successful isolation of the organism of *C. peregrina* var. *asplenifolia* and infection by the isolate in other genera, more appropriate scientific designation may be forthcoming.

The ecological importance of actinomycete-nodulated plants as pioneer species is well documented. *Dryas drummondii* and *Shepherdia canadensis* were early colonizers in recently deglaciated areas in Alaska. *Alnus crispa* usually followed and became dominant. Soil analysis under alder thickets estimated an annual accumulation of 62 kg N/ha, resulting chiefly from nodular fixation (7). *Myrica pensylvanica* appears to be a key successional plant on nitrogen impoverished coastal soils and dunes (27) and growth of young pitch pine (*Pinus rigida*) was significantly greater within *M. pensylvanica* stands (34). *Ceanothus veluinus* is one of the first plants to grow back after conifer forests in the Pacific Northwest are burned or logged (39).

Alnus oregona (Syn.: *A. rubra*) is the largest fiber producing species per unit area (17), and accounts for more than 60% of all merchantile hardwoods in the Pacific Northwest (30). *Ceanothus sanguineus, Purshia tridentata* and *P. glandulosa* are desirable grazing (30) and browse plants. *Purshia* spp. have a protein digestability coefficient slightly above that for alfalfa (*Medicago sativa*) (30). Silvester (30) reviewed many other direct uses for other nonlegume nitrogen-fixing species.

Several non-legume nitrogen-fixing species have been used to increase the growth of forest crops. *Alnus* spp. have been shown to improve fertility and physical properties of soil (35).

The soil fertility beneath a mixed stand of *Alnus oregona* and *Pseudotsuga menziesii* (Douglas fir) was greater than beneath a pure Douglas-fir stand (33). *Alnus oregona* added 200-300 kg N/ha/yr when growing in mixed forest stands and provided nitrogen for associated trees (31). A light understory of *A. oregona* added 200 pounds total nitrogen/A whereas a heavy stand added 780 pounds total nitrogen/A (4). *Alnus oregona* is currently used to improve conifer sites and stands in a rotation or as an interplanted nurse crop (17,32). *Purshia tridentata* is widely distributed in ponderosa pine (*Pinus ponderosa*) forests of the West and makes a significant contribution to the nitrogen economics of the local ecosystem (37). Wollum and Youngberg (38) found seedlings of Monterey pine (*P. radiata*) grown in containers after *Ceanothus velutinus* were comparable to those grown with 35 ppm added nitrogen. The use of *Elaeagnus umbellata* as a nurse crop significantly increased the growth of black walnuts (*Juglans nigra*) (46).

Alnus spp. and other non-legume nitrogen fixers have been widely used for reclamation of disturbed sites and sand dunes in Europe and Japan (21,30,36). The use of *A. glutinosa* for reforestation of disturbed sites in the United States was suggested by Kohnke (22) and its use, especially on strip-mines, has increased in recent years (45). Alder was particularly desirable in such situations because of their ready establishment, rapid growth, abundant leaf litter production and their ability to fix atmospheric nitrogen. The use of other nitrogen-fixing non-legumes for reclamation is promising (11).

Elaeagnus spp. and other non-legume nitrogen species have been used to develop low maintenance landscapes along several of this nation's roadsides. These plants provide perennial, aesthetically pleasing cover. The need and expense of continuous nitrogen fertilizer application is eliminated in these plantings (10,26).

Both legume and actinomycete-nodulated nitrogen-fixing species offer advantages in more traditional landscape sites. The condition of many sites is little better than those resulting from mining or highway construction. Maintenace may be reduced because of a continuous supply of nitrogen to the entire plant community.

Currently, the intentional use of nitrogen-fixing species in landscape is not common. Information on specific environmental requirements, as well as horticultural descriptions, are somewhat limited. The production and supply of nitrogen-fixing plants is limited and in some cases nonexistent. As more information on potential uses and culture of nitrogen-fixing species increases, potential markets will also increase. Nurse-

rymen should be aware of these potential sales areas.

The following nitrogen-fixing non-legumes are among those with the most immediate use in landscape and reclamation uses. Other genera and species may also provide regional and widespread uses and benefits.

Alders. Several species of alder are common internationally. *Alnus incana* as well as *A. glutinosa* are more common in Europe, although available in the United States. Distribution of other alders useful in the landscape finds: 1. *Alnus rhombifolia* used regularly in California, 2. *Alnus oregona* of major commercial importance in the Pacific Northwest, 3. *A. incana* in coldern northern climates, and 4. *A. maritima* a promising landscape species along the Atlantic Coast.

For the most part, the alders are grown for landscape use in wet areas. This group of plants may possess one of the highest transpiration rates within tree species. Therefore, they have the need and ability to live in wet landscape sites.

Propagation is commonly done by seeds which mature in late fall and are sown in the spring. Seeding techniques can be critical because the seed is fine and lightweight and cannot tolerate deep covering. Best results occur with no covering or a light, airy covering.

Seeds become non-viable without proper storage. Seeds stored in air-tight containers at 1° to 3°C (34° to 37°F) remain viable for one to two years (28). Dried seeds may benefit from cold stratification (13,28). Cultivars are generally propagated by stem cuttings or grafting (29).

Elaeagnus. This plant group includes several species (*Elaeagnus angustifolia, E. commutata, E. pungens* and *E. umbellata*) of landscape value where soils are poor or dry. Thorns and microscopic-sized structural scales are also genus characteristics.

Plants may be propagated by seed, cuttings or layering (29). *Elaeagnus pungens* is noted for several cultivars. These may be propagated by cuttings taken during midsummer and placed under mist or as hardwood cuttings in the fall (29).

Elaeagnus umbellata 'Cardinal' is one of a few woody cultivars that is propagated true from seed. Seed propagation with this species is slow. Germination restriction has been shown to be caused by inhibiting substances in the fruit or seed parts (18). This inhibition can be overcome by the production of germination promoters in the seed or stratification at 1°C (34°F) for 90 days (28). Seed collection must be timely, since plants in this genus are used for wildlife food and cover.

Shepherdia. Buffaloberry (*Shepherdia argentea*) is well

adapted to dry, poor locations in the North Central United States (6). Buffaloberry and Russett buffaloberry (*S. canadensis*), which is also adapted to poor sites, have attractive silvery foliage. Yellow and red fruit selections are available.

Seeds of both *S. argentea* and *S. canadensis* are planted in the fall or stratified for 60 to 90 days and planted in the spring (28). Acid scarification of *S. canadensis* may improve germination. Wild plants of *S. argentea* are also collected and marketed.

Sweetfern. Sweetfern (*Comptonia peregrina* var. *asplenifolia*) is a low-growing shrub native to the Atlantic Coast and Northeastern United States. It is best noted for its ability to stabilize sandy soils and do well on otherwise poor sites. While not noted for floral or fruit display, it is distinctive for leaf shape and fragrance (24).

Availability of sweetfern in the nursery trade has been limited because of both propagation problems and poor transplantability. The majority of available plants have been collected and therefore roots have been coarse and few in numbers. The plant does well when produced in containers, and container-grown plants have shown no transplanting problems.

Large-scale propagation has been limited by lack of good seed sources, poor seed germination and lack of rooting with stem cuttings. Propagation has been limited primarily to root cuttings, which means sacrificing of the parent plant. Recent work has indicated root cutting success is improved by relating cutting length to root diameter. Stem cuttings of juvenile growth originating from root cuttings and treated with Hormodin #2 have rooted with excellent success (20).

Bayberry. The blue-gray fruit and fragrance of bayberries (*Myrica californica, M. cerifera, M. gale* and *M. pensylvanica*) make their landscape interest special. These evergreen to semi-evergreen trees and shrubs are dioecious, producing fruit only on pistillate flowering plants. The wax produced on the outer surface of the fruit is used in making bayberry candles.

The most common procedure for propagation is by seed. While in storage, the waxy seed covering should be left intact. The seed will store up to one year. Before stratifying, the waxy coating should be removed mechanically. Stratification ranges from 30 to 90 days depending on species (28). Germination may be enhanced by using gibberellic acid (3,18). Cutting propagation can also be carried out in late summer using half-ripe stem cuttings (29).

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QUESTION BOX

The question box session was convened at 4:10 pm with Ralph Shugert and Bruce Briggs serving as moderators.

MODERATOR SHUGERT: Question for Gary Koller. Do you have blight problems with *Aesculus parviflora*? Have you propagated this plant?

GARY KOLLER: We have had no major problem with it. I have seen some leaf scorch in a few areas.

MICHAEL DIRR: It will propagate from root pieces, suckers and seeds.

JOE McDANIEL: *A. parviflora* is susceptible to leaf hopper damage and scorch will set in after an infestation.

RALPH SHUGERT: We can not grow it in Ohio. I think it has a heat problem.

MODERATOR SHUGERT: I have a very hardy *Tilia cordata* from a northern source. Where can I obtain rootstock of comparable hardiness?

DAVE BAKKER: From the federal experimental farm at Mordon, Manatoba.

MODERATOR SHUGERT: I have several superior selections of *Celtis occidentalis*. How can I profitably propagate them?

JOE McDANIEL: I have had success with chip budding in the summer.

MODERATOR BRIGGS: Is anyone using Roundup on nursery shade trees? If so, how often and will it harm established trees?

MIKE LEAN: We have used it at the rate of 1½ oz/gal and have had no problem on limbed-up stock of *Malus*, *Pyrus*, *Crataegus*, *Fraxinus* and *Acer rubrum*. Keep the pressure low with coarse drops for best results.

BEN DAVIS: We are using the same rate but are not taking any chances. We use a shield made from a piece of stove pipe to protect the plants.

MICHAEL SCOTT: It can be used to control suckers on crabapples without any problems.

FRANK GOUIN: Watch out with Roundup; there is a delayed reaction we have noticed on brush control. Early applications on suckers did not show up until the following year. With conifers, application after August gave us no injury.

39. Wollum, A.G. II, C.T. Youngberg and F.W. Chichester. 1968. Relation of previous timber stand age to nodulation of *Ceanothus velutinus*. *For Sci.* 14:114-118.

QUESTION BOX

The question box session was convened at 4:10 pm with Ralph Shugert and Bruce Briggs serving as moderators.

MODERATOR SHUGERT: Question for Gary Koller. Do you have blight problems with *Aesculus parviflora*? Have you propagated this plant?

GARY KOLLER: We have had no major problem with it. I have seen some leaf scorch in a few areas.

MICHAEL DIRR: It will propagate from root pieces, suckers and seeds.

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MODERATOR BRIGGS: Does Surflan have a carryover into the next year? Does it have any effect on bud or graft take?

TOM PINNEY: We have had devastating results with its use on conifer seedling beds. It does not show up immediately and the herbicide appears to affect the root system. The problem is also related to Treflan. We are now looking at $100,000 in damage.

PETER VERMEULEN: We have had some problems with the combination Surflan and Ronstar on containerized azaleas. We are not sure which is causing the problem.

BRUCE BRIGGS: In the west when young peach seedlings were treated they did not bud as well and were brittle.

MODERATOR SHUGERT: Is anyone propagating *Nyssa sylvatica*? If so, how is it done?

ELWIN ORTON: It propagates readily from seed. Give it 80 to 90 days at 4.5°C (40°F).

BRUCE MacDONALD: We have propagated it from cuttings. The plants were grown under plastic and growth started in May. Three node cuttings taken in June and treated with 0.8% IBA in talc rooted. The cuttings should be overwintered before potting.

MODERATOR SHUGERT: In mulching seedbeds in the northern states, hay or straw is often used. When should that mulch be removed and what steps follow after removing the mulch?

BERNARD FOURRIER: We watch the seeds for germination and either remove some mulch or loosen it up. We put shade back on if frost is forecast.

RALPH SHUGERT: In Nebraska we used a light mulch and just allowed the seeds to grow through it. The big danger with removing mulch is frost damage. I would rather smother a few seedlings than lose a whole crop.

HENRY KOCH: We cover all our seeds with composted sewage sludge. The sludge is composted with sawdust. The mulching is then carried out with a combination of shredded oak leaves and peat moss. This is loose enough for any seedling to grow through.

MODERATOR SHUGERT: Has anyone had any experience with pregerminating seeds and fluid drilling them?

DALE MARONEK: The University of Florida at Gainesville has conducted research on this subject, primarily with vegetable seeds.

MODERATOR SHUGERT: Will Bruce MacDonald please elaborate on jacketed cold storage versus direct cold storage?

BRUCE MacDONALD: Jacketed cold storage is really a box within a box. A stream of cold air is forced through the space between the two boxes. No cold air is forced into the storage box. Humidity is higher and the temperature is easier to control. This type of storage is very good with bareroot material. The only problem is jacketed cold storage units are much more costly to build; however, the operating costs are lower.

MODERATOR SHUGERT: Bruce MacDonald, you mentioned *Rosa laxa* as a rose rootstock, doesn't it sucker objectionally?

BRUCE MacDONALD: The advantages of *R. laxa* are threefold. It gives a uniform stand after seed germination, a good hypocotyl to bud on, and it lifts easily. It also does not sucker very much. It is not useful in areas with low soil pH.

MODERATOR SHUGERT: When dipping cuttings in acetone, is it diluted an how long are the cuttings held in the acetone?

BRUCE MacDONALD: We use it directly from the bottle. With soft cuttings it might be advisable to cut it in half. We use a quick-dip.

MODERATOR SHUGERT: What rates of Atrinal have been used most successfully on *Rhododendron* and *Ilex* for developing more compact plants?

BRUCE MacDONALD: For rhododendrons and azaleas 2%; hollies, 1%; and camellias, 0.1%. We have also tried it on fast growing liners like *Spiraea* and found 1% to be satisfactory. Higher levels cause damage.

MODERATOR BRIGGS: Is there any evidence that lighting to extend daylength during propagation is detrimental to rooting or subsequent growth?

SID WAXMAN: I have no evidence to show that it is detrimental.

LEN STOLTZ: You have to have extended lighting if you are rooting plants like chrysanthemum that are sensitive to daylength.

JIM WELLS: We root deciduous azaleas which are sensitive to daylength. Applying supplemental light to the cuttings during rooting does not appear to have any beneficial effects after rooting; however, we do add supplemental light to induce shoot growth.

MODERATOR BRIGGS: Should Japanese maples have extended light during and after rooting to induce growth?

JIM WELLS: We have found them to be sensitive to light after rooting. If you can induce them to bud break after rooting

their chances of survival are greater. The removal of leaves stimulates bud break.

BRUCE BRIGGS: Be careful on leaf removal. The proper timing is important.

MODERATOR BRIGGS: Has anyone used Atrinal on Exbury azaleas and what were the results?

JIM WELLS: We have tried it. It did cause them to break, however, it did not do a good job. We still like to mechanically prune.

MODERATOR BRIGGS: With regard to IBA, how long can powder preparations be stored, how should they be stored, and is there a simple test to check if effective?

GERALD KLINGAMAN: Paul Smeal found that powders 10 years old showed no difference.

JIM WELLS: I have some powders and liquids that I brought from England 32 years ago that are still effective.

BRENT McCOWN: Powders should be stored dry. A simple test would be to root young bean cuttings.

MODERATOR BRIGGS: Has anyone found an effective pre-treatment of cuttings to prevent transmission of crown gall to *Euonymous*?

WAYNE LOVELACE: We are using an antagonist called Norback-84 which I understand makes the plants immune for life. We have used it on our *Euonymus* cuttings and we have crown gall on the checks but none on the treated.

MODERATOR BRIGGS: How do you control algae in mist propagating beds?

BRUCE MacDONALD: Currently work in England on algae control is being conducted by Margaret Scott, Efford Experimental Horticulture Station, Lymington, Hampshire. Algofen has been tried. In the past dodine acetate has been used in mist nozzles. Possibly a weak solution of Gloquot or Sandquat could be tried. Caution should be used however because both chemicals are used on capillary beds to prevent rooting through.

MODERATOR BRIGGS: Is anyone working with growth retardants on perennials?

BILL CUNNINGHAM: Alar is used on chrysanthemum.

MODERATOR BRIGGS: I would like to know if anyone knows of an effective safe fumigant to use for sterilization of raised beds in the greenhouse?

DAVE BAKKER: Baycoven is one that I have been using.

BRUCE BRIGGS: Steam is also possible.

MODERATOR BRIGGS: How can I propagate *Mahonia* from cuttings?

CARL ORNDORFF: Stem cuttings taken about the time of the first heavy frost will root in about 5 weeks. If you let them go later they come to a stall (rooting in 3 to 4 months) while earlier cuttings show blackening of the base.

BRUCE BRIGGS: Leaf-bud cuttings also root.

BRUCE MacDONALD: We take terminal cuttings, remove the terminal flower buds, and root them directly in a 5-inch pot. Leaf-bud cuttings can also be rooted. We reduce the leaves to 2 to 3 leaflets and plant in flats without hormone. No hormone is used because we have found that it delays bud break the following year.

MODERATOR SHUGERT: Is anybody propagating mugo pine by cuttings?

VOICE: I followed up on the leaching work of Dr. Waxman and leached cuttings from seedlings with good results.

ARNOLD KLEHM: I have taken cuttings from new growth in June before the needles mature. The lower needles are stripped off and then placed in sand with IBA treatments. After rooting, the cuttings are left in the flats until the following spring.

BRUCE BRIGGS: Increased rooting may result from leaving the lower leaves on conifers.

FRANK GOUIN: There was a paper published recently in HortScience on this very subject.

MODERATOR SHUGERT: In the spring of 1979 the USDA released *Microbiota decussata*. Will someone comment on its merits and faults? Does it lend itself well to vegetative propagation?

HENRY KOCK: It roots with ease from cuttings.

DAVE BAKKER: It can be rooted in the winter like juniper. The color is lush green in summer, however, during the winter and early spring it has an off color.

MODERATOR SHUGERT: Can *Amelanchier laevis* be rooted?

CATHY FREELAND: Softwood cuttings taken in midsummer root well when placed under mist and treated with 1% auxin.

MOERATOR SHUGERT: Is anyone propagating *Populus tremuloides* or *P. tremula* 'Erecta' by cuttings?

DAVE BAKKER: They are being grafted on Lombardy popular which helps the scion root.

Thursday Evening, December 13, 1979

The Thursday evening educational program on tissue culture was convened at 7:30 p.m. with Dr. Elton M. Smith serving as moderator.

GETTING STARTED IN TISSUE CULTURE — EQUIPMENT AND COSTS

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Abstract. A pilot tissue culture laboratory can be set up for less than $1000 if alternatives of materials and equipment are investigated. Some construction skills are needed to accomplish this, although no charge has been added for such labor costs to this proposal.

Tissue culture as a method of propagation is presently used on a rather limited scale compared with its potential use. Among the reasons for this are 1) a specialized knowledge of plant anatomy and morphology is required, 2) a strict regimen must be followed to maintain asepsis, 3) all plants cannot as yet be propagated by this technique, and 4) expensive, sophisticated equipment and costly, specially designed growth rooms are needed to grow the tissues and plants during the reproduction and replication phases. The latter reason will be considered in this paper, since costs are frequently given as the reason many people with adequate knowledge do not attempt tissue culture. A 1976 article (1) stated that "for a good commercial lab, equipment alone would cost $30,000." Another article (2) at about this same time indicated that a fully equipped lab could cost up to $250,000 and, if inflation is applied to these figures, the price might be nearly doubled today. But with a little ingenuity and a look at how things were done before we had sophisticated machines, perhaps a basically equipped lab can be set up for less than $30,000. Let's examine the laboratory equipment needed and consider what alternatives are available to reduce costs and perhaps permit a pilot operation to be set up for under $1000.

Autoclave. This unit is needed to sterilize nutrient media, glassware and occasionally tools. In a medium to large culture lab it would be used 2 or more times a week depending upon

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The investigation reported in this paper (79-10-226) is in connection with a project of the Kentucky Agricultural Experiment Station and is published with the approval of the Director.

the size of the operation. A good autoclave with a chamber, 16 × 16 × 24 inches, will cost between $12,000 and $26,000 new, depending upon the degree of automation ordered. Smaller table models are available but these still cost a minimum of $2200 to $2400 and the working chambers are quite small, usually 9 to 12 inches in diameter, which makes their use somewhat inconvenient and their cost still prohibitive. Since an autoclave is basically a sophisticated pressure cooker, why not use a pressure cooker? You won't have all the convenience of an autoclave but it will do an admirable job, and the cost for a canning size cooker varies from $32 for one you have to heat on a stove to about $200 for one with an electric heater built in. Cost of "autoclave": $40-$200.

Hood or Isolation Chambers. These units are used to provide a clean work area in which new tissues or plant parts can be dissected out and placed in culture, and for making routine transfers and divisions of cultures already started. The more sophisticated types costing up to $4000 have large, open work areas which provide a constant flow of filtered air to reduce the possibility of contamination by spores and other organisms in the air. Smaller table top models cost from $450 to $1200. My original isolation cabinet was homemade in 1964 at a cost of $12 for materials. In 1976, two of my students built another isolation cabinet for their use in a special problem course, and their total cost of materials was under $20. A box 24 inches wide, 16 inches deep and 20 inches on the back side was constructed of ½ inch plywood and painted with epoxy paint. A sheet of window glass set a 60° angle served as the face of the cabinet and this was sealed to the plywood with silicon windshield sealer. A sheet of window glass large enough for the case to sit on serves well as the floor of the cabinet and is much easier to keep aseptically clean during use than would be a painted wood surface. A single bulb fluroescent fixture and a UV germicidal lamp could be installed, and this will increase the cost to about $45 for materials. The fluorescent lamp gives good lighting for working in the cabinet, and the UV lamp is turned on 30 to 45 minutes before starting work in the cabinet (but turned off while working in the cabinet) to help in maintaining sterility. Cost - $45.

Binocular Dissecting Microscope. Prices vary from $225 to $1500. I would advise against buying the cheaper models; for in an advanced lab a good "binoc" will cost $500 to $800. It is used for examining buds and tissues and dissecting out apical buds or small organs in an early stage of development. For much of the work done in a tissue culture lab high magnification is not essential. A headband binocular magnifier with 3X to 5X magnification and a focal distance of at least 3 inches is

often adequate for those instances where magnification is needed. Cost - $17.

Growth Room. This can be as elaborate as a whole new building or clean room completely outfitted for growing tissues. For the advanced lab, the room would be completely sealed except for an exhaust and entry for its air supply filtered through HEPA filters to eliminate air borne contaminates. All walls and shelves should be painted white to reflect light and to make maximum use of the light supplied. The room should have its own heating and air conditioning systems. The ballasts for the fluorescent lights should be located so that they do not pose a fire hazard. However, the heat given off by them should be utilized in the winter to heat the growth room or adjacent work areas, and during the summer the heat should be dumped to the outside atmosphere to reduce air conditioning costs. A beginning lab can utilize any room where temperatures can be maintained between 20° and 27°C (68° and 81°F). This could be an unused portion of an office or storeroom or an extra room in a home. Racks or shelves with fluorescent lights suspended 14 to 18 inches above them will need to be installed. Two shelves 2 × 8 ft with two 4 ft shoplight fluorescent fixtures each, with 2 cool-white lamps suspended above them would provide adequate space to get started. The 32 sq ft of area would accommodate any one of the following: 2400 18 cm or 1500 25 cm tubes in racks; 700 jelly or baby food jars or 336 olive jars. Since many room situations would serve to get started, only the cost of 1 sheet of plywood ($12), 4 shoplights ($16 each) and a time clock ($20) to regulate light duration at the usual 16 hr light is considered. Total Cost - $96.

Autopipettor. Used to apportion tissue culture medium into tubes and bottles. These are nice to have, and a large lab should have at least one, but at $650 to $750 each they are unnecessary for the starting lab. A 2-liter aspirator bottle with the spout at the very bottom (cost $14.50 each) with soft tubing which can be easily pinched to stop liquid flow and of a diameter to fit the aspirator bottle spout (⅜ inch I.D. gum rubber tubing, cost $4.50 for a 12 ft package) will serve very well. A large funnel with about a 6 inch diameter (glass or plastic) to pour prepared medium into the aspirator bottle and a pinch clamp ($4.00/dz) to control liquid flow are also needed. A piece of plastic pipe with holes bored in it can be fitted to the end of the rubber tubing which will allow 2 to 4 tubes to be filled at once. Total cost of the alternative - $23.

Culture Vessels. Many glassware alternatives are available which can be used for growing tissues. During the past 15 years I have tried and discarded many types. Plastic disposable ves-

sels are also available in many configurations but I would not recommend them for any but the largest commercial labs and then only in certain instances. Although the manufacturers claim they are relatively inexpensive, I believe them to be rather costly unless large quantities are purchased and used. For a beginning lab I'd suggest the following:

Unit	Size	Amount	Cost
Culture tubes	25 × 100 mm	2 Gr.	$ 76.00
Kaputs	25 mm	Pkg/500	26.00
16 oz. straightsided flint jars	89-400	2 Gr.	56.00
Petri dish (bottom only)	100 × 10 mm	2 Gr.	152.00
			$310.00

A beginning lab could get by with even less expense by using baby food jars and their lids or ordering metal lids for the 89-400 flint jars rather than using the Petri dish bottoms as closures. Metal lids with paper liners should have the liners removed before use. The advantage of the Petri dish as a closure is that more light is available to the plant tissue in the jar.

Tools. Small instruments are needed for isolating buds and tissues as well as for routine subdivision and maintenance of cultures. Three sizes of forceps will handle almost any tissue culture manipulation; 300 and 200 mm straight tipped and 115 mm curved tipped forceps. A beginning lab would not need the 300 mm forceps; these are needed when large, deep bottles such as Mason jars are used in the lab. Cost of 2 pair each of 115 mm and 200 mm forceps - $13.50.

Dissecting needles can be purchased with wood handles for $2.15/dz but a metal needle holder with replaceable tips is preferable; the holders are $2.15 (2 recommended), and 36 replaceable needles cost $2.60. Cost - $6.90.

Knives are needed for cutting and dividing the tissue. For the starting lab, one No. 3 ($3.90) and a No. 7 ($4.75) dissecting knife handles are suggested with one package of 100 No. 11 knife blades ($20.50) which will fit both handles. Cost $29.15.

An alcohol lamp is used for flaming tools and the necks of tubes and jars. A small glass one costs $1.90 and if carefully handled should last many years. A brass alcohol burner which will not break costs $13.00. Cost - $1.90; Total Tool Cost - $51.45.

Chemicals for Preparing Media. The specific medium to be used will vary somewhat with the plant or plants to be propagated. The lab has three options; 1) to purchase prepared media formulations[1] designed specifically for plant tissue culture, 2) to

[1] Flow Laboratories Inc., 1710 Chapman Ave., Rockville, MD 20852; Grand Island Biological Co., P.O. Box 200, Chagrin Falls, OH 44022; KC Biological Inc., P.O. Box 5441, Lenexa, KS 66215.

prepare all media from individual chemicals or 3) to purchase prepared salt mix for media but add agar, sugar, growth regulators and vitamins. With prepared media the lab has few optins open to it for making media constituent changes, but its preparation may be as simple as pouring the contents of a package into water and heating it to dissolve the materials. This option would require as little as $50 to $100 outlay. If the lab elects to prepare its own media, a balance in addition to chemicals must be purchased. This option also requires a knowledge of chemistry and of media used for plant tissue culture. An adequate balance for this type of lab will cost $1000 to $3000 and an array of needed chemicals, $300 to $500. The third option will give the beginning lab considerable latitude in medium formulation and is also an excellent system for a small research lab. A supply of agar, auxins (IBA and NAA), cytokinins (kinetin and benzyl adenine), vitamins (thiamine, nicotinic acid, pyroxodine) and glycine can be purchased from chemical supply houses or companies selling prepared media formulations. Sugar purchased from the grocery is far less costly than that from a chemical supply house and unless critical research is being done it is quite satisfactory. A balance, though desirable, is not necessary for this option but it would be necessary to hire a chemically knowledgeable person to prepare stock solutions of the auxins, cytokinins, vitamins and glycine. The needed quantities of each could be measured volumetrically with a pipette. The agar and sugar can be measured dry by making several weighings of the amount to be used (e.g. 7 g/l agar) and marking the volumes on a clear plastic pill vial. Rather than weighing, one volume of each of these components is used per liter of medium being prepared. The cost of this option would probably be $100 to $150.

Water. Contaminants in some tap water supplies could cause failures of tissues in culture. Double glass distilled water is preferred for media preparation; cost of a glass still is between $600-$1800. For the small beginning lab, the purchase of 5 gal carboys of distilled water to be used only for preparing media is the least costly route, but there is a continuing cost and occasionally water of questionable quality may be obtained. An alternative between these two extremes is to purchase a disposable mixed bed ion exchanger (Ultra-pure mixed bed, cost $33), an organic removal cartridge (cost $26), two wall brackets for mounting them (cost $18) and 1 or 2, 5 gal carboys for storing treated water. Depending on the minerals in your water supply, these cartridges will normally process in excess of 1000 gal of water before needing replacement. Total Cost - $77.

pH Control of Media. The price of pH meters to measure the acidity of culture media begin at $210; the better instru-

ments cost $600 to $900. For the small or beginning lab pH narrow range indicator paper which covers the pH range from 2.9 to 4.2 and 4.9 to 6.5 will work satisfactorily. Since most media are adjusted to pH 5.6 to 5.8 the lab could get by with just the latter pH range paper; a 2 roll dispenser of these papers costs $3. Culture media are usually around pH 4 as prepared and are most commonly adjusted to pH 5.6 to 5.8 for use. Sodium hydroxide (1N) is added drop wise to increase the pH value and HCl (1N) can be used to adjust the pH downward if the desired pH value is overshot. These two chemicals are available as 1N solutions for $6/liter. Total cost for pH control - $18.

Material for Achieving and Maintaining Asepsis. This is the basic requirement for all tissue culture work. A laundry bleach such as Clorox is the most common material available for reducing or eliminating contaminants on the surfaces of tissues, tools, isolation cabinets, etc. (Usually it is diluted 1:9 v/v, Clorox:water, for immersing tissues to be cultured, but dilutions from 1:4 to 1:19 v/v may occasionally be used.)

Methyl alcohol can be used for sterilizing tools by dipping and flaming and for running the alcohol lamp used to flame the tools. (Ethyl alcohol is preferable because it is less toxic but application to the Alcoholic Beverage Commission must be obtained for purchasing it for manufacturing use, and its controls are rather stringent.)

A "scrub soap" such as used by hospitals or dentists is a good investment. The hands and forearms are washed to the elbows with soap prior to beginning work in the transfer hood. A common soap can be used but the "scrub soaps" have various biocides added to better reduce organisms on the skin. A small supply of all three (bleach, alcohol and soap) should cost $3 to $5.

Miscellaneous Materials and Equipment. Equipment is needed in which to heat the culture medium during preparation; laboratory beakers of various sizes are preferred though ceramic cookware can also be used. Aluminum pans and utensils are not suitable, although stainless steel could be used. Larger vessels for heating should have a 2-liter capacity. An assortment of pyrex kitchen measuring cups will serve for the smaller glassware for measuring liquids but should not be used for heating the medium. Estimated cost - $75.

Racks for tubes can be made from 1" or 2" Styrofoam sheet insulation; a cutter can be made from conduit or thin wall tubing for cutting holes in the Styrofoam which will accommodate the size tubes being used. The sheet of Styrofoam is cut into appropriate sizes to hold a predetermined number of tubes. I cut the sheet into 4 × 12 inch pieces which will hold 18 25 cm

tubes or 30 18 cm tubes. Thin aluminum sheet or other material is sheared to a size about ¼ to ½ inch smaller dimensions than the Styrofoam and two holes are drilled at each end for passing a wire through to attach it to the Styrofoam tube holder with wire. Material cost per 2″ thick rack is 45¢; 50 racks = $22.50.

CONCLUSIONS

A producing pilot tissue culture laboratory can be set up for less than $1000 (Table 1). This proposal does make the assumption that the person setting it up has some minimal construction abilities and has some knowledge of tissue culture techniques. Before setting up a tissue culture lab the company executive who will oversee the operation and the individual who will be in charge of it should take a course in plant tissue culture methods such as that offered by the Alton Jones Center at Lake Placid, New York. Prior to this, however, the company should have made some critical analysis of its production system to determine that a tissue culture laboratory is a needed addition to their production system (3).

Table 1. Estimated total costs for starting a tissue culture laboratory.

Pressure cooker	$ 40	Water treatment	$ 77
Isolation hood	45	pH control	18
Magnifier	17	Asepsis materials	5
Lights & shelving	96	Misc. cooking &	
Apportioning equip.	23	measuring glassware	75
Culture vessels	310	Tube racks	23
Tools	52		$931
Medium chemicals	150		

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2. Anon. 1977. Tissue culture comes to Texas. *So. Florist & Nursmn*. May 6, p. 24-26.
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CAMERON SMITH: We have had back luck with hydride paper. You can build a pH meter with two integrated circuits for $25 plus about $29 for the glass electrode. I would consider building one because the hydride paper ages and goes out of calibration.

GUS MEHLQUIST: Where can you buy these materials.

LEN STOLTZ: From any of the supply houses such as Fisher Scientific. Use your letterhead.

BILL CUNNINGHAM: I might point out that a Bunsen burner or alcohol lamp is not a satisfactory way to sterilize tools. An incinerator is better.

LEN STOLTZ: You are right; however, it will burn up your tools which is costly. We use 95% ethyl alcohol because we had contamination problems with 70%.

DICK ZIMMERMAN: Alton Jones offers two courses on tissue culture. One course is 3 days long and the other is 2 weeks.

PROGRESS ON *IN VITRO* PROPAGATION OF RED MAPLE[1]

K. WELSH, K.C. SINK and H. DAVIDSON

Department of Horticulture, Michigan State University, East Lansing, Michigan 48824

Abstract. Tissue culture experiments were conducted using shoot-tips (5 to 10 mm) or single node sections to devise an *in vitro* propagation scheme for red maple (*Acer rubrum*). Inconsistent proliferation of axillary buds on shoot-tip explants occurred when they were aseptically cultured on modified Linsmaier and Skoog (LS) medium containing kinetin (K), 6-benzylaminopurine (6·BAP) or 6(*ν*-*ν*-dimethylallylamino)-purine (2ip) at 0.1, 1.0, 5 or 10 mg/l.

Actively growing shoots were a prerequisite for a high percent rooting of proliferated shoots. Eighty-five percent of shoots cultured on ½ strenght LS + 0.5 mg/l indolebutyric acid (IBA) developed roots within 10 days. Phenolic secretion that inhibited growth was controlled by preconditioning explants on potato dextrose agar or LS basal medium by a series of 3-day subcultures.

In the past few years, research efforts on *in vitro* propagation of woody plant species have experienced increased activity. Research reports have been issued on apple (1,5,6,7,12), almond (11), blackberry (3), bougainvillea (4), pear (5), and plum (5). In addition, Winton (13) in a recent review stated that at least 37 angiosperm and 19 gymnosperm trees have been regenerated as individual rooted shoots. This listing may, upon initial examination, appear impressive but for many speices regeneration was low in frequency, from embryonic tissues, or from callus. Winton's list (13) includes *Betula*, *Citrus* spp., *Hamamelis*, *Populus* and *Ulmus americana* that are of interest to nurserymen. An earlier review by Abbott (2) presents a summary of present *in vitro* successes with evergreen and conifer species.

Commercial cultivars of red maple (*Acer rubrum*) are generally propagated by budding or grafting onto red maple seedlings. In many horticultural species, this propagation technique

[1] Supported in part by a grant from the Herbert H. and Grace A. Dow Foundation, Midland, Michigan.

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DICK ZIMMERMAN: Alton Jones offers two courses on tissue culture. One course is 3 days long and the other is 2 weeks.

PROGRESS ON *IN VITRO* PROPAGATION OF RED MAPLE[1]

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Abstract. Tissue culture experiments were conducted using shoot-tips (5 to 10 mm) or single node sections to devise an *in vitro* propagation scheme for red maple (*Acer rubrum*). Inconsistent proliferation of axillary buds on shoot-tip explants occurred when they were aseptically cultured on modified Linsmaier and Skoog (LS) medium containing kinetin (K), 6-benzylaminopurine (6·BAP) or 6(*ν*-*ν*-dimethylallylamino)-purine (2ip) at 0.1, 1.0, 5 or 10 mg/l.

Actively growing shoots were a prerequisite for a high percent rooting of proliferated shoots. Eighty-five percent of shoots cultured on ½ strenght LS + 0.5 mg/l indolebutyric acid (IBA) developed roots within 10 days. Phenolic secretion that inhibited growth was controlled by preconditioning explants on potato dextrose agar or LS basal medium by a series of 3-day subcultures.

In the past few years, research efforts on *in vitro* propagation of woody plant species have experienced increased activity. Research reports have been issued on apple (1,5,6,7,12), almond (11), blackberry (3), bougainvillea (4), pear (5), and plum (5). In addition, Winton (13) in a recent review stated that at least 37 angiosperm and 19 gymnosperm trees have been regenerated as individual rooted shoots. This listing may, upon initial examination, appear impressive but for many speices regeneration was low in frequency, from embryonic tissues, or from callus. Winton's list (13) includes *Betula*, *Citrus* spp., *Hamamelis*, *Populus* and *Ulmus americana* that are of interest to nurserymen. An earlier review by Abbott (2) presents a summary of present *in vitro* successes with evergreen and conifer species.

Commercial cultivars of red maple (*Acer rubrum*) are generally propagated by budding or grafting onto red maple seedlings. In many horticultural species, this propagation technique

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is acceptable. However, red maple often exhibits graft failure sometime after planting in the landscape setting or even as young 2-2½" trees in the commercial nursery. For this reason, as well as to hasten the evaluation process and release of superior red maple cultivars into commerce, we initiated a tissue culture propagation study. The information presented herein is the result of our first two years of effort.

MATERIALS AND METHODS

Plant material for *in vitro* culture was obtained from two-year-old red maple seedlings or from mature trees of the cultivar 'Red Sunset'. Experiments were conducted with terminal and sub-terminal shoot-tips and with stem node sections. These explants, as shown by preliminary trials, were routinely disinfected in a 3% sodium hypochlorite solution for 30 min followed by 4 to 5 sterile water rinses. The shoot-tip explants were subsequently prepared for culture by aseptically removing all expanded young leaves.

Three basal media at full and one-half strength were tested: Abbott and Whiteley (1), Linsmaier and Skoog (8) salts plus Nitsch and Nitsch vitamins (10), and Cheng (5) medium. These three basal media were supplemented with auxins (IAA, IBA, NAA) or cytokinins (6·BAP, 2ip, kinetin) singly or in combination from 0.01 to 10 mg/l.

All media were adjusted to pH 5.7 after adding the agar and 25 ml was dispensed into each 125 × 25 mm culture tube. The culture tubes were sealed with Kaputs, autoclaved at 121°C (249°F) for 20 min and cooled on a slant. Cultures were placed at 1500 lux (cool-white) on a 16 h photoperiod. The temperature was 26°C±2 (79°F).

Early experiments indicated that substantial phenolic secretion was present soon after placing shoot tips in culture, particularly on those shoot tips taken from mature trees as growth declined in late July to August. Three chemicals were screened to determine their effectiveness in controlling this secretion: ascorbic acid (150 mg/l), L-cysteine (50 mg/l) and polyvinylpyrrolidone (PVP) 40,000 mol. wt. (5,10,20 mg/l). The ascorbic acid was used as a pre-soak solution on disinfected explants; whereas the latter two compounds were incorporated in the basal medium. A preconditioning treatment (5) was also evaluated for control of phenolic secretion.

RESULTS

Phenols. Phenolic secretion and subsequent injury to buds or shoot tips could not be controlled nor prevented by any of the chemicals tested in this study. There was no difference, by

visual observation, in amount of phenols produced when these materials were employed when compared to the control.

The preconditioning treatment did provide an effective method of controlling phenolic damage to plant material *in vitro*. Plant material that was badly damaged could be excluded or the slightly damaged tissues could be removed; the explant was recultured on preconditioning medium or placed into defined medium culture.

Effect of Cytokinins on Shoot Proliferation. Multiple shoot development was observed when shoot tips were cultured on Abbott and Whiteley's basal medium (1) containing kinetin (K), 6·BAP or 2ip at 0.1, 1.0, 5.0 and 10.0 mg/l. From one to 8 axillary shoots arose per shoot tip. However, this response was inconsistent with respect to number of shoots and number of explants responding with multiple shoots at each concentration of the different cytokinins. Considerable variation in multiple shoot formation was observed between identical experiments conducted with shoot tips from mature trees at different growth stages.

Experiments were also conducted using uniform, actively growing shoot tips from the preconditioning treatment. These shoots were cultured on Cheng's medium (5) plus 6·BAP at 0.1, 1.0, 5.0 and 10.0 mg/l. Initial results were promising at 1.0 mg/l 6·BAP with the induction of 2 to 5 axillary shoots per shoot tip. These results, however, could not be consistently repeated in subsequent experiments.

Jones (7) suggested that phloroglucinol (126 mg/l) in combination with cytokinins promoted shoot proliferation in apple shoot tips. This finding was not observed when applied to red maple in our studies. Node sections were cultured on Abbott and Whiteley's medium (1) plus 2ip at 0.1, 1.0, 5.0 and 10.0 mg/l either with or without phloroglucinol. All node sections placed on these media containing phloroglucinol died within one week while explants cultured without it remained alive.

Effect of Cytokinin/Auxin Combinations on Shoot Proliferation and Rooting. Abbott and Whiteley's medium (1) supplemented with combinations of K and NAA were tested for induction of shoot proliferation and rooting. These two growth regulators were used at 0.01, 0.1, 1.0, and 5.0 mg/l. No multiple shoot development was observed under these *in vitro* culture conditions. Root initiation was observed, however at 0.1 mg/l K plus 0.1 or 1.0 mg/l NAA. Varying amounts of callus were also observed at the base of these shoot tips depending on the concentration of K and NAA. The largest amount of callus occurred at the highest level (5.0 mg/l) of K and NAA.

Shoot tips were also cultured on Cheng's medium (5) con-

taining 6·BAP at 0.1, 1.0, 5.0 and 10.0 mg/l combined with 0.1 to 1.0 mg/l IBA. As with the K+NAA combinations, no shoot proliferation was observed. Rooting did occur at 0.01 mg/l 6·BAP plus 0.1 mg/l IBA. Two of four shoots on this medium combination developed roots. Those which developed roots also unfolded new leaves while those which had not developed roots did not.

Effect of Auxins on Rooting. Consistent, repeatable root initiation and elongation was observed on shoot tips cultured on Cheng's medium (15) plus 0.5 mg/l IBA. Consistently, 85 to 90% of the shoot tips developed roots within 10 days after being placed in culture. These shoot tips had been preconditioned and they were growing actively in a single stem manner with new leaf development occurring. Three lower IBA concentrations: 0.01, 0.05 and 0.1 mg/l were also tested but were not as effective in promoting root initiation and development. Higher levels of IBA were also tested but they induced undesirable large amounts of callus.

DISCUSSION

There are several possible reasons for the observed inconsistent shoot proliferation with red maple. In initial experiments, it was observed that there was a great deal of variation in the growth rate of the plant material being placed into culture. Because of this difficulty, it became necessary to establish a system to select uniform plant material for explants. This was accomplished by placing disinfected shoot-tips onto a preconditioning medium (5). However, the assumption that uniform plant material would lead to consistent shoot proliferation proved false at least in preliminary experiments since multiple shoot initiation was still inconsistent with the use of preconditioned plant material.

These findings suggest that the inconsistent shoot development may be due to limitations in the experimental or environmental parameters. Nitsch, et al. (9) reported that adenine together with a cytokinin was essential for the initiation of adventitious buds in *Plumbago indica*. Experiments with adenine and several other chemical addenda are currently underway to test their influence on red maple shoot proliferation.

We found that root development on shoot tips from cultures and from seedlings and mature trees of red maple is closely linked to their physiological stage of development. This conclusion was derived from the observation that roots developed only on shoots which were actively growing and did not when terminal growth ceased and new leaves were not being produced. This response was also confirmed by the high per-

centage of shoots which rooted when placed on IBA at 0.5 mg/l following the preconditioning treatment. These findings suggest that active shoot growth is necessary for a high percentage of rooting. Since shoots which develop in culture are growing actively, this method of rooting could be readily accomplished on a commercial scale.

The preconditioning treatment as suggested by Cheng (5) provided an excellent way to prevent phenolic damage or to remove contaminated plant material from culture prior to placing it in culture. One disadvantage with the system is the amount of labor involved since the plant material must be handled several times before it can be used *in vitro*.

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BRUCE BRIGGS: Have you tried to sterilize seeds, germinate them under sterile conditions and use the resulting plant material as your source of explant material?

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KEN SINK: We have that in mind, however, at this point we have no source of seed.

CHARLES HEUSER: Have you tried to lay the shoots down in a horizontal fashion to possibly disrupt apical dominance and stimulate bud break?

KEN SINK: No.

BRENT McCOWN: We have found with birch that the important consideration is just time in culture. We can get birch seedlings into culture in 6 months but mature birch requires 2 to 3 years. Some physiological change is occurring within the mature tissue.

INITIAL TRIALS WITH COMMERCIAL MICROPROPAGATION OF BIRCH SELECTIONS[1]

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Abstract. The rapid multiplication of *Betula platyphylla* var. *azechuanica* by micropropagation using shoot-tip cultures has been demonstrated on a commercially-feasible basis. Shoot-tips and nodal explants placed on Gresshof-Doy nutrient agar medium supplemented with 4μm benzyladenine produced actively growing shoot cultures within 6 months. Stocks could be maintained or increased by monthly subculturing after removal of the elongating shoots and division of the resultant shoot-mass. Twenty to 30 utilizable shoots could be harvested from each culture in 6 to 8 weeks after subculturing. Harvested shoots rooted with 100% success within 2 weeks when placed in peat/perlite in a rooting chamber. After a period of acclimation, these plants could be treated like young seedlings in commercial production. A comparison of the field growth of seedling and micropropagated birch showed that both had identical growth rates in the spring and summer; however the micropropagated plants stopped growth one month earlier than the average seedling. This resulted in the micropropagated plants having a smaller size at grading than the seedlings. Whether this difference was genetic or a result of the propagation technique is unknown. The micropropagated plants were highly uniform in growth and grade as compared to the seedling propagated plants.

Birch has long been a prized ornamental tree. However, its use has been limited by important pest problems, particularly bronze birch borer, *Certaocystis fagacearum*. A number of selection programs are now finding birch genotypes that appear resistant to this pest. In addition, resistance to birch leaf miner and early coloration of the bark in young propagules are also desired traits. Once final selections are made, they will proba-

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bly have to be maintained as clones; this may present problems since most birch do not readily root from cuttings. Budding and grafting are feasible but add considerable expense in production. Micropropagation may be a practical solution for the multiplication of unique and desirable birch selections.

With the support, advice, and cooperative assistance of Evergreen Nursery, Sturgeon Bay, Wisconsin, we evaluated the use of micropropagation in birch production with the hope that this technology would complement their active selection program. Since this nursery produces at least ¼ million birch liners each year and is developing an accelerated growth program, they would most likely be able to capitalize on the tremendous multiplication potential that micropropagation offers.

The use of microculture in plant culture is now very well established. Several excellent and recent reviews and symposia are available and amply cover the extent to which microculture, particularly micropropagation, is being used in the horticulture industry, e.g. Barz, Reinhard and Zenk (1); Hughes, Henke, and Constantin (3); Reinert and Bajaj (4); and the Fourth (1978) International Congress of Plant Tissue and Cell Culture. Indeed, the papers presented at this meeting represent the current state-of-the-art. Although the incorporation of micropropagation into woody plant culture has been slower than the use in herbaceous plant production, the progress with such plants as fruits and rhododendrons show that success is imminent. To our knowledge, our work with birch is the first demonstrated use of micropropagation in the culture of an ornamental tree on a commercially-feasible scale.

MATERIALS AND METHODS

Seedlings of the Asiatic white birch, *Betula platyphylla* var *azechuanica*, were obtained from Evergreen Nursery. Stem tips and node sections were removed from 12 actively-growing plants and after removal of most of the leaves, were sterilized in 10% household bleach (sodium hypochlorite) with a wetting agent added (0.05% Tween-20). After rinsing in two washes of sterile distilled water and removing any injured tissue, the explants were placed on agar solidified medium. If any exudation from the cut surfaces occurred, the culture was shifted to fresh medium.

All cultures were grown on modified Gresshof-Doy (2) nutrient medium supplement with 0.6 to 0.8% agar, 10% sucrose, thiamine (1 mg/l), nicotinic acid (0.1 mg/l), myo-inositol (10 mg/l), pyridoxine (0.1 mg/l) and benzyladenine (4μM). Cultures were grown in rooms with 24 hour fluorescent lighting (300 ft-c) and temperatures that averaged 28° to 32°C (82° to

90°F). Culture vessels were either 1 oz or 4 oz heavy glass bottles capped with Parafilm-M. Cultures were subcultured to fresh medium at least every month and at this time, any malformed tissues were discarded.

The growth characteristics of the micropropagated birch were tested in field plantings. Shoots from the cultures of one of the seedlings were rooted and grown along with a set of seed propagated plants originating from the same seed source. These two sets of plants, 600 originating from micropropagation and 600 originating from seed, were interplanted in guarded blocks of 150 plants in the field. Growth rates were recorded on 20 randomly selected plants in each block. In the fall, the plants were dug by machine and graded.

RESULTS

Explants from all the seedlings responded similarly to the microculture conditions. Lateral buds and often the apical meristem of the initial explants showed new leaf expansion and stem elongation within the first month in culture. As this new growth was subcultured on a monthly basis, growth became more rapid and lateral bud break (and thus shoot multiplication) was progressively easier to stimulate. After 6 months in culture, explants from all the genotypes that had initially survived the first subculture showed active and uniform shoot growth and multiplication (Figure 1).

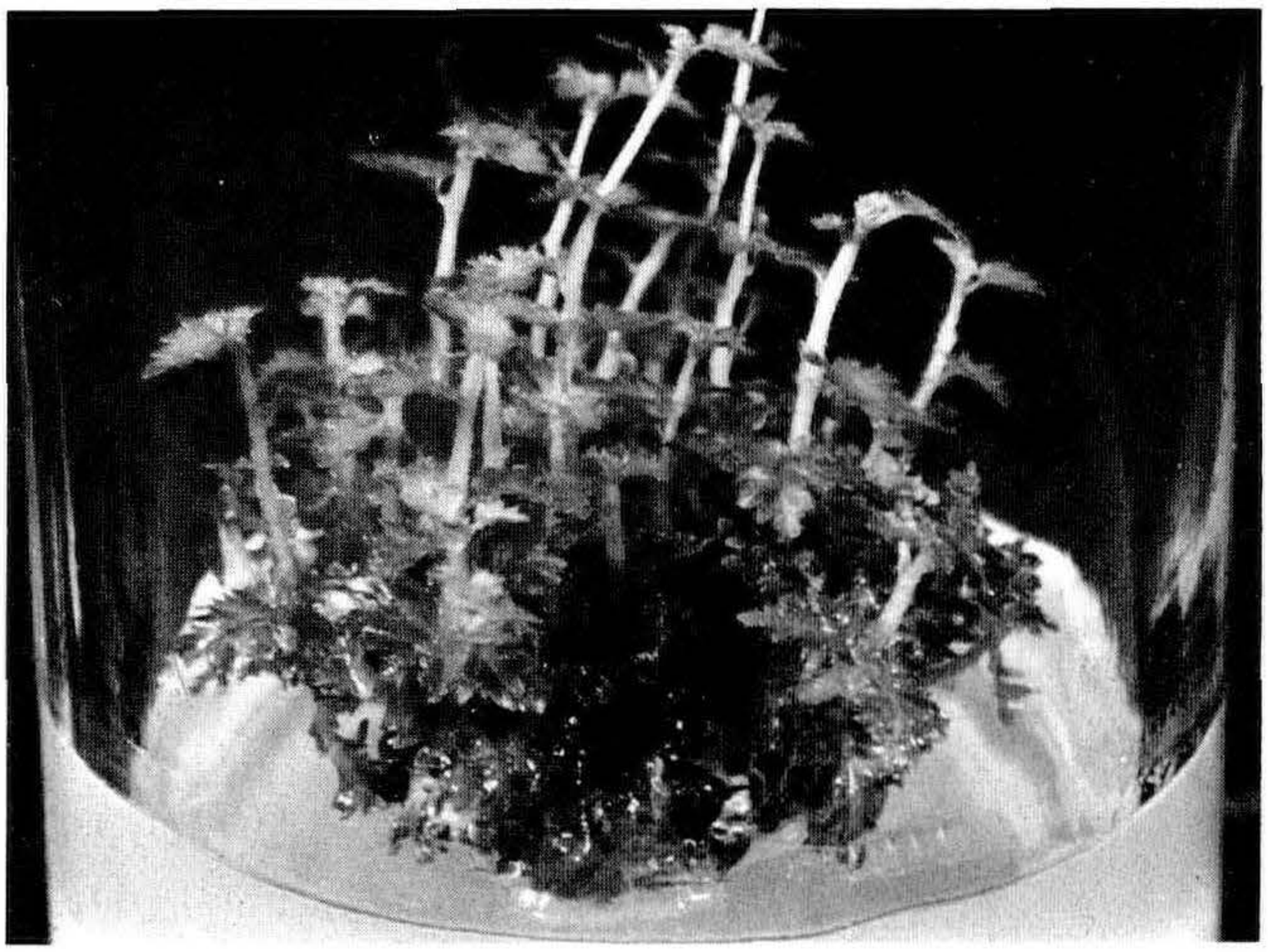

Figure 1. A shoot-tip culture of birch, *Betula platyphylla* var. *azechuanica*, showing multiple shoot development. At least 20 uniform shoots can be harvested from such cultures. After rooting, shoots can then be treated as seedlings in production programs.

The shoot-tip cultures could be multiplied by removing the

elongating shoots, dividing the basal shoot mass into 3 to 5 sections, and placing each section onto new medium. Such stock cultures were readily maintained as long as the subculturing was repeated every 3 to 4 weeks.

Shoots could be harvested from actively-growing cultures after 4 to 6 weeks of growth after subculturing. At this time an average of 20 to 30 shoots of 3 to 6 nodes in length could be obtained from each culture. It was possible to allow the same cultures to sprout a new crop of shoots and although these were numerous (up to 60 shoots per culture), the shoots were small, difficult to handle, and variable. Harvested shoots were very subject to desiccation and thus were cut into water and remained floating until placed in the rooting environment.

Shoots were rooted in 1:1 peat/perlite in a warm 30°-35°C (86°-95°F) high humidity (greater than 80%) chamber. Rooting under mist was also feasible but desiccation was more difficult to prevent. Rooting occurred within 2 weeks and was essentially 100% successful. Hormone treatments were not necessary. Once rooting occurred, the plants were shifted to a greenhouse and gradually given full sunlight and lower humidity over a 2 week period. From this time on, the plants could be treated as seedlings.

Even though the initial size of the seedlings was larger than the micropropagated plants at the time of the field planting, the growth of the two sets of plants was identical through the summer (Figure 2). However, after early September, the mi-

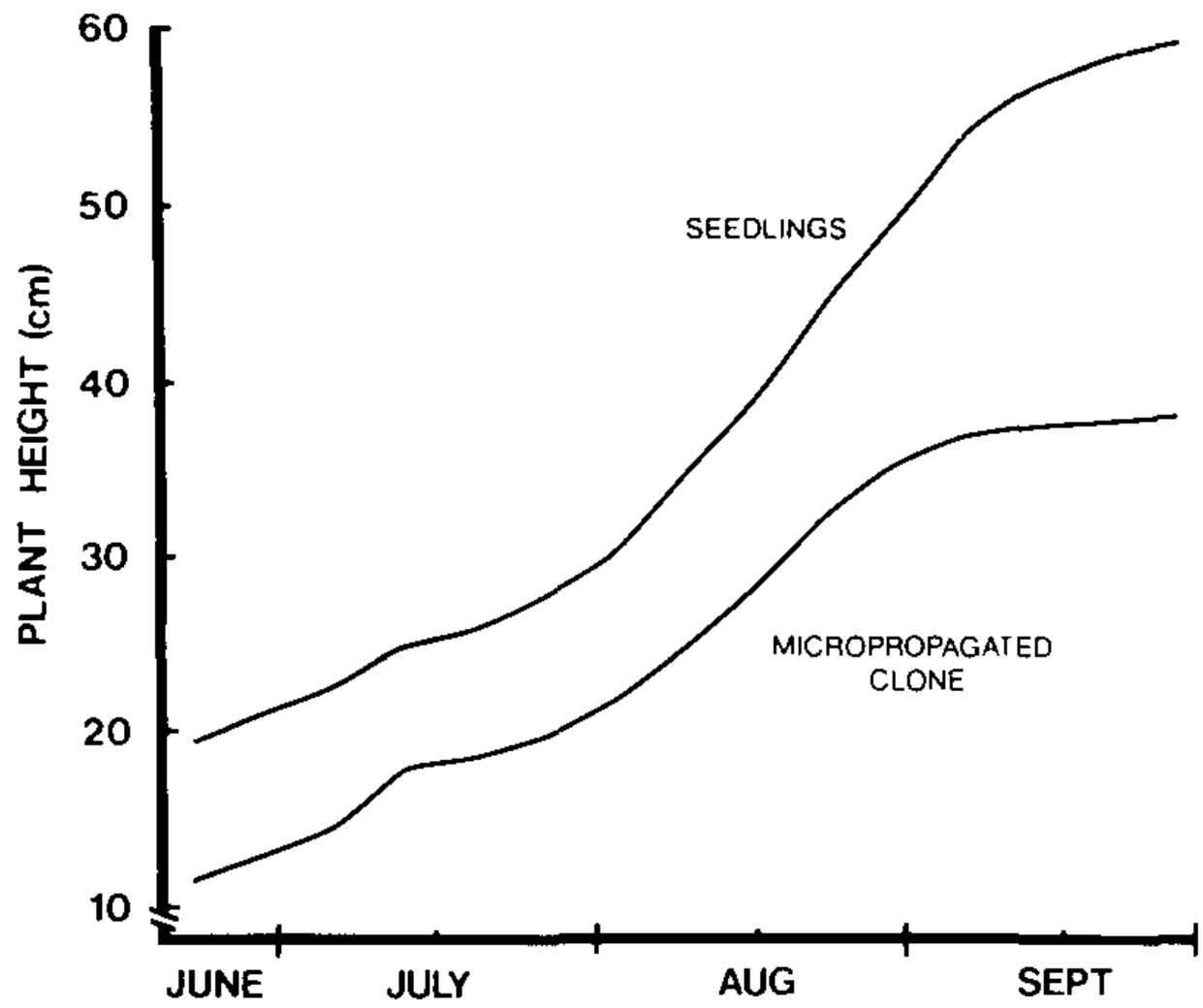

Figure 2. The growth in height of two sources of birch liners. *Betula platyphylla* var. *azechuanica*, in the field for one season. The micropropagated plants came from cultures of a seedling from the same seed source as the seedling plants. The date are from 40 plants of each source randomly selected from experimental blocks grown in the same field.

cropropagated birch slowed and stopped growth while the seedlings continued growth until the end of September. This differences in cessation of growth was also evident in the early fall coloration of the micropropagated birch.

The grading data show the result of the earlier growth cessation of the micropropagated birch (Figure 3). The seedlings averaged larger in size (seedling population peaked at 21 to 30 in. in height) as compared to the micropropagated plants (peak at 12 to 15 in. size class). However, the seedlings also showed a in. much larger range of sizes (6 to 36 in.) than did the micropropagated plants (6 to 21 in).

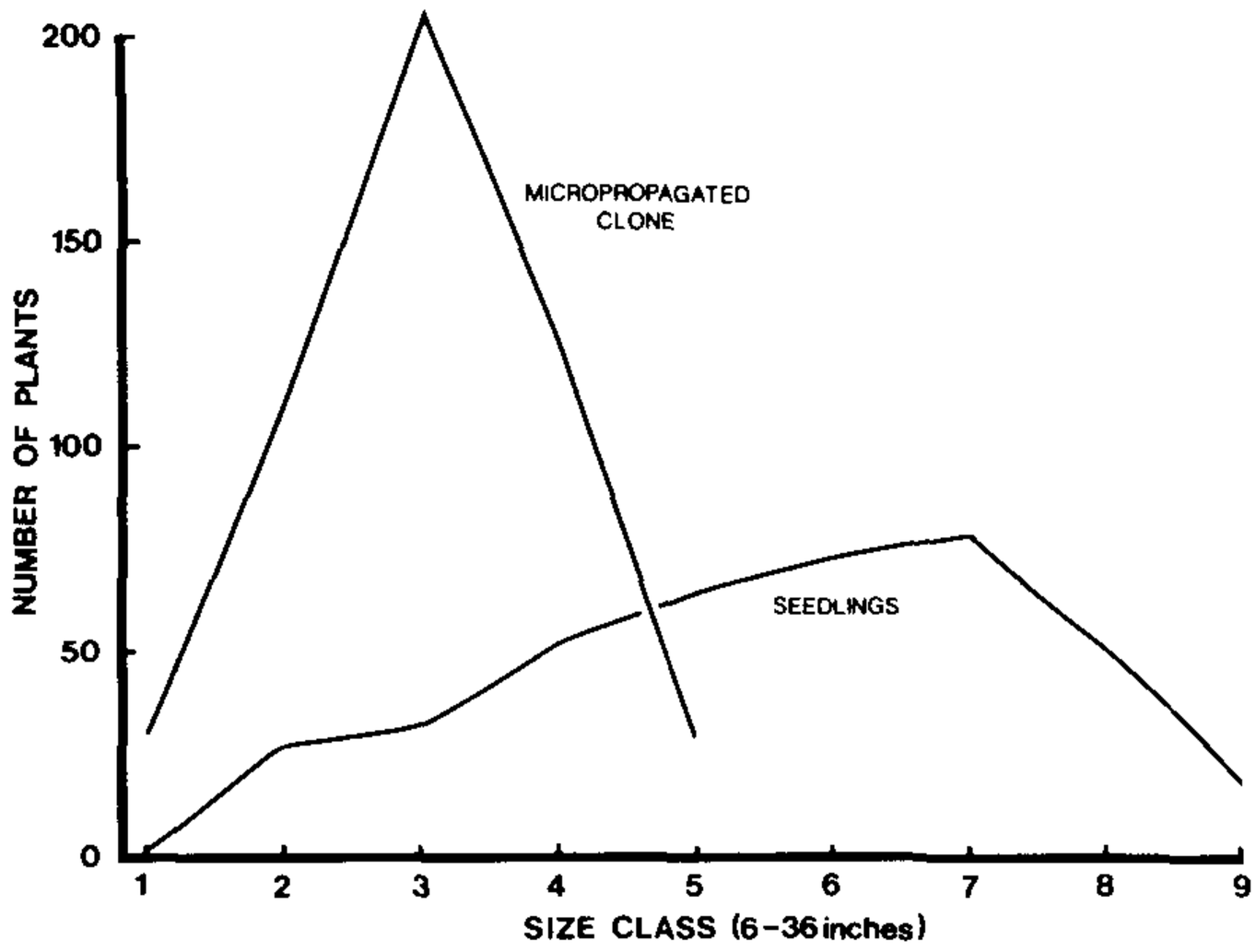

Figure 3. The grading by size (height) of birch liners, *Betula platyphylla* var. *azechuanica*, propagated by two techniques and grown in the same field for one season. The size classes were 3 inch intervals except the last class which included all plants greater than 30 inches in height. The data are from 600 plants from each source.

DISCUSSION

To our knowledge, this is the first well-documented use of micropropagation in the production of a tree species on a commercially-feasible basis. Besides rapid multiplication, additional benefits of the use of micropropagation are a minimal space allocated for stock plant maintenance, potentially disease-free propagules, and dependable, easily controlled uniformity of propagules.

Because the micropropagation techniques used here employed shoot-tip cultures and not adventitious shoot regeneration from callus, shoots evolved from preformed meristems on the original explant. Thus, given a relatively stable genotype initially, the genetic stability of the culture should remain high. Indeed, even after the hundreds-of-thousands of shoots that we

have generated, only one visually abnormal shoot has been observed. This was an albino/normal chimera, an aberrance that is readily selected against.

The observation that the microcultured shoots root rapidly and dependably contrasts with the general rooting potential of most birch species. This may indicate that micropropagated shoots differ in their physiological state (juvenility?) from cuttings taken from the usual stock plants.

Although these experiments used explants originally taken from seedlings, success has also been achieved with tissues from mature trees. In the latter case, the time to "acclimate" the explant to culture so that rapid and reproducible shoot-tip cultures are obtained may take up to several years. Again, this may indicate a gradual change in the physiological state of the cultured tissues.

The rate of multiplication appears adequate for commercial purposes. Given a conservative average of 20 shoots being produced per culture in 6 to 8 weeks, some 4000 shoots can be generated per square foot of culture shelf space per year. To produce ½ million propagules, only 125 square feet of culture shelf space would be necessary.

The performance of microcultured birch in the field is not fully understood. The observation that the growth rate of micropropagated plants was identical to that of seedlings in the spring and summer indicates that the two sets of propagules had the same growth capability. However, the early cessation of the growth of the micropropagated plants may have two explanations. Since the growth characteristics of the original seedlings that generated the cultures used to produce the microcultured plants is not known, the difference may be genetic — by chance, a genotype was cultured that characteristically goes dormant early in fall. A second explanation is that the differences in growth are a result of a physiological difference between microcultured plants and seedlings. Such differences may be traced to differences in juvenility, rooting behavior, collar physiology, or some other as yet unexplained factor. Future research will focus on this phenomenon.

One advantage of clonal propagation, in this case by micropropagation, is clearly demonstrated in the grading results. The micropropagated plants showed high uniformity as compared to the seedlings. Such uniformity in growth is particularly advantageous in accelerated growth programs where a predictable response to cultural conditions is paramount.

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JOHN HART: How do we control genetic vulnerability of the plants we produce by tissue culture?

BRENT McGOWN: This technique can be misused like any other technique in propagation. It is a point of professionalism. We can use it just as readily for good benefit. We can produce multiple genotypes for forest planting in culture easier than by standard means. It is, therefore, possible to protect against the introduction of single genotypes that would be vulnerable to plant pest problems.

DISEASE-FREE PLANTS THROUGH MICROPROPAGATION[1]

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Asexual or vegetative propagation of plants is practiced when the qualities of elite clones are not maintained in seedling progenies. Asexual propagation also perpetuates any systemic infection caused by viruses or vascular wilt organisms. Micropropagation can eliminate such infections and, in some cases, is the only available method for obtaining healthy plants. Four methods of micropropagation currently are being practiced. Three of these have limited usefulness due to the possibility of propagating somatic mutations. In as much as current and future investigations could change this, they will be briefly discussed. The fourth, tip meristem culture, has been used for a quarter of a century to eliminate viruses from infected plants and is the basis for the commercial production of cultured car-

[1] Journal Paper No. 8446. Approved by the Director.

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[2] Respectively, Research Assistant and Professor, Department of Plant Pathology, University of Missouri-Columbia.

nations, chrysanthemums and geraniums.

Callus tissue can be induced on many plant species, aseptically removed, and cultured under in vitro conditions. Culture of such tissue provides healthy plants but problems associated with ploidy and mutation restricts its usefulness to those crops where those abnormalities can be detected and rogued. It appears to be a promising method for propagating conifers (1,2,12) and poplars (14). In addition, it was physiological studies with callus culture which led to the development of defined media and identification of the proper environmental conditions essential for successful conditions. Since the individual cells of the culture are similar they have the potential to develop into a complete plant as was postulated by Haberlandt (4). This was accomplished some 50 years later by Muir *et al.* (8).

Anther and pollen culture have intrigued plant scientists since the late 1940's. If anthers or pollen of certain plant species are placed on media containing appropriate mineral and organic constituents then exposed to the correct environmental conditions, plantlets will develop. These plantlets are haploid but can be restored to the diploid condition with colchicine. Since few viruses pass through pollen most of these plants will be healthy but different from the parent. While this technique will not provide duplicates of the parent, it does have great potential for developing parental lines of hybrids for such crops as corn, *Zea mays* L. It also is being used for crop improvement since the Chinese have developed new cultures of rice, tobacco and wheat from pollen cultures (C. Nitsch, personal communication).

Regeneration of plants from protoplasts presently is one of the more exciting areas of research. While successful regeneration of plants has been limited to a few species the possibilities appear to be unlimited. Already scientists in Kansas have developed a new potato cultivar from the high quality 'Russet Burbank' with a yield potential twice that of the parent (A. Ayers, personal communication). Isolation of protoplasts involves the separation of leaf cells, generally mesophyll, and the enzymatic removal of the cell walls (13). Properly protected against plasmolysis, these naked protoplasts will develop into complete plants when exposed to the correct combinations of media constituents and environmental conditions. Since the regenerated plantlets may differ from the parent plant and viruses can be retained by the protoplast, this method presently is more useful for developing new cultivars than for obtaining healthy plants from diseased cultivars.

Tip meristem culture represents a micro method of propagation from shoot apices. In 1941, Dimock (3) obtained healthy plants by propagating the shoot apices from chrysanthemums *infected with Verticillium albo-atrum Reinke and Berth.* This study led Yoder Bros. Inc. to establish their disease-free chrysanthemum program. Subsequently, Limasset and Cornuet (6) found the concentrations of viruses were progressively lower in serial sections approaching the apical meristem. In about half of the cases no virus could be detected in the apical meristem itself. This prompted Morel and Martin (7) to postulate that virus-free plants identical to the "mother plant" might be obtained by meristem culture. This technique involved the excision of the apical dome (ca. 0.1 mm × 0.25 mm) which is composed of rapidly dividing cells and covered with bud scales. The dome, generally including 1 or 2 leaf primordia, is aseptically removed then placed on an appropriate medium and, if optimum conditions prevail, will develop into plantlets. Using the tip meristem technique, Morel and Martin obtained virus-free plantlets but were unable to induce rooting. These plantlets were then grafted to virus-free plantlets and developed into healthy plants of the mother plant genotype. Presently, tip meristem culture is the most useful method to produce genetically identical healthy plants from the diseased mother plant and is the only method by which healthy plants have been obtained from some infected cultivars of strawberries, potatoes and many floral crops. Some examples of economically important crops where healthy clones have been obtained from infected cultivars by tip meristem culture are listed in Table 1.

Using tip meristem culture, healthy plants have also been obtained from virus-infected cultivars of at least 15 different species of floral crops (11). The apparent greater success of tip meristem culture in floral crops may reflect emphasis, although most floral cultivars are relatively easy to propagate vegetatively. Species or cultivars which are easy to propagate by routine methods generally respond more favorably to tip meristem culture than species or cultivars which are difficult to propagate. Once we understand such physiological factors as dormancy and juvenility and define the correct cultural constituents and environmental conditions, it seems likely that tip meristem culture can be used to produce healthy plants from most species of higher plants.

TIP MERISTEMS WORK IN MISSOURI

We became interested in tip meristem work, primarily as a means of obtaining healthy clones from tree cultivars infected with viruses which could not be eliminated with heat therapy. We have had a virus certification program for nursery fruit trees

Table 1. Some horticultural and forest species in which complete, virus-free plants have been obtained by tip meristem culture from previously infected clones.

Plant	Disease	Reference
Vegetable		
Cauliflower	turnip mosaic	*J. Hort. Sci.* 49:273
Sweet potato	internal cork	
	rugose mosaic	*Japan Agric. Res.* Quart 6:1-7
	feathery mottle	
Potato	paracrinkle, PVX	*Ann. Appl. Biol.* 45:422
	PVX, PVS	*Advan. Hort. Sci.* Appl. 1:144
	PVX, PVY, PVS	*Proc. 10th Intern. Botan. Congr.*, *Edinburgh*, 485 pp.
	PVS, PVM, PVX PVS	*Phytopathology* 58:199
	Spindle tuber (viroid)	*Phytopathology* 60:1857
Fruit		
Strawberry	vein banding, crinkle yellows complex	*Plant Dis. Rptr.* 47:298
Banana	cucumber mosaic	*Phytopathology* 64:320
Gooseberry	vein banding	*J. Hort. Sci.* 43:289
Raspberry	mosaic	*Ann. Phytopath.* 3:493-501
Forest		
Cassava	unidentified	*In Vitro* 8:421
Poplar	unidentified	*In Vitro* 7:269

for a quarter of a century and, although healthy clones of most popular cultivars are available, occasionally all clones of a cultivar may be infected with one or more viruses. The intense interest in the early coloring, spur and compact types of fruit trees compound this condition since these types generally arise as mutations, natural or radiation-induced, on trees which may be infected. Heat treatment followed by propagating the shoot tips (50 to 70 mm) on healthy seedlings will result in healthy trees but certain viruses, such as the stem grooving or brown line (SGV), are not affected by that. In *Prunus* material successful shoot tip grafting is so difficult to achieve that this method is not very useful. Our work thus far has stressed apple although some preliminary studies on a *Prunus* clone infected with the green ring mottle virus appear promising.

Our work started in 1976 when we were unable to locate any trees of a certain high quality cultivar which were not infected with SGV. Within a month we developed a defined medium (Table 2) which supports the growth of meristems up to 5 cm in six weeks. All attempts to induce rooting failed so we investigated the possibility of grafting which has been used to obtain health citrus trees (9). In our studies it was shown (5) that the meristem can be grafted directly to the hypocotyl of a germinating seedling from which the cotyledons and epicotyl had been aseptically removed. Meristems from plantlets developed from meristems also can be used. These would permit additional therapy such as the use of malachite green which en-

abled Norris (10) to eliminate potato virus X from the infected cultivar, Green Mountain. Using meristem grafting we have obtained several plants from two apple cultivars which were infected with SGV. Preliminary tests indicate that these plants are free from SGV. If further tests corroborate these observations and the cultivar's characteristics are maintained, these plants will replace the infected ones and the cultivars will enter our certification program.

Table 2. Composition of nutrient solution for apple meristem culture.

MINERAL SALTS

Macroelement	mg/l	Micro elements	mg/l
NH_4NO_3	1650	H_3BO_3	6.2
KNO_3	1900	$MnSO_4 \cdot 4H_2O$	22.3
$CaCl_2 \cdot 2H_2O$	440	$ZnSO_4 \cdot 4H_2O$	8.6
$MgSO_4 \cdot 7H_2O$	370	KI	0.83
KH_2PO_4	170	$Na_2MoO_4 \cdot 2H_2O$	0.25
Na_2-EDTA	37.3	$CuSO_4 \cdot 5H_2O$	0.025
$FeSO_4 \cdot 7H_2O$	27.8	$CoCl_2 \cdot 6H_2O$	0.025

ORGANIC CONSTITUENTS

Vitamins	mg/l	Growth Regulators	mg/l	Carbon Source	mg/l
Nicotinic acid	1	Benzyladenine	0.1126	Sucrose	20
Thiamine HCl	10	Gibberellin A_3	0.03		
Pyrodoxine HCl	1				
i-inositol	100				

pH adjusted to 5.7 with NaOH or HCl.

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HOUCHANG KHATAMIAN: Strawberries are small plants and can be heat-treated in a growth chamber. Can we heat-treat the explants or do we have to grow small plants?

DAN MILIKAN: I think the thing to do is to heat-treat to remove the virus diseases. If you run into a virus, such as the stem grooving virus, which resists the heat treatment we have been successful in the grafting of the meristems on to a seedling.

RON GIROUARD: Are you limited to only one season for your buds?

DAN MILIKAN: We have taken apple buds year round. Terminal buds grow best. I feel that the bud scales are the source of the inhibiting factors, not the meristem.

THE LABORATORY OF MICROPROPAGATION AT CESENA, ITALY

RICHARD H. ZIMMERMAN

Fruit Laboratory,
Agricultural Research, Science and Education Administration
U.S. Department of Agriculture
Beltsville, Maryland 20705

In 1976, a growers' cooperative (Centrale Ortofrutticola alla Produzione) in Cesena, Italy, began planning a tissue culture laboratory for large-scale production of several horticultural crops. Dr. Carmine Damiano, of the Istituto Sperimentale per la Frutticoltura in Rome, was instrumental in designing and organizing the laboratory and in consulting on problems once tissue culturing got under way. P. Boxus, of Gembloux, Belgium, also served as a consultant on the project.

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The laboratory was built in the basement of the main building of a Technical Agricultural Institute in Cesena. The laboratory consists of a media preparation room, a dishwashing and autoclave room, a transfer room, a large growth room, and office and storage space. The rooms are large, well-lit and constructed so that maintaining a clean work environment is facilitated. The capital cost for the laboratory was about $200,000.

The laboratory facilities are well designed with a good work flow from one section to another. Six large laminar flow hoods are located in a large transfer room which is separate from, but with good access to, the other parts of the laboratory. Up to 10 technicians can be transferring cultures simultaneously. The growth room has the capacity of nearly 20,000 half-liter canning jars which are used for growing the cultures.

Starting with 250 to 300 strawberry meristems in culture provided by Dr. Damiano in August, 1977, the laboratory had some 36,000 strawberry explants growing by the end of December, 1977. In the first full year of operation (1978), about 800,000 plants were produced; this was nearly doubled in the second year, with a further increase to 3 million plants planned for the third year. Strawberries accounted for most of the first year's production, slightly more than half of the second year's, and will be about one-third of the third year's. Cultivars propagated this way include 'Aliso', 'Gorella', 'Pocahontas', 'Tioga', 'Belrubi', 'Sequoia', 'Primella', and 'Redgauntlet'. Other plants being propagated are rootstocks of apple ('M26'), cherry, and peach ('GF 677', 'GF 43', 'St. Julien 655-2', 'Damasco 1869'), 'Calita' Japanese plum, and broccoli and cauliflower types. Techniques for mass production are being developed, or possibilities being explored, for a wide range of other crops including apple, pear, cherry and Chinese gooseberry or kiwifruit (*Actinidia*) cultivars and a number of vegetable and floricultural crops.

The medium used for growing strawberries is that of Boxus whereas a modified Murashige and Skoog medium is used for the other fruit crops. The medium composition is varied according to the crop and the cultivar. Technical grade agar is used at 4 to 5 g/liter to give a very soft gel. They also now use 2 g of agar supplemented with 8 to 10 g/liter of pectin, the type used for making jam. They have tried 5 brands of pectin but only 2 gel satisfactorily. When pectin is added to the medium, the pH is adjusted after adding the pectin and agar; otherwise, the pH is adjusted before adding the agar.

For the peach rootstocks, an elongation stage is added after the shoot multiplication stage to produce longer shoots which are easier to handle for rooting. The medium used for elonga-

tion has BA reduced from 0.6 to 0.1 mg/liter and GA_3 increased from 0.1 to 0.5 mg/liter. This stage lasts about 2 weeks and the rooting stage which follows lasts 2 to 3 weeks.

The laboratory has 9 plastic greenhouses with approximately 1800 m^2 (18,000 ft^2) of growing space for acclimating plants produced in tissue culture. Rooted strawberry plants are removed from the agar medium and planted in ground beds filled with peat in the plastic greenhouses. These beds are covered with a sheet of plastic film for several days until the plants are established and then this extra plastic is removed. After 30 to 40 days, the plants are dug and shipped bareroot. Rooted understocks of apple, cherry, peach and plum are planted in a peat-perlite (4:1 or 5:1) mix in a variety of containers including paper pots and Styrofoam trays. The proper peat is extremely important to get good growth of the plants; only TKS-1 peat is used now. After planting, the beds are covered with a plastic sheet which is lifted gradually after several days to harden the plants.

About 70% of the rooted explants are sold before acclimation. The peach rootstocks sell for 18 to 36 cents (150 to 300 lire) per rooted plant directly from the tissue culture container or 35 to 70 cents (285 to 575 lire) for a well-rooted plant in a paper pot ready to go to the field. Strawberry plants sell for 13 cents (110 lire) per rooted plant directly from culture and 20 cents (170 lire) for a well-rooted, acclimated plant to be used as a mother plant in the nursery.

The technical aspects of the work at the Laboratory for Micropropagation are under the direction of G. Zuccherelli, V. Venturi and G. di Paoli, while S. Barducci serves as business manager for the cooperative and laboratory. There are about 6 other employees in the laboratory and several additional ones in the greenhouse. Additional workers are brought in as needed; for example, during a busy period in the spring, the transfer hoods are used 14 hours a day, necessitating 2 shifts of workers.

Unquestionably, this laboratory has the most efficient design of any that I have yet seen. Further, it has been very well managed, as evidenced by their rapid progress in just 2 years. Anyone planning to set up a large commercial laboratory would be well-advised to visit Cesena.

Friday Morning, December 14, 1979

Dr. Harold Davidson, served as moderator of the morning session.

A SIMPLIFIED ENTRY INTO TISSUE CULTURE PRODUCTION

LYDIANE KYTE and BRUCE BRIGGS

Briggs Nursery
Olympia, Washington 98501
(see page 90 — Western Region)

PAUL READ: Would you comment on stock plant manipulation and cultivar differences?

BRUCE BRIGGS: I feel that you should bring the stock plant into a greenhouse and give it the best growing conditions. Do not water the tops so as not to contaminate the new growth. This is the best we have devised to get the plant into the proper condition. In conifers they have taken mature tissue and grafted it onto juvenile understock. After they get that to grow they put it in tissue culture. There is, considerable cultivar differences in rhododendrons. Cytokinins appear to be the factor most influencing success.

DICK JAYNES: Do cuttings from tissue cultured plants propagate more readily than cuttings from older plants?

BRUCE BRIGGS: Yes.

COMMERCIAL APPLICATION OF TISSUE CULTURE IN FRUIT PRODUCTION

JOHN GANZER

Stark Brothers Nurseries and Orchards Company
Louisiana, Missouri 63353

Why are we interested in tissue culture? Our interest is based on the need for virus-free plant material, for the rapid buildup of new cultivars and rootstocks, and as a means for propagation of difficult-to-root plant materials. For many years we have conducted our own heat-treating program to get cultivars virus free. It is a slow process to build up this material once it is clean. Tissue culture will give us the tool to produce sufficient quantities for our needs. Another use will be for the buildup of new cultivars as we find them. At present it takes as long as 5 to 7 years to get into full production with a new cultivar. Rootstocks take as long. The third use is to propagate difficult-to-root plants. An example would be selected strains of Carpathian walnut, such as 'Lake's'.

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Our involvement came from discussions with suppliers on the future of the rootstock business and the fact there were many new rootstocks on the horizon and some old ones which had the viruses removed, but development of enough stocks to satisfy the market would be slow.

Tissue culture with its promise of high populations in a short time was very appealing. One of the west coast suppliers suggested we talk with the people at the Oregon Graduate Center located in Beaverton, Oregon. The Center had been working with Weyerhauser Corporation on conifers and was achieving notable success. With this in mind Oregon Rootstock, Willow Drive Nursery, A. McGill & Son, and Stark Bro's. approached the Center offering to underwrite research on woody deciduous materials. They were eager to try. We then selected material for the Center to work with. The list is as follows: 'EMLA 27' apple rootstock, 'Pixy' plum rootstock, 'Antonovka KA 313' apple rootstock, 'Crimson Sentry' maple, 'MAC-9' apple rootstock, 'St. Julien ×' plum rootstock, 'EMLA 7' apple rootstock, 'Lake Carpathian' walnut, 'Stark Jumbo' apple, 'Bradford' pear and 'Kwik Crop' walnut.

The list is predominantly rootstocks as we felt this was our immediate problem area. In less than 6 months successful shoot and root initiation had been achieved on some of the plants and in another 6 months the process had been shortened from 3 steps in the lab to 2 steps for some cultivars. This past spring 100 lot quantities of liners were planted and budded with various cultivars. The Oregon Graduate Center was interested in putting this process into commercial application.

All through the venture the Oregon Center's focus has been on the commercial application of tissue culture. The emphasis has been as simple a process as possible to produce a plant that is acceptable to the nursery trade. As a result of this work the original group of nurseries has now formed a corporation and have built a commercial lab in Oregon. The building is about 1800 square feet in size and consists of a transfer room, a preparation room, two culture rooms, a supply closet and an office. Four people will staff the lab to begin with. The Oregon Graduate Center will act as advisor until the supervisor technician is ready to assume the responsibility for the operation.

Transferring will begin in January, 1980 and we expect the first commercial crop the following summer. Our immediate goal is to produce one million plants per year. The growing cycle is 6 weeks. This is from the beginning of the shoot initiation stage until we transplant it to soil and move it to a mist chamber for hardening off. One of the most critical steps in the process is pre-conditioning before shoot and root initiation. The

material must be pathogen-free. The plant is pre-conditioned on a non-hormonal nutrient medium for 1 to 4 weeks to enhance the response of the tissue to shoot multiplication medium. The explants are transferred to a shoot initiation medium. This medium is a low auxin medium (0.5 to 2.5 μM). Using this method, 50 to 100 shoots per explant are produced. The low auxin content of the various media is to avoid abnormalities in the plant. These abnormalities would be anatomical or genetic and would result in a plant not suitable for planting or budding. Every attempt is being made to tailor the plant for the job intended. The Oregon Graduate Center is adjusting the chemical makeup of the media to do this. The plants grown by the lab will be decided by the corporation as the ones most needed by its members and we will share the success and failures equally.

Preliminary chromosome counts of all the material grown so far indicated a mutation rate of approximate 3%. We do not feel this is critical and in fact find this much in nature especially in the high sunlight areas of the west. However, we are still checking and looking for better ways to ensure the genetic uniformity of the resultant plants produced from tissue culture.

Our knowledge of the nuts and bolts of tissue culture is limited to the belief that this is a promising propagation method that needs to be explored. Rather than attempting to do it on our own, we got together and funded a promising program. We are somewhat behind other labs at the moment but believe our time has been well spent in preparation so we can make this venture a success with a minimum of pitfalls.

Along this line we have helped fund research done at the University of Missouri. Dr. Millikan is heading this project and we have seen his work on 'Kwik Krop' walnut and 'Blushing Golden' apple. We are also helping Dr. Jim Anderson at the University of Arizona and Dr. Wilbur Anderson of the Northwest Washington Research and Extension Unit on his 'Red Delicious' apple project. We hope by helping on projects like these information that otherwise might take years to introduce can be helped along by continuing interest of the commercial nurseries.

COMMERCIAL PROPAGATION OF HERBACEOUS PERENNIALS BY TISSUE CULTURE

MARK ZILIS, DOUGLAS ZWAGERMAN, DAVID LAMBERTS, and LAWRENCE KURTZ

Walters Gardens, Inc.
Zeeland, Michigan 49464

A wide range of herbaceous perennial species can be efficiently propagated on the commercial level using plant tissue culture techniques. Maximum productivity is achieved by finding the optimal physical and chemical conditions for the multiplication and rooting of propagules *in vitro* and in the transition to the soil environment. Utilization of these methods at Walters Gardens, a large wholesale producer of herbaceous perennials, has enabled rapid introduction of new cultivars, propagation of plant species difficult to produce by cuttings or divisions, and production of disease-free plants. The end result has been an increase in the quantity and quality of healthy, vigorous plants.

LABORATORY FACILITIES AT WALTERS GARDENS

The tissue culture laboratory at Walters Gardens covers over 1200 square feet and contains two culturing rooms, a preparation room, a transfer room, and a high humidity room for transplants. Within the culturing rooms, 576 square feet of lighted shelf space is available for the growth of plant tissues. The preparation room contains the equipment used to mix media including an autoclave, refrigerator, sink, a water filtration system, and glassware. The transfer room holds 2 laminar flow hoods, each 6 feet in length. In the high humidity room, 192 square feet of lighted shelf space is available for hardening new transplants.

Four full-time and two part-time people are employed in the laboratory. The main jobs involved in running the facilities are media preparation, transfer work, transplanting, cleanup, and supervision.

HERBACEOUS PERENNIALS IN CULTURE

As a group, herbaceous perennials are easy to propagate *in vitro*. The wide diversity is shown in Table 1 which lists 50 herbaceous perennial species in 18 botanical families produced at Walters Gardens by tissue culture. Tissues from all of these species have been cultured, multiplied, and rooted *in vitro*.

Reasons for propagating a species by tissue culture vary but many of the plants represent introductions of species or cultivars new to the Walters Gardens line of products. For exam-

Table 1. Examples of herbaceous perennial species which can be propagated by tissue culture at Walters Gardens.

Family	Species	Explant	Regeneration/ Multiplication System
Apocynaceae	*Amsonia tabernaemontana*	Shoot tip (ST)	Axillary shoot proliferation
Asclepiadaceae	*Asclepias tuberosa*	ST	Embryoids within callus
Boraginaceae	*Brunnera macropylla*	ST, flower bud, leaf, roots	Adventitious shoot formation from callus
Campanulaceae	*Campanula elatines* var. *garganica*	ST	Axillary shoot proliferation
Campanulaceae	*C. glomerata* 'Superba'	ST	Axillary shoot proliferation
Campanulaceae	*C. rotundifolia*	ST	Axillary shoot proliferation
Campanulaceae	*C. linifolia* (Syn.: *C. scheuchzeri*)	ST	Axillary shoot proliferation
Campanulaceae	Lobelia cardinalis	ST	Axillary shoot proliferation
Caryophyllaceae	*Dianthus gratianopolitanus*	ST	Axillary shoot proliferation
Caryophyllaceae	*Gypsophila paniculata*	ST, flower bud	Axillary shoot proliferation
Caryophyllaceae	*Herniaria glabra*	ST	Axillary shoot proliferation
Caryophyllaceae	*Silene vulgaris* (Syn.: *S. cucubalus*)	ST	Axillary shoot proliferation
Caryophyllaceae	*Petrorhagia Saxifraga* (Syn.: *Tunica saxifraga*)	ST	Axillary shoot proliferation
Compositae	*Aster novi-belgii*	ST	Axillary shoot proliferation
Compositae	*Chrysanthemum maximum*	ST	Axillary shoot proliferation
Compositae	*C. morifolium*	ST	Axillary shoot proliferation
Compositae	*Coreopsis* sp.	ST, flower bud	Axillary shoot proliferation
Compositae	*Inula ensifolia*	ST, leaf	Axillary shoot proliferation and direct shoot formation from leaf base.
Compositae	*Liatris aspera*	ST	Axillary shoot proliferation
Compositae	*Ratibida pinnata*	ST	Axillary shoot proliferation
Compositae	*Rudbeckia fulgida* var. *speciosa*	ST	Axillary shoot proliferation
Fumariaceae	*Dicentra spectabilis*	ST	Axillary shoot proliferation
Hyperiaceae	*Hypericum calycinum*	ST	Axillary shoot proliferation
Labiatae	*Ajuga reptans*	ST	Axillary shoot proliferation
Labiatae	*Lamiastrum Galeobdolon* (Syn.: *Lamium Galeobdolon*)	ST	Axillary shoot proliferation
Labiatae	*Nepeta cataria*	ST	Axillary shoot proliferation

Leguminosae	*Thermopsis caroliniana*	ST	Axillary shoot breaks
Liliaceae	*Hemerocallis* sp.	Flower bud	Shoots developed from callus; callus can be multiplied
Liliaceae	*Hosta* fortunei 'Aoki'	Flower scape sections	Shoot formation directly from scape; multiply by axillary shoot proliferation
Liliaceae	*H. fortunei* 'Hyacinthina'	Dormant veg. bud	Axillary and adventitious shoot formations
Liliaceae	*H. lancifolia*	Flower scape sections	Shoot formation directly from scape; multiply by axillary shoot proliferation
Liliaceae	*H. plantaginea*	Flower scape sections	Shoot formation directly from scape; multiply by axillary shoot proliferation
Liliaceae	*H. undulata*	Dormant veg. bud	Axillary shoot proliferation
Liliaceae	*Lilium* cvs.	Flower bud	Bulblet at multiplication from fl. bud
Liliaceae	*Maianthemum canadense*	ST	Axillary shoot proliferation
Polemoniaceae	*Phlox glaberrima*	ST	Axillary shoot proliferation
Polemoniaceae	*P. paniculata*	ST	Axillary shoot proliferation
Polemoniaceae	*P. sublata*	ST	Axillary shoot proliferation
Primulaceae	*Dodecatheon meadia*	ST	Axillary shoot proliferation
Primulaceae	*D. jeffreyi*	ST	Axillary shoot proliferation
Ranunculaceae	*Aquilegia caerulea*	ST	Axillary shoot proliferation
Ranunculaceae	*Thalictrum aquilegifolium*	ST	Axillary shoot proliferation
Rosaceae	*Geum triflorum*	ST	Axillary shoot proliferation
Rutaceae	*Dictamus albus* 'Rubra'	ST	Axillary shoot proliferation
Saxifragicaceae	*Astilbe* × *arendsii*	ST	Axillary shoot proliferation
Saxifragicaceae	*Bergenia cordifolia*	ST	Axillary shoot proliferation
Saxifragicaceae	*B. ciliata* (Syn.: *B. ligulata*)	ST	Axillary shoot proliferation
Saxifragicaceae	*B. stracheyi*	ST	Axillary shoot proliferation
Scrophulariaceae	*Erinus alpinus*	ST	Axillary shoot proliferation
Scrophulariaceae	*Mimlus rigens*	ST	Axillary shoot proliferation

ple, *Petrorhagia saxifraga* (Syn.: *Tunica saxifraga*), *Campanula rotundifolia, Bergenia cordifolia, Gypsophila paniculata* cultivars, and *Chrysanthemum morifolium* selections have been produced for those reasons.

Tissue culture propagation becomes essential when conventional methods of production are inefficient. For example, field-grown *Hosta* plants yield from 3 to 6 divisions after two years of growth, making rapid buildup of large numbers of plants impossible. By culturing dormant vegetative buds or sections of the flower scape, the rate of *Hosta* multiplication can be accelerated several thousand times. At the present time, over 25 *Hosta* species and cultivars are in culture at Walters Gardens. Other plants produced by tissue culture for similar reasons include *Bergenia cordifolia* cultivars, *Dictamus albus* 'Rubra', and *Lilium* cultivars.

Other advantages of *in vitro* propagation include the ability to produce disease-free material, excellent growth characteristics of cultured plants, the means to develop new cultivars, a speedup of breeding work, and capabilities to propagate large numbers of plants from a small amount of explant material. Also, many species which have been neglected in the horticulture trade, but exhibit excellent ornamental value, can be rapidly introduced. For example, several native American perennials possess colorful and unusual flowering characteristics that rival the best of the cultivated herbaceous perennials, yet they are rarely produced by nurseries. Rapid propagation by tissue culture will enable species such as *Dodecatheon meadia* (common shooting star), *Lobelia cardinalis* (cardinal flower), *Geum triflorum* (prairie smoke), and *Amsonia tabernaemontana* (willow amsonia) to become part of the commercial trade in the near future.

TISSUE CULTURE SYSTEMS FOR HERBACEOUS PERENNIALS

Axillary Shoot Proliferation System. Many types of explants can be used to propagate herbaceous perennials *in vitro* including shoot tips, flower buds, flower scapes, leaves, dormant buds, embryos, and roots (Table 1). For all types, however, the initial goal is the same — to produce shoots. Regeneration in 47 of the 50 species listed in Table 1 involves obtaining shoots directly from the explant in response to specific growth regulator combinations within the medium. Once shoots develop, they can be subcultured for axillary shoot proliferation or for rooting. All explants are surface sterilized in 10% Clorox for 17 minutes followed by 3 rinses in sterile water before culturing.

Shoots can be obtained directly from all types of explant tissues. The easiest route to shoot production utilizes cultured shoot tips from which axillary shoots can be proliferated. This can be done with 90% of the Table 1 species. Flower bud explants, however, can also directly regenerate shoots if taken at an immature stage of development. This has been observed in cultures of *Aster novi-belgii*, *Coreopsis* spp., *Rudbeckia fulgida* var. *speciosa*, *Hosta* 'Nakaimo', and *Gypsophila paniculata*. Cultured flower scape sections are also useful in directly regenerating *Hosta* shoots (8). Shoots can also arise from cultured leaves or leaf sections in many species including *Inula ensifolia*, *Hosta* 'Aoki', *Phlox paniculata*, *Rudbeckia fulgida* var. *speciosa*, and *Bergenia cordifolia*. Although roots readily develop callus, direct shoot formation is rare in culture. Sterile roots (ones developed adventitiously in culture) of *Phlox sublata* have regenerated adventitious shoots.

Once uncontaminated shoot cultures are obtained, they can be subcultured for further proliferation of axillary shoots. Growth cycles from 2 to 8 weeks or more should be established. For many species, the cycle length is critical. Although greater numbers of shoots will develop over extended culturing time, shoot quality usually deteriorates past an optimal time. This can subsequently lower rooting percentages and transplanting survival.

Maintenance of the proper physical environment is essential during shoot multiplication. Generally, temperatures between 20° and 30°C (68° and 86°F) and 300 to 400 footcandles of light from cool-white fluorescent lamps are optimal for culturing herbaceous perennial shoots. Lower light intensities (down to 100 f.c.) tend to slow multiplication and produce poorer quality shoots in such species as *Bergenia cordifolia*, *Gypsophila paniculata*, and *Dicentra spectabilis*. Other species, though, including those in the family Compositae, can be cultured under a broader range of growing conditions.

Shoots produced *in vitro* should be rooted *in vitro*. Although some research (2) has suggested rooting tissue-cultured shoots directly into soil, this technique is not efficient for the production of herbaceous perennials. Rooting cultured shoots can be easily accomplished *in vitro* for most herbaceous perennial species (Table 2).

The proper physical environment within the rooting container leads to success in the rooting and transplanting processes. High light conditions (800 to 1200 f.c. from cool-white fluorescent lamps) and temperatures between 20° and 30°C (68° and 86°F) are optimal for most species. The agar concentration of the rooting medium is another critical factor. Levels between

Table 2. Rooting and transplanting responses for 22 major herbaceous perennial species produced by tissue culture at Walters Gardens.

Species	Rooting Percentage	Transplant Survival[1]
Ajuga reptans	+++	+++
Aster novi-belgii	+++	+++
Bergenia cordifolia	+++	+++
Campanula Elatines var. *garganica*	+++	+++
C. glomerata 'Superba'	+++	+++
C. rotundifolia	+++	+++
C. linifolia (Syn.: *C. scheuchzeri*)	+++	+++
Chrysanthemum maximum	+++	+++
C. morifolium	+++	+++
Dicentra spectabilis	++	+++
Dictamus albus 'Rubra'	+	+
Dodecatheon meadia	+++	+
Gypsophila paniculata	+++	+++
Hosta fortunei 'Aoki'	+++	+++
H. fortunei 'Hyacinthina'	+++	+++
H. lancifolia	+++	+++
H. plantaginea	+++	+++
H. undulata	+++	+++
Lobelia cardinalis	+++	+++
Phlox paniculata	++	+++
Rudbeckia fulgida var. *speciosa*	+++	+++
Petrorhagia Saxifraga (Syn.: *Tunica saxifraga*)	+++	+++

[1] +++ = 80% or greater; ++ = 50 to 80%; + = less than 50%.

10 and 14 grams per liter create dry conditions that enable leaves produced *in vitro* to withstand dessication following transplanting. Length of culture time during rooting also seems to be an important factor. Periods from 2 to 4 weeks are typical for most crops while longer periods *in vitro* reduce survival after transplanting.

The transplanting operation is relatively simple. The rooted plants are removed from the mason jars, transplanted into soil, and placed in a growing room where the relative humidity is maintained at 50%. Light levels are kept at 300 to 400 f.c. for 2 to 3 days after which they can be increased to 1200 f.c. Most crops remain under high humidity for 3 to 10 days and, then, are transferred to the greenhouse. Response to transplanting has been excellent for most major species (Table 2).

Thus, the basic system for the culture of most herbaceous perennial species utilizes axillary shoot proliferation. The system involves regeneration of shoots directly from explant tissues and the proliferation of axillary shoots. Subcultured shoots are rooted under conditions of high light in mason jars containing media with an agar concentration of 10 to 14 g/l. After rooting, the plants are transplanted into soil and moved to conditions of high humidity.

Other Systems of Propagating Herbaceous Perennials *In Vitro.* Although most herbaceous perennials produced by tissue culture at Walters Gardens utilize axillary shoot proliferation, three other regeneration systems have been used: an embryoid germination system; a system in which shoots develop from callus; and the formation of bulblets. Generally, though, these systems have been employed only when attempts to proliferate axillary buds have failed.

Propagation of *Asclepia tuberosa* via asexual embryogenesis represents a relatively unique system. Callus tissues obtained from shoot tip explants develop embryoids in response to growth regulator supplements in the medium. Individual embryoids or callus can be continually subcultured to yield more embryoid-containing callus. To induce embryoid germination, whole cultures are smeared onto the surface of a growth regulator-free medium in quart mason jars. After shoots and roots develop from the germinating embryoids, they can be transplanted into soil. Light levels during the germination period should be maintained at 600 to 800 f.c. from cool-white fluorescent lamps.

An intermediary callus step is necessary in the propagation of *Brunnera macrophylla* and *Hemerocallis* (although other species can be propagated this way in addition to axillary shoot tip proliferation). Shoot tips, flower buds, leaves, and sterile roots of *Brunnera macrophylla* develop callus when cultured in *darkness in response to the proper growth regulator additions* in the medium. Shoots develop in the callus and subsequently the cultures are transferred to light. Little axillary shoot proliferation is noted. Such shoots can be rooted and transplanted in the same manner as axillary shoots.

Daylily flower buds also develop callus in darkness on the proper medium. When callus tissues are subcultured and grown in light, shoots arise which then initiate adventitious roots. These can be transplanted into soil. Similar useful systems for iris (3) and tetraploid daylily cultivars (4) have been developed.

The third alternate system of herbaceous perennial propagation involves the production of adventitious bulblets. Tissues from two members of the lily family, *Lilium* cultivars and *Eremurus* × *isabellinus* (Syn.: *E.* × *shelfordii*), the Shelford desert candle, develop bulblets when cultured *in vitro.* Callus developed from *Eremurus* × *isabellinus* embryos regenerate bulblets in light or darkness in response to specific auxin and cytokinin combinations. Bulblets and callus tissues can be subcultured for the continuous production of bulblets. Rooting techniques are being finalized.

Bulblets can develop directly from *Lilium* flower buds cul-

tured in darkness. It is also possible to initiate bulblet formation directly from the tips of inverted sterile roots. Anderson (1) described a system for the production of lily bulblets from cultured bulb scale sections and for root production from the bulblets. Regardless of explant source, subcultured lily tissues will continuously produce bulblets in light or darkness in response to several growth regulator combinations in the medium. After rooting, the bulblets can be transplanted into soil.

CULTURE MEDIA CONSTITUENTS

The basic medium used for culturing herbaceous perennials *in vitro* consists of inorganic salts, sucrose, vitamins, agar, and water. The inorganic salt formula is identical to the Murashige and Skoog formula (5) except for the KH_2PO_4 concentration which is increased to 300 mg/l. In cultures of a few species, however, the concentrations of the major salts must be reduced to 25 or 50% of full strength during rooting and, occasionally for multiplication, to achieve the optimal response. Sucrose is included at 30 g/l while thiamine·HCl, nicotinic acid, and pyridoxine·HCl are used at 0.5 mg/l each. During multiplication 8 to 10 g/l of agar are incorporated but the level is increased to 10 to 14 g/l during rooting.

Certain combinations of growth regulators contained in the culture medium stimulate the regenerative responses. Most herbaceous perennials proliferate multiple shoots in response to 1.0 to 10.0 mg/l benzyladenine (BA), with or without naphthaleneacetic acid (NAA), in the concentration range 0.02 to 1.0 mg/l. Forty of the 47 species listed in Table 1, multiplying by axillary shoot proliferation, respond better to BA than to other cytokinins while 27 of the 40 utilize a combination of BA and NAA. Six species, however, formed multiple shoots best when kinetin or kinetin plus NAA was included in the medium. Gibberellic acid (GA_3) also has been useful in combination with cytokinins and/or auxins for shoot multiplication. Eight species listed in Table 1 require GA_3 for maximum axillary shoot proliferation. Other growth regulators, such as the auxins, indoleacetic acid (IAA), indolebutyric acid (IBA), and 2,4-dichlorophenoxyacetic acid (2,4-D) and the cytokinin, 2-isopentenyladenine, have not proven effective in the shoot multiplication process. Typical growth regulator combinations used in the proliferation of shoots were described for cultures of four *Hosta* species (8) and two *Phlox* species (6) and for the woody perennials, *Viburnum lentago* (7) and *Prunus cerasifera* 'Thundercloud' (10). Growth regulator requirements for the stimulation of embryoid formation in *Asclepias tuberosa* (9) and for the production of shoots from callus of *Hemerocallis* (4)

have also been explained.

Cultured shoots develop adventitious roots either on the basal medium or on media containing IBA in the range 0.1 to 2.0 mg/l. Of the 50 species listed in Table 1, 20 formed adventitious roots best on media lacking growth regulators, while 29 required IBA and one used IAA. Although NAA can be effective in stimulating root initiation, it seems to inhibit root growth. The addition of IAA has been generally ineffective in the rooting process and 2,4-D stimulates callus and inhibits shoot growth.

RESPONSE OF PLANTS PRODUCED BY TISSUE CULTURE

Greenhouse and field plantings of the hundreds of thousands of plants produced by the Walters Gardens tissue culture laboratory have proven highly successful. Fantastic growth characteristics are typical of tissue culture-derived plants. Increases in branching and in the production of side shoots have been noted for many crops. Large, multi-branched *Gypsophila paniculata* plants with increases in the number of flowering shoots contrast sharply with those produced by cuttings which are usually weak and spindly. Propagation *in vitro* of disease-free baby's breath has also eliminated crown-gall problems. Numbers of side shoots used for divisions have increased many times in plantings of asters and chrysanthemums. Similarly, field plantings of *Bergenia cordifolia, Petrorhagia Saxifraga* (Syn.: *Tunica saxifraga*), *Chrysanthemum maximum, Hosta ventricosa,* and other species have yielded excellent results.

Genetic stability has also been typical of the species listed in Table 1. Some plants, including *Gypsophila paniculata, Aster novi-belgii,* and *Hosta* spp. have been subcultured many times without obvious changes in phenotype.

Changes in leaf variegation characteristics, however, have been noted in *Ajuga reptans.* Under high axillary shoot multiplication rates, certain *Ajuga* cultivars lose variegated characters. For example, the yellow-green cultivar 'Variegata' can revert to solid green, while the mixed yellow-purple-green cultivar 'Burgundy Glow' reverts to bronzy-green. This problem, however, can be eliminated by reducing the medium cytokinin concentration, thereby slowing the shoot multiplication rate.

COST ANALYSIS

Preliminary analysis of cost data indicates that production of herbaceous perennials by tissue culture can be competitive with conventional propagation techniques. Based on a "per plant" basis, transfer labor costs consist of 52% of total ex-

penses, while media materials and preparation (9%), transplanting (15%), overhead (12%) and other labor (12%) comprise the remainder. The benefits of tissue culture, such as improvement in quality and rapid availability of large quantities of material, however, are initially hard to analyze cost-wise, but certainly must be included in any final economic projects.

CONCLUSIONS

High quality herbaceous perennials can be produced efficiently by tissue culture techniques. *In vitro* propagation can be applied to a wide range of plant species and is economically viable. Production of shoots directly from the explant and their multiplication by the proliferation of axillary shoots has been used for most species. The proper rooting environment enables success after transplanting. The final products exhibit vigorous growth characteristics. Tissue culture is an excellent technique for the propagation of herbaceous perennials.

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DICK ZIMMERMAN: I would like to comment on your agar concentrations. Your use of high agar concentrations is going in just the opposite direction of the work in Europe. Agar is a relatively expensive item and they are doing very well with concentrations as low as 4 grams per liter. In some cases they are using 2 grams and supplementing this with pectin.

MARK ZILIS: High agar levels are useful in acclimatizing

plants from the *in vitro* environment to the soil environment. With the high production rates in tissue culture we are not concerned about material costs. In a cost study we found that media costs consumed about 9% of total expenditures. We feel that you get a higher percentage of transplants with higher agar.

BRUCE BRIGGS: You mentioned the use of GA. Have you noticed any slowing up in rooting of your plants, as we have found with woody material?

MARK ZILIS: We have found that it increased axillary bud break in asters but have not noticed any significant root inhibition.

ROOT AND SHOOT GROWTH RATE RELATIONSHIPS OF TWO JAPANESE HOLLY CULTIVARS DURING PROPAGATION

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Abstract. Cuttings of *Ilex crenata* Thumb. 'Helleri' and 'Rotundifolia' were rooted and grown in polyvinyl chloride pipe sections from which longitudinal sections could be removed for root observations. Plants were fertilized at either 150 or 300 ppm N with a 20N-8.7P-16.5K soluble fertilizer. Rate of root and shoot growth was determined through 2 to 3 flushes of growth following rooting by taking weekly measurements of shoots and roots. Root growth of both cultivars usually preceded a shoot growth flush by 1 to 2 weeks. This growth pattern was observed at both fertility levels.

The propagation of woody nursery plants in small containers is widely practiced in the nursery industry. Following rooting the plants are fertilized and grown in these containers until they are large enough to transplant to the field or larger containers. A well balanced root and shoot system is necessary if these plants are to survive transplanting shock. Gilliam and Wright (3) demonstrated that fertilizer treatments of rooted cuttings which encourage top growth may limit root growth. This indicates that some control over root and shoot growth is possible. Before control can begin, however, some knowledge of root and shoot growth patterns during and following rooting are required.

This study was made to determine the pattern of root and shoot growth during and following rooting of *Ilex crenata* 'Helleri' and 'Rotundifolia' grown at two fertilizer levels following rooting.

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MATERIALS AND METHODS

Experiment 1. Single-stem 'Helleri' cuttings, 7 cm long, were taken Feb. 8, 1977, and placed in metal flats containing a medium composed (by vol) of 2 peat: 2 perlite: 1 Weblite (Webster Brick Company, Roanoke, VA 24012). Cuttings were rooted under intermittent mist (10 sec/10 min) and subsequently grown in a greenhouse at 28°C (82°F) (day)/21° (70°F) (night) under natural photoperiod until Sept. 30, when longday conditions were maintained with incandescent light at about 162 lux from 11 pm until 2 am. After 4 weeks in the propagation bench, when roots became visible, 50 uniform rooted cuttings were transplanted into polyvinyl chloride (PVC) pipe sections, 3.8 cm diam × 30.5 cm long, containing the above medium.

For viewing and measuring root systems, a longitudinal section was cut from one side of each pipe (Figure 1) according to Murdoch (5). The section was secured in place with masking tape and a rolled sheet of transparent acetate plastic was inserted to cover the inside of each pipe. A piece of nylon shade cloth was wired to the bottom of each pipe to retain the growing medium. Pipe sections with transplanted cuttings were then placed at a 56° angle against a shelf with the window side down.

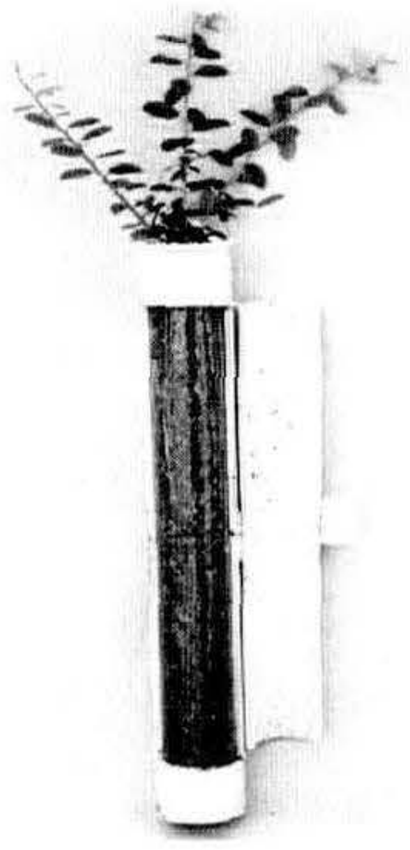

Figure 1. System used for measuring root and shoot growth during rooting and growth of 'Helleri' and 'Rotundifolia' holly.

Twenty ml of 20N-8.7P-16.5K soluble fertilizer was applied weekly at levels of 150 or 300 ppm N. Micronutrients were applied once with a Hoagland and Arnon (4) micronutrient solution in which 5 ppm of iron was supplied in the form of NaFeEDTA. A randomized block design with 5 plants per treatment in each of the 5 replicates was used.

On April 24, 3 shoots and 3 roots per plant were selected for weekly measurements until Dec. 13. Growth occurring between measurements was determined, divided by the number of days in the period, and plotted as growth rate ($-$cm day^{-1}).

Soluble salt levels were determined for 5 tubes (1 from each replicate) on Oct. 5 and showed low readings indicating low fertility in tubes. Fertilization was changed on Oct. 14 by placing the tubes in a tub containing the fertilizer solution.

Experiment 1 was repeated from Sept. 18, 1977 to Feb. 2, 1978, except that cuttings were rooted directly in the pipe sections.

Experiment 2. Single stem 'Rotundifolia' holly cuttings, 7 cm long, were propagated, grown, and measured as in Experiment 1 with the following exceptions: (1) cuttings were rooted directly in the pipe sections under intermittent mist to prevent transplant shock; (2) fertilizer treatments were begun July 26, 1977; (3) a randomized block design with 5 plants per treatment in each of the 4 replicates was used; (4) measurements were taken weekly from July 28, 197 to Dec. 27, 1977.

RESULTS AND DISCUSSION

Root growth of both cultivars of Japanese holly in all experiments was episodic with each root flush usually preceding a shoot flush by 1 to 2 weeks (Figure 2 and 3). Growth patterns for 'Rotundifolia' holly (Experiment 2) were identical to 'Helleri' holly and therefore are not shown. Episodic responses were observed at both fertility levels in each of the 2 experiments and the rate of root growth for each experiment and cultivar was shown to be greater at 300 ppm N than at 150 ppm, although not significantly at the 5% level (data not shown).

Exceptions to the chronological order of root growth to shoot growth occurred in Experiment 1 and 2. Following the 2nd root and shoot growth flush in Experiment 1, there was a period of 2 to 3 months in which no shoot growth occurred (Figure 2). Root growth, however, continued throughout this period of inactive shoot growth. After bottom fertilization was begun on Oct. 14, shoot growth began again within 3 weeks with a concurrent decrease in root growth.

Data from the repeat of Experiment 1 (Figure 3) shows the normal patterns of shoot growth for 'Helleri' holly grown under adequate nutritional programs following rooting. This experiment presents a clear picture of the chronological relationship of root to shoot growth.

A period of active root growth preceded each shoot flush of 'Helleri' and 'Rotundifolia' holly. The above results may be explained in the following manner. Nitrogen absorbed by plant roots tends to react first with carbohydrates in the roots (1,6). As the root system develops to the extent that it can absorb higher levels of fertilizer, nutrients in excess of what is needed

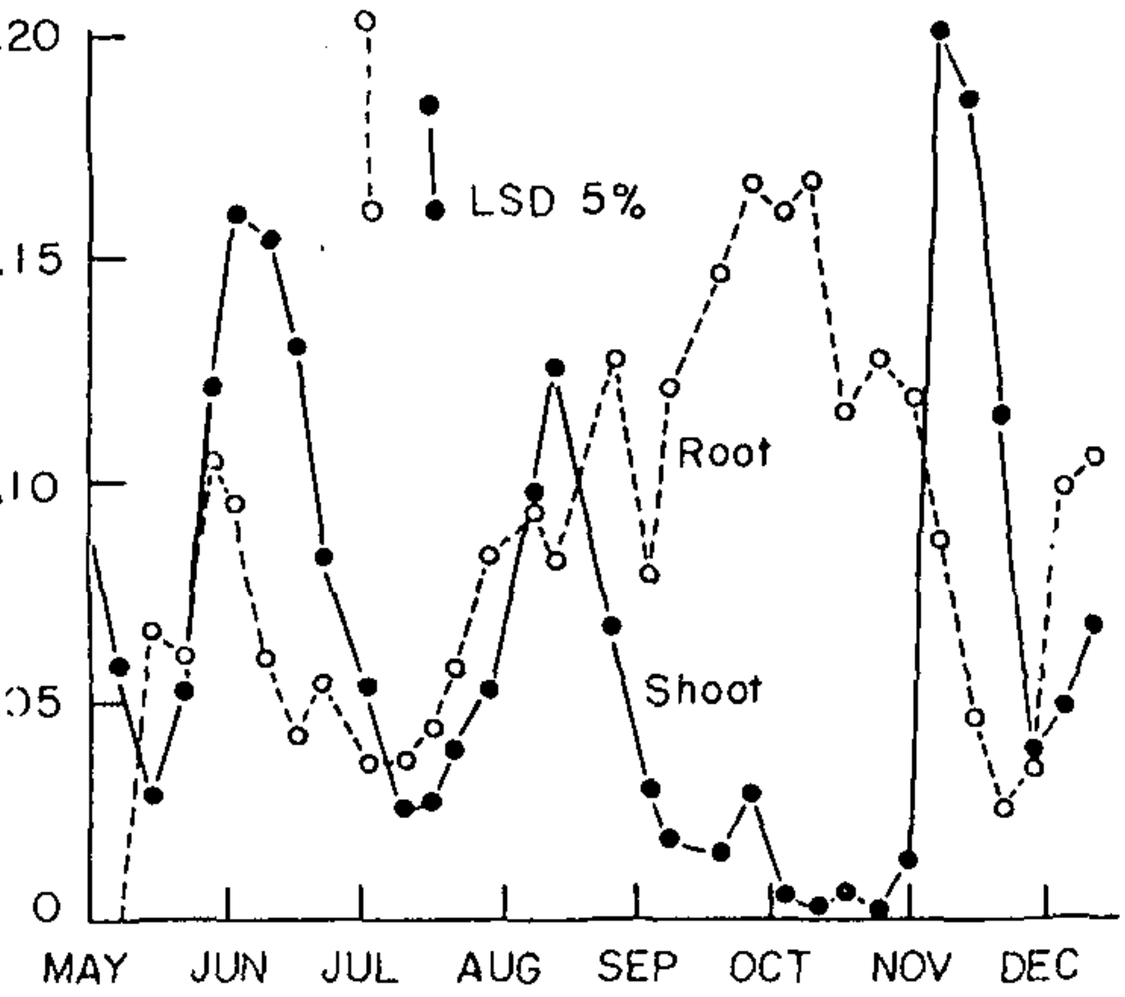

Figure 2. Root and shoot growth rates of 'Helleri' holly grown at 300 ppm N applied as 20N-8.7P-16.5K soluble fertilizer.

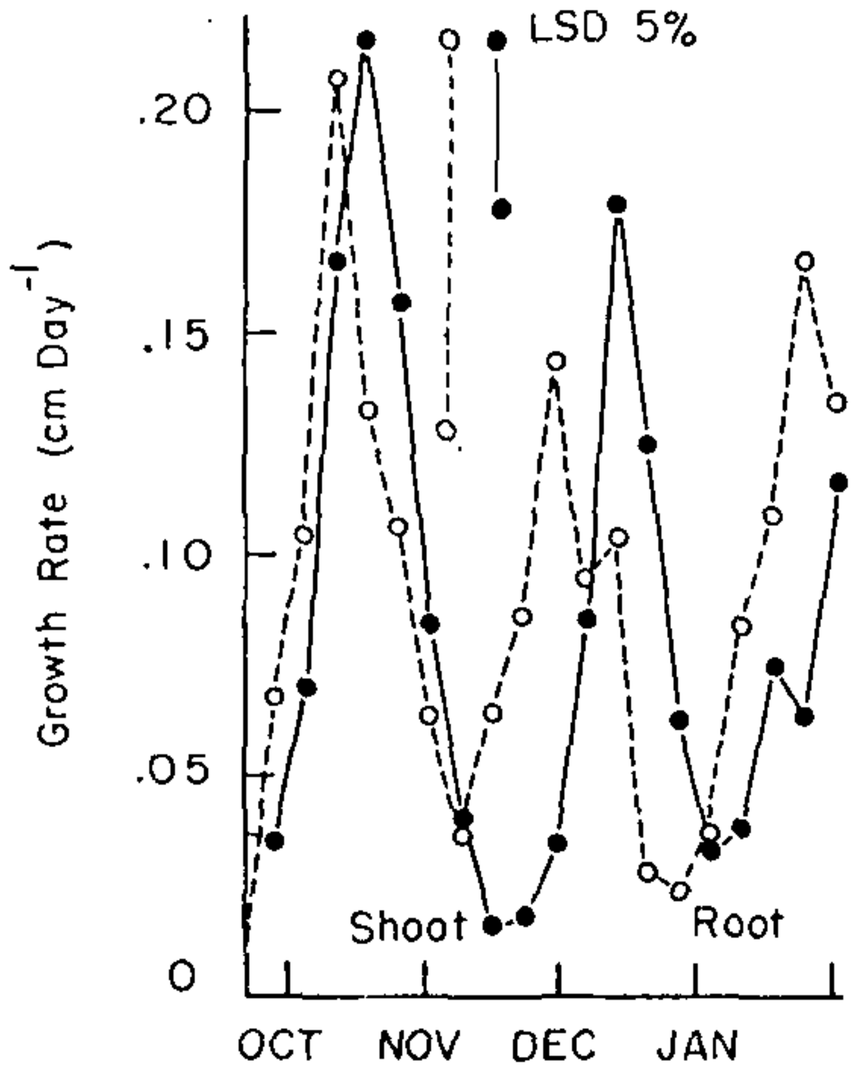

Figure 3. Root and shoot growth rates of 'Helleri' holly grown at 150 ppm N applied as 20N-8.7P-16.5K soluble fertilizer.

for root growth are translocated to the plant tops where they are used in conjunction with carbohydrates for protein synthesis and shoot growth. Consequently, less carbohydrates remain for translocation to the roots, and root growth is then limited relative to the shoot growth. Since root growth, and hence nutrient absorption is at a low level, new shoot growth eventually depletes the nutrients level within the plant, and growth of the plant top ceases. Carbohydrates become available again for

translocation to the roots, root growth and nutrient absorption begins again, and the cycle repeats itself. In agreement with this theory, Gilliam and Wright's data (2) show with 'Helleri' holly that the tissue nitrogen concentration of the plant top is at its highest level when shoot growth begins and at its lowest level when shoot growth ceases.

Periods of active root growth preceding successive top flushes would explain further results obtained by Gilliam and Wright (3) who found fertilizer to be more efficiently used by 'Helleri' holly when applied during a period following the cessation of shoot elongation and preceding the next flush of shoot growth.

A nutritional correlation between periods of root and shoot growth as described above would also explain the 2 to 3 month periods in Experiment 1 in which no shoot growth occurred (Figure 2). The 20 ml of fertilizer solution applied to each plant at the soil surface was insufficient to penetrate to the lower portions of the containers where root growth was most active. The low fertilizer level was adequate for root growth which continued until fertilizer levels were increased by bottom fertilization. When higher fertilizer levels reached the roots in the lower portions of the tubes, root growth decreased and shoot growth increased. This implies that if more root growth is desired on small liners, then relatively low fertilizer rates are required.

A question that this study introduces is the proper time to transplant rooted liners to the field. If plants were transplanted following a shoot flush then a period of root growth would quickly follow establishing the plant in the field or container in respect to water and nutrient uptake. If plants were transplanted following a root flush and just before a shoot flush then considerable stress would be placed on the plant by the increased top development with no concurrent root growth.

With this knowledge, and if similar trends are recorded for other container-grown woody plants, nurserymen should be able to positively manipulate both root and shoot growth by timing fertilizer applications and varying the rate of fertilizer applied.

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Friday Morning, December 14, 1979

NEW PLANT FORUM

Jack Alexander and Michael A. Dirr, Moderators

MODERATOR DIRR: Our first speaker on this portion will be Dr. Sidney Waxman who has three plants he would like to discuss.

SIDNEY WAXMAN: *Pinus strobus* 'Yu Coon' is a dense fast growing shrub or small tree grown from seed obtained from a witches' broom. Unlike normal white pines, it retains the lower branches. Its dense branching develops naturally without pruning. The dimensions of this plant, after having been grown for 15 years, are 10½ feet tall and 7 feet broad.

Larix × *eurolepsis* (unnamed cultivar) is a weeping, spreading tree. Its most interesting characteristic is that the major branches tend to grow horizontally and undulate, while the secondary branches weep. Its winter character is also of interest.

Sciadopitys verticillata (unnamed cultivar) has several characteristics that make it desirable. The foliage is deep green. The needles do not bronze in the winter but retain their green color and become glossy. Also this particular tree was selected from among many others because of its ability to root easily. Cuttings taken during the past 10 years have rooted consistently with high percentages.

MODERATOR DIRR: Elwin Orton has one plant to present.

ELWIN ORTON: *Pyracantha coccinea* 'Rutgers' is the result of a cross 14 years earlier. We have had it under test that long and I believe that it will be a replacement for the cultivar 'Lowboy'. In contrast to 'Lowboy', which is extremely susceptible to scab, 'Rutgers' has been absolutely free of scab and fireblight for 14 years.

MODERATOR DIRR: Edmund Mezitt has two *rhododendron* plants he would like to present.

ED MEZITT: The first rhododendron is *R.* 'Weston's Pink

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MODERATOR DIRR: Edmund Mezitt has two *rhododendron* plants he would like to present.

ED MEZITT: The first rhododendron is *R.* 'Weston's Pink

Diamond'. This plant is a hybrid derived from breeding a petaloid *R.* 'PJM' seedling with *R. mucronulatum* 'Cornell Pink'. The flower is a pleasing pink and is also petaloid. The plant is slightly evergreen and easily propagated from cuttings.

The second is *R.* 'Olga' which is a cross between a pink form of *R. mucronulatum* and *R. minus*. The cultivar 'Olga' has evergreen foliage, good winter color, and blooms about one week after *R.* 'PJM'. This cultivar is vigorous in growth and the fowers are a deep pink.

MODERATOR DIRR: The next speaker will be Harold Pellett.

HAROLD PELLETT: The first plant is a seedling of *Aesculus sylvatica*. We like it for its foliage characteristics in summer and fall. It holds its foliage all summer and has been free of scorch. The leaves are dark, glossy green in summer and maroon in fall. We are going to submit the name 'Autumn Splendor'.

I would next like to introduce the next plant *Forsythia mandschurica* 'Vermont Sun' for my brother. 'Vermont Sun' is recommended for trial as a substitute for *F. ovata* and less hardy forms of *Forsythia*. Flower buds are cold hardy to about −31° to −34°C (−25° to −30°F) and blooms about one week earlier than *F. ovata* at the University of Vermont Horticultural Research Center in South Burlington. 'Vermont Sun' is a slower grower than *F.* × *intermedia* 'Lynwood' and has a mature height and spread of 8 feet.

MODERATOR DIRR: Our next speaker, Gary Koller, has four interesting plants to discuss.

GARY KOLLER: The first plants are grasses. *Miscanthus sinensis* 'Gracilimus' grows to 10 feet with ¼ inch wide leaves and *M. sinensis* 'Variegatus' is noted for leaf blades striped with white or yellowish color. *M. sinensis* 'Giganteus' is another interesting cultivar which grows to 12 feet.

A vine that has done well under dry, shadey conditions is *Ampelopsis brevipedunculata* 'Elegans'. An interesting feature is the white swirl pattern in the leaves and when it is grown properly you get touches of pink.

MODERATOR DIRR: Jack Alexander has a list of plants he would like to present.

JACK ALEXANDER: *Cedrus deodara* 'Shalimar' is a new introduction from the Arnold Arboretum. It is perfectly hardy in the Boston area. The branch tips are slightly pendent. It is probably the hardiest *C. deodara*. Last year we had −21°C (−6°F) and had no damage. We have had some success propagating it from cuttings in the fall using 5,000 ppm 2,4,5-TP.

Cladrastis lutea 'Rosea' differs from the species only by the presence of pink flowers.

Pieris japonica 'Valley Valentine' grows to be 5 feet high. The plant has dark purple winter buds which open to a dark pink that fades some. The florets are closer to red than 'Valley Rose' or 'Flamingo'. The new growth comes out red. If you want propagating material contact Bob Ticknor, N. Willamette Exp. Station, Amora, Oregon 97002.

The next plants were provided by the Soil Conservation Service.

Juniperus conferta 'Emerald Sea' reaches 1 to 2 feet and has a spread of 8 to 10 feet. Its main attribute is the fact that it retains its' blue-green color throughout the winter. It is hardy to −23°C (−10°F) and tolerates salt spray. The plant is recommended for sandy soil and it also tolerates drought well.

Populus × *canadensis* 'Imperial' is a male cultivar recommended as a windbreak and is hardy to −34°C (−30°F). This plant is very fast growing, up to 4 feet a year. The plant has an ultimate height of 50 to 80 feet and it maintains a columnar habit. Rodents and deer can damage the plant.

Salix purpurea 'Streamco' is a shrub which is recommended for stream bank plantings. The plant is easily propagated from cuttings and does well in wet locations.

MODERATOR DIRR: I have a few plants that I would like to present.

Pyrus calleryana 'Whitehouse' was released in 1978 by the USDA. The plant is supposedly distinctly upright and maintains a central leader. You can obtain scion wood from the U.S. National Arboretum, Washington, D.C.

Viburnum plicatum tomentosum 'Shasta' is a low growing type to 6 feet and almost twice as wide with distinct horizontal branching. The flowers are the main asset. The sterile florets are almost 2 inches across. It is hardy to USDA zone 5b.

MODERATOR DIRR: Dixon Hoogendorn has two plants to present.

DIXON HOOGENDORN: *Ilex verticillata* 'Compacta' is much slower growing and more compact than other *I. verticillata* cultivars. It also is self pollinating. The bright red fruit is long lasting. It can be propagated by softwood cuttings taken in June.

Rhododendron 'Silvery Pink' is a compact, evergreen plant with small leaves and silvery pink flowers. The plant is quite conspicuous from a distance. We have had two severe winters in a row with temperatures down to −26°C (−15°F) and we saw

no evidence of bud blast or leaf injury. The bloom period is 7 to 10 days after *R.* 'PJM'.

MODERATOR DIRR: Joe McDaniel has three plants to present.

JOE McDANIEL: *Maclura pomifera* 'Altamont' is the name of a thornless selection of osage orange that I have selected. The plant is a staminate form and has a more upright branching habit than is usual for the species.

Magnolia 'Spring Joy' is a cross between *M. kobus* var. *stellata* 'Royal Star' and *M.* 'Wada's Memory'. *M.* 'Spring Joy' has more tepals than *M.* 'Wada's Memory' and the flower opens later than *M.* 'Royal Star'. Its color is prevailingly white with a touch of pink at the base. *M.* 'Spring Joy' will mature larger than *M.* 'Royal Star' which is one of the more vigorous *M. kobus* var. *stellata* cultivars.

Magnolia 'Paul Cook' is the result of a cross between *M. sprengeri* and a seedling of *M.* × *soulangiana* 'Lennei'. This cultivar has been hardy through all the bad winters at Urbana, Illinois. It has light pink blooms, as much as 11 inches across, which are borne on stronger growing trees than *M.* × *soulangiana*.

BACK TO THE BASICS OF ROOTING

H.B. TUKEY, JR.[1]

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Cornell University
Ithaca, New York 14853

The phenomenon which nurserymen call rooting is really a combination of several processes and chemical interactions, often separated into root initiation and root development. In the first, cells capable of rejuvenating and becoming meristematic, receive appropriate chemical signals and start dividing. In the second, these meristematic groups of cells called root initials respond to different sets of signals and continue division and elongation into young roots, aided by factors in the environment.

Physiologists ask the nature of the signals, which cells perceive them, and why root cells are produced and not some other type. These are important considerations, because the theory of totipotency suggests that all cells in plants have the

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genetic information to make a complete new plant.

First, what types of cells have the ability to rejuvenate, de-differentiate or to divide again, and where are these cells located? Many cells are so differentiated that it is difficult if not impossible for them to divide again. As examples, the vessels in the xylem which carry water and nutrients upwards from the roots to the stems are thick-walled and are dead in most respects, and thus are not able to divide. Similarly, sieve tubes in the phloem which carry sugars and hormones and other substances usually downwards from the leaves to the roots do not become meristematic again, and thick-walled cells such as fibers are not likely candidates for division. Instead the parenchyma cells, large blocky cells found throughout plants in many tissues, can revert to meristematic activity very easily, and it is generally the parenchyma cells which start division to form root initials.

Location is another interesting question. Why don't all of the parenchyma cells in a stem become meristematic and produce roots? Usually, in stems parenchyma cells near or just outside the phloem, in phloem rays, or in the interfascicular region between vascular bundles most often produce root initials. In roots, secondary roots usually develop from the pericycle area, just outside the phloem. Although other cells can produce roots, particularly those in tissue cultures, in intact plants parenchyma near the phloem tissue is most likely.

Interestingly, the vascular cambium which is responsible for the formation of most other cells in plants usually does not produce root initials, even though these cells apparently have the information to do so.

A basic scheme for root initiation and development (Fig. 1) was prepared many years ago (2) and is still not worked out completely. The first step was the identification of indoleacetic acid in 1934. IAA, produced in developing buds, young leaves, root tips, pollen, and fruits, was the first natural growth regulator in plants to be identified. Within months of its identification, IAA was added to cuttings to promote formation of root initials, although other compounds such as indolebutyric acid (IBA) and naphthaleneacetic acid (NAA) were found to be of greater commercial use because of stability and mobility. The movement of IAA downward in a stem from the young buds and accumulating at the base of a cutting, or addition of IBA at the base of the cutting, is one signal for root initiation.

However, it has been known for many years that there are growth regulating compounds other than auxins which are necessary for root initiation. The work of van der Lek (9), Went (10), and others pointed toward the existence of such com-

pounds, and the term "rhizocaline" was coined for such unknown substance(s). The work of Hess (5) and students made some of the first separations of root promoting substances other than auxins, named cofactors 1, 2, 3 and 4, and later found in many plants. The levels and balance of these 4 cofactors were used to explain differences in rooting in juvenile and adult ivy, and among rhododendron cultivars (6).

However, an increasing amount of evidence suggested that levels of cofactors and auxins do not always correlate well with rooting, as in explaining differences in rootability among chrysanthemum cultivars (12), and bougainvillea, among others. These results lend support to the scheme in Fig. 1 which proposes that an enzyme is necessary to complex auxins and cofactors to provide the primary stimulus for root initiation. Despite some work, a single enzyme has never been isolated from a plant, which added to auxins and cofactors induces rooting. However, recent work just completed in England (1) has isolated a polyphenolic oxidase enzyme from apple cuttings, which when added in a crude preparation to apple cuttings, improves rootability at times when the cuttings would not normally root well. Although the enzyme has not been purified, and has not shown to be active in all plants, the research supports the idea that auxins, cofactors, and a complexing enzyme are all needed for root initiation, and without any of the three, rooting will not occur.

The work of Bassuk (1) and others (4) also suggests that there may be more than 4 cofactors in plants. In fact, there may be specific compounds in specific plants and even individual cultivars which may act as cofactors, such as phloridzin in apple. Many so called secondary metabolic products in plants have been shown to have a positive effect upon root initiation in a particular plant or group of plants, but when applied to a wide range, do not seem to be successful (7).

Therefore, the scheme first proposed by Bouillene and Bouillene-Walrand (2) 25 years ago is on the verge of being proved correct. Auxins are necessary, and in softwood cuttings which are producing large amounts of auxins, additional applications may be helpful but not necessary. However, in hardwood cuttings which are not growing and in which the levels of auxins may be lower, exogenous applications have been very useful. However, as any propagator knows, even large applications of auxins do not always produce roots.

Second, cofactors, which may be very specific for each plant, are also necessary for root initiation. Since most cofactors have never been identified conclusively, they are not added to cuttings commercially at the present time. Thus, taking cuttings

at the right time or treating them with the correct environmental factors may influence the development of these cofactors. The use of externally applied cofactors may increase as more is learned of their specific role in initiation.

And third, an enzyme similar to that hypothesized to conjugate auxins and cofactors has been found in apple cuttings, and if this enzyme is universally found in plants, and if it is effective in other species, perhaps an important biochemical riddle of root initiation will be closer to being solved.

These results suggest some explanation of why roots develop near phloem tissue. Auxins and cofactors are translocated primarily in the phloem, so interruption of the phloem when taking a cutting will allow accumulation of these materials at the base of the cutting in the phloem or nearby cells. Perhaps the enzyme necessary for complexing auxin and cofactors may be located in the cells of the pericycle area adjacent to the phloem. If this is the case, then the combination of auxins, cofactors, and enzyme, would be present in one location, stimulating parenchyma cells nearby to rejuvenate and become root initials.

It is important to know precisely the effect of a chemical or treatment on rooting, because the same substance may have differing effects upon different stages of root production. For example, relatively high concentrations of auxin are necessary for root initiation, concentrations which are inhibitory to further root development. The gibberellins limit root development by stimulating competing growth, although they apparently have no direct effect upon initiation. Abscisic acid and certain other inhibitory substances such as B-Nine which, in some plants, promote rooting (8) do so by interfering with the depressing effects of gibberellins. Further, chemicals which seem to act as cofactors may instead have an indirect effect upon root initiation, as in the effect of catechol which protects IAA from destruction, thus improving root initiation (3,4). Mineral nutrients, which have been shown to aid rooting of herbaceous and softwood cuttings (11) have an influence upon root development, but little effect upon initiation.

Carbohydrates are important also in rootings. But as Figure 1 shows, the greatest effect of carbohydrates is in root development rather than root initiation. Since carbohydrates cannot be added to cuttings effectively, it is important to regulate sugar content in other ways. Hardwood cuttings already contain large amounts of stored sugars, and this explains why conservation of carbohydrates is so important, by such means as cooler temperatures and lower light intensity. In contrast, softwood and herbaceous cuttings do not have large amounts of stored carbohyd-

rates and production during rooting is important. This explains why leaves are left attached and why warm temperatures and relatively high light intensities are preferred for softwood and herbaceous cuttings, as long as transpiration can be controlled, as by intermittent mist.

*No longer is it sufficient to talk about "rooting." Instead ef*fects of treatments must be associated with the specific processes which occur during root production and a more precise appreciation of the nature of these processes by plant propagators is necessary.

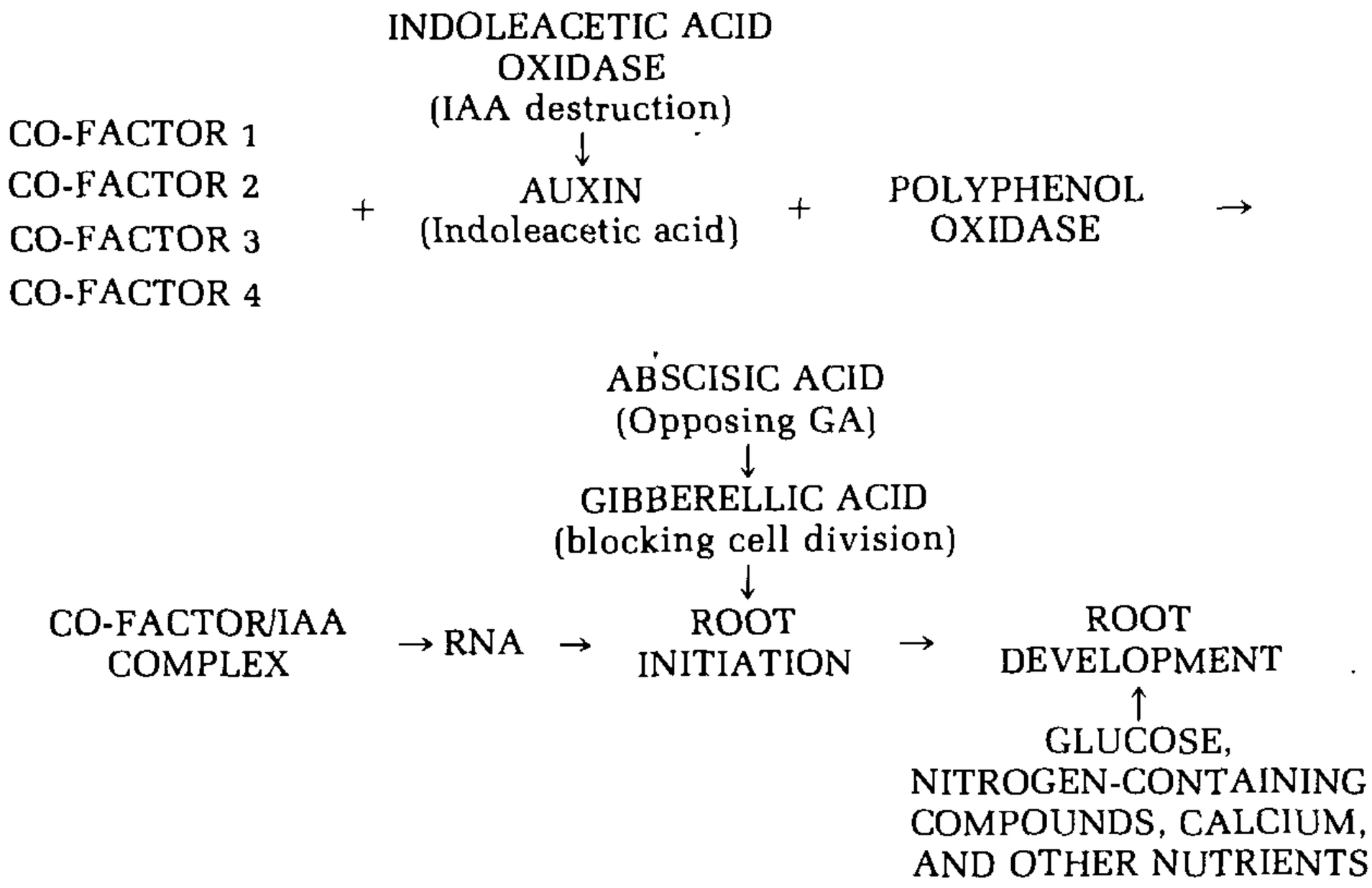

Figure 1. Scheme of root production (from 4).

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JIM WELLS: I understood that the cambium was the seat of all adventitious formation.

HAROLD TUKEY: In general we do not get roots coming directly from cambial cells. Most root initials arise from cells near the cambium which are young and can dedifferentiate.

MICHAEL DIRR: How is a large macromolecule, such as a protein, getting into the root initial cells? It seems a little dubious to me.

HAROLD TUKEY: In the experiments reported from East Malling, they have taken the crude extract, applied it back to other plants, and it works. You would not expect large molecules to get into the cells but it does work. It has worked on apple and some other woody plants.

MICHAEL DIRR: How do they know it is the enzyme and not some other material?

HAROLD TUKEY: They can not prove that at this point. However, it has been purified of hormones, such as the auxins.

WHY PROPAGATE FLOWERING TREES?

JACK SIEBENTHALER
Clearwater, Florida 33518

One of the joys of observing the changes of season throughout most of the United States stems from the opportunity to view the magnificent fall coloring that graces our landscaped neighborhoods and wooded acres.

Curiously, while many northerners long for the chance to loll under the evergreen palms and other flora of the Sunshine State, southern residents complain that we do not have the wonderful change of seasons with its colorful foliage. Many of these people have simply not stopped to take stock of the wonderful color displayed by the many species of tropical trees that abound in Florida.

While not an absolute substitute for the rainbow of color accompanying the frost periods of the north, many flowering trees do bloom in the cool weather months of the Deep South. Many valuable introductions from more exotic areas can be used along with those presently grown to give color during the fall and winter.

Surely, few sugar maples are more spectacular than the glory of mature *Chorisia* in November or the budding explosion of a specimen *Tibouchina* parading its royal purple flowers! As an added bonus, many of our most attractive flowering trees repeat their bloom cycle during the year.

We can realistically forecast the increased use of flowering trees in the warmer regions of Zones 9 and 10 for several reasons. Many promotional groups have recognized the successes of California organizations, which have fostered the systematic use of flowering tree species for many years. Their results are now enjoyed by millions of tourists and residents alike. Public entities, such as parks and public works departments, have recognized the aesthetic benefits that can be achieved as a bonus, in addition to the normal benefits of using trees properly in the public-scape. There is also growing recognition that nothing succeeds more than flowering trees in providing the material benefits of attracting the paying public to such attractions as theme parks, golf courses and other "play for pay" enterprises. And, finally, there is recognition, as belated as it may be, that the aesthetic enhancement of our educational facilities does benefit from the use of color, available in large part from flowering trees.

Along with increased usage of this fine group of plants comes recognition of the need for better methods of use and

propagation. Cultivar selections need to be recognized in order to improve flowering trees in the same way as other lines of ornamentals. Propagation techniques in many instances need to be updated in order to provide an adequate supply of the better plants. Certain cultivars certainly appear to be prime candidates for micropropagation methods, which are being so successfully adopted in other areas. Trained growth methods of propagation and growing on would seem to justify more experimentation and adaptation for certain species that have heretofore been little used because of poor methods of growing. For example *Koelreuteria formosana*, golden rain tree, often develops a crooked trunk. This plant can be trained to grow straight by the simple method of placing trees can-to-can in the nursery. Trees are stronger when trained this way than when they are staked. Finally, the selection of species and the determination of a carefully selected production-size list will go far to encourage the increased usage of flowering trees. Such a list could be a valuable guide in choosing the correct plants for given locations. An assured availability of liners of an adequate size and quality will go far toward increasing the numbers of the better flowering tree species in common usage.

Only a small percentage of the potentially desirable flowering tree species found on the face of the earth are actually being successfully propagated and merchandized. The following list includes only a small sample that is being successfully utilized and it can be greatly extended through selection of cultivars or increased plant introduction practices.

Acacia
Bauhinia
Brachychiton
Callistemon
Cassia
Chionanthus
Chorisia
Delonix
Erythrina
Eucalyptus
Jacaranda
Koelreuteria
Lagerstroemia
Magnolia
Melaleuca
Peltophorum
Stenocarpus
Tabebuia
Tibouchina
Tipuana

In summary, it would seem appropriate for those who have the proper facilities for introducing, experimentally growing and improving propagation techniques to recognize the need for more flowering trees. The popularity of the limited number of public displays such as Walt Disney World, Cypress Gardens, Orlando Parks System, should be recognized as a signal for progress in the plant world.

BREEDING AND SELECTING RHODODENDRONS AND AZALEAS

PETER E. GIRARD, SR.

Girard Nurseries, Geneva, Ohio 44041

I would like to talk to you today about plant breeding. It is nothing new to many of you. Most of you have done some of it. The question is how successful we are in breeding plants. Some propagators hybridize plants just for pleasure and the possible chance that a marketable seedling will result. Some propagators are more critical and use a system for their hybridization. This, of course, is the best method.

The first step is to write down what is wanted from a cross. Do we want to gain hardiness, compactness, certain foliage color, or improved flower texture?

The next step is to find out all we can about the parent plants we intend to use. This is important. Even though the parent is attractive, recessive undesirable characteristics may appear in its offspring. Therefore, we need to know the origin of the parent plants in order to predict what we may expect from the next generation. Our breeding record is shown in Table 1.

I set out many years ago to try to develop an azalea that would withstand the occasional −29°C (−20°F) temperatures that we experience in northern Ohio. Many of the parents we tried were failures. However, we made one cross that seemed very favorable. We used a very hardy Japanese-Korean azalea, *Rhododendron yedoense* var. *poukhanense*, with an *R. obtusum* × *R. kaempferi* cultivar to give desirable color. We obtained about 200 seedlings from this cross and, of these, only three or four had the improved color and good growth habit we wanted. We took two of these and crossed them with a *R. kaempferi* type of azalea called 'Carmen.' This cross gave us several good choices with large flowers and varying growth habits. We continued working with the offspring from this cross until we got what we wanted — an attractive azalea that could withstand our weather. Years ago we grew all our azaleas in field rows with no protection. This was certainly a test for winter hardiness, and we lost many. We did not mind as long as we had at least a couple that could survive. It was from these few seedlings that we started.

We continued to improve the evergreen azalea until we now have a number of them on the market. But we are not satisfied yet. Now we are working with evergreen azaleas that are hardy and yet can be forced during the winter and used for

Table 1. Breeding record.

CROSS _____ YEAR _____

SEED PARENT NAME _____

POLLEN PARENT NAME _____

RESULTS OF CROSS _____

SEED GERMINATION _____ AMT. SEEDLINGS _____

AMT. TRANSPLANTED IN FLATS _____ IN POTS _____

EVALUATION _____ YEAR _____

HARDINESS _____ GROWTH HABITS, UPRIGHT _____

BROAD UPRIGHT _____ LOW COMPACT _____ LOOSE _____

FLOWERS: COLOR _____ BLOTCH _____ REVERSE _____

FORMATION: AMT. PETALS _____ SINGLE _____ TRUSS _____

HOSE-IN-HOSE _____ DOUBLE _____ SIZE _____ TEXTURE _____

FOLIAGE SHAPE _____ COLOR _____ SIZE _____ TEXTURE _____

GLOSSY ___ HAIRY _____ FALL, WINTER COLOR _____

HABIT OF GROWTH: GOOD _____ FAIR _____ POOR _____

EVALUATION RESULTS: GOOD _____ FAIR _____ POOR _____

GROW ON FOR FURTHER TESTS _____ ELIMINATE _____

greenhouse culture. We want something that can be used as a permanent gift, not one that will freeze as many greenhouse azaleas do. We do have a number now that are being used for forcing for Easter.

As we worked further, we became interested in deciduous azaleas. We had been growing *R. molle* for a number of years. However, we found that growers were losing interest in plants of this type because of *Botrytis* and other fungus problems. We had a number of deciduous azaleas from Europe and found we had some that looked very promising. Several were almost free of *Botrytis*. We used these to do our breeding and discovered the disease-free characteristic will pass on to the seedlings. We are now developing them for the truss-type flowers as many of these are loosely flowered around the plant. Some of these seedlings have very large flowers in a wide range of colors. These characteristics will make deciduous azaleas good items for the garden trade.

Third, a continuous spray program keeps the stock

disease-free. And finally, our own records are constantly used as a guideline for improving previous methods.

We have also been involved in breeding rhododendrons, whose flower types are shown in Figure 1. Originally we had many growing problems because of the poor type of plants that were available. At first I bought anything that had a nice color. However, not all rhododendrons will grow in all areas. *Rhododendron catawbiense* and *R. maximum* are the only two species that are reliably hardy in our area. We began breeding using these two species and have added others to our program as we went along. We are now working with the *R. yakusimanum* and are getting very good results.

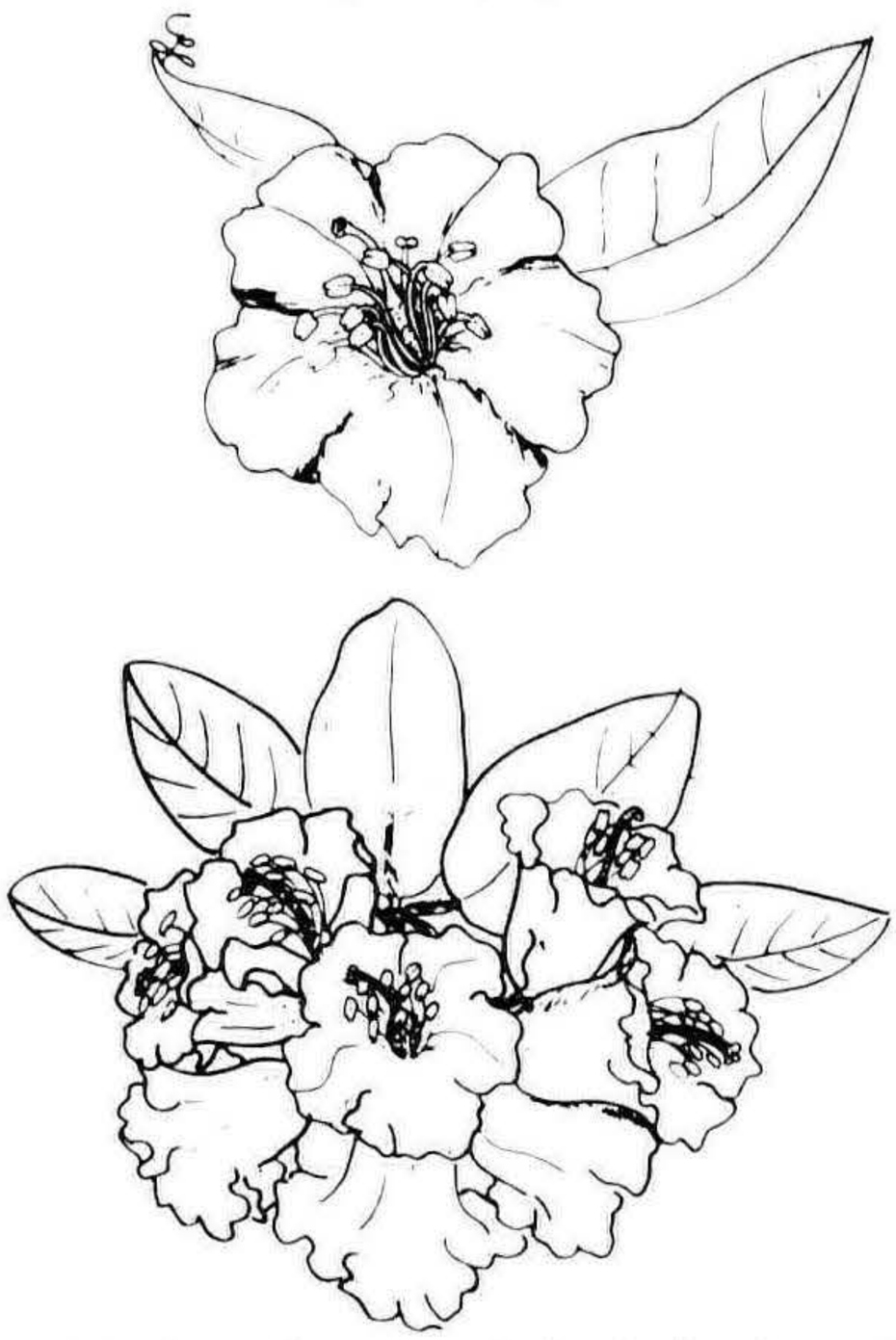

Figure 1. Single floret (top) and truss of rhododendron (below). Drawing by Leslie Eller, Mercyhurst College, Erie, Pennsylvania.

In breeding we try to prevent as much contamination as possible. We start by removing the petals to expose the stamens and pistil. Figure 2 shows the anthers, the filaments, stigma and the other parts of the flower. If a good clean pollen is used to make a good clean cross, results will be the ones desired. However, if petals are left on and a little pollen is dabbed on the pistil, results are unpredictable. We start by removing the petals from an unopened bud, exposing the pistil and the stamens. We then remove the stamens and put the desired pollen on the pistil. The pistil itself attracts no insects, which improves the chances for a clean cross that is free of contamination. Figure 3 shows the pistil developing into a seed pod. An entire seed pod, or capsule, and a cross-section of the seed in the pod are

also shown in Figure 3. The process of making the cross is shown in Figure 4.

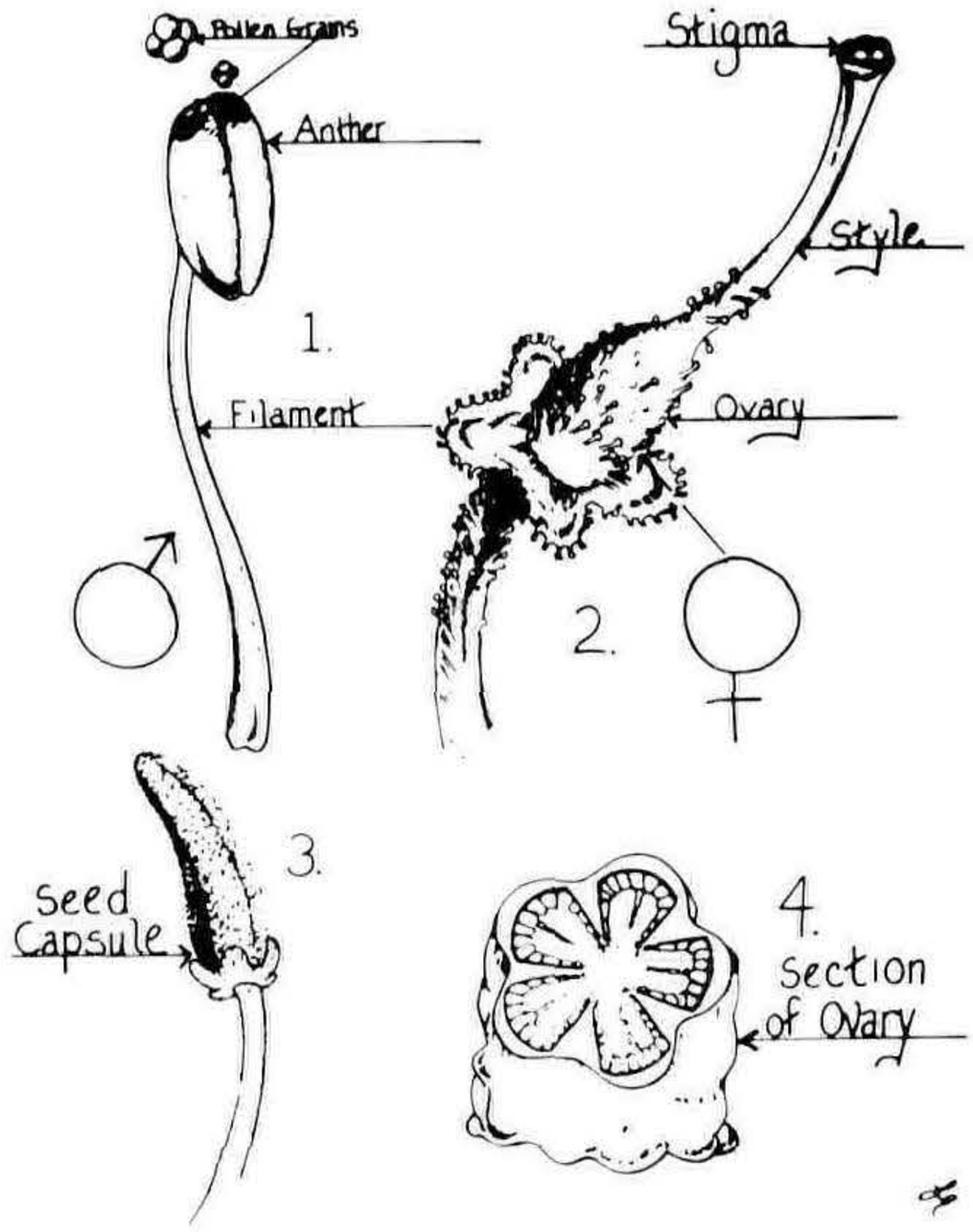

Figure 2. Flower structure of rhododendron showing separate flower parts. Drawing by Leslie Eller, Mercyhurst College, Erie, Pennsylvania.

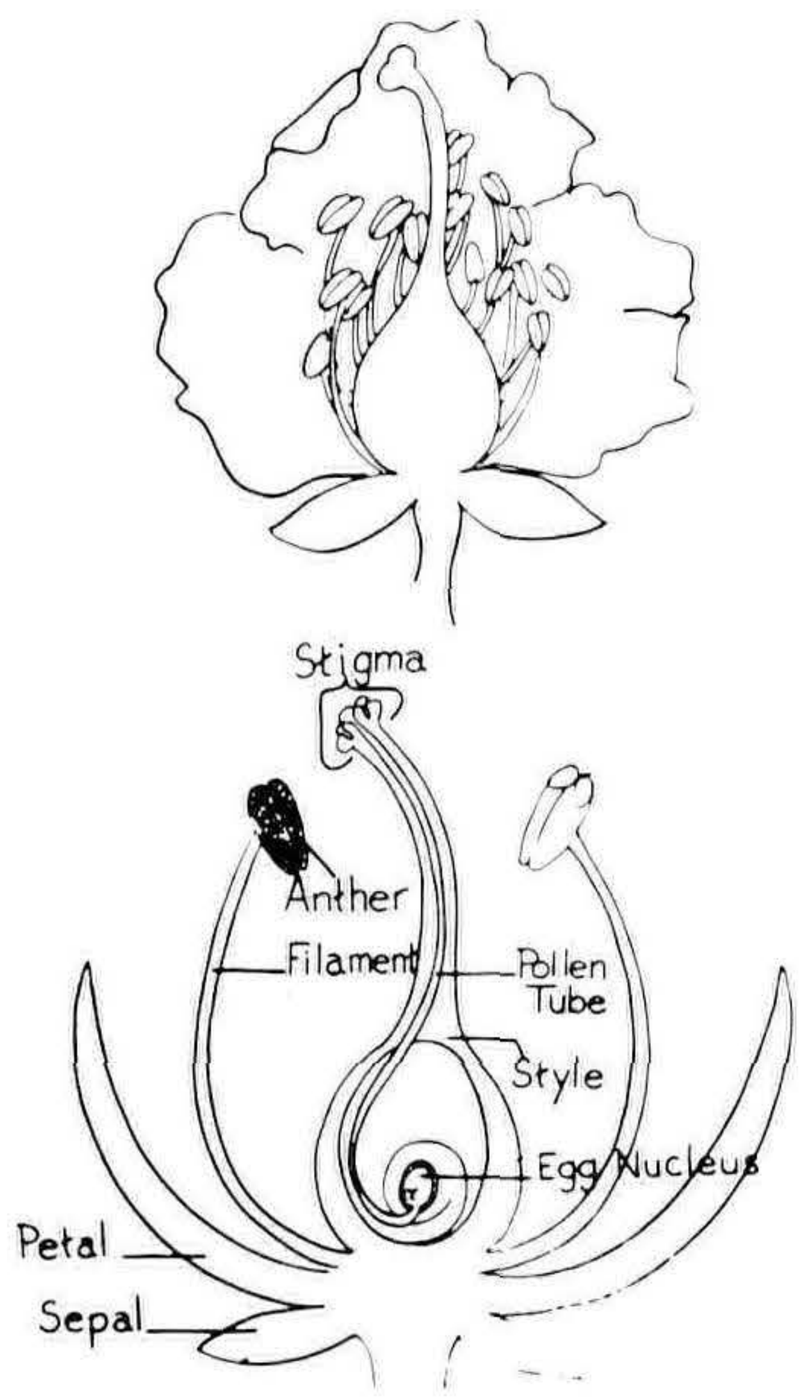

Figure 3. Reproductive parts. Ovary cross-section. Drawing by Leslie Eller, Mercyhurst College, Erie, Pennsylvania.

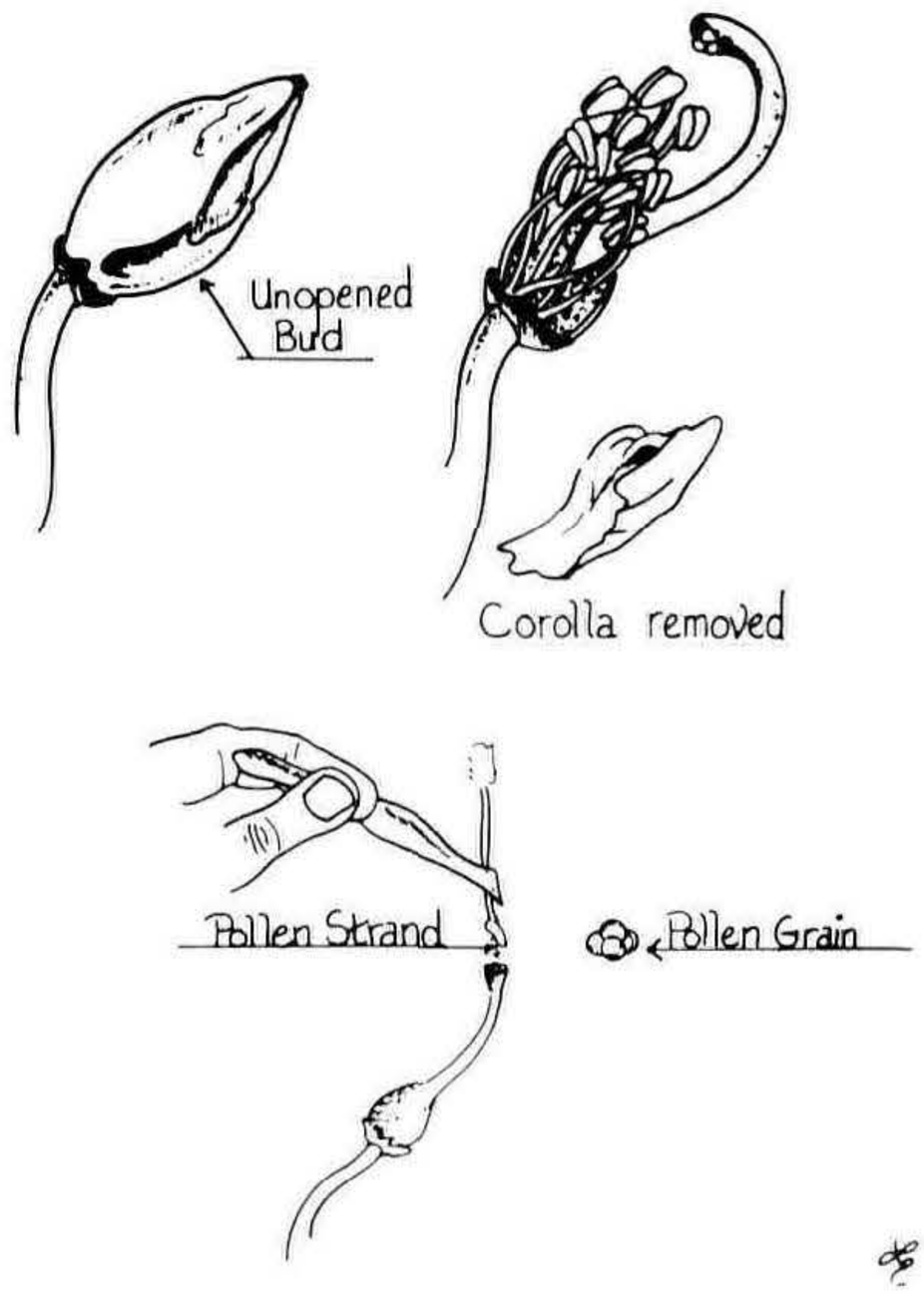

Figure 4. Pollination of pistil; stamens removed. Drawing by Leslie Eller, Mercyhurst College, Erie, Pennsylvania.

The capsules should be harvested while green and then allowed to dry. Seeds are very small and must be planted on top of the planting mixture. They must, of course, be kept moist. We usually have 35 to 50 percent germination. We use a planting board, which we make from fiberglass. There are 280 pins in the board that mark the flat and make it easy to insert the seedlings. To help in handling the tiny plants we use a large pencil painted with nail polish on the end so that the peat moss will not stick. We have been transferring seedlings to beds in the lathhouse in the spring. However, we plan to put everything in pots from now on. We intend to eliminate all field growing.

We have more trouble growing in the beds than we do in pots. We have trouble with bark splitting, especially on the one year plants. It is due to the heavy mulch that we use and the difference in the temperatures in the mulch and the air, which causes this cracking on the stem. In the cans we get very few cracks.

The plants will be in 4-liter containers in two years. We have 55 greenhouses where seedlings are kept. After containerizing they are grown in full sun until fall when they are moved into quonset houses and covered during the winter. Sales usually start in April before it is necessary to move plants back to the field.

This is a summary of the work we are doing with rhododendrons and azaleas. We are constantly changing and at-

tempting to improve our techniques. In closing, I would like again to emphasize the importance of keeping records. It is only on the basis of written information that a logical procedure can be developed.

PROPAGATION IN UNHEATED HOUSES

PETER VAN DER GIESSEN
Cottage Hill Nursery
Irvington, Alabama 36544

Until a few years ago, we though it was necessary to heat every house throughout the cold season. Each house was equipped with a butane-burning Modine heater set at 15.5°C (60°F). Our heating bill during the period of October through March was over $6000 for heating seven houses, a typical expense for our area. With the spiraling cost of operation and equipment, we are always searching for ways to cut costs.

During the fuel shortage of 1976 we decided we must find a method that would produce a crop without requiring so much fuel. Since then we have experimented with houses closed at each end, with houses open at each end, with different soil mixes and with other variations in technique. Although we are not certain exactly why, I can tell you about the methods that have worked for Cottage Hill and perhaps you can adapt these methods to your own operation.

Over the last few years we have developed a heating method for our propagation that has saved us an increasing amount each winter. While this method does not eliminate heat entirely, it cuts our winter gas expense to a fraction of our original cost.

Success in propagation depends on a few basic rules. Cuttings must be taken from disease-free stock. Cleanliness throughout the operation is essential. And certainly we must keep accurate records for both information and comparison with future crops.

At Cottage Hill we take cuttings from young, healthy and vigorous container grown plants. The young plants yield a cutting that will root within a shorter period than a cutting taken from old overgrown stock. Secondly, a continuous spray program keeps the stock disease-free. And finally, our own records are constantly used as a guideline for improving previous methods.

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In the past our cuttings were made during the early part of

the summer and were often kept in the propagating houses until the following spring. Today we take cuttings the year round, which allows us to produce a crop every six months.

All our propagation is done in Quonset-type houses covered with single layer 6 mil poly and 50% Saran shadecloth. The houses are 100 feet by 32 feet. We stick cutting directly in either 2¼ or 3¼ inch pot containers. Most of the Glenn Dale and Kurume azaleas are stuck in 2¼ inch pots, as are *Ilex crenata* and most other upright small-leaved plants. *Ilex cornuta*, *Photinia*, *Camellia* and other broad-leaved plants are grown in 3¼ inch pots. Empty pots are set in flats placed on a wagon and filled with soil. The filled flats are then put in the greenhouse on either black poly or clam shells. After pots are placed, a herbicide, either Ronstar or Lasso[1], is broadcast at the rate of 1½ pounds per 2000 square feet. Misting is done prior to sticking the cuttings. Each house is equipped with a timer set at 15 seconds per ½ hour. We stick the cuttings when the soil has reached the right moisture level. We use the same soil mix for all our plants (azaleas, conifers and broad-leaved evergreens). The medium consists of 4:3:1 pine bark, shavings and sand, modified with Scott's Pro-Gro 24-9-9 plus minor elements, iron sulphate and uramite. We add 5 pounds dolomite lime and 4 pounds clacium carbonate per cubic yard. The physical properties of this medium gives us the aeration and drainage required to grow a quality plant within a shorter period. At Cottage Hill, we use the same mix throughout the growing cycle. The pH at potting time is around 6.8 and usually levels off between 5.8 and 6.2.

Cuttings taken in the field are of young wood about 3 inches long. In most instances we do not strip the bottom leaves or use a rooting hormone. As a disease deterrant we soak the cuttings in a solution of Polyram[2] before sticking. We soak the entire cutting for 30 minutes, then stick immediately.

Our first experiment to conserve heat while propagating was on a house of azalea cuttings ('Copperman', a Glenn Dale hybrid; *R. indicum*, (Syn.: *R. macracanthum*) 'Red Ruffles'; 'Gumpo'; and four other cultivars of *R. indicum*) taken on October 10. By November 20 a good rooting action could be observed on nearly all cultivars. The lowest temperature recorded during that period was in the upper 30's F. On December 15 the plants were given a liquid feeding of 20-20-20 water soluble fertilizer at 200 ppm. Later, on January 4, a dry feeding of 25-10-10 was applied at the rate of 1½ pounds per 100 square feet. On

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[1] Scotts ProGrow Ornamental Herbicide 1 (Ronstar 4%), oxadiazon, O.M. Scott Co.; Lasso, alachlor, Monsanto.

[2] Polyram-Comb; metiram, Niagra Chemical Company

January 8 an open flame heater was installed. A 20 gallon container of water was placed on top to create a high humidity in the house, which raised the temperature a few degrees. At this time we applied the fungicide Daconil[3] as a precautionary measure and repeated this every two to three weeks. Between January 8 and 20 the lowest outside temperature recorded was −7°C (19°F) and, although the plants showed active growth, no damage was recorded. The first week of February the herbicide Ronstar was applied at 1½ pounds per 2000 square feet. This resulted in a slight tip burn, probably caused by the excessive moisture on the plants at the time of application. In the long run this was beneficial, since the plants showed many breaks several weeks later. However, I would hesitate to recommend this method of pinching. By April 15 the plants were ready for transplanting. These transplants produced salable plants by the following fall and spring. We considered this experiment successful enough that we have gradually converted our other houses to this method.

One house stuck with *Ilex* species in August 1, 1978, went through the winter without any damage, although it was one of the worst winters in our area. Out of the 36,000 cuttings stuck, 100 per cent were transplanted the following spring.

On October 1, 1978, 26,000 *Ilex vomitoria,* 16,000 *Ilex vomitoria* 'Pendula' and 22,000 *Ilex crenata* 'Helleri' were stuck. Again, rooting was almost 100 percent. *Ilex vomitoria* 'Pendula' did show some losses.

The final and most crucial test was a house of camellias. On November 7, 1978, 40,000 cuttings of 25 *Camellia japonica* and *Camellia sasanqua* cultivars were taken and placed in a house without heat. We considered the results to be phenomenal. Over 90 percent of the cuttings came through the winter and developed into suitable liners even though we experienced severe losses in our established container plants. We feel our success is related to the almost 100 percent humidity. The air is heavy with moisture. We have found that soil may even freeze in containers at the perimeter of the houses, yet we have no root or top damage.

What was gained by taking these chances? Our heating bill for that year for 13 houses, plus an office, was $236, a saving of well over $6,000 in spite of rising fuel prices.

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[3] Daconil or Bravo, chlorothalonil, Diamond Shamrock

COMMERCIAL MICROPROPAGATION OF RHODODENDRONS

RANDALL E. STRODE, PATRICIA A. TRAVERS and
RAYMOND P. OGLESBY

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Hollywood, Florida 33023

Abstract. Young shoot tips from rhododendron #704-792-1450 were excised from the mother plant two weeks after a flush of growth was initiated. This tissue proved quite productive in a modified Murashige and Skoog (MS) salt solution with added organic constituents and 5 mg/l of N^6-(Δ^2-isoentenyl)-adenine (2iP) and 1 mg/l indole-3-acetic acid (IAA). Plants rooted well and were transferred to soil with 90 percent survival rate.

The tissue culture industry in Florida is growing rapidly. Four years ago the laboratory at Oglesby Nursery was the only one in the state: now there are 21. Oglesby Nursery is also one of the pioneers in the propagation of hardwood species.

Plant tissue culture is a new adventure when it is used for propagating hardwood plants, which seem to be more difficult than most of the plants used previously. During the past four years we have been propagating primarily foliage plants. Producing hardwood plants will provide a new opportunity for tissue culture laboratories. We have had good success with rhododendron and have been able to develop our technique because of the excellent support of growers and other individuals not only in Florida but throughout the country. Clonal propagation using tissue culture as the tool for propagation of new superior rhododendron cultivars may save the rhododendron farmer 5 to 7 years in developing sufficient stock for large volume sales. This method also is an answer for propagating clones that are difficult to root by conventional methods.

The purpose of this work was: (1) to adapt rhododendron #704-692-1450 to tissue culture techniques; (2) to provide Rhododendron Farm with large numbers of these plants; (3) and to determine if this tissue-cultured cultivar will remain consistently true-to-type.

This rhododendron is a superior deep crimson red that has been grown successfully on Cape Cod. It is a selection made by Ted Richardson, Rhododendron Farm, Mountain Home, S.C. and is expected to receive an Hl hardiness rating from the American Rhododendron Society.

MATERIALS AND METHODS

Dr. Wilbur Anderson, N.W. Washington Research & Extension Unit, Mt. Vernon, Washington, has developed a workable general system for rhododendron tissue culture (1,2), and our purpose was to develop a workable system for this particular

rhododendron. We found that it was necessary to alter the hormone concentrations in the Anderson medium for this cultivar. The basic medium in which we grow all our tissue culture plants is a standard salt mix of macro- and micro- nutrients. This is no different from what might be used for any plants but quantities must be precise. Our most successful rhododendron mixture is somewhat lower in ammonium and potassium salts than the usual solutions. The Anderson medium and two hormone variations were tried: 25 mg/l 2iP with 5 mg/l IAA, 15 mg/l 2iP with 4 mg/l IAA (Anderson) and 5 mg/l 2iP with 1 mg/l IAA.

The rhododendron 704-692-1450 was tip-trimmed to stimulate lateral breaks and placed in a dry, air conditioned room with 16-8 hours light-dark cycles. By removing the plants from the humid Florida climate (which encourages development of fungal and bacterial disease) we were able to obtain clean tips suitable for culture. After a flush of growth, the tips were cut with a pen knife, placed in a mason jar with a screen lid and put under running water for 15 minutes. They were cut to a size of 3 mm × 5 mm by removing leaf and stem tissue, and agitated for 10 minutes in a 10 percent Clorox solution. The shoot tips were then cut to a 1 mm × 2 mm size, with a scalpel and forceps using 30× dissecting microscope under a laminar flow transfer hood. This is about the smallest size we can handle easily. The small size is more likely to be disease-free since we take the youngest portion of the tip and discard older portions each time the tissue is cut. The tiny shoot tips were then rinsed for 10 seconds in 10 percent Clorox, rinsed in sterile water and placed in the various stage I and II media (Table 1).

The media were prepared in 1 to 5 liter portions. The pH was adjusted to 5.7 with drops of 1 m solution of NaOH and HCl. The media for stage I and II were dispensed in 25 × 150 mm tubes (Bellco Co., Vineland, N. J.), 10 ml per tube, by means of a funnel, rubber tube, clamp and a plastic tube (40 cm) with holes of the appropriate size to fill 4 tubes at the same time. The tubes were closed with Kaput closures (Bellco Co., Vineland, N. J.). The tubes with medium were placed in stainless steel racks of 36 and autoclaved at 250°F for 15 minutes at 15 pounds of pressure.

The cultures were placed in a culture room at 27°C (81°F) and given 100 ft-candles of light on a 16-8 hour light-dark cycle. At 6-week intervals the plants were moved to fresh medium.

The stage III medium was prepared in 5-liter batches in a large stainless steel stock pot. It was then transferred to two 4,000 ml Kimax bottles which have an outlet at the bottom

Table 1. Composition and concentration comparisons between the Murashige-Skoog (MS) and revised rhododendron formulas for Stages I and II.

Inorganic salts (mg/l)	Murashige — Skoog	Rhododendron (Revised)	Rhododendron (Anderson)	Rhododendron (Revised)
NH_4NO_3	1650	400	400	400
KNO_3	1900	480	480	480
$MgSO_4.7H_2O$	370	370	370	370
$CaCl_2.2H_2O$	440	440	440	440
KH_2PO_4	170	—	—	—
$NaH_2PO_4.H_2O$	170	380	380	380
$FeSO_4.7H_2O$	27.84	55.7	55.7	55.7
Na_2EDTA	37.24	74.5	74.5	74.5
$MnSO_4H_2O$	16.9	16.9	16.9	
$ZnSO_4.7H_2O$	8.6	8.6	8.6	8.6
H_3BO_3	6.2	6.2	6.2	6.2
KI	0.83	0.83	0.83	0.83
$CoCl_2.6H_2O$	0.025	0.025	0.025	0.025
$CuSO_4.5H_2O$	0.025	0.025	0.025	0.025
$NaMoO_4.2H_2O$	0.25	0.25	0.25	0.25
Organic materials (mg/l)				
Sucrose		30,000	30,000	30,000
Bactoagar		10,000	10,000	10,000
i-Inositol		100	100	100
adenine sulfate		80	80	80
N^6-(Δ^2-isopentenyl)-adenine (2iP)		25	15	5
Indole-3-acetic acid (IAA)		5	4	1
Thiamine HCl		0.4	0.4	0.4

(#14605). Aluminum foil was placed over the opening at the top and 1 foot of amber tubing was attached to the bottom. A pinch clamp was placed at the dispensing end of the tube. Aluminum trays (EKCO Products, Inc. #705-30) were placed in a mylar bag and autoclaved. Both the medium and trays were autoclaved for 15 minutes at 250°F, 15 pounds pressure.

Clear polystyrene lids (EKCO Products, Inc.#9105-10) for the trays were soaked for 30 minutes in a bucket with a 10 percent Clorox solution. They were then rinsed with hot sterile water. This procedure was done under a laminar flow hood. The medium was then dispensed into the sterile trays under a laminar flow hood and covered with the sterile lids. The third stage container, now complete, was placed on an enclosed cart to cool.

The stage III area in the culture room was provided with 1000 ft-candles of light on a 16-8 hour light-dark cycle at 28°C (82°F).

RESULTS AND DISCUSSION

Of 30 initial explants cut and put in culture, 21 developed into clean, healthy cultures. The remaining 9 turned brown,

died or showed signs of contamination. All 21 cultures responded reasonably well regardless of the test medium. However, at the two highest concentrations no discernible plants developed. The higher concentrations produced a mass of green tissue resembling callus; but when the green clusters were placed on the medium with lower concentrations of hormones, tiny plants emerged within 3 weeks.

After 4 subcultures, each at 6 week intervals, the medium that proved best for #704-692-1450 contained 5 mg/l 2iP and 1 mg/l IAA. Subsequent culturings gave 22.9 plants per culture (tube) every 6 weeks. The tubes contained discernible plants in clusters with elongated stems. The tops were removed for stage III and the base, with multi-stems, was placed in a fresh stage II medium.

The tops, after being removed from the cluster, were rooted in the aluminum tray in stage III medium. Within 5 weeks 90 percent rooting was achieved and the plants were moved to the glasshouse to be planted in soil and acclimated for the outside environment.

We must now experiment with methods of acclimation to the outside as these plants are very succulent with a thin cutin layer and less than the usual amount of pigments to help protect them. We are presently using a humidity tent during the first few days of this period. The plants have all the desirable characteristics of any high quality plant. They are vigorous, healthy and may also have residual effects of high level hormones, which may give more branching. Sanitation is extremely important at this stage.

We must also watch carefully for possible aberrations of both leaves and flowers although, so far, reports from Dr. Anderson have been favorable. He has followed several clones through the entire growth and bloom cycle and has found few changes from the parent plants.

Our purpose was to develop a technique for providing this rhododendron in commercial quantities in a relatively short period of time. We feel confident that this is now possible on a commercial basis.

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FIELD PROPAGATION TECHNIQUES FOR CONIFEROUS EVERGREENS

BILL LAWSON

Bush Ranch, Inc.
Thomasville, Georgia

At Bush Ranch we produce about 5 million bare-root coniferous evergreen liners per year. We have several unique practices in our production system. I will discuss three of them this morning but first I will explain how we prepare our field beds for propagation.

Everything is done outside in open beds, each holding approximately 100,000 liners. We start preparation by tilling the soil. We then take a soil sample, make the necessary adjustments with fertilizer and lime, apply a nematacide and a prophylactic dose of fungicide and, finally, fumigate the soil by injecting Brozone.[1] This is a form of methyl bromide, which we use because it is effective at low temperatures, and we do most of our fumigating during the cold season.

After soil preparation is completed, we install galvanized pipe mist lines. Eight 48-inch beds are irrigated by a single line, 4 beds on each side. Each of these 8-bed sections has a single time clock that controls both the mist and irrigation systems so that it is possible to irrigate, mist, or both at the same time.

As stated earlier, we follow three unusual practices that I believe will be of interest to you. The first of these is our practice of sticking these coniferous evergreen liners in the summer, in contrast to the usual recommendations. One reason for doing this is to help balance our labor requirements throughout the year, since most of our harvesting and shipping is done during fall and winter. We are able to achieve reasonable success by rooting at this season. However, I do not feel I can recommend widespread use of this practice. Watering is extremely critical; a small error can result in a tremendous loss. In most cases there is no real advantage to summer sticking; however, it can be done, and I encourage you to experiment with this idea.

Our second unique practice is sticking cuttings right in the field. Nothing special has been done to the soil except for the fumigation and fungicide treatments. As you well realize there

[1] Brozone: Dow Chemical Company

4. Pierik, R.L.M. and H.H.M. Steegmans. 1975. Analysis of adventitious root formation in isolated stem explants of rhododendron. *Sci. Hort.* 3:1-20.

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Thomasville, Georgia

At Bush Ranch we produce about 5 million bare-root coniferous evergreen liners per year. We have several unique practices in our production system. I will discuss three of them this morning but first I will explain how we prepare our field beds for propagation.

Everything is done outside in open beds, each holding approximately 100,000 liners. We start preparation by tilling the soil. We then take a soil sample, make the necessary adjustments with fertilizer and lime, apply a nematacide and a prophylactic dose of fungicide and, finally, fumigate the soil by injecting Brozone.[1] This is a form of methyl bromide, which we use because it is effective at low temperatures, and we do most of our fumigating during the cold season.

After soil preparation is completed, we install galvanized pipe mist lines. Eight 48-inch beds are irrigated by a single line, 4 beds on each side. Each of these 8-bed sections has a single time clock that controls both the mist and irrigation systems so that it is possible to irrigate, mist, or both at the same time.

As stated earlier, we follow three unusual practices that I believe will be of interest to you. The first of these is our practice of sticking these coniferous evergreen liners in the summer, in contrast to the usual recommendations. One reason for doing this is to help balance our labor requirements throughout the year, since most of our harvesting and shipping is done during fall and winter. We are able to achieve reasonable success by rooting at this season. However, I do not feel I can recommend widespread use of this practice. Watering is extremely critical; a small error can result in a tremendous loss. In most cases there is no real advantage to summer sticking; however, it can be done, and I encourage you to experiment with this idea.

Our second unique practice is sticking cuttings right in the field. Nothing special has been done to the soil except for the fumigation and fungicide treatments. As you well realize there

[1] Brozone: Dow Chemical Company

are still pathogens present and, unless you as a propagator can learn to manage them, you will find direct sticking in the soil is a disadvantage.

We maintain only a small number of stock plants as we prefer to cut from young growth. We have found it works well to take cuttings from the liners that will be dug the coming fall and winter. The plants we do have in our stock block are also young and are replaced frequently.

I do recommend the third practice we follow that is different from usual methods. We do not strip our cuttings. If we had to strip our wood, it would reduce our production by 2 million plants a year. This is our main reason for not stripping. The second reason is that we did not read the book; we started by simply taking the cuttings and sticking them in the ground. They rooted quite well. We accidentally found that this method had other advantages besides speed. Our biggest propagation problem is basal rot at the bottom of the stem. The primary reason for this is inserting the cuttings too deep. We want to keep the cuttings as shallow as possible, near the surface of the soil where there is more oxygen. We try to stress the importance of shallow planting to our employees. However, if we are propagating woody material with a bare stem or if we strip the evergreens, we find the tendency is to put them 2 or 3 inches deep. Leaving these lower branches helps control this depth problem.

Still another advantage is that soil fills in around these lower branches and helps support the cuttings once they are inserted. This stabilizes the cutting until it roots.

The fourth reason we have for not stripping cuttings is that this reduces the legginess of the plant since the liners have branchlets down to the soil line at the time of digging. By that time the cutting will have shed most of the branches below the soil line so the plant has done the stripping for us.

We find no advantages to stripping coniferous evergreen cuttings. We propagate a great many *Thuja*, and I might comment on our manner of placing these cuttings in the beds. There seems to be an advantage in orienting the fans of branchlets in a north-south position. We have no definite explanation as to why this practice is beneficial but feel it may be because they are better exposed to east-west sun. It may also be because there is better aeration when we align the cuttings so that they do not touch.

Harvesting techniques are important. We have 2 machines that dig under the beds. One of these oscillates, digging somewhat deeper than the standard undercut, which makes it better for larger material. Most of our plants, however, are harvested by running the standard machine under the beds several times.

We are then able to lift the cuttings easily and retain most of the root system.

We try to retain as many roots as possible, but it is just as important to see that these roots never dry out. We believe this to be the key to success. We carry wet, not just moist, burlap to the field and use it to cover cuttings as soon as they are dug. They are kept wet until they are returned to the packing shed. There the liners are graded, tied in bundles of 26, packed in moist sphagnum, wrapped in plastic, and put in wire-bound boxes for shipment. We then place them in a cold storage room until shipped. We think it is beneficial to hold the liners in storage for about a week before shipping.

Workers sit directly on the ground to stick cuttings, working down first on side of the bed and then the other. We have designed a board, which serves as a dibble and can be used to open one row and close the previous one at the same time.

We pay on a piece rate basis, and any one of our employees can cut and stick 1500 cuttings an hour. We pay for a plant when it is actually in the soil. These workers are able to make much more than minimum wage. However, it takes 4 or 5 years for an individual to develop this skill. We have probably screened 100 planters to find 8 who can produce satisfactory liners at this speed.

CHARLIE PARKERSON: Do you use a rooting hormone?

BILL LAWSON: We have and we find an increase in rooting of about 20 percent. However, the worker in the next bed was able to stick twice as many cuttings in the same length of time. From an economic standpoint it is better for us to increase the number of cuttings stuck than to use a hormone, even though we do not get quite as good percentage rooting on some items.

VIRGINIA LASSITER: What kind of spinner do you use in the field?

BILL LAWSON: We use normal Rainbird spinners for irrigation. For misting we use a brass oil burner type nozzle. We make our own screens for these. It readily disassembles and cleans. It has a low rate, and our cycle is very coarse in contrast to that used in most propagation units. In July our cycle would be approximately 5 minutes on, 10 minutes off.

MODULAR AIR-LAYERING AND CHEMICAL TREATMENTS IMPROVE ROOTING OF LOBLOLLY PINE

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Abstract. A new, rapid, standardized air-layering system, in combination with several chemical formulations applied to the branch girdles, gave over 60 percent rooting and survival of 8-year-old loblolly pine.

INTRODUCTION

With present methods, cuttings of most forest tree species are difficult to root. Finding the right combination of rooting technique and root-promoting chemicals is essential for improving rooting success. This paper describes the combination of an improved air-layering method with several chemical formulations not previously tested on girdles for rooting loblolly pine air layers.

Rooting techniques. With conventional rooting techniques for cuttings, decreased photosynthesis and lack of food reserves cause pine foliage to age prematurely and turn yellow, and the cuttings to die. Rooting can be improved in a growth chamber with enriched CO_2 and long days of high light intensity (4), but this method is expensive and unsuitable for operational production.

Since 1955 it has been known that girdling to increase food reserves in pine shoots can improve rooting success (13). A more recent procedure is to girdle the branch 1 to 2 months before taking the cutting, apply a rooting powder paste, and wrap with saran and foil (5). Photosynthates and growth regulators, not translocated out of the shoot via the severed phloem, accumulate above the girdle, inducing callusing and rooting. In pines (5,9,10) and hardwoods (6,7,8), this method has greatly improved rooting.

However, girdled cuttings rooted in the greenhouse are frequently difficult to establish. Roots are usually sparse and some may be broken when removed from the propagating bed. Also, this branch girdling method requires expensive greenhouse mist-propagation facilities.

Mergen (13) was the first to use conventional air-layering for rooting pines. But sealing polyethylene against the stem is difficult and the moss may dry out, or it may get too wet from rain running down the stem. A saturated medium causes shoots to decay, and excessive drying kills the roots. A better sealing film and a standardized amount of moisture-holding rooting

medium were needed.

In preliminary experiments with slash pine (*Pinus elliottii* Engelm. var. *elliottii*), I compared several rooting media and wrapping materials for air-layering. Kys-Kubes[1] (Keyes Fibre Company, New Iberia, Louisiana) were selected as the rooting medium because they gave more rooting and less mortality, and they were easier to apply than cellulose blocks (BR-8, E.C. Geiger, Harleysville, Pennsylvania), pressed peat (Jiffy-7, E.C. Geiger, Harleysville, Pennsylvania), sphagnum moss, or vermiculite-perlite. The BR-8 held too much water and, except Kys-Kubes, the others dried out too rapidly. Kys-Kubes are pressed growing-blocks of peat, vermiculite, and cellulose fibers. Parafilm (Curtin Matheson Scientific, P.O. Box 53387, New Orleans, Louisiana), a highly flexible, self-sealing, waterproof laboratory film, sealed better than saran or polyethylene film.

Root-promoting chemicals. Chemicals that promote rooting include auxins, phenolic cofactors, and growth retardants for root initiation, sugars for root growth, and fungicides for inhibiting growth of microorganisms causing basal rot. A formulation from these classes of chemicals in a 1-1-10-10-1 ratio powder (IBA[2], PPZ, powdered sucrose, captan, and daminozide) improves rooting of ungirdled pine cuttings in a growth chamber (6). The formulation also helps rooting of girdled cuttings in the greenhouse when the powder is applied to the girdle (7). Later unpublished experiments indicate that a 1-1-20 (IBA-PPZ-sucrose) formulation is more effective than the 1-1-10-10-1 powder on the girdle (data available on request). Apparently captan and daminozide are not beneficial when applied to the girdle.

For the present study, I tested the hypothesis that adding PPZ and IBA would improve rooting over IBA alone applied to the girdle, that also adding sucrose would improve rooting over IBA-PPZ, and that one or more of 10 chemicals added individually to IBA-PPZ-sucrose powder would improve rooting even more.

MATERIALS AND METHODS

In early June 1979, five terminal branches in the lower crown of 8-year-old loblolly pines (*P. taeda* L.) growing in south Mississippi were tagged for girdling. Only vigorous branches well exposed to the sun were selected. The experi-

[1] Use of trade, firm, or corporation names is for the reader's information and convenience. Such use does not constitute official endorsement or approval by the U.S. Department of Agriculture to the exclusion of any other suitable product.

[2] See appendix for abbreviations and sources of chemicals.

mental design was completely randomized, with 24 treatments (rooting powders), four trees (replicates) for each treatment, and five girdled shoots on each tree — 480 air layers, 20 per treatment. Rooting powders were prepared by methods described in earlier studies (5,9). Each rooting powder was assigned to four trees at random. The 24 treatments comprised various combinations of IBA, IBA + PPZ, IBA + PPZ + SUC at two levels, and IBA + PPZ + SUC + one of 10 other chemicals (see appendix). The 10 chemicals used were tested at two levels, generally at 5 to 10 times the optimal concentration found when chrysanthemums (*Chrysanthemum morifolium* Ramat.) were used as a rapid bioassay (manuscript in preparation; data available on request).

For the modular air-layering method, I stripped away about 3 inches of needles about 10 inches below the terminal bud, removed a 1-inch ring of bark, coated the distal cut surface with an aqueous slurry of the appropriate powder on a camel hair brush, covered the treated girdle with a split, moistened Kys-Kube, and wrapped the Kys-Kube with Parafilm and then foil (Figures 1-6). Before being applied, Kys-Kubes were soaked overnight in water and then split on one side with pruning clippers, and the excess water was squeezed out. The Kys-Kubes were then opened like a book, placed over the treated girdle, closed, and sealed tightly against the stem with an 8-inch length of 4-inch-wide Parafilm. To reduce solar heating, I covered the Parafilm layer with a 5 × 9-inch strip of heavy duty aluminum foil. I applied the 480 air-layers in 2½ days, about 2 minutes per layer.

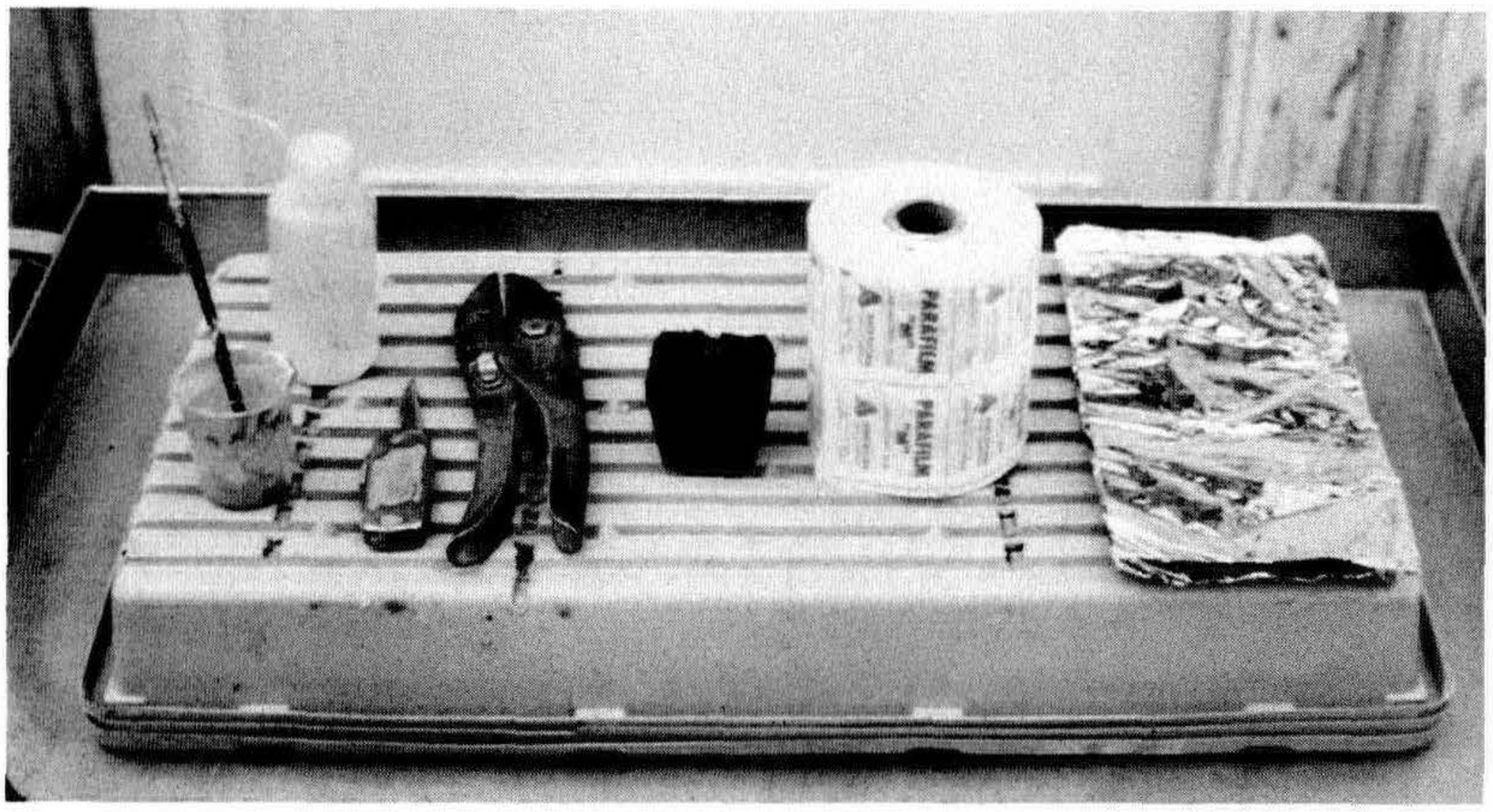

Figure 1. Materials needed in the field for modular air-layering. *Left to right:* rooting powder slurry with camel hair brush, water bottle for wetting slurry as it dries, pocket knife for making girdle, clippers for splitting Kys-Kube, moistened half-split Kys-Kube, Parafilm, and foil.

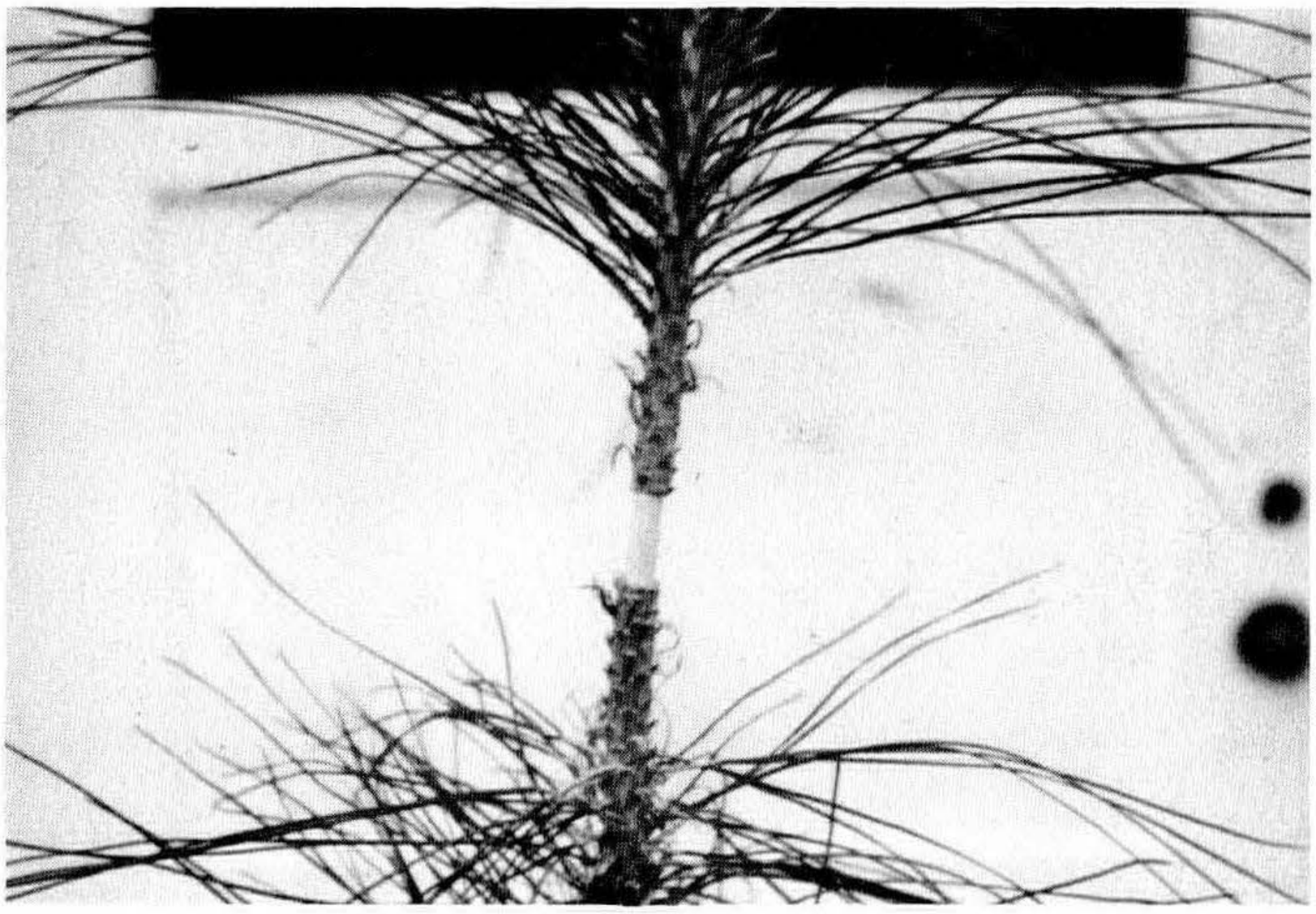

Figure 2. Girdled pine shoot.

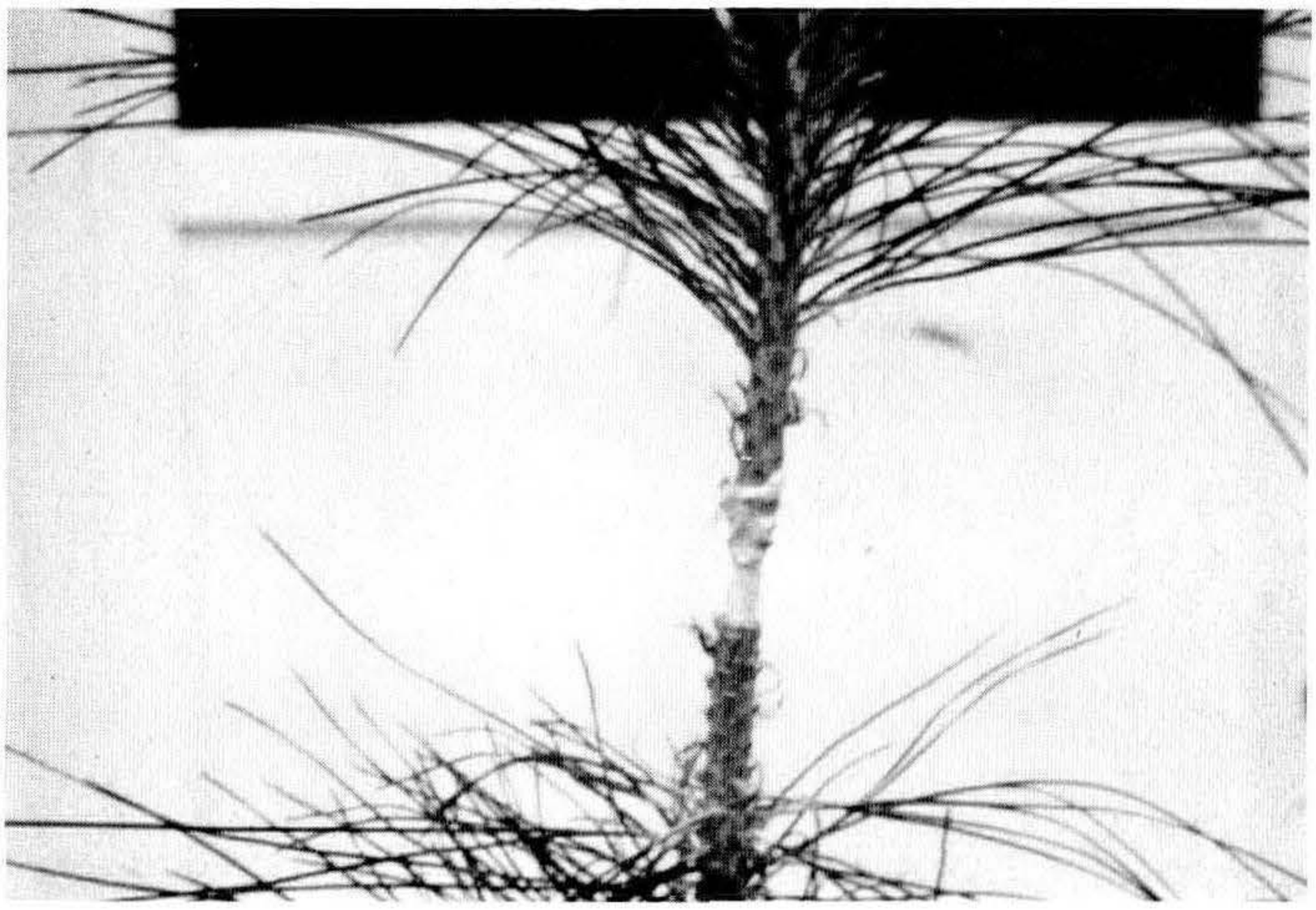

Figure 3. Rooting powder slurry applied to upper girdle.

After 2, 3, and 5 months, when roots appeared either under or penetrating the Parafilm, I severed the cutting just below the Kys-Kube. The foil was carefully removed, but the Parafilm was not disturbed where roots had penetrated it. Rooted cuttings were planted directly in an outside bed containing equal parts of peat, vermiculite, and perlite. Light sprinkling and shade, provided as a precaution to prevent excessive drying, were discontinued after 10 days, when roots had become established. Plants were given biweekly fertilization with 50 g soluble 20-20-20 fertilizer plus 1 g trace element concentrate dissolved in 20 l water.

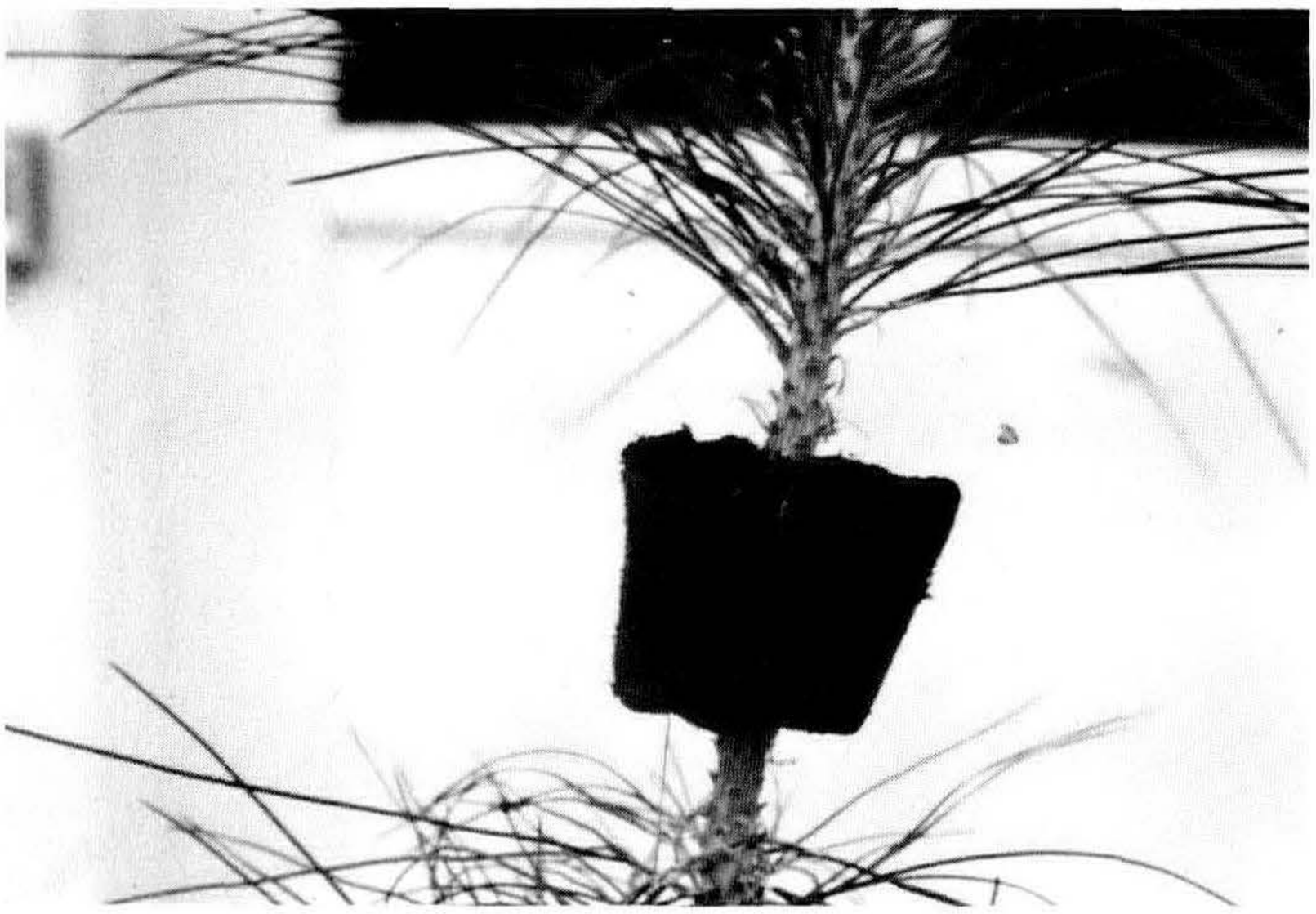

Figure 4. Half-split moistened Kys-Kube applied over treated girdle.

Figure 5. Kys-Kube wrapped tightly with Parafilm.

Two unusual events added unexpected variation to the experiment. Hurricane Frederic broke off 88 (18 percent) of the branches before they had rooted. Also, birds pecked holes in the foil and Parafilm on many of the girdles. This allowed rain to saturate the medium, killing 179 (37 percent) of the girdled branches. To be conservative, I eliminated only those branches affected by the hurricane from the analyses.

RESULTS AND DISCUSSION

Of 392 air-layered branches unaffected by the hurricane,

Figure 6. Final wrap of aluminum foil.

196 (50 percent) rooted and an additional 17 (4 percent) were still alive after 5 months. Despite extensive shoot death, over 70 percent rooting was obtained with 1-1-20 (IBA, PPZ, sucrose) plus either cortisol, pyrogallol, Stemtrol, or chlorogenic acid (Figure 7). Both PPZ and sucrose added to IBA appeared to in-

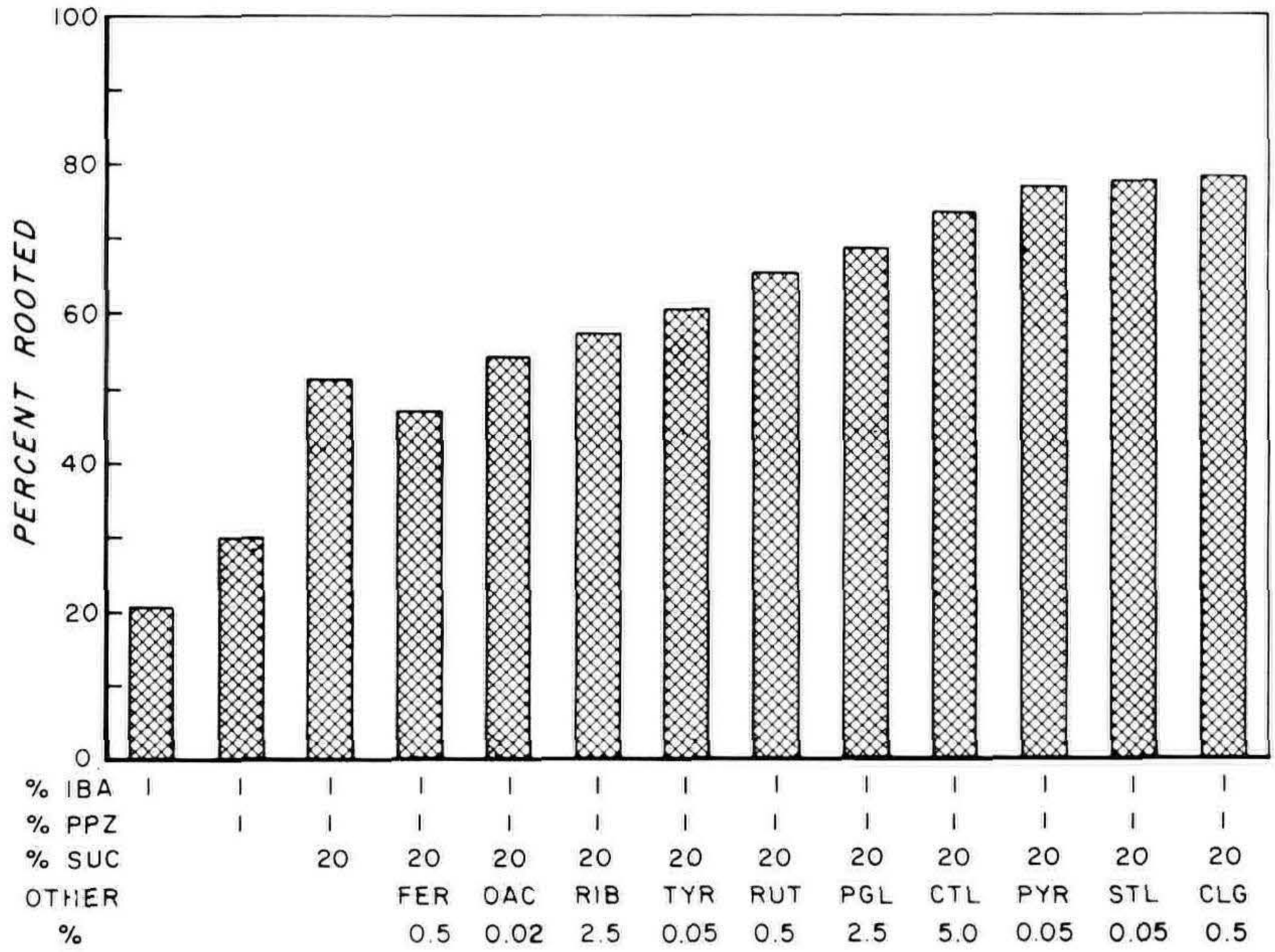

Figure 7. Rooting response by treatment. Girdled branches broken by wind omitted in calculation of rooting percentages.

crease rooting over IBA dose. Phloroglucinol, rutin, and tyrosine seemed to increase rooting over the 1:1:20 treatment also.

Most rooted air-layers had extensive root systems (Figure 8) and became established rapidly after planting, so misting and shading could be discontinued after 7 to 10 days. Overall survival (86 percent) in the nursery bed was much better than had previously been obtained with girdled cuttings from older pines. Cuttings that died were generally those that were brought to the nursery with small root systems. It appears important, therefore, to give ample time for an adequate root system to develop while the cutting is on the tree. Yet the cutting must be taken promptly when the root system is fully developed. otherwise the large root system soon dries out the Kys-Kube and roots die.

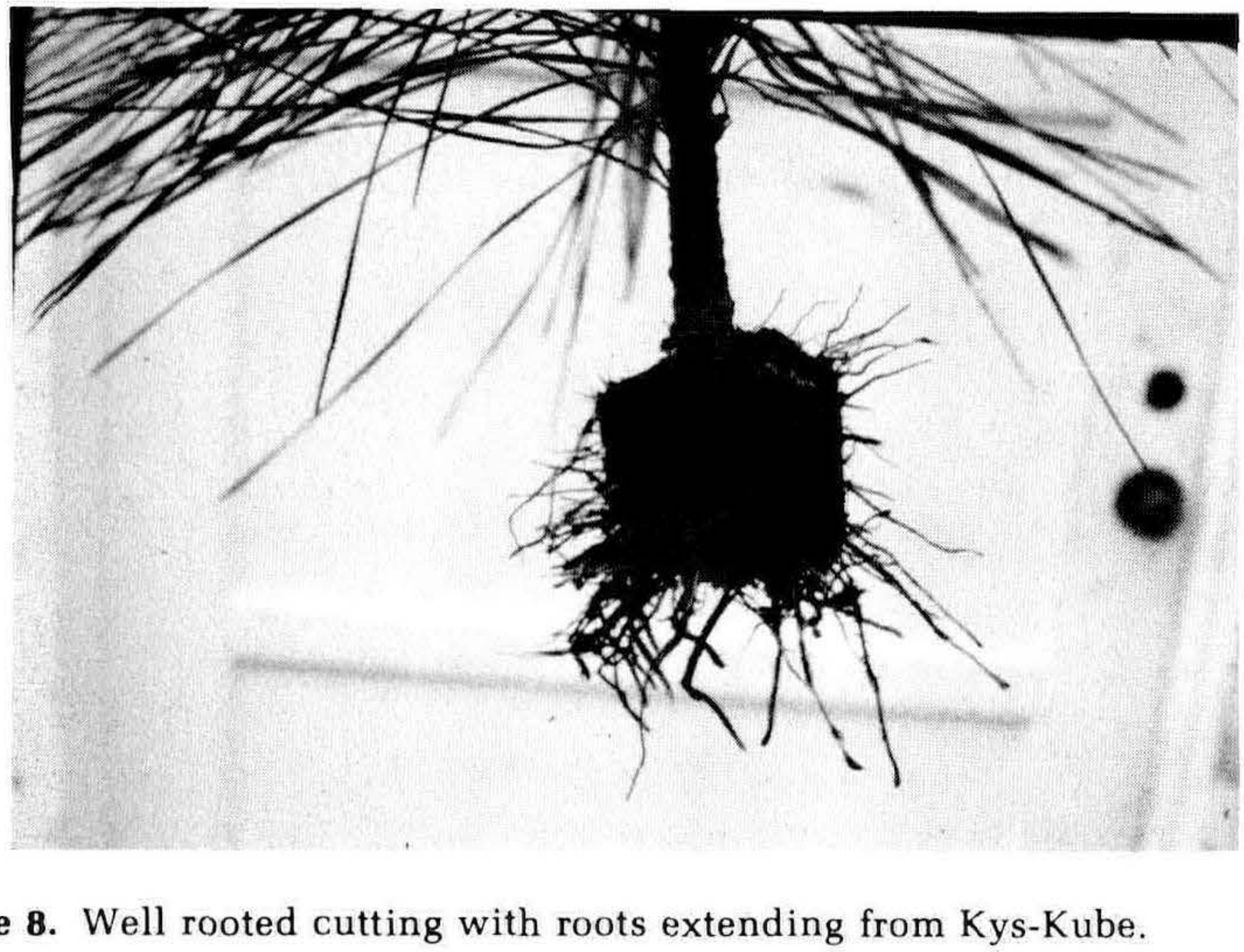

Figure 8. Well rooted cutting with roots extending from Kys-Kube.

This method of rooting pine is an improvement over the method I described in 1975 (5). The new method incorporates Mergen's (13) basic technique, chemical treatment improvements that have since been developed, and improved materials that control moisture levels.

Appendix. Abbreviations and names of chemicals mentioned in the text

Abbreviation	Chemical compound	Ref. No.
CLG	chlorogenic acid	15
CTL	cortisol (hydrocortisone)	12
FER	ferulic acid	15
IBA	indolebutyric acid	13
OAC	OAC 2582 (3-hydroxy-5-methyl-isoxazole)	14
PGL	phloroglucinol	16
PPZ[1]	1-phenyl-3-methyl-5-pyrazolone	4
PYR	pyrogallol	3
RIB	ribose	1
RUT	rutin	11
STL	Stemtrol (piproctanyl-bromide)	2
SUC	sucrose (10X confectioners sugar)	4
TYR	tyrosine	15

[1] Source: K & K Laboratories, Plainview, N.Y.

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TROPICAL FOLIAGE PLANTS FOR PROPAGATION

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The intent of this article is to provide an overview of the tropical foliage plant industry in Florida, indicate differences which exist between South Florida and Central Florida nurseries, mention some techniques of macro-propagation utilized for major groups of foliage plants and suggest plants which deserve more use in the industry.

UNIQUE ASPECTS

There are a few unique aspects of the foliage plant industry, particularly as they apply to the plant propagator. First there is very little documentation of propagation techniques for tropical foliage plants. One only has to review past Proceedings of International Plant Propagators' Society to discover the few papers which apply to tropical foliage plants. The same can be said for other journals such as the Journal of the American Society for Horticultural Science and HortScience. One of the most productive areas of the literature for information on certain groups of tropical foliage plants is within journals prepared by several plant societies. In most cases the commercial foliage plant propagator must conduct considerable research to determine the best techniques to propagate high quality plants most economically.

Little technology is available on tropical and semi-tropical seeds of ornamental plants. Propagators are particularly concerned with collection, storage and germination procedures best for tropical foliage plant seeds. Hopefully seed technology research can be encouraged where seed is collected and in locations where it is stored and germinated.

There is need for much taxonomic research to provide correct horticultural names for many foliage plants now in the trade. Of the 70 or so international registration authorities for

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There is need for much taxonomic research to provide correct horticultural names for many foliage plants now in the trade. Of the 70 or so international registration authorities for

major groups of horticultural plants the only foliage plant group which has an authority is *Begonia*. Unfortunately many technical names or horticultural names of plants now in industry literature are incorrect. A coalition of plantsmen and taxonomists is needed to provide technical and acceptable common names for many important tropical foliage plants.

Large quantities of vegetative propagation material and seeds are imported from the tropics. Vegetative propagules are then either rooted or, in the case of rooted cuttings, potted and finished in Florida. Propagators and growers should watch for plant material which may be suffering from physiological disorders induced by improper post-harvest handling of products from the tropics. Introduction of pests and disease-causing organisms which may not be well established in the United States is a perennial threat when using imported propagules.

Many foliage plants are chimeras, which are often expressed as variegated patterns in the foliage and stems. The proportion of variegated foliage plants is much higher than in ornamentals used for exterior landscaping. Some chimeras must be watched closely because the variegated patterns are not always stable. Propagators must constantly rogue from stock or imported propagules to maintain cultivars true-to-type.

Production schedules for many foliage plants, particularly the small sizes, are relatively short when compared with most landscape ornamentals. Schedules are prepared on a year-round basis because of the warm climate or artificially manipulated growing environment within a greenhouse that permits continuous plant growth. Propagators must carefully schedule space for propagation and production year-round to use nursery space efficiently.

PRODUCTION AREAS

Foliage plant production in Florida is concentrated primarily in two areas. The Central Florida production center is situated primarily within Orange, Lake and Seminole counties, and South Florida production extends from Palm Beach county through Dade county. The predominate plant species and sizes of plants vary considerably between the Central and South Florida centers. In South Florida, nurseries produce most of the foliage in 2-gallon containers and larger. The larger plants are frequently trees consisting of palms, figs, schefflera and a few others. In South Florida most foliage plants are either grown in full sun initially and later finished in shadehouses or, as is the case with most intermediate size material, plants are grown in polypropylene-covered shadehouses from beginning to finish.

Although there are some shadehouses in Central Florida,

most plant propagation and production is conducted in greenhouses covered with fiberglass or glass. Most plants produced in Central Florida are grown in pots up to 1-gallon capacity. Greenhouses provide growers with greater control of environmental factors, particularly water and temperature. Table 1 provides a breakdown of product mix in Central and South Florida and combined figures for statewide mix.

Table 1. Foliage plant product mix in Central and South Florida and statewide. 1975[x]

Product	Area		
	Central	South	Statewide
	----------	Percentage	----------
Philodendron scandens subsp. *oxycardium*	21	2	14
Dracaena spp.	6	20	11
Philodendron spp. (other)	7	5	6
Ficus spp.	2	12	6
Dieffenbachia spp.	6	3	5
Palms (other)	2	9	5
Brassaia actinophylla	2	8	5
Maranta spp.	5	1	3
Epipremnum (Scindapsus)	4	1	3
Totem pole plants	3	2	3
Ferns	2	4	3
Peperomia spp.	4	1	3
Sansevieria spp.	3	1	3
Syngonium spp.	4	1	2
Combinations	4	z	2
Hanging baskets	2	2	2
Aphelandra spp.	3	1	2
Aglaonema spp.	2	1	2
Chamaedorea elegans	2	2	2
Aralias	1	3	2
Hoya spp.	3	z	2
Terrarium plants	2	z	1
Codiaeum	1	2	1
Other	8	15	11

[z] Less than 0.5%

[x] Adapted from Smith, C.N. and J.R. Strain. 1976. Proceedings of Florida State Horticultural Society. 89:274-278.

IMPORTANT PLANT GROUPS

The foliage plant industry in central Florida began about 1913 with a grower who wanted to produce Boston fern for northern markets. By the late 1920's several ferneries were established in the Apopka-Zellwood area and were marketing small bare-rooted Boston fern plants throughout northeastern United States. Now Boston fern and its many cultivars are sold primarily as established potted plants and hanging baskets.

Since *Nephrolepis exaltata* cultivars are propagated by division of stock plants, propagators must watch stock plants and

cull variants not true to type because variants are rarely superior to existing cultivars. Cultivars now in the trade have occurred from sports in production.

Many other ferns which are propagated routinely by spore propagation deserve more emphasis in the trade. Unfortunately a number of spore-propagated ferns promoted by industry, such as *Adiantum* and *Pteris*, are soft plants not tolerant of most interior conditions where humidity is low. Fern genera, *Cyrtomium* and *Pellaea*, include several species which are well adapted to indoor conditions.

Early spore propagation procedures involved hanging spore bearing plants over beds of peat moss and allowing natural dissemination of spores to occur within greenhouses. As young sporophytes developed to the transplant stage they were removed from beds and transplanted to finishing pots. This procedure does not permit accurate scheduling of spore-grown plants in a given area. It is now recommended that spore-bearing fronds be collected when the sori reach the proper condition for collection and be held in envelopes for drying where spores are released. The spores can then be stored and sown on rigid production schedules.

In South Florida, *Sansevieria*, was one of the first foliage plants to be of major economic importance Throughout much of the 1930's *Sansevieria trifasciata* 'Laurentii' was grown in open field beds in the coral rock soils between Miami and Homestead, Florida. Most of the early plants produced were exported to Europe. *Sansevieria* is still grown in South Florida in the same manner as it was in the 1930's, but there is no exportation.

Variegated cultivars of *Sansevieria*, such as *S. trifasciata* 'Laurentii', *S. trifasciata* 'Golden Hahnii', *S. trifasciata* 'Bantel's Sensation' and *S. trifasciata* 'Futura', must be propagated by crown division rather than leaf cuttings to maintain desired patterns of variegation. Plants of these cultivars propagated from leaf cuttings will revert back to the species, *S. trifasciata* which has no variegation. Two of the newer cultivars of *Sansevieria* include *S. trifasciata* 'Futura' and *S. trifasciata* 'Moonshine'.

Sansevieria is also propagated to a limited extent in Central Florida. Typical production in this area occurs in either shadehouses, which are covered for cold protection with polypropylene film through the winter, or in conventional greenhouses. Most Central Florida production utilizes the species and cultivars of *Sansevieria* which can be propagated successfully by leaf cuttings.

It is interesting to note that the first foliage plant to be pat-

ented was *Sansevieria trifasciata* 'Hahnii', the birdnest sansevieria. This patent was issued in 1941, 11 years after the Townsend-Purnell Plant Patent Act was passed. Both *S. trifasciata* 'Hahnii' and 'Silver Hahnii' can be propagated by leaf cuttings true-to-type.

Another genus within *Agaveaceae* is *Dracaena*. This important family of foliage plants has yielded new cultivars which are spectacular. *Dracaenas* are relatively sensitive to fluoride toxicity which can be derived from the water supply, the propagation medium or the potting soils used for finishing plants. The most common source of fluoride is from soils containing superphosphates. Dracaenas are propagated from either semi-hard terminal cuttings or hardwood cane cuttings.

Madagascar dragon tree, *Dracaena marginata* has yielded two interesting cultivars, 'Tricolor' and 'Colorama' the last several years. Several *Dracaena,* particularly cultivars of *D. fragrans* are propagated from hardwood cuttings. These cultivars are usually somewhere between 1½ to 2½ inches in diameter and are obtained from tropical areas in lengths up to 6 feet and occasionally longer. Cane sections are stuck basal end down in the propagation medium, which is often placed in the finishing containers. Rooting occurs and usually one to three shoots emerge near the top of the cane giving it a tree-like effect. A few plants in the Lily family, *Liliaceae* are used as foliage plants. One of the more popular genera — *Asparagus* is propagated almost exclusively be seed production. *Asparagus setaceus* (Syn.: *A. plumosus)* and *A. sprengeri* are well adapted to use as foliage plants in bright light areas. Some growers are growing this plant in tapered cell trays, such as the Speedling® tray, which are direct-seeded. Another foliage plant in the lily family is false sea onion, occasionally called pregnant onion because bulblets are produced at the base of the plant.

The aroid family, *Araceae,* is the most important family in terms of numbers of foliage plants produced. Some of the more important genera include: *Philodendron, Dieffenbachia, Aglaonema* and *Caladium.* The most important single aroid is *Philodendron scandens* subsp. *oxycardium,* the heartleaf philodendron, which constitutes approximately 11% of all of the foliage plants grown in Florida (Table 1). There are many other desirable *Philodendron* species and hybrid philodendrons. Several hybrid *Philodendron* developed by the late Robert McColley include: 'Emerald Duke', 'Emerald King', 'Emerald Queen', 'King of Spades', 'Majesty', 'Painted Lady', 'Pincushion', 'Prince Dubonnet', 'Red Duchess', 'Red Emerald', 'Red Princess', 'Royal King' and 'Royal Queen'. *Philodendron* are propagated three ways. Single-eye or leaf-bud cuttings, which

have one leaf and a short section of stem including a single bud, are used primarily for the small-leaf vine types of *Philodendron* such as *P. scandens* subsp. *oxycardium* and *P. scandens* subsp *scandens*. Large-leaf vine types are propagated primarily from terminal cuttings, which include 2 or 3 fully expanded leaves and stems. They often have roots already developed on them. *Philodendron* that have a rosette habit of growth, such as *P. selloum*, are grown from seed.

Several newer *Dieffenbachia* of the amoena type include *Dieffenbachia* 'Tropic Snow' and *Dieffenbachia* 'Golden Beauty.' There are also a number of new dieffenbachias being introduced to the trade from breeding programs and plant selection programs of the *D. maculata* parentage. Most *Dieffenbachia* are propagated through stem tip cuttings, although cane sections with one or more nodes can be used if stock is limited or small plants are desired.

Aglaonema is another very important genus of aroids which somewhat resembles *Dieffenbachia* in habit of growth. Aglaonemas are very adaptable to indoor conditions and have very few pests. Aglaonemas are propagated primarily by terminal stem cuttings but may be grown from small stem sections as described for *Dieffenbachia*. Several cultivars worthy of propagation include 'Fransher', 'Pseudo-bracteatum', 'Silver King', 'Silver Queen' and 'Snow Queen'.

Devils ivy or pothos are very reliable indoors and are produced essentially the same way as heartleaf philodendron. Being variegated, both golden photos and marble queen pothos should be monitored for the desirable pattern of variegation. Shoots which have either too much green tissue or too much of the variegated pattern should be cut away and removed from stock areas. At the time vines are cut for leaf-bud cuttings, each leaf-bud cutting should reflect the desired pattern of variegation in the finishing plant. Cuttings with too much or too little green tissue should be discarded because plants developing from them normally have an undesirable balance of color.

Monstera deliciosa, called cutleaf philodendron in the trade, is propagated in Florida primarily by air-layering. *Monstera* can also be grown from seed.

Spathiphyllum, or peace lily, produces showy flowers reliably indoors under low light intensities. Several cultivars of *Spathiphyllum* are grown from seed. A few nurserymen are selecting and breeding *Spathiphyllum* for superior branching habit, leaf shape and flowers.

One can hardly discuss the aroids without mentioning *Caladium*. There are approximately 60 to 70 cultivars of *Caladium* now produced commercially in Florida, primarily on

muck soils near Sebring and Lake Placid. These plants are grown for their tubers in much the same way as potatoes are produced. Chips of whole tubers are cut and planted in spring. Plants continue to grow and develop new tubers through summer and fall. With the onset of cold weather tops die back and the tubers are harvested and held under controlled temperature and humidity until they are graded, packaged and shipped. Few plants surpass *Caladium* for foliage color indoors.

Another important family of foliage plants is *Araliaceae.* The most important single genus within the aralia family is *Brassaia. Brassaia actinophylla,* the umbrella tree is grown exclusively from seed. Much of the *Brassaia* is sown in germination beds and then transplanted when the seedlings reach the 2- to 3- leaf stage. Considerable success has been achieved by some growers by direct seeding into molded peat blocks. Direct seeding eliminates much of the transplant shock and root rot problems to which most of the aralia family is susceptible.

Schefflera arboricola was introduced to Florida in some quantity several years ago and was grown primarily from cuttings until seed sources were established. More recently the plant is being grown primarily from seed. Because of genetic variability in the seed a few selections have been made that may become significant cultivars some day. One Florida nurseryman is growing a self branching form of *Schefflera arboricola,* which has a mounded or globose form and fine textured leaf. The same nurseryman has also selected a type which has distinct ivy-like leaves with fused leaflets. Time will tell whether either of these selections becomes significant.

Tupidanthus calyptratus has been grown for several years on the West Coast. It strongly resembles schefflera except the leaves have more substance, greater mite resistance and more cold tolerance than *Brassaia actinophylla. Tupidanthus* is propagated from seed and to a limited extent through tissue culture.

False aralia, *Dizygotheca elegantissima* is a charming tree-like foliage plant which has a strong central leader without lateral branches. False aralia is propagated primarily from seed but a few forms with unique foliage have been selected and must be propagated by stem cutting procedures.

Aralias in the genus *Polyscias* are quite beautiful small interior trees. Unfortunately, there is considerable confusion in the nomenclature of *Polyscias.* Although there are approximately 25 types in cultivation, we have only a few reliable names in use. *Polyscias* 'Hoak' is one of the new variegated forms. *Polyscias fruticosa* 'Elegans' is an excellent choice for a small potted plant, especially attractive in a bonsai container.

All polyscias are conventionally propagated from either semi-hardwood or hardwood cuttings.

One of the early foliage plants to be produced primarily in South Florida was the genus *Ficus*. *Ficus elastica*, one of the early foliage plants produced in South Florida, with its long leaves has been replaced by several cultivars with broader, shorter leaves such as *Ficus elastica* 'Decora'. Since 'Decora' was introduced there have been other cultivars including: 'Robusta', 'Honduras', 'Rubra' (= *F. decora*), 'Asahi' and 'Bicolor'. Most of the large-leafed *Ficus*, such as *Ficus lyrata* and *Ficus elastica* cultivars, are propagated from air layers in South Florida.

When small plants are desired or propagation material is extremely scarce, *Ficus elastica* cultivars can be propagated from single node cuttings. These consist of a section of stem with a healthy bud and a leaf, which may be trimmed back ½ or ⅓ its length. Small plants propagated from leaf-bud cuttings have a unique shape because of a gradation from small to normal size leaves toward the top.

Ficus benjamina, the weeping fig is the most useful fig indoors where fine texture and graceful branching habit is desired. Most weeping figs are produced from semi-hardwood cuttings under mist.

The genus *Peperomia* is reported to have over 1000 species. Unfortunately, only about 50 of these have been reported in *Hortus Third*. Peperomia now comprise about 2% of the Florida product mix but with increased interest in small plants, and plants that are durable under low light levels, *Peperomia* should increase in popularity. Use of improved sanitation practices and better fungicides which control *Pythium* and *Phytophthora* root and stem rots well aid in production of *Peperomia*, which are normally propagated by terminal stem cuttings, leaf-bud cuttings or leaf cuttings.

Hoya, a member of the milkweed family, *Asclepiadaceae*, is a durable group of foliage plants which withstands considerable moisture stress and some chilling. Hoya are usually propagated with single-node stem cuttings but multiple node cuttings are occasionally used. Some of the more popular cultivars include: 'Argentea Picta', 'Compacta', 'Compacta Regalis', 'Krinkle 8', 'Mauna Loa', 'Rubra' and 'Tricolor'.

Plants in *Euphorbiaceae* include a number of useful succulents and crotons. The genus *Codiaeum* is a popular foliage plant in Europe. Crotons are enjoying renewed popularity in the United States because improved cultivars have better holding quality indoors than many of the landscape cultivars used in South Florida landscaping. If crotons for interiorscapes are

grown under shade, they are well adapted to medium and bright light locations indoors. Crotons are propagated primarily from terminal soft wood cuttings.

Many species of palms can be utilized for exterior landscaping in warmer climates of the Southern United States and and a few of these are useful as interior plants. *Rhaphis excelsa,* is propagated by division of clumps because seed sources are not available in Florida. Other species of Raphis are propagated from seed, as are plants of the genus *Chamaedorea. Chamaedora elegans, C. erumpens* and *C. seifrizii* are especially popular indoor palms. Seeds of most palms are relatively short-lived and should be planted soon after collection if maximum germination percentage is desired. Palm seed should also be germinated at relatively high temperatures, preferably between 27° and 30°C (80° and 85°F). The flesh on the seed of *Chamaedorea* is thin and does not inhibit germination. Conversely, a number of other palm species with rather fleshy fruit should have the flesh removed prior to germination. A relatively new and promising *Chamaedorea* now grown in Florida is *C. cataractarum. Chamaedorea cataractarum* is relatively short and branches freely.

Because of the devastating influence of lethal yellowing disease of palms in South Florida and on islands of the Carribean, a significant number of new palm species have been introduced, primarily to the Ft. Lauderdale Agricultural Research Center, for evaluation of their resistance to the disease. It is reasonable to predict that some of the smaller palms will lend themselves to indoor use. Several years of screening will be required to fully determine the growth habits and adaptability of these new palms to indoor conditions.

Although not considered a foliage plant, × *Citrofortunella mitis* (Syn.: *Citrus mitis*), the calamondin is an attractive pot plant when grown properly for use indoors or on the patio during the summer months in the north. It is propagated by air layers, semi-hardwood cuttings or softwood cuttings. Air layering will produce a fruiting plant in the shortest period of time.

Several begonias with beautiful foliage are good indoor plants. In general the cultivars of *Begonia* with long internodes or those that have distinctive aerial branching can be propagated either by terminal stem cuttings or single or multiple node stem cuttings. Begonias such as *Begonia rex* and many of the smaller types of fancy-leafed begonias that do not produce aerial branches are usually propagated by leaf-blade cuttings or lead blade sections. A few begonias such as iron cross begonia, *Begonia masoniana,* are extremely difficult to propagate from leaf cuttings and are usually produced from seed or through tis-

sue culture.

Aphelandra and *Fittonia*, members of *Acanthaceae*, are attractive foliage plants. *Aphelandra* is grown as a flowering plant or without flowers to feature its variegated foliage. *Aphelandra* propagation is somewhat complex because of the plant's response to light intensity. In most cases the stock plants of *Aphelandra* stock must be maintained at light levels less than 700 foot candles to keep them vegetative. If the light levels rise above 1000 to 1100 foot candles, plants initiate and develop flower buds — desirable in finished plants but not in stock. Propagators and producers of flowering *Aphelandra* must maintain stock and production areas with two light regimens. 'Dania' is the most popular cultivar of *Aphelandra squarrosa*. 'Apollo' with its highly variegated leaves and 'Red Apollo' with distinct red pattern on the foliage undersurface give *Aphelandra* additional pictorial characteristics.

The white nerve plant *Fittonia vershaffeltii* var. *argyroneura* is propagated primarily by terminal cuttings. About three years ago a miniature fittonia, the cultivar 'Minima,' with a leaf size approximately ¼ to ⅓ that of the species, was introduced and is now widely grown. More recently the cultivar 'Angel Snow', a variegated form of 'Minima', was introduced.

The bromeliad family, *Bromeliaceae*, has a number of species and cultivars which should become more widely accepted with time. Many of these plants are extremely durable inside, displaying either foliage color or flower and fruit color over a period of two months or more. Serious drawbacks to acceptance of bromeliads in the past has been cost and inability of the consumer to care for plants properly. Bromeliads are being more widely grown now and more plant care information is available. Over-watering of bromeliads by consumers should not be as much of a problem as in the past. Several of the more outstanding and widely available genera of bromeliads are *Aechmea, Cryptanthus, Guzmania, Neoregelia* and *Vriesia.*

Most bromeliads can be propagated from seed while some of the selected variegated forms and other hybrids with unique characteristics must be vegetatively propagated from offsets.

Some of the most beautiful foliage plants belong to *Marantaceae*, including the genera *Maranta* and *Calathea*. Calatheas have been traditionally difficult to grow because of nematodes, poor soil aeration, fluoride toxicity and a few other problems. A few speciality growers are now producing certain species of *Calathea* in quantity and this group should more likely be available in the future. A number of these plants are very well adapted to indoor conditions and should be propagated. The two primary techniques of propagation include division of

clumps and, with a few species which will produce seed, seed propagation. Some of the more outstanding and promising species and cultivars of *Calathea* include: *C. bella, C. leopardina, C. louisea, C. ornata* 'Roseo-lineata', *C. picturata* and *C. roseopicta*.

The cactus family, *Cactaceae* has an enormous number of interesting species and cultivars. Many of the barrel types and other thick-stemed cacti must be propagated by seed. Their propagation requires a long term, usually taking well over a year to get small specimen plants. Several of the flat-stemed cacti such as the Christmas cactus are conventionally propagated by stem cuttings. It is usually desirable to let cuttings callus slightly before sticking them. This allows for sufficient wound healing to provide some protection against certain disease causing organisms. Christmas cactus has been a popular plant in recent years. A number of popular cultivars of Christmas cactus are: 'Christmas Cheer', 'Christmas Magic', 'Kris Kringle', 'Lavender Doll', 'Lavender Lady', 'Peach Parfait', 'Red Radiance' and 'White Christmas'. A third type of propagation which is used with cacti is graftage. Several variegated types of barrel cacti and crestated cacti are either very slow growing on their own or have no capability to grow on their own because of their lack of chlorophyll. After plants are cleft-grafted, the graft union heals in several weeks. The stock can then be rooted in a pot and grown for a period of time until the plant is well established. Most grafted cacti utilized in Florida are grafted in Japan.

One can visualize the enormous number of foliage plant species and cultivars being produced, some in large quantities and others in very small numbers. Some of those which have not surfaced yet as economically important plants will eventually challenge the plant propagator. There is a distinct and urgent need to have documentation of the technical information generated by researchers and commercial propagators of foliage and other tropical plants in the Proceedings of the International Plant Propagators' Society. This should pose a challenge to expand the International Plant Propagators' Society membership into semi-tropical and tropical areas of the world and increase the knowledge-sharing process of the Society.

A selected list of tropical foliage plants with scientific and common names is given in Table 2.

Table 2. Selected List of Tropical Foliage Plants Including Recent Botanical Name Changes.[1]

SCIENTIFIC NAME	COMMON NAME
Aeschynanthus pulcher	*Lipstick plant*
Aglaonema commutatum var. *elegans*	Silver evergreen
A. commutatum 'Fransher'	Fransher evergreen
A. cripsum (A. roebelinii: schismatoglottis roebelinii)	Painted evergreen
A. × 'Silver King'	Silver king evergreen
A. (numerous cultivars & species)	
Aloe barbadensis (A. perfoliata var *vera, A. vera)*	True aloe
Ananas comosus (A. sativus)	Pineapple
Aphelandra squarrosa 'Dania'	Dania zebra plant
A. squarrosa 'Apollo'	Apollo zebra plant
Araucaria heterophylla	Norfolk Island pine
Ardisia crenata (A. crenulata)	Coralberry
Asparagus setaceus (A. plumosus)	Fern asparagus (asparagus fern)
A. densiflorus 'Sprengeri' *(A. sprengeri)*	Sprenger asparagus (Sprenger fern)
Aspidistra elatior (A. lurida)	Cast-iron plant
Beaucarnea recurvata	Ponytail
Begonia masoniana	Iron-cross begonia
B. × *rex-cultorum (B.* × *rex)* (numerous cultivars)	Rex begonia cultivars
Brassaia actinophylla (Schefflera actinophylla)	Australian umbrella tree
Calathea insignis	Rattlesnake plant
C. makoyana	Peacock plant
Chamaedorea elegans (C. humilis; Collinia elegans)	Parlor palm
C. erumpens	Bamboo palm
C. Seifrizii	Reed palm
Chlorophytum comosum 'Variegatum'	Striped spider plant
Chrysalidocarpus lutescens (Areca lutescens)	Yellow palm, areca palm, cane palm
Cissus rhombifolia (Vitis rhombifolia)	Grape ivy
C. rhombifolia 'Ellen Danica'	Ellen Danica grape ivy
Codiaeum variegatum (numerous cultivars)	Croton cultivars
Coffea arabica	Common coffee, coffee plant
Cordyline terminalis 'Baby Doll' (*Dracaena terminalis* 'Baby Doll')	Baby doll ti
C. terminalis (numerous other cultivars)	
Crassula argentea	Jade plant
Cryptanthus bivittatus	Earth star
Dieffenbachia amoena	Giant dumb cane
D. amoena Tropic Snow'	Tropic snow dumb cane
D. maculata 'Rudolph Roehrs' (*D. picta* 'Rudolph Roehrs')	Rudolph Roehrs dumb cane
Dizygotheca elegantissima (Aralia elegantissima)	False aralia

[1] Botanical name changes according to *Hortus Third*, when applicable.

Table 2. (continued)

SCIENTIFIC NAME	COMMON NAME
Dracaena angustifolia 'Honoriae' (*Pleomele angustifolia* 'Hornoriae')	
D. deremensis 'Compacta'	Compact dracaena
D. deremensis 'Janet Craig'	Janet Craig dracaena
D. deremensis 'Warneckii'	Warneckii dracaena
D. fragrans	
D. fragrans 'Massangeana'	Corn plant
D. marginata	Madagascar dragon tree
D. marginata 'Colorama'	Colorama dragon tree
D. sanderana	Belgian dracaena
D. surculosa (D. godseffiana)	Golf-dust dracaena
D. surculosa 'Florida Beauty' (D. *godseffiana* 'Florida Beauty')	Florida beauty dracaena
D. thalioides (Pleomele thalioides)	Lance dracaena
Epipremnum aureum (Pothos aureua; Raphidophora aurea; Scindapsus aureau)	Devil's ivy, golden pothos
Fatsia japonica (Aralia japonica; A. sieboldii)	Japanese fatsia
Ficus benjamina (F. nitida, impart)	Cuban laurel fig
F. benjamina var. *benjamina*	Weeping fig
F. benjamina 'Exotica' (F. exotica)	Exotic fig
F. elastica 'Decora'	Decorative indian rubber tree
F. elastica 'Robusta'	Robust indian rubber tree
Ficus layrata (*F. pandurata* Hort.)	Fiddle-leaf fig
F. pumila (*F. repens* Hort.)	Creeping fig
Fittonia Verschaffeltii var. *argyroneura*	Silver nerve plant
F. Verscheffeltii argyroneura 'Minima'	Miniature silver nerve plant
Gynura procumbens (G. sarmentosa)	Purple passion vine
Hedera helix 'Needlepoint'	Needlepoint English ivy
H. helix (numerous other cultivars	English ivy (numerous other cultivars)
Hoya carnosa 'Compacta'	Compact wax plant
H. carnosa 'Variegata'	Variegated wax plant
H. carnosa (numerous other culitvars)	Wax plant (numerous other cultivars)
Maranta leuconeura var. *leuconeura* (*M. leuconeura* 'Massangeana')	Prayer plant
M. leuconeura var. *erythroneura*	Red-vein prayer plant
Monstera deliciosa (Philodendron pertusum)	Ceriman, split-leaf philodendron
Neoregelia carolinae	Blushing bromeliad
N. carolinae 'Tricolor'	Tricolor blushing bromeliad
N. exaltata 'Compacta'	Compact boston sword fern
N. exaltata 'Fluffy Ruffles'	Fluffy ruffles sword fern
N. exaltata (numerous other cultivars)	Sword fern (numerous other cultivars)
Peperomia caperata 'Emerald Ripple'	Emerald ripple peperomia
P. obtusifolia	Oval-leaf peperomia
P. obtusifolia 'Variegata'	Variegated oval-leaf peperomia
P. scandens 'Variegata'	Variegated philodendron

Table 2. (continued)

SCIENTIFIC NAME	COMMON NAME
P. (numerous other species and cultivars)	Peperomia (numerous other species and cultivars)
Philodendron × 'Burgundy'	Burgundy philodendron
P. panduriforme (P. bipennifolium?)	Fiddle-leaf philodendron
P. × 'Red Princess'	Red princess philodendron
P. scandens subsp. *oxycardium (P. oxycardium; P. cordatum)*	Heart-leaf philodendron
P. scandens subsp. *scandens* f. *micans (P. micans)*	Velvet-leaf philodendron
P. selloum	Lacy-tree philodendron
Phoenix roebelenii	Pygmy date palm
Pilea cadierei	Aluminum plant
Pilea cardierei 'Minima'	Miniature aluminum plant
P. nummulariifolia	Creeping Charlie
P. 'Silver Tree'	Silver tree pilea
Pittosporum tobira	Japanese pittosporum
Platycerium bifurcatum (P. alcicorne)	Common staghorn fern
Plectranthus australis	Swedish ivy
Podocarpus macrophyllus (P. longifolius)	Southern yew, yew pine
Polyscias balfouriana 'Marginata' (Aralia balfouriana)	Variegated Balfour aralia
P. *fruticosa (Aralia fruticosa)*	Ming aralia, ming tree
Pteris ensiformis 'Victoriae' *(P. Victoriae)*	*Victoria table fern*
P. (numerous other species and cultivars)	Table fern (numerous other species and cultivars)
Sansevieria trifasciata	Snake plant
S. *trifasciata* 'Futura'	Futura snake plant
S. *trifasciata* 'Hahnii'	Bird's-nest sansevieria
S. *trifasciata* 'Laurentii'	Goldband snake plant
Schefflera arboicola	Dwarf schefflera
Scindapsus pictus 'Argyraeus' *(Pothos argyraeus)*	Satin pothos
Sedum morganianum	Burro's tail
Senecio mikaniodes (S. scandens)	German ivy
S. *Rowleyanus*	String-of-pearls
Spathiphyllum × 'Clevelandii'	Cleveland peace lily
S. × 'Mauna Loa'	Mauna Loa peace lily
S. *wallisii*	Miniature peace lily
Syngonium podophyllum 'Emerald Gem' (*Nephthytis podophyllum* 'Emerald Gem')	Emerald gem arrow-head vine
S. *podophyllum* 'Green Gold'	Green gold arrow-head vine
S. (numerous other species and cultivars)	Arrow-head vine (numerous other species and cultivars)
Tolmiea menziesii	Piggyback plant
Yucca *elephantipes*	Spineless yucca
Zebrina pendula	Wandering jew

MACROPROPAGATION OF TROPICAL PLANTS AS PRACTICED IN FLORIDA

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Propagation techniques employed with the more commonly grown tropical foliage and landscape ornamental plants in Florida are similar in most instances to those used for temperate zone plants. Nursery production of tropical plants in south Florida was summarized by Neel at the 1975 Eastern Regional IPPS meeting, and propagation of selected species was discussed in that paper (1). This paper summarizes the various methods of plant propagaion (other than tissue culture) which are utilized in the Florida nursery industry. Commonly grown tropical foliage, landscape, and fruiting plants are presented separately. Examples of special considerations or treatments are presented for each category. For the purpose of discussion, in this paper foliage plants refers to those grown and adapted for use indoors in homes, offices, stores, malls, and similar locations.

FOLIAGE PLANTS

Because over 50 percent of the foliage plants produced in the U.S. are grown in Florida, mostly within 100 miles of Orlando, I shall begin with this category.

Most foliage plants are propagated either by cuttings and/or seed (Table 1). Vegetative propagation requires stock plants and a rooting facility, both of which increase costs. However, cutting-grown plants are usually ready for sale sooner than are seed-grown plants and do not exhibit the genetic diversity of the latter. Some juvenile foliage plants differ from adult plants in leaf morphology or other growth characteristics. *Hedera, Sygonium, Dizygotheca, Dieffenbachia* all have differences in their juvenile and adult forms. Cuttings from juvenile or adult plants may be used, depending on which characteristics are desired, or seed may be sown.

Seeding may be done in beds (*Chrysalidocarpus*), in trays (*Schefflera*), or in liner pots (*Asparagus*). Trays of seedlings may also be bought from commercial sources.

In the larger nurseries mechanized equipment is frequently used to fill containers, sow the seed or stick cuttings, and to place the containers in the propagation area. Artificial, sterile media are typically used. Smaller nurseries of less than 2 acres generally use more hand labor. Germination and rooting are usually done under intermittent mist in a covered house under

partial shade, often on raised benches. Bottom heat is used by some growers, especially in the central and northern part of Florida, and is especially desirable for palms (2). Florida-grown plants destined for sale in California must be grown on raised benches at least 18 inches (46 cm) off the ground in a certified nematode-free medium.

Seed of several species of foliage plants can be obtained from mature plants growing in south Florida. Examples of such plants are *Dizygotheca, Chrysalidocarpus, Brassaia, Philodendron selloum, Asparagus, Monstera, Spathiphyllum, Ardisia, Podocarpus, Chamaedorea, Beaucarnea,* and *Zamia*. Commercial seed brokers and companies fill deficits in local supplies and provide other types of seed.

Seeds should be removed from fleshy fruits before planting as the pulp often contains germination inhibitors. In addition, its decomposition increases the risk of disease and insect infestation. Depulped seeds of *Arecastrum* were shown to germinate significantly better than uncleaned seeds by Neel in an unpublished experiment. The seeds of *Caryota* and some other species of palm are embedded in flesh containing oxalic acid crystals. These will enter the skin and cause severe pain if one uses bare hands to clean the seeds.

Seed freshness is vital, as viability of many tropical plant seeds decrease rapidly following harvest. Special handling can prolong seed life, but it is best to plant as soon after the harvest or the opening of the sealed package as possible. *Monstera* seeds lose their viability in a few days after removal from the fruit, *Spathiphyllum* after a few weeks and *Chrysalidocarpus* after a few months.

Cuttings and seedlings are usually planted more than one per container to provide a full-appearing plant faster than would be the case were single plants pinched to induce branching. Many foliage plants exhibit strong apical dominance and develop few branches naturally. Many nurseries take tip cuttings to promote branching and to provide propagation materials. Cuttings and seedlings must be transplanted without delay. Tropical plants grow rapidly, and roots are damaged unless transplanting is done promptly.

Rooted or unrooted cuttings of foliage plants are also sold by specialized commercial nurseries. Some of these firms are located in Florida but most are located in Puerto Rico or Central America. Bareroot plants entering the U.S. are inspected for diseases and insects before shipment to the purchaser. Inspections are made at the USDA plant quarantine facility located at the International Airport in Miami. State inspectors also check plants in nurseries for pests and diseases.

Most foliage plant cuttings initiate roots without the aid of rooting hormones. However, these can significantly increase the number of roots while decreasing the time necessary for rooting. Fungicidal and bactericidal treatments, both pre- and post-planting, are widely used to control diseases in seeds and cuttings.

Protection from temperatures below 10°C (50°F) is necessary in the production of quality foliage. *Aglaonema, Dieffenbachia, Polyscias,* gesneriads, and some *Dracaena* species are among the more cold sensitive plants. In south Florida saran houses are usually covered with plastic; fuel oil burners are used to supply heat on cold nights. Steam heat is used in many fiberglass houses in central Florida, where temperatures may remain below 10°C (50°F) for several days and drop well below freezing at night. Stock fields of more cold-tolerant plants in south Florida are protected from rare episodes of freezing temperatures with overhead sprinklers.

LANDSCAPE PLANTS

Central and South Florida woody plant nurseries produce subtropical and tropical species primarily for use within the state. North Florida nurseries sell throughout the southeastern U.S. Demand for landscape material is subject to fluctuations in the economy which, in turn, affect construction. However, the continued influx of people seeking the sun makes the outlook good for continued high demand for woody plants in Florida in the 1980's. Many nurseries either stopped or drastically curtailed production of landscape plants in the early 1979's as foliage plant production became more profitable. This, combined with a great increase in population, has resulted in shortages of many kinds of landscaping plants, especially larger-sized trees. The increased demand has driven prices up and resulted in more nurseries returning to landscape plant production.

About 90 percent of the production is in containers, 10% in the ground. Almost all of the production is in full sun. Field-grown plants are started from container plants. As with foliage plants, landscape plants are nearly all started from seeds, cuttings or both (Table 2). A few species may be best propagated by air layering. Tissue culture techniques have not been developed as widely on woody plants as they have with foliage plants, and few tissue-cultured plants are presently being supplied to the landscape nursery trade. This will probably change in the next decade as tissue culture research continues.

Seeds of many kinds of tropical and subtropical landscape plants can be collected locally. These are usually sown soon

after harvest, as is the case with seeds of foliage plants. Seeds of some leguminous tropical trees have very hard seedcoats and require scarification or a hot water treatment, as do those of some temperate zone trees. Seeds are usually sown in flats or beds in a sheltered location. Intermittent mist may be used during germination. Tree seedlings are planted one per pot while shrubs are planted from two to five per pot. Soil-containing media are typically used in most landscape nurseries for starting seedlings and for subsequent transplanting. Frequently this is a mixture of sand, peat, muck and coarse sawdust. Coconuts can be laid on the ground outside and simply covered with sawdust. They can also be planted in containers, pointed end down. During germination the cavity in the coconut becomes filled with the cottony mass that is formed as the milk breaks down and nourishes the developing embryo.

Softwood and semi-hardwood cuttings are stuck 3 to 5 per pot under intermittent mist. This is usually under partial shade but may also be done under full sun if a windbreak encloses the misting area. Cell packs or peat pots may also be used for rooting. Smaller sized rooting containers are usually filled with a more porous medium than normal potting soil to compensate for their decreased drainage.

Growth of most tropical plants is at a minimum during the cool, dry winter months, November through February, and the availability of suitable cutting material from local plantings decreases drastically. Rooting and subsequent cutting growth are also decreased as days shorten and temperatures fall so that liner production of tropicals is least in winter. Under spring through autumn conditions cuttings root in 2 to 4 weeks, although up to 12 weeks may be required for some species. Rooting hormones are widely used on cuttings of landscape plants.

Calcium carbonate deposits and iron discoloration on foliage are two problems faced by a number of nurseries in the southeastern part of Florida. Chemical treatment of the water to lower the pH and to change the oxidation state of the iron has been beneficial in severe cases. The use of surface waters eliminates iron staining but does not solve the lime problem.

At least one widely used landscape plant in Florida is not propagated commercially at present. This is *Sabal palmetto*, the cabbage palm, which is the Florida state tree. Mature specimens are all dug from the wild and planted directly on the job. Several kinds of cycads formerly were also dug from the wilds of Florida and Mexico, but this practice has been stopped due to the implementation of the endangered species act. Cycads are included in the list of plants covered. Large specimens of ponytail palm (*Beaucarnea*) are also dug in Mexico and sold in

Florida nurseries, but these are also easily propagated from seed.

Grafting. Gardenias in Florida are commonly cleft grafted onto *G. thunbergia* for nematode resistance. The rootstocks are grown from seed obtained from locally grown plants or from a commercial source. The stock is allowed to attain a stem diameter of ⅛ to ¼ inch (3 to 6 mm) before grafting.

Jacaranda scions from especially attractive trees are sometimes grafted onto seedlings. This is done not only to increase a desirable plant, but because the seedlings, due to juvenility, take many years to bloom, whereas a grafted tree blooms the second year following grafting.

Casuarina cunninghamiana, Australian pine, is sometimes grafted onto *C. equisetifolia* because the latter does not develop root suckers, while *C. cunninghamiana* does not produce the objectional seed cones of *C. equisetifolia*.

TROPICAL FRUITS

There is much interest in south Florida in the culture of tropical fruits, both by amateurs and industry. South Florida produces most of the nation's limes and mangos as well as avocados, lemons and papayas. The University of Florida has a Research Center at Homestead, which dedicates much effort to bettering tropical fruit crop production. The USDA maintains a plant introduction facility in Miami where all types of plant materials are evaluated as to their suitability for introduction into this country. The Rare Fruit Council International and the Broward County Rare Fruit and Vegetable Council both promote the use of and research on tropical fruits by local residents.

Grafting of selected superior seedlings is frequently done because cuttings from mature fruiting plants often will not root (Table 3). Also, many hobbiests do not have mist facilities. Most nurseries grow only mango, citrus, and avocado. The approach, side veneer, and cleft grafts are most frequently used, while budding is used on citrus. Most tropical fruit plants make attractive additions to the landscape and should be more widely used in the areas where they will grow.

Citrus is budded mainly onto sour orange (*C. aurantium*), trifoliate orange (*Poncirus trifoliata*), or Cleopatra mandarin (*C. reshni*). The various rootstocks impart certain qualities to the fruit itself. In addition, they allow the trees to grow in poorly drained soils. The grafting process also maintains the adult nature of the scion, which results in thornless growth and early fruiting, sometimes as early as a year from budding. Dormant buds are taken from wood below the second or third growth flushes from round (in cross section) stems. Budding can be done whenever the bark "slips", typically from April through October.

Persea (avocado) does not root from cuttings. Superior cultivars are cleft, side veneer or side grafted onto seedlings. Seeds are planted in pots or plastic sleeves as they become available in the fall and winter months. Germination is hastened and improved by cutting from ¼ to ½ inch (6-13 mm) off the tip of the seed. Within a few weeks the shoot emerges from the seed. Commercial grafting of avocadoes is done during the winter months. Some early-planted seed is ready to graft later that same season. The scion buds must not be in active growth at the time of grafting. Partial shading of grafted plants is beneficial.

Mangifera (mango) cuttings will not root. Approach and side veneer grafting are both used. Chances for a good take are greatest during the rainy season of May through September. Seeds are planted during the fruiting season, which is also from

May through September. Some seedlings may be large enough for grafting in the same season, while the others are grafted a year later.

Averrhoa carambola is a fruit gaining in popularity as better cultivars are found among seedlings or are introduced from abroad. It is side veneer or approach grafted onto seedlings or is air-layered. Seedlings will fruit in 2 to 3 years from seed but most produce inferior quality, sour fruit. However, the trees are quite ornamental with pink blossoms and bright yellow, ribbed fruit.

In the side veneer graft method, as used by tropical fruit hobbiests, the scion can be up to about 12 inches (30 cm) long. The stock and scion should ideally be of about the same diameter. They are cut longitudinally in half and the scion cambia mated to the stock cambia before wrapping in plastic tape. For more difficult-to-graft species, the base of the scion can be left free of the stock and inserted into a small plastic bag containing water. The bag is tied to the stock and can be refilled as often as necessary to keep the scion alive while the graft union forms (Figure 1).

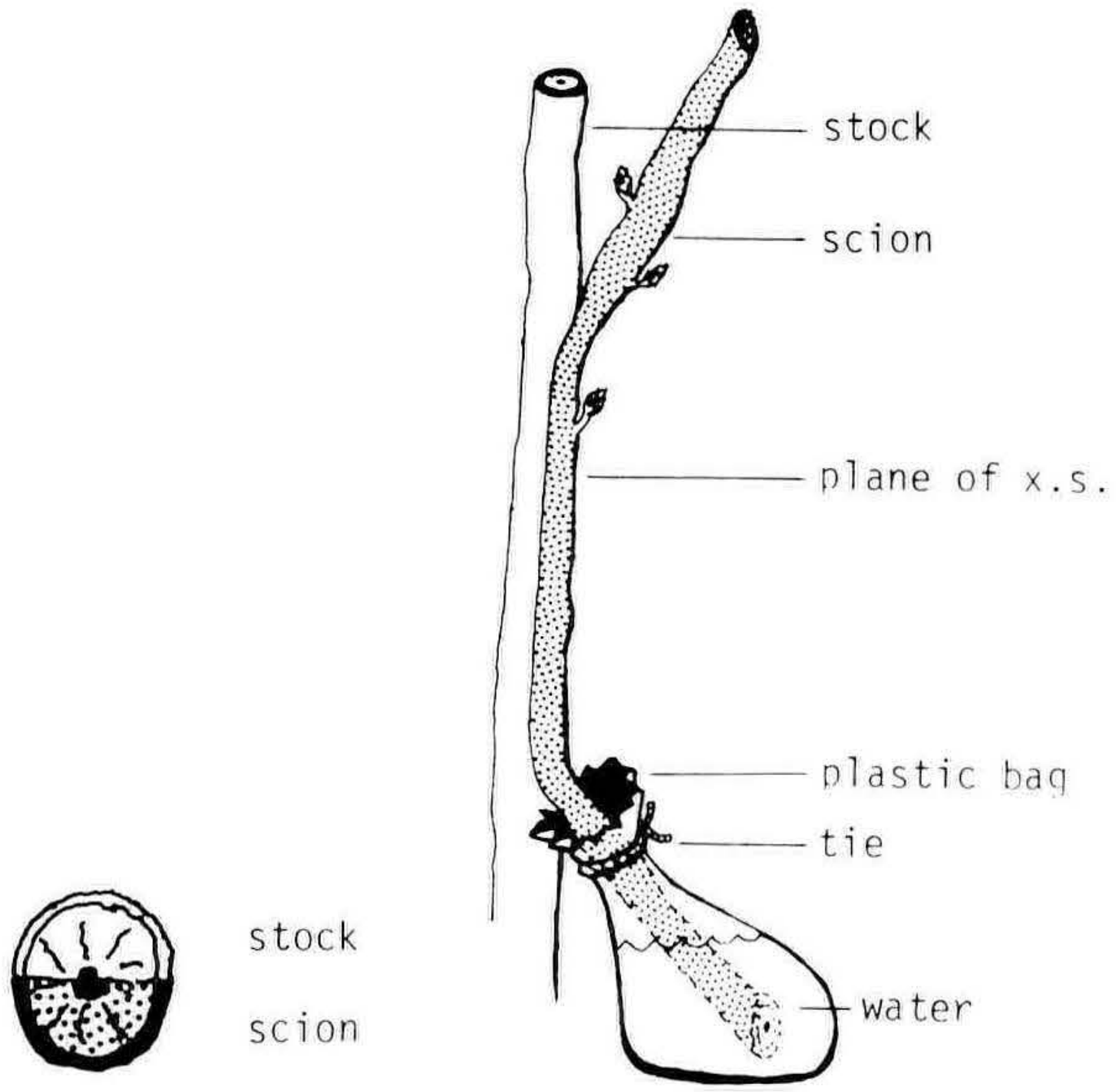

Figure 1. Left: Cross section through center of side veneer graft. Stock and scion are of similar size to provide a better match of their cambium layers. Graft is held with plastic tape or rubber bands.
Right: Side view of graft. If scion has leaves the upper part may also be covered with a plastic bag to reduce drying. Water may be added as needed. After the union takes, the lower part should be cut off.

Table 1. Propagation methods used for fifty commonly grown tropical foliage plants in Florida.

Scientific Name Common Name	Seeds	Cuttings[1]	Air Layers	Divisions	Runners	Used in Landscape
Aglaonema sp.						
Aglaonema		1		3		
Aphelandra squarrosa						
Zebra plant		1				
Araucaria heterophylla						
Norfolk Island pine	1	3				x
Asparagus densiflorus 'Sprengeri'						
Sprengeri asparagus	1	3				x
A. densiflorus 'Myers'						
Foxtail asparagus	1	3				x
A. setaceus						
Plumosa fern	1	3				x
Beaucarnea recurvata						
Ponytail palm	1					x
Begonia sp.						
Various begonias	1	2				x
Brassaia actinophylla						
Schefflera	1					x
Bromeliads	1	2				x
Cacti	2	1				x
Chamaedora sp.						
Bamboo. Parlor Palm	1					x
Chlorophytum comosum						
Spider plant				3	1	
Chrysalidocarpus lutescens						
Areca palm	1					x
Cissus rhombifolia						
Grape ivy		1				
Codiaeum variegatum						
Croton		1	2			x
Cordyline terminalis						
Ti plant		1		3		x
Crassula sp.						
Succulents, jade, etc.		1				x
Cycads						
Cycads	1			3		
Dieffenbachia sp.						
Dieffenbachia cvs.		1				
Dizygotheca elegantissima						
False aralia	1	3				x
Dracaena deremensis						
'Janet Craig', 'Warneckii'		1				x
D. fragrans 'Massangeana'						
Corn plant		1				x
D. marginata						
Red-edged dracaena		1				x
Epipremnum aureum						
Golden pothos		1				x
Ficus benjamina var. *benjamina*						
Benjamin fig		1	3			x
F. elastica						
Rubber tree		2	1			x
F. lyrata						
Fiddle-leaved fig		3	1			x
Gesneriads						
African violets, episcia	2	1	2	2		
Howea fosteriana						
Kentia palm	1					x
Hoya carnosa						
Wax plant		1				
Maranta sp.						
Prayer plant		1	2			
Monstera delicosa						
Pertussum						
Split-leaved philodendron	2	1				x
Nephrolepis exaltata						
Boston fern	3 spores				1	x

1 = a common method; 2 = an alternate method; 3 = a rarely used method

Table 1. (continued)

Scientific Name Common Name	Seeds	Cuttings[1]	Air Layers	Divisions	Runners	Used in Landscape
Peperomia sp.						
Peperomias		1				
Pilea sp.						
Pilea		1				
Philodendron seluom						
Self-heading philodendron		1				x
P. scandens subsp. *oxycardium*						
Heartleaved philodendron		1				
Platycerium bifucatum						
Staghorn fern	2 spores			1		
Pleomele sp.						
Pleomele		1				x
Podocarpus macrophylla						
Buddhist pine	1	3				x
Polyscias fruiticosa						
Ming & parsley aralias		1				x
Rhaphis excelsa						
Lady palm	1					x
Sansevieria trifasciata						
Snake plant		1		1		x
Schefflera arboricola						
Dwarf schefflera	1	2				x
Schlumbergera truncata						
Christmas cactus		1				
Spathiphyllum × 'Mauna Loa'						
Peace lily	1					
Syngonium podophyllum						
Nepthytis	1	1				
Yucca elephantipes						
Spineless yucca		1				x

1 = a common method; 2 = an alternate method; 3 = a rarely used method

Table 2. Propagation methods used for fifty commonly grown landscape ornamental plants in Florida.

Scientific Name Common Name	Seeds	Cuttings	Air Layers	Divisions	Used as Foliage Plant
Acacia auriculiformis					
Ear acacia	1[a]				
Acalypha wilkesiana					
Copperleaf		1			
Acer rubrum					
Red maple	1				
Allamanda cathartica					
Yellow allamanda		1			
Arecastrum romanzoffianum					
Queen palm	1				x
Bauhinia blakeana					
Hong Kong orchid tree	1		2		
Bischofia javanica					
Bishopwood tree	1	2			
Bougainvillea glabra					
Bougainvillea		1			
Bucida buceras					
Black olive	1	2			
Butia capitata					
Jelly palm	1				
Callistemon viminalis					
Bottlebrush	2	1			

a. 1 = a common method; 2 = an alternate method; 3 = a rarely used method

Table 2. (continued)

Scientific Name Common Name	Seeds	Cuttings	Air Layers	Divisions	Used as Foliage Plant
Carissa macrocarpa					
Natal palm		1			x
Casuarina sp.					
Australian pines	1	1			
Chrysobalanus icaco					
Cocoplum	2	1			
Cinnamomum camphora					
Camphor tree	1				
Coccoloba uvifera					
Sea grape	1	3			
Cocos nucifera					
Coconut	1				
Crinum americanum					
Crinum lily	3			1	
Cycas sp.					
Cycads	1				x
Delonix regia					
Royal poinciana	1				
Eucalyptus sp.					
Eucalyptus	1				
Eugenia uniflora					
Surinam cherry	1				
Euphorbia milii					
Crown of thorns		1			
Ficus microcarpa					
(Syn.: *F. retusa* 'Nitida')					
Cuban laurel		1			
Gardenia augusta					
(Syn.: *G. jasminoides*)					
Gardenia		1			
Grevillea robusta					
Silk oak	1				
Hibiscus rosa-sinensis					
Red Chinese hibiscus		1			
Ilex vomitoria					
Vomitoria holly		1			
Ixora coccinea					
Red ixora		1			
Jacaranda acutifolia					
Jacaranda	1				
Jasminum volubile					
Wax jasmine		1			
Juniperus chinensis 'Kaizuka'					
Hollywood juniper		1			
J. virginiana					
Eastern red cedar	1				
Lagerstroemia speciosa					
Queen's crape myrtle		1			
Lantana montevidensis					
Trailing lantana		1			
Ligustrum japonicum					
Japanese wax-leaf privet		1			
Livistona chinensis					
Chinese fan palm	1				
Murraya paniculata					
Orange jessamine	1	2			

a. 1 = a common method; 2 = an alternate method; 3 = a rarely used method

Table 2. (continued)

Scientific Name Common Name	Seeds	Cuttings	Air Layers	Divisions	Used as Foliage Plant
Nerium oleander					
Oleander		1			
Phoenix roebelenii					
Pygmy date palm	1				x
Pittosporum tobira					
Japanese pittosporum		1			x
Plumbago capensis					
Leadwort		1			
Quercus virginiana					
Live oak	1				
Rhododendron sp.					
Azalea		1			
Roystonea elata					
Florida royal palm	1				
Strelitzia reginae					
Bird-of-paradise	1				x
Swietenia mahagoni					
West Indian mahogany	1				
Tabebuia caraiba					
Silver trumpet tree	1				
Trachelospermum jasminoides					
Confederate jasmine		1			
Virburnum suspensum					
Sandanqua viburnum		1			

a. 1 = a common method; 2 = an alternate method; 3 = a rarely used method

Table 3. Propagation methods used for fifty tropical fruit plants in Florida.

Scientific Name Common Name	Seeds	Cuttings	Air Layers	Grafting
Ananas comosus				
Pineapple		1[a]		
Annona reticulata				
Custard apple	1			3
Annona squamosa				
Sugar apple	1			3
Antidesma bunius				
Bignay	1	2		3
Artocarpus heterophyllus				
Jackfruit	1			3
Averrhoa carambola				
Carambola	2			1
Blighia sapida				
Akee	1			
Calocarpum sapota see *Pouteria sapota*				
Carica papaya				
Papaya	1			
Carissa carandas				
Karanda	2	1		
Casiminoa edulis				
White sapote	2			1

a. 1 = a common method; 2 = an alternate method; 3 = a rarely used method

Table 3. (continued).

Scientific Name Common Name	Seeds	Cuttings	Air Layers	Grafting
Chrysophyllum cainito				
Star apple	1			3
Citrus sp.				
Lime, Lemon, Orange, etc.	3			1
Clausena lansium				
Wampi	1			3
Diospyros discolor				
Velvet apple	1			
D. digyna				
Black sapote	1			3
Dovyalis caffra				
Kei apple	1			
D. hebecarpa × *D. abyssinca*				
Tropical apricot		1		
Eriobotyra japonica				
Loquat	1			2
Eugenia aggregata				
Cherry of the Rio Grande	1			
E. grasilensis				
Grumichama	1	3		
E. luschnathiana				
Pitomba	1			
Euphoria longan				
Longan	3		1	
Feijoa sellowiana				
Pineapple guava	3	1		
Flacourtia indica				
Governor's plum		1		3
Garcinia livingstonei				
Imbe	1			
Harpephyllum caffrum				
Kafir plum	1			
Litchi chinensis				
Lychee	3		1	
Macadamia integrifolia				
Macadamia nut	2		1	
Malpigha glabra				
Barbados cherry	1			
Mammea americana				
Mamee sapote	1			
Mangifera indica				
Mango	3			1
Manilkara zapota				
Sapote	1			3
Melicoccusi sapodilla bijugatus				
Spanish lime	1			
Muntigia calabura				
Strawberry-tree	1	1		
Musa × *paradisiaca*				
Banana		1		

a. 1 = a common method; 2 = an alternate method; 3 = a rarely used method

Table 3. (continued).

Scientific Name Common Name	Seeds	Cuttings	Air Layers	Grafting
Myrciaria cauliflora				
Jaboticaba	1			
M. glomerata				
Yellow jaboticaba	1			
Passiflora edulis				
Passion vine	1	1		
Persea americana				
Avocado	2			
Pouteria campechiana				
Egg fruit	1			
P. sapota				
Mamay	2			1
Psidium lottorale var *longipes*				
Strawberry guava	1	1		
Rubus niveus				
Mysore raspberry		1		
Spondias mombin				
Yellow mombin		1		
Synsepalum dulcificum				
Miracel fruit	1	2		
Syzygium cumini				
Jambolan plum	1			
S. jambos				
Rose apple	1			
Tamarindus indica				
Tamarind	1			
Vitis rotundifolia				
Muscadine grape		1		
Ziziphus mauritiana				
Indian jujube	1			

a. 1 = a common method; 2 = an alternate method; 3 = a rarely used method

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1. Neel, P.L. 1975. Production of selected ornamental species in south Florida. *Proc. Intl. Plant Prop. Soc.* 25:368-373.
2. Poole, R.T. and C.A. Conover. 1974. Germination of Neanthebella palm seeds. *Proc. Fla. State Hort. Soc.* 87:429-430.

GEORGIA PEAT: 100,000,000 YD³ OF MEDIUM

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Abstract. The formation of peat bogs in southern Georgia and northern Florida is unique in many respects when compared to peat bogs elsewhere in this country. The bogs are characterized by steep drainage slopes, deep peat deposits, and rapid past development. Analysis of peats from such bogs

Table 3. (continued).

Scientific Name Common Name	Seeds	Cuttings	Air Layers	Grafting
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M. glomerata				
Yellow jaboticaba	1			
Passiflora edulis				
Passion vine	1	1		
Persea americana				
Avocado	2			
Pouteria campechiana				
Egg fruit	1			
P. sapota				
Mamay	2			1
Psidium lottorale var *longipes*				
Strawberry guava	1	1		
Rubus niveus				
Mysore raspberry		1		
Spondias mombin				
Yellow mombin		1		
Synsepalum dulcificum				
Miracel fruit	1	2		
Syzygium cumini				
Jambolan plum	1			
S. jambos				
Rose apple	1			
Tamarindus indica				
Tamarind	1			
Vitis rotundifolia				
Muscadine grape		1		
Ziziphus mauritiana				
Indian jujube	1			

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Abstract. The formation of peat bogs in southern Georgia and northern Florida is unique in many respects when compared to peat bogs elsewhere in this country. The bogs are characterized by steep drainage slopes, deep peat deposits, and rapid past development. Analysis of peats from such bogs

shows a high micronutrient content, low pH, moderate cation exchange capacity, good water holding capabilities, low soluble salts, and adequate pore space to be considered a horticulturial peat. In organic matter content these peats rank among the highest in the world.

GEOLOGIC FORMATIONS

At least four geologic formations were involved in producing the conditions necessary for the development of the Georgia/Florida peat bogs. Two of these formations are underlying limestone layers, the Chattahoochee and Suwannee limestones. The remaining two overlying layers consist mostly of sands with a few thin interbedded lenses and laminae of sandy clay. These sandy layers are the Miccosuckee and Hawthorne formations.

The steep-sided depressions which formed the peat bogs are called sinkholes. These closed depressions were produced by the dissolving of the underlying Chattahoochee and Suwannee limestones creating solution cavities. When these cavities grew so large that the ceiling became too weak to support the overlying materials, the ceiling collapsed creating depressions in the overlying sands and clays of the Miccosuckee and Hawthorne formations. Most of the depressions are sealed from the cavities below by Hawthorne clays. The water level of the depression areas seem to be maintained by springs which come to the surface where clay lenses of the Miccosuckee and Hawthorne formations out-crop on the slopes of the sinkholes. Often there is a perched water table above these clay lenses and layers, which furnish the water for the springs.

The peat bogs are approximately 8000 years old based on Palynological studies done by Watt (3,4) and the studies of the lakes of North Central Florida done by Pirkle and Brooks (2). Prior to that time the water table was depressed during the Wisconsin glacial eustatic sea level depression but was raised during the post-glacial rise in the eustatic sea level and the possible post-glacial climate change (2,4).

Peats from these Karst bogs are characterized by unusually high organic matter contents. This fact indicates a very rapid accumulation of organic material and near optimum anaerobic conditions preventing its decomposition. The peats formed in deep water with little fluctuation in water level. Bottom temperatures were cool and constant while oxygen content of bottom sediment was low.

Steep slopes around the bogs added to the input of organic debris from surrounding areas and speeded organic accumulation. Inorganic nutrients from these steep slope drainage fields probably fueled the ecosystem almost as though the plant life were being fertilized. Increased inorganic nutrient input pro-

duced accelerated eutrophication with abundant aquatic plant growth. The subsequent death and partial decay of these plants gave rise to the peats we find today.

The bottom layers of peat consist mostly of *Sphagnum* and other bryophytes mixed with limnetic aquatic plants. Layers nearer the surface contain increasingly larger components of reed-sedge peat while surface peat is almost entirely ericoid (heath) or wood peat.

The bogs rarely if ever go dry. Few such bogs drain to branch runs or creeks. This lack of a flushing action, as would typically occur if drainage were consistent, has caused the bogs to act as traps for both organic residue and inorganic nutrients.

CHEMICAL AND PHYSICAL PROPERTIES OF GEORGIA PEAT

Peats from South Georgia bogs are strongly acidic and have moderate cation exchange capacities. Their percent water holding capacity by volume is not as great as sphagnum-like peats, but their salts level is low (Table 1).

To aid in perspective, the characteristics of twelve horticultural peats analyzed by Conover and Poole (1) are included. (Tables 1 and 2).

Table 1. Cation exchange and water holding capacities, pH, and soluble salts levels of 12 peats.

Product no.	CEC (meq/100 cc)	% WHC by volume	pH	Soluble salts*
1	310	73.45	4.2	0
2	444	33.65	4.0	0
3	317	71.62	4.4	0
4	365	66.58	4.1	0
5	760	77.82	3.9	5
6	625	80.36	3.7	205
7	580	45.48	4.0	10
8	286	67.32	3.8	210
9	385	76.44	3.8	70
10	690	35.26	3.9	224
11	275	88.61	4.2	0
12	120	51.89	4.0	31

* Soluble salts levels as high as 1000 ppm would be considered acceptable — 500 ppm or below is suggested.

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Tables 3 and 4 give corresponding information for Georgia peat. The bulk density of Georgia peat is high, yet it has moderate aeration as expressed by its percent capillary and non-capillary pore space.

Table 2. Non-capillary, capillary and total pore space found in 12 peats.

Non-capillary pore space %	Capillary pore space %	Total pore space %	Product no.
20.80	58.12	78.92	12
18.23	53.60	71.83	10
13.90	69.88	83.79	8
12.65	72.52	85.17	11
12.40	66.10	78.50	3
10.82	80.58	91.40	9
9.28	70.16	79.44	5
7.97	63.13	71.10	2
5.70	84.41	90.11	6
5.30	70.72	76.02	1
4.00	49.80	53.80	4
1.95	54.69	56.64	7

* Reprinted from Florida Foliage Growers, Vol. 14: Number 7, July 1977

Table 3. Cation exchange and water holding capacities, pH, and soluble salts level of Georgia peat.

Product no.	CEC (meq/100 cc)	% WHC by volume	pH	Soluble salts
GA.	354	66.17	3.8	87

Table 4. Non-capillary, capillary and total pore space found in Georgia peat.

Product no.	Non-capillary pore space, %	Capillary pore space, %	Total pore space, %
GA Peat	14.20	71.22	85.42

One of the most surprising facts about these peats is the very high organic matter content and low ash. Organic matter ranges from a low of approximately 84 percent to a high of 98 percent.

The native micronutrient content of the peat is well balanced due, in part, from input by hundreds of species of plants over thousands of years and by drainage from surrounding slopes. The nutrient content is much higher than that of most shallow-bog peats.

Table 5. Inorganic nutrient content of peat from Georgia bogs[1]

Samples taken at 10 feet depths					
P	K	Ca	Mg	Fe	Mn
1323	217	4005	448	952	52
B	Cu	Zn	Mo	Na	Al
5	4	39	38	74	6473
Si	Co	Cr	Ni	Pb	Cd
290	4	7	1	18	1

[1] Means, in parts per million, calculated from 50 random samples

Tables 5 and 6 give nutrient content of bogs at two different depths.

Table 6. Inorganic nutrient content of peat from Georgia bogs.[1]

Samples taken at surface					
P	K	Ca	Mg	Fe	Mn
1708	222	9147	1064	1625	149
B	Cu	Zn	Mo	Na	Al
7	.4	20	.4	77	6838
Si	Co	Cr	Ni	Pb	Cd
566	7	5	1	26	4

[1] *Means, in parts per million, calculated from 50 random samples*

USE AS A HORTICULTURAL MEDIUM

Conover and Pool (1) summed-up an analysis of peats by saying that selection of a peat for use as a horticultural medium depends on personal preference, cultural practices, cost and availability. All peats are capable of growing plants, but cultural practices are less stringent for peats with the better physical characteristics.

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PINE BARK CONTAINER MEDIA — AN OVERVIEW

F.A. POKORNY

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Considerable research has been conducted to develop a standardized potting medium for growing flower, bedding and woody plants in containers. However, potting media in use by flower growers and nurserymen are varied. Imported peat moss has been an important source of organic matter used in potting media because it has been readily available at moderate cost. As costs continue to rise, growers will continue to seek less costly substitutes for peat moss which will impart the same desirable physical and chemical properties to their potting mixtures.

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Tree bark, a by-product of the forestry industry, is an or-

ganic material that has undergone evaluation in recent years as a peat moss substitute for greenhouse and nursery crops (1,8,9,14,17,20,22,24,26,29). The advantages of using bark, either hardwood or softwood are: 1) it is a renewable resource; 2) it is currently available at lower cost to the grower than imported peat moss, and 3) bark can be processed by hammer-mill and screening to provide a material that is reproducible, thus providing a standardized product. In the South, pine bark is used in ever-increasing quantities by nurserymen in the formulation of potting media for container grown plants. An outstanding characteristic of pine bark is its resistance to decay. This is important to the container-plant producer since rapid decomposition of the organic fraction can result in rapid alteration of the air-moisture relationship existing within the medium. Overwatering and poor drainage can result if rapid structure loss occurs in the root media.

PHYSICAL AND CHEMICAL CHARACTERIZATION OF PINE BARK

Large slabs and pieces of pine bark are removed from a log in the debarking process; this material is seldom usable as a potting medium component. Processing by hammer-milling and screening is needed to reduce the particle size range to one which is suitable for plant growth. Even with hammer-milling and screening, the physical characteristics of processed pine bark vary considerably. Milled pine bark from six commercial nurseries was subject to particle size analysis in the laboratory (Table 1). None of the six pine barks tested were similar in particle size distribution nor in their physical properties (21). Mixing these pine barks with other components, which also vary in their texture and physical properties, results in potting mixtures that are quite different in physical properties (33). Thus, very different cultural programs are needed to grow a uniform crop in each different medium. Additionally, changes in the physical characteristics of the potting components from one potting period to the next necessitate additional changes in the in the

Table 1. Particle analysis (% wt) of pine bark amendment obtained from 6 commercial nursery sources.

Screen opening		Pine bark source					
NBS sieve #	mm	A	B	C	D	E	F
4	4.76	13.6	9.8	8.5	4.4	23.3	26.4
8	2.38	20.4	17.2	41.2	18.2	11.8	25.6
10	2.00	7.6	7.1	10.1	9.2	3.8	7.4
18	1.00	18.7	19.3	19.9	23.7	11.1	15.6
20	0.84	4.8	5.7	3.7	6.5	3.2	3.2
30	0.59	8.7	10.2	5.0	10.7	5.8	5.3
40	0.42	7.7	9.3	3.5	9.3	5.6	3.7
Pan		18.6	21.4	7.9	17.8	35.0	12.4

cultural program employed.

Research at the University of Georgia has shown that milled pine bark with 70 to 80% of the particles in the range of 1/40 to 3/8 inches in diameter and 20 to 30% of the particles smaller than 1/40 inch is very satisfactory as a potting medium and/or potting medium amendment (Table 2). This particle distribution is similar to that reported for hardwood bark by Gartner et al. (8,9). If the pine bark used is too coarse, insufficient water retention may result in poor plant establishment, poor growth, and/or plant death. Conversely, if an excess of fine bark particles are present, surplus water is retained, air is excluded from the medium, and poor growth results.

Table 2. Desirable particle size distribution for milled pine bark used as a potting medium and soil amendment.

NBS sieve no.	Screen opening mm	percent by wt
4	4.76	0.4
8	2.38	18.6
10	2.00	9.0
18	1.00	28.3
20	0.84	5.4
30	0.59	11.3
40	0.42	8.5
Pan	<0.42	18.6

Pine bark is acidic with an initial pH ranging from 4.1 to 5.0 (4,14). The pH of pine bark does not rise substantially with age. Preplant addition of dolomitic lime at the rate of 13 lbs./cu. yd. is necessary to raise the pH into the range of 6.0 to 7.0 (Table 3). If calcitic and dolomitic limestone are used, about 90 days are required for the necessary pH change to occur (25). For rapid pH adjustment, hydrated lime (8.3 lbs./cu. yd.) (Table 3) may be added at the time of mixing, but 7 days should be allowed before potting so that plant injury does not occur (19).

The chemical composition of milled pine bark is given in Table 4. Milled pine bark is low in both macro- and micronutrients needed for plant growth. Therefore, a fertilization program providing adequate nutrients is needed if optimum plant growth is to be achieved.

Table 3. Lime requirement for a pine bark potting medium.

meq Ca per 10 g bark	Equilibration pH	lbs $Ca(OH)_2$ / yd^3	lbs $CaCO_3$ / yd^3	lbs $Ca(Mg)\ CO_3$ / yd^3
0	3.90	0	0	0
2	4.90	2.8	3.8	4.1
4	5.84	5.5	7.5	8.2
6	6.32	8.3	11.2	12.3

Table 4. Spectrographic analysis of milled southern pine bark used as a potting medium amendment.

Element	Water extract	Total
N	—	0.28%
NH_4-N	0.33 ppm	—
NO_3-N	0.67	—
P	9.0	0.02
K	27.6	0.10
Ca	7.6	0.51
Mg	1.6	0.14
B	0.15	9.33 ppm
Cu	0.17	76.94
Fe	ND*	790.40
Mn	0.01	118.85
Zn	0.06	111.60

* ND = not detectable.

FRESH, AGED, OR COMPOSTED BARK

One question a grower contemplating the use of pine bark frequently asks is: Shall I use fresh, aged or composted bark in my potting medium? In the South, large quantities of aged pine bark are used. Aging refers to the stockpiling and weathering of bark after hammer-milling and prior to its use. The aging process usually takes place on open-air stockpiles established by the bark producer or commercial grower. No fertilizer additions or pH adjustments are made during the aging period (3 to 18 months or more), nor is an attempt made to control the moisture content within the bark stockpile. During this aging period, the stockpile may undergo slight decomposition as evidenced by a buildup of heat, but temperatures attained within the pile are insufficient to kill pathogenic organisms (14). If the stockpiles are very large, partial decomposition will occur due to inadequate aeration within the depths of the pile. Under these conditions, compounds may be formed which are toxic to plants. Aging or weathering of pine bark enhances its wettability.

In contrast to aging, composting is the biological degradation of pine bark under carefully controlled conditions. Fertilizer additions (particularly N), the regulation of pH, moisture and aeration in the compost pile are important factors in the composting process. Composting procedures for both hardwood and softwood barks are summarized in detail by Hoitink and Poole (14). The advantages of compositing lie in the reduction of the carbon to nitrogen ratio, which minimizes the competition between plant and microorganisms for nitrogen, and in the destruction of pathogenic organisms due to the heat buildup within the compost pile (13,15). In contrast to hardwood bark, mandatory composting of pine bark is unnecessary.

Table 5. Growth index and fresh wt of *Ilex crenata* 'Rotundifolia' grown in fresh and aged milled pine bark-sand potting media.[1]

Medium (v/v mixtures)	Date of harvest							
	3/17		4/17		5/17		6/17	
	Growth[2] index	Fresh wt (g)	Growth index	Fresh wt (g)	Growth index	Fresh wt (g)	Growth index	Fresh wt (g)
1:1 fresh bark-sand	19.0[a]	24.5[a]	—	—	—	—	—	—
1:1 fresh bark-sand+1.0% N	18.7[a]	25.0[a]	—	—	—	—	—	—
1:1 bark (aged 1 mo.)-sand	—	—	20.0[a]	27.5[a]	—	—	—	—
1:1 bark (aged 1 mo.)-sand+1% N	—	—	18.7[a]	24.8[a]	—	—	—	—
1:1 bark (aged 2 mo.)-sand	—	—	—	—	22.5[a]	26.1[a]	—	—
1:1 bark (aged 2 mo.)-sand+1% N	—	—	—	—	22.3[a]	29.6[a]	—	—
1:1 bark (aged 3 mo.)-sand	—	—	—	—	—	—	28.3[a]	39.1[a]
1:1 bark (aged 3 mo.)-sand+1% N	—	—	—	—	—	—	28.7[a]	41.7[a]
1:1 bark (aged 6 mo.-1 yr.)-sand (control)	18.1[a]	23.4[a]	18.6[a]	22.4[a]	21.2[a]	24.3[a]	24.4[b]	25.8[a]

[1] 10 plants per treatment except 6/17 harvest (5 plants per treatment).

[2] Growth index $= \frac{\text{Ht} + \text{spread}}{2}$

[a] Means within a column followed by a common letter are not significantly different (5% level).

Self (29) and Self and Pounders (30,31) have shown that many plants can be grown successfully in fresh pine bark without the necessity of composting. Plantings delayed for 30 days following composting were also satisfactory, but in plantings made after composting 60 days poor results were obtained due to excessive leaching and salt accumulation, which depended upon the fertilizer additives incorporated (29,32).

In studies at the University of Georgia *Ilex crenata* 'Rotundifolia,' holly, were grown under a standard fertilization program in media containing fresh pine bark or pine bark aged from 1 to 6 months. Plants of similar size, fresh weight and quality were obtained whether or not N was added preplant to compensate for potential N competition (Table 5). Laboratory tests indicate that only ¼ lb. N/cu. yd. will provide adequate N for microorganisms acting on the pine bark (unpublished data).

THE WETTING PROBLEM

Milled pine bark, sometimes hot-air dried to facilitate processing and storage, and fresh pine bark are very difficult to wet (5). The wetting characteristics of the bark potting medium at the time of planting is a critical factor in the growth cycle of a plant since an initial growth delay, due to moisture stress, has been reported (11). Hydrophobicity, the initial resistance to wetting encountered with a dry pine bark medium, is probably due to chemical and/or physical factors. Most or all bark particle surfaces are covered with organic chemicals that resist water adsorption; rough particle surfaces cause an interfacial tension that resists adsorption and movement of water (4). Also, the quantity and size of pores within the particles are too small to allow entry of water (4,7).

Initial moisture content of bark particles influences infiltration, absorption and retention of applied water (Figure 1). With an initial moisture content of 34% or less (wet wt basis), milled pine bark resists water infiltration and holds insufficient moisture to adequately support plant growth (3). Therefore, the potential exists for total crop failure. Thus, a pine bark medium should be thoroughly wet prior to planting to ensure rapid plant establishment and development.

One way to overcome the difficulty in wetting is through the use of surfactants, which are chemical wetting agents. Approximately 24 surfactants have been evaluated for their effectiveness in overcoming resistance to wetting of dry pine bark. Nine have been found to be effective in achieving threshold wetting (35% wet wt basis) at concentrations ranging from 0.1% to 1.0% (Table 6). No phytotoxicity was observed at minimum concentrations required for threshold wetting.

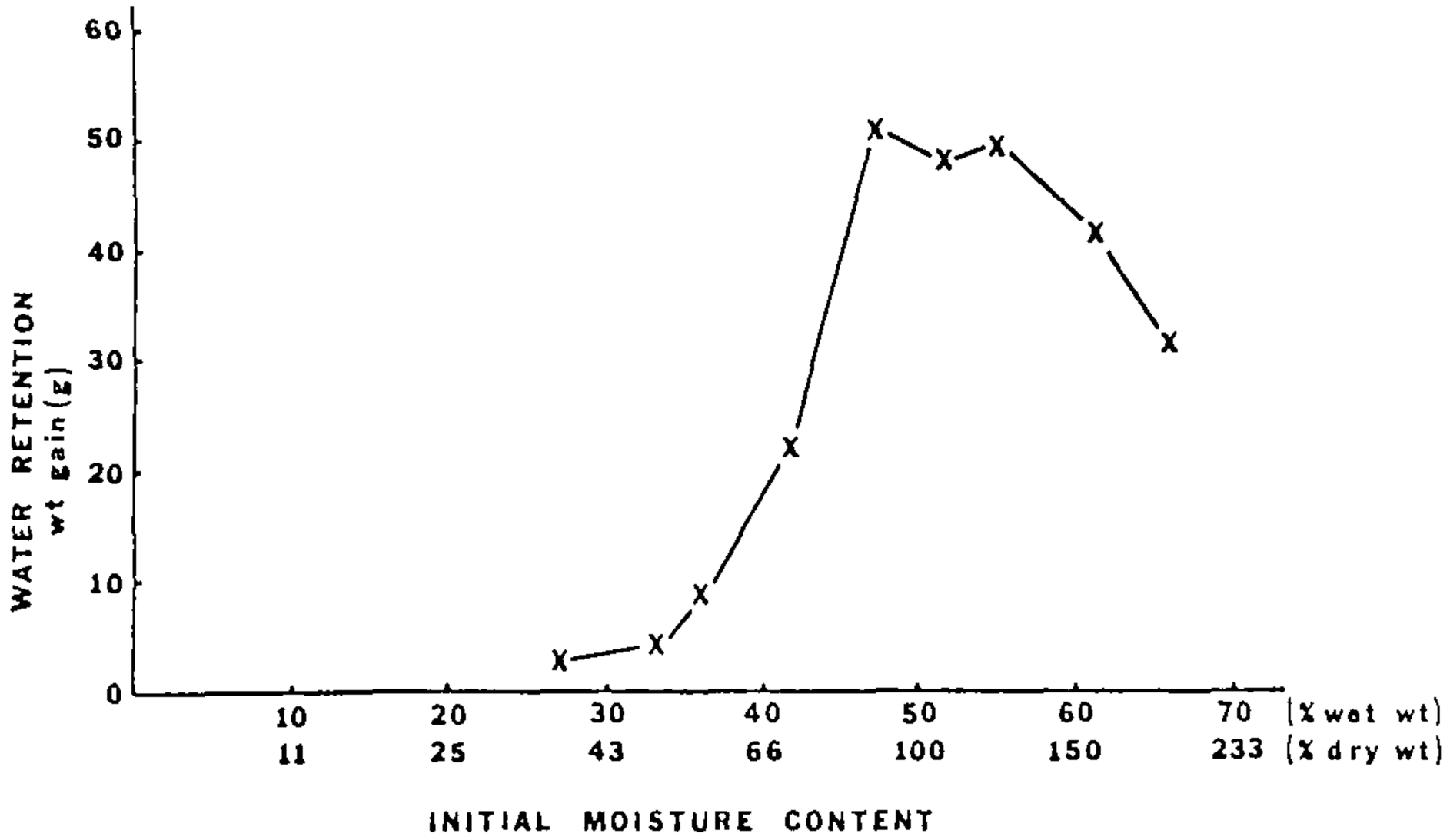

Figure 1. Influence of initial moisture content on water retention of milled pine bark.

Table 6. Surfactants and minimum concentration required to achieve threshold wetting (35% wet wt basis) of dry milled pine bark.

		Minimum concentration required					
Surfactant	Type	0.1%	0.2%	0.3%	0.4%	0.5%	1%
Neutronyx 600	non-ionic	—	x	—	—	—	—
Aqua Gro	non-ionic	—	—	—	x	—	—
Gafac PE510	anionic	—	—	—	—	x	—
Hydro-wet	non-ionic	—	—	—	—	—	x
Firechem	non-ionic	x	—	—	—	—	—
Triton CF-54	non-ionic	x	—	—	—	—	—
Triton DF-16	non-ionic	—	x	—	—	—	—
Triton X-100	non-ionic	—	x	—	—	—	—
Triton X-114SB	non-ionic	—	x	—	—	—	—

POTTING MIXTURES

Successful plant growth has been achieved with a wide range of potting media containing pine bark (Table 7). At the University of Georgia excellent results have been obtained with 1:1:1 v/v/v soil, sand, pine bark, 1:1:1 v/v/v soil, perlite, pine bark, 1:1 v/v pine bark, sand, 1:1 v/v pine bark, perlite, and in 100% pine bark (20,22). It has not proved necessary to incorporate peat moss since a fine grade of milled bark (Table 3) has been utilized as the organic amendment.

EARLY PLANT GROWTH DELAY AND WATER RELATIONS

Initial delay in plant growth has been reported when plants are grown in media containing milled pine bark (11). This prob-

Table 7. Partial range of potting mixtures utilizing pine bark as an organic component.

Potting medium (mixtures, v/v basis)	Crop grown	Literature citation
100% pine bark	*Pilea, Rhododendron obtusum, Saintpaulia, Coleus, Begonia semperflorens*	2, 22, 25, 26
3:1 pine bark-sand	*Centaurea cineraria*	16
1:1 pine bark-sand	*Saintpaulia, Coleus, Gardenia jasminoides 'Radicans', I. crenata* 'Rotundifolia', *Rhododendron obtusum*	17, 20, 22
1:1 pine bark-perlite	*Saintpaulia, Gardenia jasminoides* 'Radicans', *Ilex cornuta* 'Burfordii'	20, 22
1:1 pine bark-vermiculite	*Chrysanthemum*	6
7:3 pine bark-vermiculite	Nursery crops	6
2:1:1 pine bark-peat-sand	*Ilex crenata* 'Hetzii', *Pinus thunbergii Quercus shumardii, Betula nigra, Carya illinoensis*	10, 12, 34
2:1:1 pine bark-peat-shale	*Rhododendron obtusum*	26
1:1:1 pine bark-peat-shale	*Rhododendron obtusum*	26
1:1:1 pine bark-peat-sand	*Rhodendron obtusum*	17
1:1:1 pine bark-soil-peat	*Rhododendron obtusum*	17
1:1:1 pine bark-soil-sand	*Pyracantha, I. cornuta* 'Burfordii', *Gardenia jasminoides* 'Radicans', *Saintpaulia*	10, 22
1:1:1 pine bark-soil-perlite	*Saintpaulia, Coleus*	22

lem has been simulated in the laboratory at the University of Georgia and results indicate it is not nutritional in nature. Rather, early growth delay, particularly with herbaceous plants, appears to be moisture related. Moisture retention in the surface 1 to 2 inches of a 1:1 pine bark-sand medium is less than in a 1:1 peat-sand mixture. Thus, newly transplanted seedlings, rooted cuttings, and/or liners tend to undergo moisture stress during the first several weeks after transplanting. However, once roots become established, plants rapidly develop. By changing the particular distribution of the pine bark to a finer grade or by frequent syringing for the first several weeks after transplanting, the problem can be eliminated.

Frequent irrigation to provide adequate moisture levels with pine bark media is necessary during the first 30 days after planting. Once plants become established, less watering is required (Figure 2). Pine bark retains less water than peat moss, but apparently more of the water held by pine bark is available for plant use.

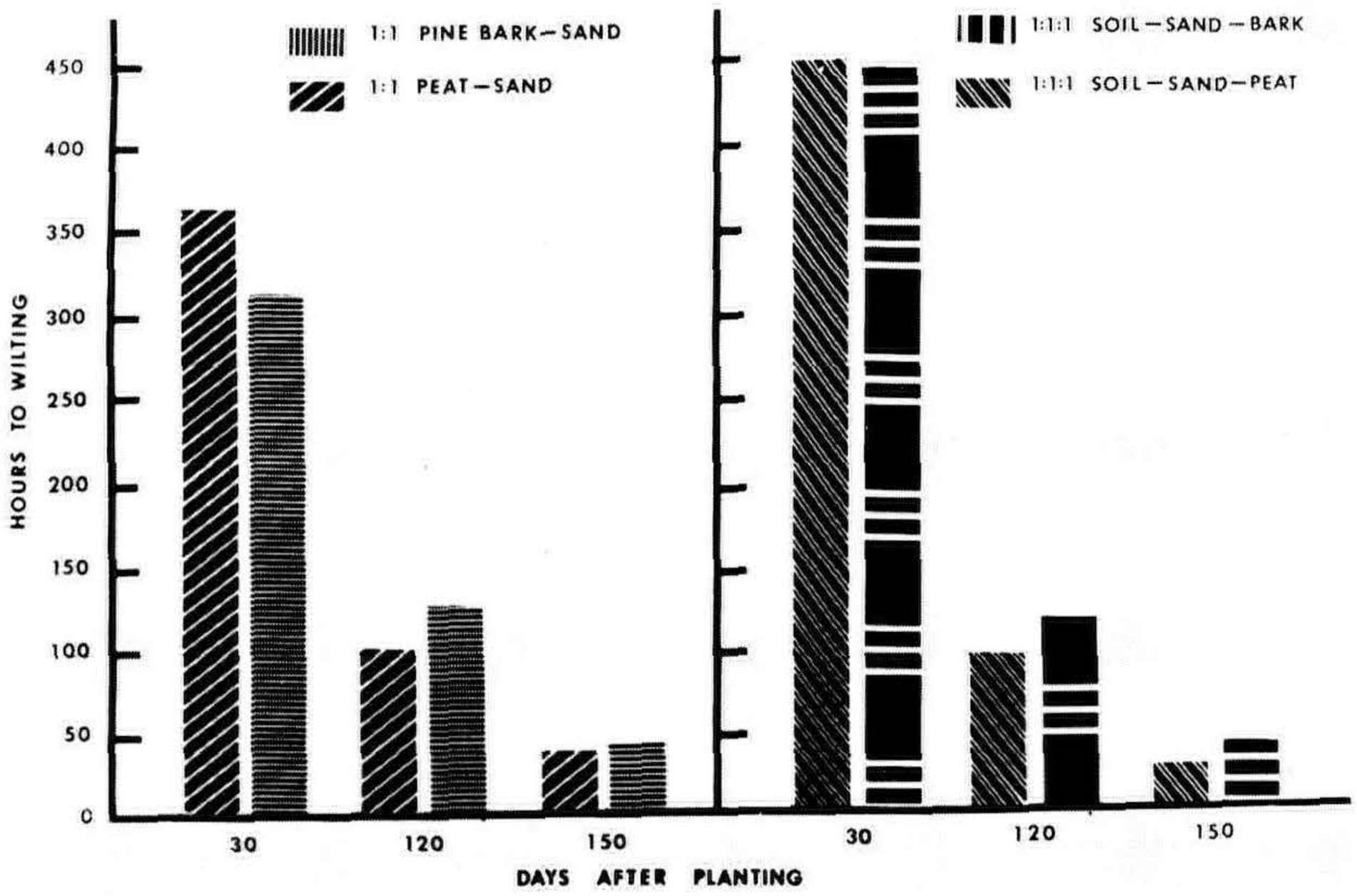

Figure 2. Influence of peat moss and pine bark as potting medium amendments on available soil moisture as exhibited by wilting of the indicator plant, *Hypericum* 'Hidcote'.

FERTILIZATION

In recently completed research in Georgia, it was found that nitrate base fertilizers (calcium nitrate, potassium nitrate) are preferred N sources for fertilization in comparison to ammonium sources of N. When ammonium supplied over 50% of the N, plant growth was suppressed (Table 8). Research indi-

cates that this growth suppression is due to the tie-up of the ammonium by the pine bark particle rather than due to ammonium toxicity (1,18,23). Self (28) has shown that Osmocote 18-5-11 at 5 or 10 pounds./cubic yard and Special 7 are adequate for azalea growth. If Birmingham slate is included as a potting mix amendment, iron could be deleted from the preplant fertilizer addition (27).

Table 8. Effect of nitrogen source on dry weights of *Lycopersicon esculentum*, Mill., 'Beefsteak' plants grown in various sand/pine bark potting media in containers.

N source ratio		Sand/bark ratio				
NO_3	/ NH_4	75/25	50/50	25/75	0/100	Mean
		Dry wt (g)				
100	0	7.0	6.9	6.0	5.3	6.3
75	25	6.7	6.6	5.8	5.5	6.2
50	50	6.2	6.4	5.5	5.5	5.9
25	75	5.2	5.3	5.3	4.7	5.1
0	100	3.4	4.2	4.4	4.2	4.1

CONCLUSION

In the final analysis, each grower must decide upon a potting mixture that is most adaptable to his needs and develop a management program that will produce the best plant at the lowest cost. Milled pine bark can be utilized successfully in potting media for container plants and plant growth comparable with other organic soil amendments can be achieved.

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FACTORS AFFECTING QUALITY OF COMPOSTS FOR UTILIZATION IN CONTAINER MEDIA[1]

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A variety of publications from the United States

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(9,10,16,22,28), Norway (27), Belgium (4,5,6), Finland (18), and Japan (30) have discussed composting of tree barks for use in container media. Although differences in properties of bark from tree species are considerable, established methods for production of high quality composts are remarkably similar. The composting process comprises a complex series of biological events that remove mostly cellulose (wood and cambium) and various toxins (24,29) from bark and leave humic acid, lignins and a variety of microorganisms as major end products. In this article, key factors are discussed that affect the composting rate of tree barks and quality of the end product. Information presented is based on research performed at the Ohio Agricultural Research and Development Center during the past 8 years as well as research at other institutions. Some guidelines were established in cooperation with various commercial operations that produce composts for container media.

Composting process. Composting has been defined as the biological decomposition of organic constituents in wastes under controlled conditions. An important term in this definition is "controlled" which distinguishes composting from natural rotting or putrefaction such as occurs in open dumps, manure heaps, or in field soil (11). Basically the process can be divided into three phases: 1) an initial phase of 1 to 2 days during which easily degradable soluble compounds are decomposed, 2) a thermophilic phase (possibly several months) during which high temperatures occur and in which mostly cellulose is degraded, and 3) stabilization, a period during which the rate of decomposition decreases, temperatures decline, and antagonistic and other ambient temperature microorganisms recolonize the compost. A detailed description of the composting process is given in: "Composting, a study of the process and its principles" (11).

Bark used for container media generally is composted in windrows (3 to 4 m wide, 2 to 2.5 m high). Since the process is aerobic, windrows should not be covered with polyethylene but may be under a roof in areas of high rainfall. The surface on which windrows are placed should provide adequate drainage to avoid anaerobic pockets in the base of windrows.

The oxygen concentration in the gas phase of a windrow should be maintained above 0.1% and preferably between 5 to 12% (8,26). The optimum temperature for composting of hardwood bark is 40° to 55°C (4,6). At high temperatures lower rates of decomposition occur (19). However to reach thermophilic conditions (>40°C) throughout a windrow, temperatures in the center of a windrow usually reach 55° to 70°C (16).

The optimum pH for composting ranges from 6.5 to 8.5

(6,21). The pH of fresh bark ranges from 4.0 to 5.5. Addition of ammonium nitrate does not raise the pH significantly, whereas urea or anhydrous ammonia does (5,16,27). This is the primary cause for higher rates of decomposition observed in bark treated with ammonium N sources (4,5,6).

The optimum moisture content during composting is 50 to 65% on a wet weight basis (6,20). Moisture contents below 40% significantly reduce the rate of decomposition (11). Higher levels may result in accumulation of free water in the bottom of windrows and yield a spoiled silage odor. Frequent turning after free standing water is removed usually corrects this problem due to drying of particles and aerobic decomposition of fermentation products. However, sour compost in which the pH has dropped below 4.0 is no longer usable. Readings as low as pH 1.9 have been encountered (2). These samples were extremely toxic and when used killed all vegetation.

Aeration, moisture content and particle size are interrelated. Coarse bark aerates better and can be stacked in higher windrows than finely ground bark. However, coarse bark dries out readily and water may have to be added to keep the moisture content at optimum levels. Equipment should not be driven onto stacks in the preparation of windrows since it causes compaction and subsequent fermentation (2,16).

The length of time during which high temperature (thermophilic) decomposition occurs can be reduced significantly by careful control of optimum conditions for composting. Aeration with fans (negative pressure) attached to perforated drainage pipe (8,26) reduced the composting period (Beltsville system) for hardwood bark from 6 months to 4 weeks if followed by 1 month of "stabilization". More sophisticated composting machines (mechanized aerated tanks or aerobic digestors) may reduce this period even further (2 weeks, followed by 1 month stabilization) thus reducing the acreage and heavy equipment needed.

During forced aeration, the moisture content must be monitored carefully and may be maintained above 65%. Excessive aeration dries bark rapidly (below 40%) resulting in low rates of decomposition and may cause ammonia loss. Additional water may have to be added (overhead irrigation), depending upon the season. In this system 50% of the N should be applied as ammonium nitrate to avoid ammonia loss as a result of high pH (above 7.4). In practice 30 second aeration bursts each 20 minutes are adequate to maintain optimum levels in windrows. Fans should be on the down-slope end of pipes. A small hole in the pipe just in front of the fan allows drainage water to escape without reducing aeration pressure significantly.

Tree age and species. Generally, trees are classified as hardwoods and softwoods. Barks from hardwoods such as oak, maple, poplar and alder are typically high in cellulose content (readily degradable carbon) and decompose readily (1). However, barks from softwoods, such as lodgepole pine, eastern red cedar and various spruce species also are high in cellulose (1). Bark from these trees require 1 kg N/m^3 for decomposition during 4 to 6 months composting (16,23,27,30). On the other hand, western white pine, hickory and black walnut contain less cellulose in bark (1) but require composting before use. Finally, barks from large tree specimens of cypress, western larch, Douglas-fir, and white, shortleaf, loblolly, slash and longleaf pines contain little cellulose (1). Less nitrogen is required to decompose these barks to a point where excessive nitrogen deficiency does not occur.

Tree age at harvest has a significant effect on the amount of cellulose as compared to lignin in bark, and subsequently, the nitrogen requirement. Young trees contain proportionly more cellulose in the "top" and branch terminals. Bark from these sources, therefore, requires more nitrogen for decomposition (27). Bark from young pine trees, therefore, needs to be composted, whereas that of older trees generally need not be unless it is to be stored in polyethylene bags. Any type of fresh bark, during storage in sealed bags decomposes. Under such conditions fermentation products are produced which are toxic to a variety of plants.

Debarking and grinding. Various types of debarkers are in use. Ring and drum debarkers remove little wood from logs and, generally, produce bark with a wood content of less than 10%. Rosserhead debarkers remove considerable wood in addition to bark. The percentage of wood in this bark will vary depending on the time of year at which bark is harvested (27). Hosmerhead debarkers follow the contour of the log and remove less wood than Rosserhead debarkers and, therefore, are more suitable for harvesting of bark used in container media.

In the 1960's, whole tree chippers were introduced by the paper industry. Entire trees are chipped in the woods and bark is separated from woodchips at the mill by screening. These screenings may contain up to 60% wood and are not suitable for use in container media unless they are composted for long periods, perhaps for several years. In addition to causing nitrogen deficiency on plants, an excessive amount of wood in bark also negates the disease suppressive effect of bark compost. Sawmills that wish to produce bark for container media, therefore, need to deal with sawdust, woodchips and bark separately.

Considerable data has been published on optimum particle

size of barks for utilization in container media (3,9). Standards need to be developed. Generally, bark for container media is hammermilled and screened so that all particles pass through a 12.5 mm screen. The ratio of small, medium and large particles determines the percentage pore space at container capacity and the soil moisture characteristic of a medium. No formula is available that may be used to predict such properties. Generally, therefore, large particles should be small enough to avoid handling problems during potting but large enough to assure a high porosity. On the other hand adequate quantities of fines are needed to raise the cation exchange and moisture holding capacities to acceptable levels. Addition of small amounts of sphagnum peat has improved properties of composted hardwood and spruce bark growing media (6,27). Size of bark particles dictates the amount of peat and neutral light weight aggregate (expanded shale, perlite, styrofoam or pumice) that needs to be added to adjust physical properties to optimum levels.

Chemical additives before composting. From a variety of reports (2,4,16,18,23,27) it can be concluded that: a) ammonia is a better source of nitrogen for composting than nitrate, and b) phosphate generally increases the decomposition rate. Optimum amounts of additives for composting are 1 kg N and 0.3 kg P_2O_5 /m^3 bark. Higher amounts of N(2-3 kg/m^3) result in excessively high pH readings (5,16,27). Under such conditions free ammonia kills the microflora. Such high amounts of N, therefore, increase the length of time required for decomposition since it will not start again until after the excessive quantities of ammonia have been fixed or dissipated. Part of the added nitrogen may be replaced successfully with poultry manure (30). Addition of all N in the form of poultry manure may decrease the pore space in the bark mixture to undesirable levels resulting in fermentation and problems during utilization.

Stabilized composts may be too high in pH for ericaceous plants. This can be corrected by adding elemental sulfur and iron sulfate (9,16). This, however, should not be added before composting since the pH will be decreased resulting in lower rates of decomposition. Addition of magnesium sulfate (0.5 kg/m^3) to composted hardwood bark (before or after composting) has improved growth of a variety of crops (23).

Quality control. After decomposition, it is usually not possible to visually examine bark compost for wood content and, therefore, determine whether nitrogen deficiency will occur in plants in container media. Chemically, however, the cellulose concentration in refuse composts can be determined with a cuprammonium assay. The procedure, however, is lengthy and has

not been applied successfully to hardwood bark compost. Meaningful chemical assays for humic acid content in composts are not yet available.

Mature bark compost should have a "topsoil odor", a pH of 6.4 to 7.2 and a low soluble salts content. The "topsoil" odor is caused by mesophilic actinomycetes that do not recolonize bark until after temperatures decline. Producers of composts for container media, therefore, must use plant bioassays (cucumber or tomato) to test for nitrogen requirements of the compost (16).

Before packaging, composts should be lower than 40% in moisture content or possibly lower, since moisture generated during further decomposition accumulates in plastic bags. To avoid additional decomposition nitrogenous fertilizer should not be added to compost during bagging. Stabilized composts may be packaged and stored for a year or longer. However, partially decomposed bark may self-heat and become sour due to lack of oxygen supply in bags in storage or during transit. Stacks on pallets in storage should be spaced to assure adequate ventilation.

The length of time during which hardwood bark needs to be composted depends on many factors. So far effects of cellulose concentration in bark of the tree species used in addition to the composting method have been discussed. The proportion of bark in a growing medium also has an effect. Increasing proportions of bark in a peat-bark medium required longer and longer periods of composting in windrows to produce 'Bright Golden Anne' chrysanthemum plants equal in quality to the controls (23). With 1:1 mixtures of bark-peat, only 1 month of composting was needed; with 2:1 mixtures. 2 months, 3:1 mixtures, 6 months and with bark alone, 10 months of composting were required to produce total plant growth equal to control plants.

Preparation of container media. Typically, media are prepared after composting, although ingredients may be mixed before. Grinding or excessive mixing after composting breaks particles and exposes cellulose inside large particles and results in additional decomposition and nitrogen deficiency (16). Chemicals utilized in small quantities, therefore, should be premixed with neutral aggregates to decrease the time required for uniform mixing.

Sphagnum peat may be added before composting, but the pH needs to be adjusted to above 5.0 to start the composting process. Aeration of windrows also is more difficult if peat is added before composting, while excessive moisture contents may occur in uncovered windrows that contain peat in areas of high rainfall. This may be avoided by adding pumice, expanded

Figure 1. Compost being removed from an aerated bioreactor tank and placed onto conveyor belt. The compost is aerated by fans through perforated floors and turned frequently to expose all organic matter to thermophilic conditions. Tank (4 × 7 × 150 m) on left filled with cow manure and on right with hardwood bark.

shale or other coarse light-weight aggregates. Generally, it is not advisable to add peat before composting. Success of plant growth in container media amended with composts largely depends on the physical properties of the mix and adequate information on these properties is not available.

Disease control. This subject was reviewed in detail in a previous paper (16) and will only be summarized here. Composting involves self-heating at temperatures in excess of 40°C for several weeks and above 70°C for 1 week or more (4,11,16,27). This kills or inactivates plant pathogens, except for some heat-resistant viruses such as tobacco mosaic virus (TMV) and possibly others (13). Composts prepared from vegetable wastes, in particular tomato wastes, therefore, may be contaminated with TMV. In general, composts should not be sterilized since this will kill beneficial microorganisms. Composting on a concrete pad prevents excessive recontamination with plant pathogenic microorganisms.

Hardwood bark compost has fungicidal properties (7) and suppresses all soil-borne plant pathogens that have been examined (13,14,15,25). Composted Douglas fir (17) and pine bark

(12) suppress a wide range of pathogens but pine bark does not suppress *Rhizoctonia solani*. Generalizations, therefore, cannot be made regarding disease suppression by composts. Addition of large amounts of wood to hardwood, Douglas fir, and probably other types of barks destroys the disease suppressive effect against *Phytophthora cinnamomi* and possibly some other pathogens as well (17).

Figure 2. Appearance of roots in a medium consisting of composted hardwood bark, Canadian peat, perlite, 4:3:2 by volume. The medium was not sterilized, and no additional fertilizer was applied.

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PLANNING, RECORDING, AND REPORTING PROPAGATION PROCEDURES AND RESULTS

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In obtaining new information from experimental studies, a set of procedures has been developed by the scientific community which, over the years, has worked very well and is generally adhered to.

For the IPPS, it is advisable for us to follow this same pattern in planning, conducting and reporting experimental projects (1,2). This article has been prepared to assist Society members in setting up experiments, recording results, and preparing their papers for publication in the IPPS Proceedings.

The general outline of these accepted procedures, and how they transform into a manuscript ready for publication are listed below and will be discussed using the final sections of the completed articles as an outline:

1) **Title of article.** Considerable thought should be given in selecting a title which will be brief yet informative and complete. The title of the article is *all* the reader will see in literature citation lists or reviews so the title should be as informa-

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2) **Authors names and addresses.** Often more than one author is involved in the project. Be sure all persons who have made significant contributions to the project are included as authors. It can be a diplomatic problem sometimes deciding whether a co-worker should also be a co-author or merely receive an acknowledgement for his efforts. The degree of contribution is the criterion to use in making such a judgement. The institution where the work is done should be listed as the address so it will receive credit for its contributions. If one or more of the authors has since moved, or will move, to another location this can be indicated as a footnote giving the new address.

3) **Abstract.** The abstract should be thought of as a very brief condensation of the entire article: what was done, what was found out, and what were the significant conclusions from the work. If the title of the article interests the reader, he will next read the abstract to see if the article is about what the title says it is and, if so, may feel it is worth his time to study the article in detail. The abstract serves a very useful purpose but is often difficult to prepare, putting into a few words the really significant points in the article.

4) **Introduction.** This should be short and may or may not be labelled as an introduction. An introductory paragraph is necessary, however, giving some background about the problem, stating the importance of the project, the necessity for doing the work and what new information is needed.

5) **Review of literature.** It is important to determine the current status of knowledge about a subject before the planning and actual work on the project begins. This may save repeating work already done elsewhere with the knowledge already well accepted. A thorough literature review may give some good clues from other articles as to how to plan the work and what methods to use. Sometimes it is helpful to contact previous workers on the same subject directly and talk to them about pitfalls to avoid and to gain suggestions from them for the proposed project.

Good sources of published articles to study dealing with various aspects of plant propagation are:

Proceedings of the International Plant Propagators Society. An issue has been published each year since 1951. An index for Vols. 1 through 22 is available. The Proceedings contain invited papers presented each year at all the Regional Annual Meetings.

The Plant Propagator — (IPPS Newsletter) Vols. 1 through 25 have been published. This contains short contributed articles.

Journal of the American Society for Horticultural Science, the earlier *Proceedings* of the *ASHS*, and the companion publication, *HortScience*. These publications contain many articles dealing with various aspects of plant propagation. The last issue of the Journal each year contains an index for that year. These publications would be in libraries of universities having agricultural colleges.

Horticultural Abstracts. Monthly publication prepared by the Commonwealth Bureau of Horticulture and Plantation Crops, East Malling Research Station, Maidstone, Kent, England. Abstracts of articles on all phases of horticulture including plant propagation, taken from journals from all over the world are listed by subject matter. Horticultural Abstracts would be available in the library of universities having agricultural colleges.

U.S.D.A. Current Research Information System (C.R.I.S.). Those working in the U.S.D.A. and State Agricultural Experiment States who prepare annual progress reports under this sytem are eligible to use C.R.I.S. to obtain computer print-outs describing work in progress and the investigations involved on a given subject throughout the system. For example, a request for: PLANT PROPAGATION/CUTTINGS brought a stack of progress reports ¾" thick.

Look in the literature citations of articles you have at hand for further references of interest to the project. Often all the published literature on a subject can be tracked down in this way if good library facilities are available.

6) **Materials and Methods.** Here the description of the materials used in the experiment and the methods involved are discussed. Considerable planning should take place before the actual onset of the work. The plots should be planned so that some type of statistical analysis of the data can be made. Replicates of the various treatments are required for statistical analysis, laid out so that all receive equal treatment except for the treatment under test. It is necessary to be able to determine whether any differences obtained in the experiment are due to the treatment (s) being given or are due merely to chance.

There are some simple, easy to read, statistic books available to assist in setting up experimental plots (4).

The materials and methods described in the article should be detailed enough so that someone else could repeat your experiment from the information given. Dates, temperatures, humidity, moisture levels, light intensity and exact and correct names of plant materials used are items that should be stated.

All pertinent factors should be mentioned. For example, if rooting percentages are being reported from cuttings of a plant known to be almost impossible to root, but the cuttings were taken from a one-year-old seedling plant rather than from a mature plant, this should be stated so the reader will know that the juvenility factor is likely to be involved.

7) **Results.** Take copious, diary type notes throughout the course of the experiment. They may help explain unexpected results at the end of the trial. Keep precise numerical records of all changes taking place. For example, it is of little value to state, "that the plants in group A were larger than those in group B". Measure the height of either all, or a representative sample of plants in replicate lots of both groups. Data can be presented either in tables or as graphs.

Tables should be a condensation of raw data, brief and arranged so that the comparisons being made are obvious. Tables should also contain the statistical analysis of the data. Do not repeat data presentation in tables, graphs, and narrative. Let the narrative supplement the basic presentation of results in tables or graphs. Plan the legend for the table or graph carefully to explain clearly what the data being presented is about. Footnotes are often helpful in supplementing the legend. Graphs should be drawn with black India ink on heavy paper. Lettering should be done with press-on letters or a lettering guide (never with a typewriter). Letters on the graph should all be the same size and large enough so they will not disappear when the graph is reduced for publication (5).

When submitting graphs or drawing for the IPPS publications prepare them exactly as they need to be for publication. Do not submit pencil sketches as we have no facilities for preparing the final inked drawings.

We should be using more photographs in the IPPS Proceedings than we do. Photographs are often very effective in presenting results. For publication, use only black and white prints made on glossy, high contrast paper. Take photographs of plants out-of-doors in solid light shade, rather than in sunlight, so that distracting shadows do not appear. Take close-up shots of plants with only a few comparisons in the photo. Do not include labels in the photo; these can be added in the legend. For example, three groups of plants in a photo could be identified and described in the legend as "left", "center", and "right". A professional photo shop should develop negatives and make prints.

Prepare each figure or table on a separate sheet of 8½ × 11 paper. When preparing a figure remember that the legend goes below the figure, but in a table the legend is across the top.

8) **Discussion of results.** This is often the most difficult part of the paper to prepare but it can be the most interesting. The pertinent new information from the experiment can be pointed out and related to existing information on the same subject. Does it agree or disagree with information from previous similar studies? Statements as: "These results are in agreement with those reported by Jones ( )" are better than, "Jones' ( ) conclusions are in agreement with our results". Jones reported first. Unexplained results can be mentioned as well as areas where further work is needed. The importance of the new information developed can also be stressed.

9) **Acknowledgements.** Thank persons who aided in the study in work or advice, but not sufficiently to warrant recognition as a joint author. Give credit for financial assistance from any grant funding agency or commercial grower or industrial group.

10) **Literature Cited.** This consists of papers mentioned in the literature review and discussion sections. Only pertinent articles are usually listed to keep this section from becoming too lengthy. For IPPS publications, use the style for literature citations found in recent issues of the IPPS Proceedings.

We have been considering so far articles resulting from planned experiments where several different treatments may have been given. Some of the valuable articles appearing in the IPPS Proceedings are based, however, on results obtained by many years of observations with particular plants under particular conditions by observant horticulturists or plant propagators. This experience often involves hundreds of thousands of plants for a number of years. While no controlled experiments are set up the information obtained from such practical situations is invaluable and is certainly worth recording in the Society publications.

One of the great strengths of the IPPS is the mingling of information resulting from work by the Society members trained in the use of scientific methodology with articles resulting from observations over the years by our nursery members who have accumulated considerable information by dealing with great quantities of plant material year after year.

After the article has been written in a first draft it is advisable to have several persons read it over for clarity, grammar, and brevity. Be particularly careful to use correct plant nomenclature, using the latest accepted species and cultivar names. Consult a recognized authoritative work (3,6) to check the plant names you are using. Note that in IPPS publications, in conformity with modern plant science terminology, the word, *cultivar*, is used rather than the word, *variety*. Be careful, too, of

the word "media", which we use a lot: "media" is plural — "medium" is singular.

The final article should be typed double spaced on heavy bond white 8½ × 11 inch paper (not legal size). Three copies should be prepared — two, including the original, to go to the Regional Editor, one of which will be sent on to the International Editor. One copy should be kept by the author or authors. Carbon copies, which can get blurred, should not be submitted to the editors.

For publication in the IPPS Proceedings, all manuscripts are edited first by the Regional Editor, then the International Editor, then are checked by the Botanical Editor for accuracy of plant names. The manuscripts then go to the printer in batches, Region by Region, in the order they are received. Galley proofs are returned to the Regional Editors who sends to each author the galley proof of his, or her, article. Corrections or changes can be made by the author, Regional Editor, or International Editor at this stage. Changes should be held to a minimum, since the Society is charged for any changes made at the galley proof or at later stages. After corrected galley proofs have been received from all six Regions and Chapters (which takes about 9 months), they are returned to the printer who makes all corrections and returns a set of page proofs to the International Editor. These are compared with the corrected galley proofs for accuracy. At this stage a Table of Contents and an Index is prepared. The Secretary-Treasurer prepares the membership directory as well as an annual report to go in the front part of the book. A final "silver" proof is sent by the printer to the International Editor for a last inspection before printing is done. All photographs and line drawings have been inserted at this stage and must be checked for correctness.

After all copies are printed they are mailed by the printer in Sacramento, California to all members whose dues have been paid.

About 12 months are required from the time the first Region's manuscripts are received until the book is finally published.

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SYSTEMS APPROACH FOR OPTIMIZING NURSERY OPERATIONS

B.P. VERMA

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Mechanization of any operation is done for the purpose of increasing its efficiency. Often the attitude is taken that machines are installed to replace workers. Instead we should view mechanization as a means of improving workers' efficiency and making their jobs easier. Men and machines must work together in an integrated fashion before an overall system can be improved. Machines do not necessarily improve every situation. We must look at the entire operation before we can decide whether or not a machine is needed for a particular job. To often a machine is installed at one point in production while operations before and after are not changed. As a result the machine cannot be utilized on a continuous basis. Systems analysis can help pinpoint such problems.

Systems analysis using a dynamic computer simulation model is a logical-mathematical representation of a system used for analyzing and identifying problems in a wide variety of industrial and agricultural problems. Numerous simulation models have been developed and usefully employed in various decision-making processes and identifying critical problems in systems ranging from scheduling tillage operations to harvesting and handling agricultural products. However, this valuable technique has not been employed for nursery production analysis. This paper briefly explains how this technique can be used for analyzing a simple system and then describes the analysis of two nursery operations, soil mixing and transporting containers to the field.

Let us consider a simple system consisting of a barber and customers who are seeking the services of the barber. For our example, let us consider that only one barber is available and customers arrive randomly. It is to be determined whether there is a need to add another barber to provide an efficient service so

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Let us consider a simple system consisting of a barber and customers who are seeking the services of the barber. For our example, let us consider that only one barber is available and customers arrive randomly. It is to be determined whether there is a need to add another barber to provide an efficient service so

that the customers do not have to wait for a long time. The first step in analyzing this problem requires a complete model description and the collection of necessary data.

The model description is schematically shown in Figure 1. The customers arrive at somewhat arbitrary intervals, which may depend on the time of day and the day of the week. When a customer arrives, he is serviced immediately if the barber is free and no other customer is waiting; otherwise, he enters a waiting line. The customers leave the waiting line on a first in first out (FIFO) basis. The customers seek three types of service, (a) hair cut, (b) a hair cut and shave, and (c) a shave only. The time required for service will depend on the type of service he is seeking. After the service to a customer is completed, he leaves and the next customer enters for the barber's service.

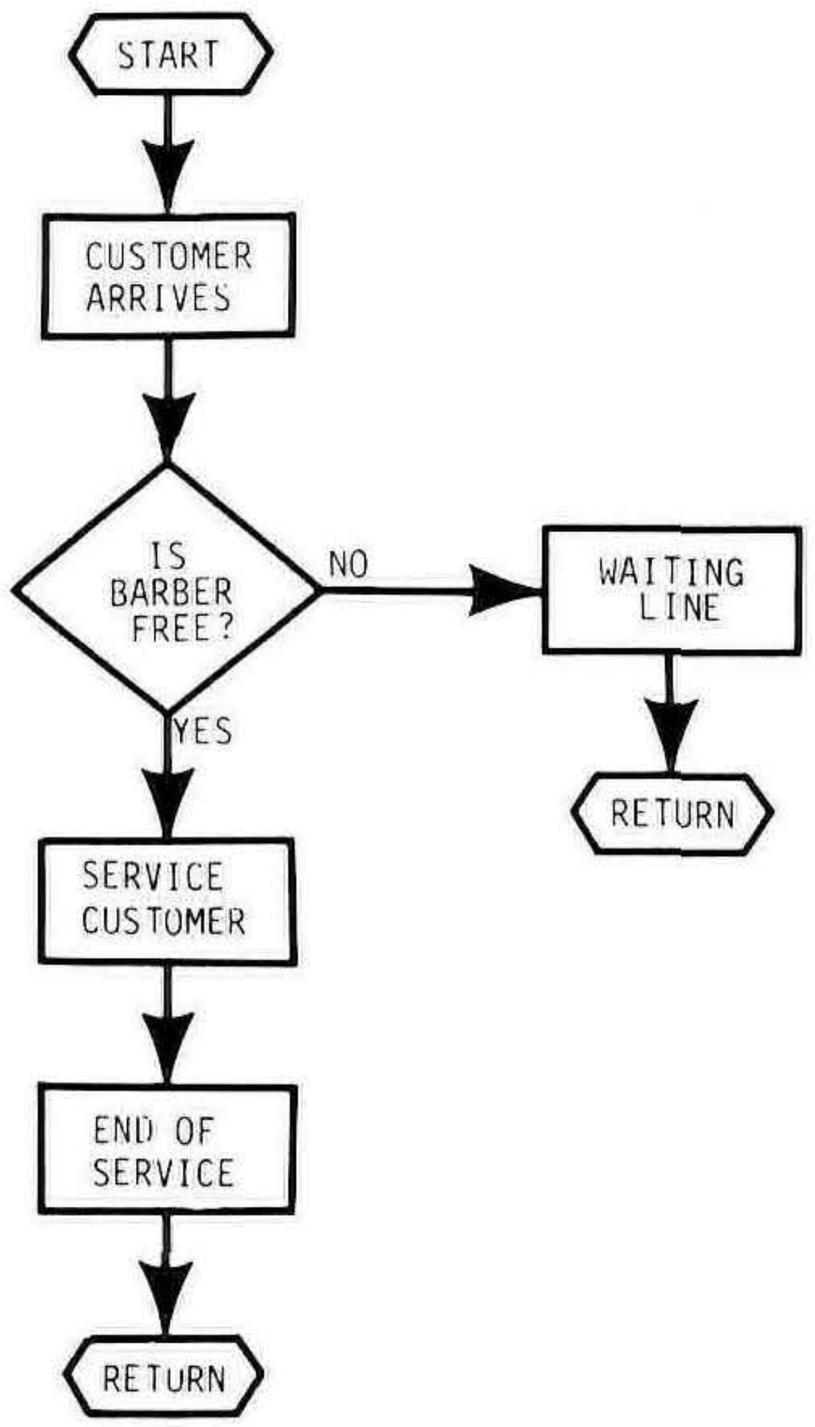

Figure 1. Model description by flow diagram of the barber shop operations.

Time data are carefully collected to develop the distributions for the arrival frequency of the customers for the time of day and the day of week, type service desired by the customers, time required to provide the service, time spent by the customers in the waiting line and the time the barber is free.

A computer model is developed in which each step of the system is carefully programmed. The time a customer arrives is determined by the use of random numbers and the frequency distribution developed from the data. The first customer is attended by the barber immediately and the time of completion of

his service is scheduled depending on the type of service sought. The type of service and time of completion is also determined by the frequency distributions developed from the collected data and random numbers generated for the particular customer. The arrival of the second customer is then scheduled and he is set to receive the service if he arrives after the first customer leaves, otherwise, he is scheduled to go to the waiting line. The third customer is similarly scheduled and so on. With each customer all the statistics are recorded and after the end of the day complete information is analysed to see the amount of waiting time, percent of time the barber is busy, etc. If excessive waiting time is recorded, the computer model can be altered to have two barbers servicing customers and similar information, such as waiting time, percent of time barbers are busy, etc. can be gathered. It is possible to then analyze to see if another barber is needed on a full-time basis or required only on some days on a part-time basis. Additionally, the cost of adding another barber can be calculated to see if it would be of economic benefit.

NURSERY OPERATIONS

From the example of the barber shop operations analysis it should be evident that any system which requires discrete and continuous operations and in which occurrences take place in a somewhat arbitrary manner, computer model analysis can be effectively used to determine those changes that will improve system output. In a similar manner, nursery operations which deal with materials handling and scheduling of sequential events can be analyzed for optimizing labor, machine and economic inputs. A system of soil mixing, container filling and container handling was proposed by Verma (7) and discussed briefly as follows. Preliminary computer models of the two sub-systems, soil mixing and container transport to the field, will be explained later in the paper.

System of Soil Mixing, Container Filling and Container Handling. A system of soil mixing, container filling and container handling is shown by the schematic diagram in Figure 2. The soil is mixed by a continuous mixer (5) and fed into a container filling machine. A container stripping machine separates the containers and places them on a belt where they are filled by the filling machine. The filled containers travel on the conveyor belt. Rooted cuttings are potted in the filled containers by hand labor as they move on the belt. The flats with the rooted cuttings are stored on inclined rollers. Laborers reach over the belt to pick up rooted cuttings from the flats. After a flat is emptied, the laborer removes the empty flat and the next filled flat rolls to the end of the inclined roller. The potted containers

move to the end of the belt where they are hand loaded onto a 4 foot × 7 foot pallet moving under the belt.

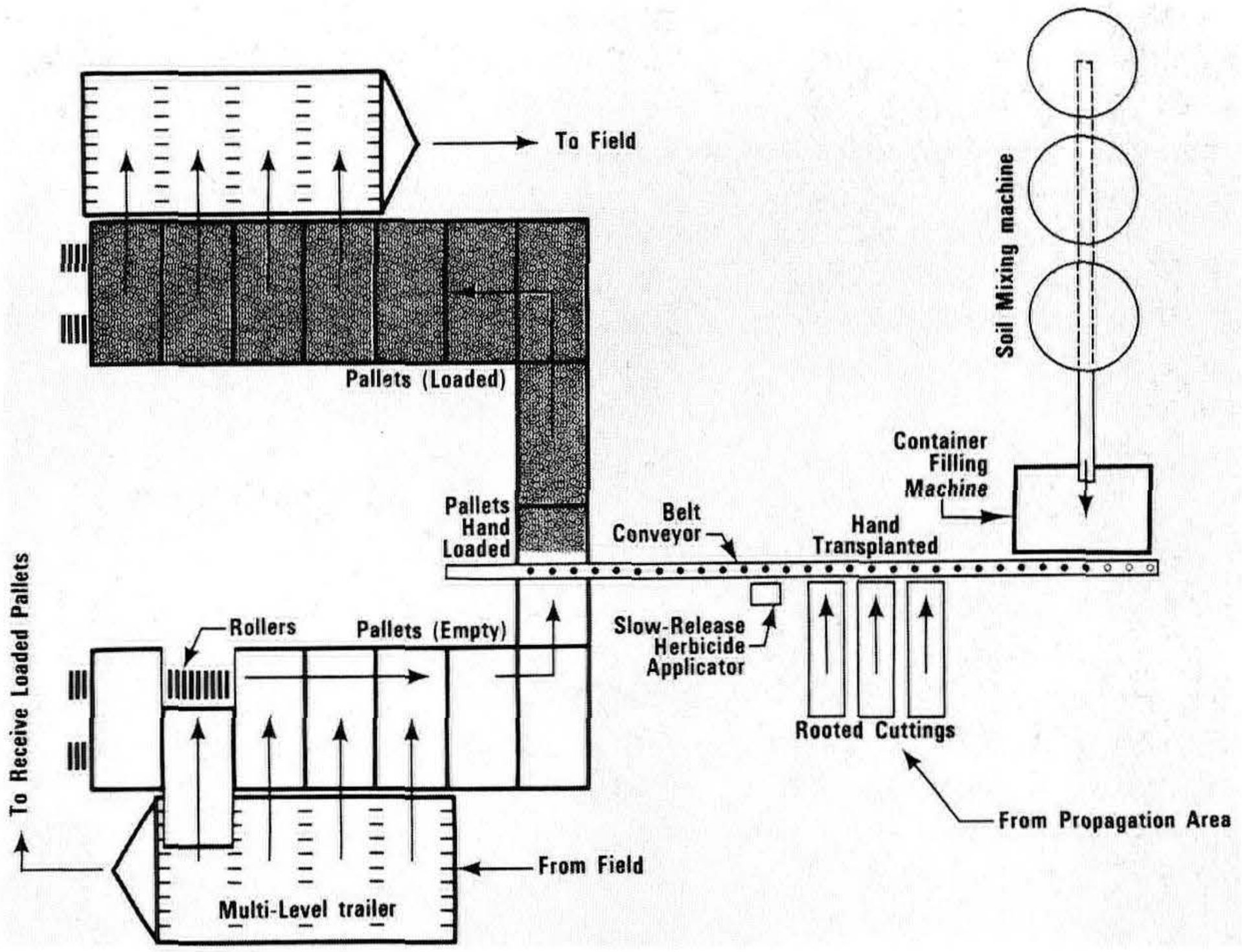

Figure 2. Overall system for soil mixing, and container filling, handling and transport.

A palletized trailer and pallets were designed for transporting containers to the field. The trailer bed is made out of 7 foot long sections of roller conveyor placed across the trailer. The rollers are placed at distances so that they support the pallets on both edges. This provides an easy way to roll the pallets in or out of the trailer bed. An arrangement was made so that the pallet can be positioned in an overhang position or taken out completely. For other details refer to Verma (7).

At the potting area a U-shaped roller conveyor layout provides an arrangement for the empty pallets to move under the belt for receiving the potted containers. The sequence of operation envisioned is that a trailer from the field will come to the U-shaped roller conveyor, unload the empty pallets brought from the field onto the conveyor and go to the other end for the loaded pallets. The loaded pallets are slid onto the trailer and the trailer will be ready to return to the field where the containers are placed on the growing area.

The overview of the proposed system as described above is an alternative method of accomplishing a task common to all container nurseries. A multitude of mixing, container filling

and transporting methods are presently employed by nurserymen. However, none of them are fully analyzed to provide a streamlined method for utilizing the labor and machines used in performing this task. For this specific system, two subsystems are analyzed in greater detail, which will be combined into the analysis of the complete system and compared with the present day system at a future time.

Sub-System I: Soil Mixing. The soil mixing operation utilized in this system is a machine developed by Verma (5). The basic components of the machine are hoppers, a conveyor belt and a rotary mixer. The materials are metered from the hoppers onto the conveyor belt forming ribbons of materials layered on each other. The rotary mixer intercepts the layered ribbons of materials, mixes them thoroughly and deposits the mixture on the belt. The mixed material is then conveyed to the container filling machine.

Let us assume that three materials are to be mixed in the following proportions: Material 1, 50%; Material 2, 25%; and Material 3, 25% by volume. One hopper is designated for each material. These materials are stored in separate pile some distance away from the hoppers and a front end loader is used to bring the materials from the piles to load the hoppers when they are nearly empty. One part-time laborer is required to drive the loader for filling hoppers. When the loader is free it is parked at pile 1 and the laborer is assigned to perform another operation in the system. Objectives in the design of the mixing operation are (a) to have laborer free approximately 80% of the time to do other operations, (b) to have a mixing rate equal to the rate needed by the container filling machine and (c) to have all hoppers at least 10% full so that mixing is not stopped.

It can be readily envisioned that several factors affect the soil mixing system: (a) Size of hoppers, (b) Mixing rate, (c) Size of loader bucket, (d) Speed of loader, (e) Distances between the respective piles and hoppers and (f) Time when the filling of hoppers is initiated. The soil mixing rate was set to fill approximately 30 "one-gallon" containers per minute. Hopper 1 was designed to have twice the capacity of hoppers 2 and 3 because the volume of material 1 in the soil mix was twice that of materials 2 and 3. Similarly, the capacity and speed of the loader were assigned with a range within which they may vary. Other variables were also assigned values (Table 1). Where it was appropriate, a range was assigned so that a value within the range may be randomly selected during the computer simulation. The system layout is schematically shown in Figure 3.

To simulate accurately the mixing operation, a flow diagram, Figure 4, was constructed describing the sequence of op-

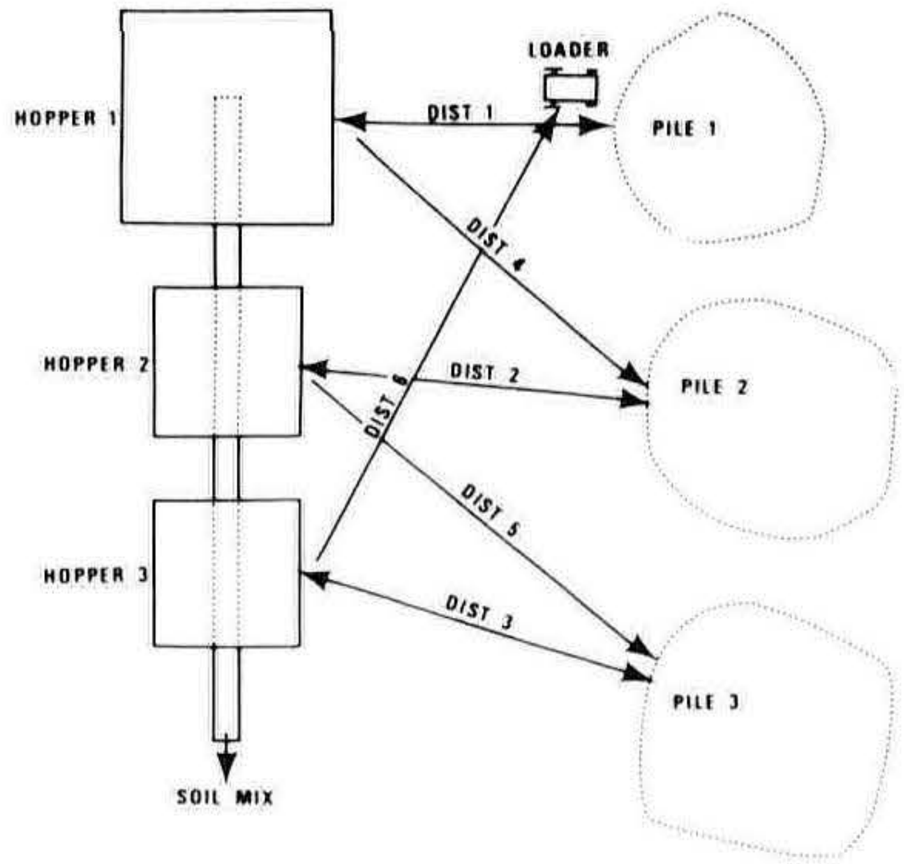

Figure 3. System layout for the soil mixing operations.

Table 1. List of variables and their values for the soil mixing system.

Variable	Description	Values
DIST (1)	Distance between hopper 1 and pile 1 (meters)	50
DIST (2)	Distance between hopper 2 and pile 2 (meter)	60
DIST (3)	Distance between hopper 3 and pile 3 (meters)	50
DIST (4)	Distance between hopper 1 and pile 2 (meters)	75
DIST (5)	Distance between hopper 2 and pile 3 (meters)	60
DIST (6)	Distance between hopper 3 and pile 1 (meters)	72
SPDL	Speed of loader (meters/minute)	144 to 225
CAPL	Capacity of the loader bucket (Cubic meters)	0.34 to 0.45
RATMX	Rate of soil mixing (cubic meters/minute)	0.075
SOIL 1	Percent of material 1 in the soil mix by volume	50%
SOIL 2	Percent of material 2 in the soil mix by volume	25%
SOIL 3	Percent of material 3 in the soil mix by volume	25%
HCAP (1)	Capacity of hopper 1 (cubic meters)	4.5
HCAP (2)	Capacity of hopper 2 (cubic meters)	2.25
HCAP (3)	Capacity of hopper 3 (cubic meters)	2.25
BCAP	Percent of the capacity of hopper 1 at which the loading begins	25%
HOP	Percent of the capacity of any of the three hoppers at which mixing stops	10%

erations. All hoppers were initially assigned to have enough material to start soil mixing. The loader is initially parked in pile 1. At each time increment a check was made to see if the hopper 1 has emptied to BCAP (25% hopper 1 capacity). If BCAP did not occur it was asked if it was the end of the day. If the day had ended, the simulation was completed for the day, otherwise the time was incremented and once again the question was asked if BCAP has occured. When BCAP occurred, it

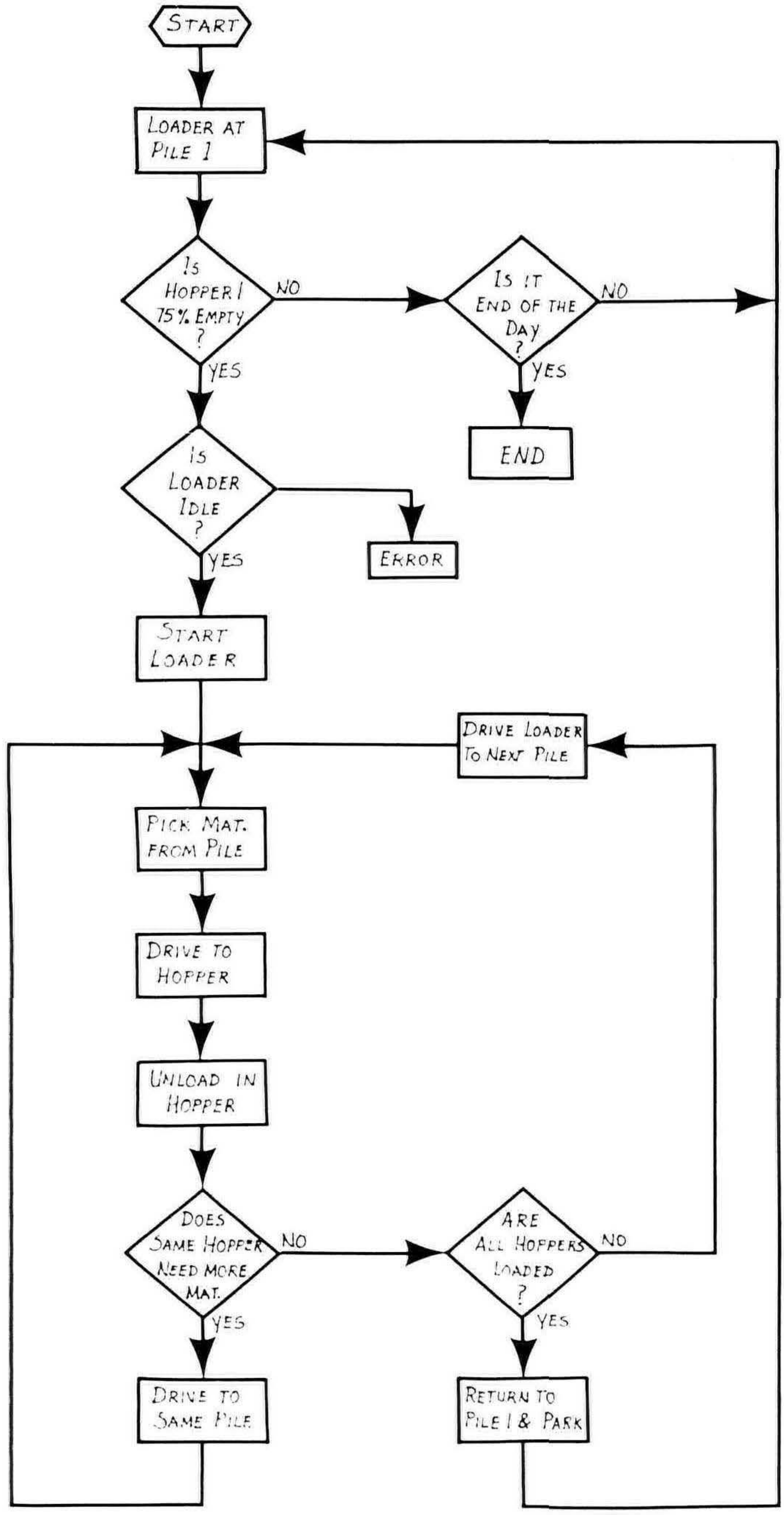

Figure 4. Model description by flow diagram of the soil mixing system.

was determined if the loader was busy. If the loader was found to be busy, an error message was printed. This was done because it would show that the hoppers are metering out the materials faster than the loader can load. Therefore, the designed system is inadequate. However, if the loader is not busy, the time to start the loader is calculated. Then time for picking material in the loader bucket, travel time to hopper 1 and time for unloading the bucket into the hopper is calculated. The amount of material dropped in the hopper is added to the amount already in the hopper. At this point, it is determined if another load can be accommodated in the hopper without overfilling it. If another load is needed, the travel time back to the same pile, time for loading bucket, travel time from the pile to hopper and dump time is calculated and the hopper status is updated. Suppose the hopper is now full, the loader is directed to go to the next pile and start loading the next hopper until it is full. Similar procedures are repeated until the last hopper is full at which time the loader is directed to return to pile 1 and park. The loader waits in pile 1 until BCAP occurs again when another loading sequence is started.

During the entire simulation, accurate statistics were recorded and maintained. Table 2 lists the values of various variables obtained for a 600 minutes soil mixing run. It was found that the loader and laborer were free approximately 81% of the time to perform other operations and hoppers 1, 2, and 3 had 2.67, 1.39 and 1.4 cu m of material on an average, respectively. The hoppers were always more than 10% full, therefore, the mixing was never stopped for lack of material in the hoppers. A total of 56, 27, and 27 loads of materials 1, 2 and 3 were dropped in hoppers 1, 2, and 3, respectively. The system was, therefore, designed to meet all objectives. Had we failed in meeting our objectives, we could redesign the system until satisfactory results were obtained.

Additionally, a plot was made of the amount of material in each hopper, permitting a visual inspection of the conditions that existed during the entire 600 minute run.

Sub-System II: Container Transport to Field. The container transport system is designed to utilize pallets and a trailer which uses pallets to form the bed. The trailer and pallet designs were briefly discussed earlier.

An empty trailer arrives at the loading dock where it receives four pallets loaded with the potted containers. The trailer then leaves for the field where the containers are set on the growing area. The trailer and the driver wait until the four pallets are empty. The trailer then returns to the unloading dock where the empty pallets are unloaded onto the roller conveyor

Table 2. Results of the computer simulation for the soil mix system.

Variable	Description	Value	Standard Deviation
QSTAR	Number of times loader started	6	
FREE	Mean percent of time loader and laborer were free	80.9	9.5
QSEQ	Number of loading sequences	6	
FILLA	Number of times hopper 1 was loaded	56	
FILLB	Number of times hopper 2 was loaded	27	
FILLC	Number of times hopper 3 was loaded	27	
TWORK	Time it took to drop load (minutes)	0.81	0.19
SSA	Mean amount of material in hopper 1 (cu.m)	2.67	0.94
SSB	Mean amount of material in hopper 2 (cu.m)	1.39	0.51
SSC	Mean amount of material in hopper 3 (cu.m)	1.40	0.51

and then it is scheduled to go to the loading dock. If either the loading dock is busy with another trailer or there are less than four loaded pallets, the trailer is assigned to a waiting line. When the dock becomes free and there are four loaded pallets, the trailer is pulled out of the waiting line and goes to the loading dock.

Before the trailer leaves for the field, it is determined whether there are enough rooted cuttings for potting. If the number of rooted cuttings goes below a predetermined number, the trailer is scheduled to detour from the field to the propagation area where it picks up four pallet loads of rooted cuttings. The trailer then travels to the rooted cuttings storage area (marked rooted cuttings in Figure 2), unloads the four loaded pallets, picks up four empty pallets and goes to the unloading dock. The process is then repeated.

The system objectives are to determine the minimum number of trailers that can move the potted containers to the field and bring rooted cuttings from the propagation area to the potting area so that (a) there are always enough rooted cuttings and the potting is not stopped, (b) the loaded pallets are moved out to the field at such a rate that there are never more than 8 pallets waiting at the loading dock, and (c) the trailer time at the waiting line is a minimum.

The container transport system was designed as shown in Figure 5. Various distance and time data required to perform tasks were chosen for the system and are listed in the Table 3. A range of values were assigned to those variables which are expected to occur. During the simulation a value within the

Table 3. List of variables and their values for the container transporting system.

Variable	Description	Value
DISTLF	Distance between the loading dock and field (m)	1080
DISTFG	Distance between the field and propagation area (m)	720
DISTGP	Distance between the propagation area and the area where root cuttings are stored at the potting area (m)	1080
DISTFU	Distance between the field and unloading dock	1350
TRIPPU	Time required to travel from the rooted cutting area to the loading dock (min.)	0.4 to 0.6
NOPPT	Number of pallets per trailer	4
NOPPP	Number of plants per pallet	100
NOLPP	Number of rooted cuttings per pallet	800
RATPOT	Number of containers potted/min.	26.7
SPOT	Travel speed of trailer (m/min)	144 to 225
TRIPUQ	Trip time from the unloading dock to waiting line (min)	0.3 to 0.7
TRIPUL	Trip time from the unloading dock to loading dock (min)	0.4 to 0.6
TRIPQL	Trip time from the waiting line to loading dock (min)	0.4 to 0.6
TWORK	Time required to unload pots in the field (min)	10 to 14
TWORK	Time required to load pallets with rooted liners in the propagation area (min)	2 to 4
TWORK	Time required to unload pallets with rooted liners and load empty pallets (min)	1.5 to 2.5
TWORK	Time required to unload empty pallets on the unloading dock (min)	1.5 to 2.5

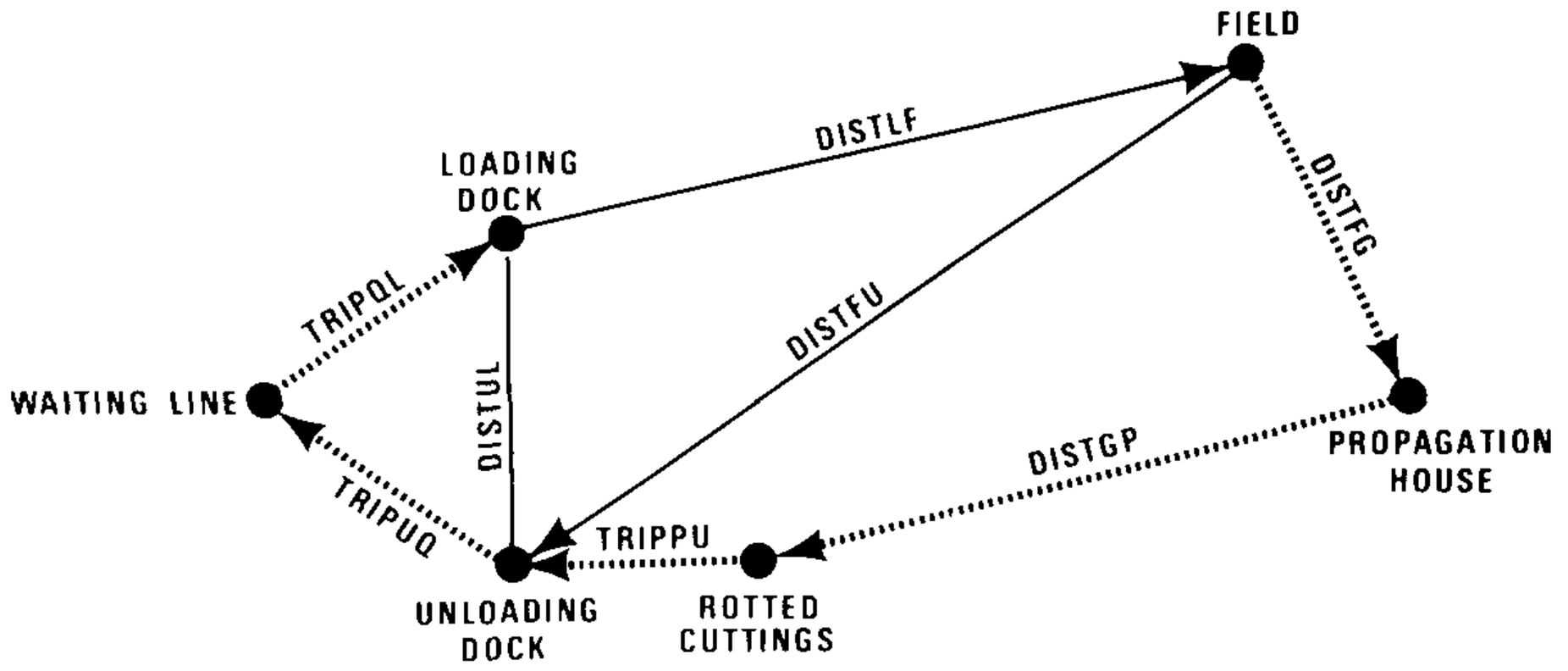

Figure 5. System layout for the container transporting operations.

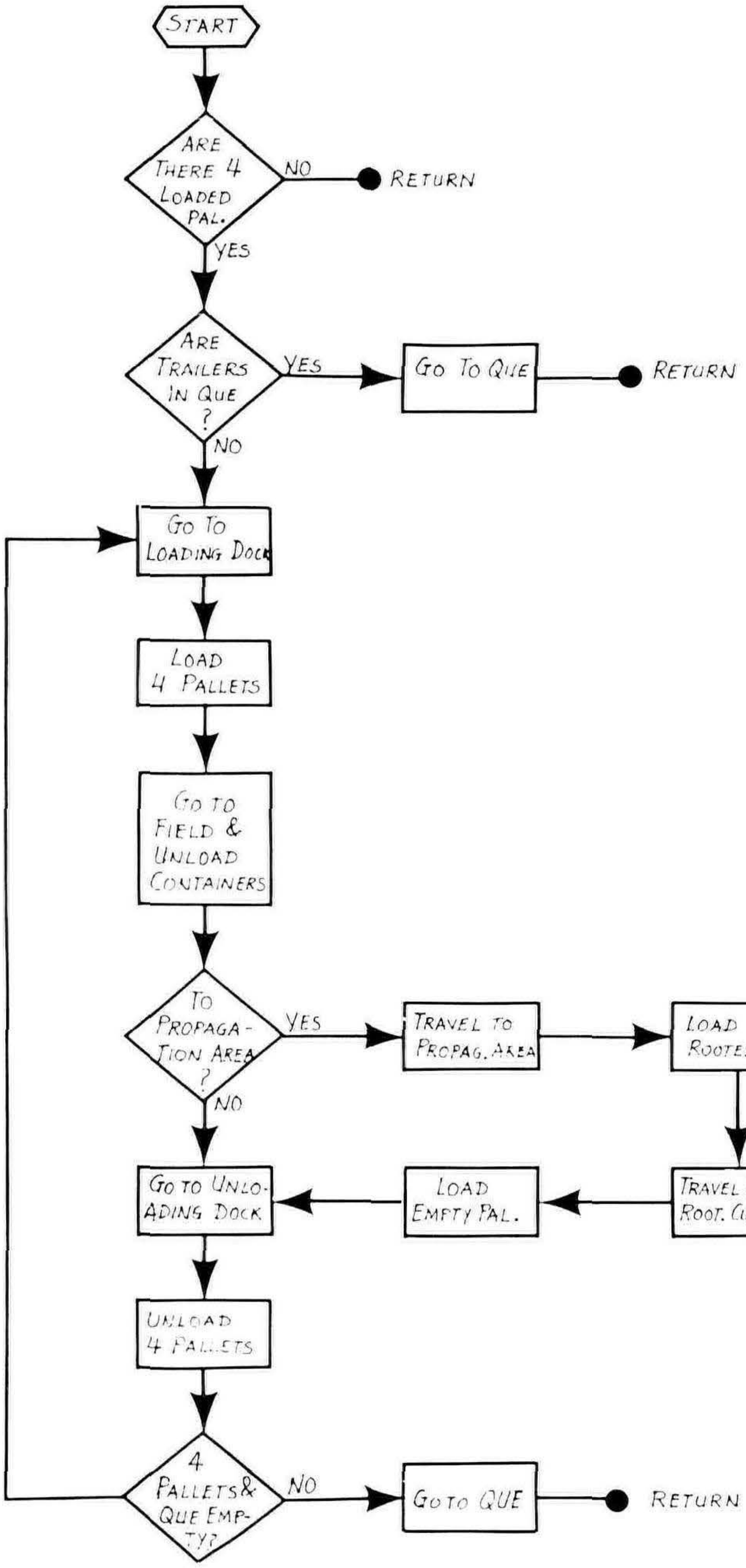

Figure 6. Model description by flow diagram of the container transporting system.

range was randomly selected.

To accurately simulate the container transporting system, a flow diagram was contructed describing the sequences of operation (Figure 6). Each step was carefully simulated in the computer model with the assigned range of values for each variable. Three runs were made using one trailer, two trailers and three trailers moving the containers in the system.

During the entire simulation, accurate statistics were recorded. It was found that when three trailers were used they were in the waiting line for an average of 15.15 minutes with maximum and minimum waiting times of 41.5 and 3.5 minutes. When the number of trailers was reduced to two in the system, the average waiting time was reduced to 0.125 with minimum and maximum of 0.0 and 1.0 minutes. In both cases, the number of loaded pallets on the dock did not exceed 8 pallets during the entire simulation. However, when one trailer was used, no time was spent in waiting, but the number of pallets at the loading dock exceeded the 8 pallet limit. In fact, at the end of the 600 minute simulation nearly 84 loaded pallets had accumulated on the dock. In all three cases the trailer was detoured to the propagation area at a mean interval of 137.1 minutes with maximum and minimum being 201.5 and 94.9 minutes.

From these results it was obvious that one trailer could not transport containers and bring rooted cuttings to keep pace with the rest of the system. Three trailers were an excessive commitment for moving containers and too much time was being wasted in the waiting line. Two trailers were able to keep pace with the rest of the system and there were no significant losses of time.

CONCLUSIONS

The simple example of the barber shop and the two simulations of the nursery operations show how systems simulation can assist significantly in designing nursery operations. To often machines have been introduced in a system without upgrading the other segments. Invariably, this has resulted in faulting the machine performance, whereas, the blame should have been placed on the support component. System analysis will minimize chances of such occurences and will provide a means of upgrading the utilization of labor, machine and other resources. Future analysis will incorporate all components into an overall system which will be efficient at all levels.

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PIECE WORK RATES AND APPLICATIONS IN PLANT PROPAGATION, PRODUCTION, SHIPPING, AND CONSTRUCTION

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We became interested in piece work applications several years ago when we realized our production rates were not as good as some other nurseries around the country. There were, in fact, tremendous differences in efficiencies from one nursery to another. Several nurseries were using piece work rates in preparing and sticking cuttings, filling pots and transplanting liners to larger containers. Our first attempt at piece work was in our propagation department and involved filling 2¼ inch pots and preparing and sticking cuttings. We met with a great deal of resistance from our employees, which could be expected with any change, especially one involving their income. It didn't take long before the better workers realized they could make 1½ times their normal pay if they worked efficiently.

We soon started applying piece work to many other nursery operations. There are advantages and disadvantages; however, the advantages are far greater. Probably the greatest advantage is that we have an established fixed cost for each operation. Other advantages to this system are the following: the jobs require fewer employees, employees make more money, we are able to attract better workers, and most employees prefer piece work. We no longer need be concerned about getting a job

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We soon started applying piece work to many other nursery operations. There are advantages and disadvantages; however, the advantages are far greater. Probably the greatest advantage is that we have an established fixed cost for each operation. Other advantages to this system are the following: the jobs require fewer employees, employees make more money, we are able to attract better workers, and most employees prefer piece work. We no longer need be concerned about getting a job

completed. The disadvantages are: there is a tendency to take short cuts on jobs, resulting in poor quality; there is a requirement for greater record keeping; jealousy may develop among workers because of differences in amount of income. The problem of poor quality can be dealt with quite easily by simply not paying for improperly done work. We have found an actual improvement in quality as employees now choose their own liners, grade, containerize and return small liners to the liner bed. We have tried using a potting machine but have found that it takes a much larger crew than we presently use if liners are graded in a way we expect. Conscientious workers soon realize they will be rewarded.

To establish piece work rates, we study the job to be done and determine the current cost. We then must decide if this cost is reasonable and if we are willing to pay that amount for piece work. We have found that if we offer them our current cost, they will usually increase production by 50 to 100% and will not waste time on breaks, lunch or rainy weather. We guarantee them a minimum of their hourly rate. If they cannot make this much, it is better for them to be replaced. Employees are in this way always able to evaluate their own performance. Good employees can make at least 1½ times their hourly rate.

Even after careful calculation and thought we have in some instances set rates too low or too high. They must be high enough to provide an incentive but not so high that the employee is able to make excessively more than on other jobs. We have consistently had trouble finding workers willing to divide liriope and on occasion have even hired outside help for this. We calculated our cost and set a piece rate of about 5 cents. Employees found they could make 2 or 3 times the hourly wage by dividing liriope. Unfortunately, it had been costing us that much. We did not change our rate until that crop was completed but did then reduce it and are still able to get plants divided efficiently.

Construction is paid on a piece work basis, and each operation is paid for separately. We have taken each step and figured its cost as a basis for establishing the piece work rate. The first step in building one of our Quonset houses is to cut the sleeves, ream them, and drill the holes. We are presently paying 40 cents per sleeve for this complete operation. The second step is to drive the sleeves in the ground, level and cement them in place. Next, pipes are bent and put into the sleeves. Purlines are put in the top, the fourth step. Ends of houses are completed, with wood used where needed for fastening the plastic. We found that we reduced the cost of building a Quonset house by 50 percent, it took about half the time, and employees made

twice as much when paid on a piece work basis.

We also pay for propagation in this way. Taking, preparing and sticking the cuttings are considered one operation. Filling containers and placing them in a house is another. The containers are watered after they are placed in the house. Seedling propagation is also handled on a piece work basis.

We have designed trailers to help solve the problem of getting containers and soil to the field. We feel the biggest problem is not in getting the soil and plants into containers but in moving them to the field. These trailers are made to hold enough soil for 2500 containers, which is slightly more than two people can fill by their morning break. They tow the trailer in and refill at that time and again at the noon and afternoon breaks. Extra time is not needed to refill the trailer during the day. On the average two people can fill more than 6500 containers each day, which includes obtaining both the containers and the soil. Piece rate also speeds up the process of placing containers in the field. We find that not only are trailers then parked as close as possible to the area being filled but that also more containers are carried each trip from the trailer to the bed.

I would like also to point out that piece rate is especially effective in improving employee performance on jobs not done frequently. Since they do not have an opportunity to develop skill in such cases, it is particularly important to provide an incentive for speed. We do very little staking and tying, and have found paying by piece rate has speeded up the process considerably.

There are some jobs that are difficult to place on a piece work basis, but these can be put on an incentive plan. We have found incentive pay can greatly increase efficiency on jobs such as weeding, for example. We give a cash bonus at the end of 3 months if a worker has kept an assigned area weed free during that time. We have also found it quite effective to give truck drivers a $5 bonus for each load that is completely delivered. This reduces the necessity of second trips to deliver single orders that might easily have been delivered on the first run if the driver had conscientiously attempted to do so. Spraying, pruning and certain spot jobs are also paid on an incentive basis. Incentives for workers are very important for successful business operation.

PLANT COST ESTIMATION: THE SOUTH FLORIDA FOLIAGE CASE

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How many of you know your individual plants costs? Few nurserymen know their cost for producing plants of a given cultivar, species or size. Most, however, make decisions where such information would be of great value. Why should nurserymen be concerned with individual plants costs?

1. Knowledge of individual plant costs will allow managers to insure that production costs are absorbed and a profit is earned when the price lists are developed.

2. This knowledge also allows managers to produce plants that return higher profits.

3. Plant cost can also serve as the basis for inventory valuation. The plant inventory is of particular importance when the nurseryman is concerned with a financial analysis since "growing plants" are usually the largest single investment item. Therefore, an accurate assessment of the nurseryman's net worth depends on accurate valuation of the plant inventory.

ACCOUNTING SYSTEMS

A general accounting system is in use at most commercial nurseries. The system is designed for reporting aggregate costs and profit. If a single crop was finished in one accounting period, the individual plant cost could be calculated directly from the general accounting records by dividing the total cost for the accounting period by the number of plants produced. Most nurseries produce several species requiring varying production times. Nurserymen must find another way to determine plant costs. Cost accounting can be used.

Cost accounting is an extension of the general accounting system. The record keeping system allows the input costs to be identified with specific plants. The costs that cannot be allocated directly to each plant are counted as overhead expenses and apportioned to individual plants on some common basis. A major drawback of cost accounting is that records beyond those for tax purposes are required.

Since record keeping is expensive, few nurserymen keep records beyond those required by law. Nevertheless, a cost accounting system would seem a must for at least the more complex nurseries. The nature of the nursery, the existing accounting system, and the degree of plant cost accuracy desired de-

termine the sophistication of the cost accounting system needed. Therefore, a cost accounting system needs to be tailored for each individual nursery.

For those nurserymen that do not want a unit accounting system, there are numerous ways of approximating individual plant costs from existing nursery records. Let's examine one method and see how it works for one nurseryman.

PLANT COST ESTIMATION FROM EXISTING NURSERY RECORDS

If a nurseryman is asked how much it costs him to produce a given plant, he usually begins to allocate the various inputs and their costs. Typically, the nurseryman enumerates the container and cutting costs and sometimes the cost of the growing medium. The other costs associated with production of a plant are more difficult to allocate directly to specific plants. The plant cost is the sum of the allocated costs plus some portion of the remaining costs. One way to apportion the remaining costs to individual plants is on the "rent" basis. Simply stated, the necessary growing space is rented to the plants. The plant cost is the sum of any allocated costs plus the "rent". The "rent" charged to each plant is determined by the amount of growing space required, the length of growing period, and the rental rate. A commonly used rental unit is a square foot, and a convenient way to state the growing time is in terms of weeks. The rental rate can then be stated as the cost per square foot per week.

USING THE WORK SHEET

To provide some assistance in applying the "rent" method of estimating plant costs, this technique has been generalized into a work sheet. The work sheet allows the user to allocate any portion of the annual nursery costs to individual plants and provides guidance and space for apportioning the remaining costs to the specific plants. Space is provided for calculating the cost of 10 plants (see Figure 1).

Estimating the plant costs for a South Florida foliage nursery illustrates the application of the work sheet.

SOUTH FLORIDA FOLIAGE NURSERY CASE

The nursery has 43,200 square feet in propagating and finishing space. Table 1 provides information on the plants for which a production cost estimate is desired. The allocated cost includes the cost of container, cutting, soil, and fertilizer. Table 2 shows the expense for 1977. Table 3 shows an investment of $159,345 on which a 10% return was desired. Let's find the cost

to produce each plant.

Table 1. South Florida foliage nursery production, 1977.

Plant	Size	Allocated cost	Weeks to grow	Sq. ft. required	Percent loss
D. marginata	6 in.	$0.65[a]	8	1	2
D. marginata	10 in.	2.12[b]	16	2.5	0
T. marginata	10 in.	3.02[c]	20	2.5	2

[a] container - $.075, soil - $.05, 1 cutting for $.40, and fertilizer - $.125.
[b] container - $.37, soil - $.25, 3 cuttings for $1.35, and fertilizer - $.15.
[c] container - $.37, soil - $.25, 3 cuttings for $2.25, and fertilizer - $.15.

Table 2. South Florida foliage nursery production costs, 1977

Item	Dollars
Cash costs	
Containers[a]	$ 5,235
Soil[a]	2,787
Cuttings[a]	26,627
Fertilizer[a]	1,081
Unallocated cash cost	92,913
Total cash costs	128,643
Non-cash costs	
Depreciation — bldgs. & improvements	3,365
Depreciation — machinery & equipment	1,803
Total non-cash costs	5,168

[a]an allocated cost

Table 3. South Florida foliage nursery investment, 1977.

Item	Dollars
Growing plants	50,661
Building & improvements	23,951
Machinery & equipment	4,733
Land	80,000
Total	159,345

Work Sheet Instructions and Explanation. The completed work sheet for the South Florida Foliage Nursery is shown as Figure 1.

Column 1. Names of the plants produced, listed in Table 1, are entered in column 1 of the work sheet.

Column 2. The unallocated cost per square foot per week is calculated in the space provided on the work sheet. The steps are:

1. Enter unallocated annual costs of $98,091 from Table 2, on line A.

2. Enter the investment of $159,345 from Table 3, on line B.

3. The desired rate of return on the investment (10%) is en-

tered on line C.

4. Multiply the investment by the desired rate of return ($159,345 × 10%) to get the annual investment cost of $15,935. Enter the annual investment cost on line D.

5. Add the annual investment cost and the unallocated annual cost (15,935 + $98,081). Enter total of annual unallocated costs plus annual investment cost ($114,016) on line E.

6. Enter the square feet in production (43,200) on line F.

7. Divide the annual costs on line E ($114,016) by the square feet in production (43,200) and enter $2.64 on line G.

8. Enter 52 on line H if the nursery was in operation for a full year.

9. Divide the annual unallocated cost/sq. ft. ($2.64 on line G) by 52, and enter the unallocated cost/sq. ft./week, $.051, on line 1 and in column 2.

Column 3. The number of weeks required to grow each plant to salable size, as provided in Table 1, is entered in Column 3. For example, the 10-inch *Dracaena marginata* requires 16 weeks to grow. The growing time used should include time that the bench is open for cleaning or repairs before a new crop is placed for growing. The growing time does not include the time that the plant occupies the bed space waiting to be sold.

Column 4. The square feet required to grow the plant should be entered in Column 4. The square feet should be in decimal terms rather than fractions. For example, if ½ square foot is required, then enter ".5".

Column 5. The unallocated cost per plant is calculated by multiplying the amounts in Columns 2, 3, and 4 for each individual plant. The product should be entered in Column 5.

Column 6. The allocated cost for each plant from Table 1 should be entered in Column 6. In the South Florida Foliage Nursery case, the allocated costs per plant are the cuttings, soil, fertilizer, and containers.

Column 7. The total cost per plant is the sum of the allocated (Column 6) and unallocated (Column 5) costs. The total cost per plant are:

6 inch *D. marginata*, $1.06
10 inch *D. marginata*, $4.16, and
10 inch *T. marginata*, $5.57.

Column 8. Not all plants reach a salable size because of damage in handling, among other things. Thus, the cost per plant needs to be adjusted for these losses. To do this, the percentage of the crop expected to reach a salable size should be entered in Column 8.

WORK SHEET FOR CALCULATING FOLIAGE NURSERY PLANT COST

Column 1 Plant	Column 2 Unallocated cost/sq.ft./week	Column 3 Weeks to grow plants	Column 4 Space per plant	Column 5 Unallocated cost per plant	Column 6 Allocated cost per plant	Column 7 Total cost per plant	Column 8 Percent salable plants	Column 9 Adjusted plant cost
1. 6" D. marg.	.051	8	1	.41	.65	1.06	.98	1.08
2. 10" D. marg.	.051	16	2.5	2.04	2.12	4.16	1.00	4.16
3. 10" T. marg.	.051	20	2.5	2.55	3.02	5.57	.98	5.68
4.								
5.								
6.								
7.								
8.								
9.								
10.								

Instructions:

Column 1. Enter the individual plant names for which a cost will be estimated.

Column 2. Calculate unallocated cost per square foot per week as follows:

a.	Unallocated annual costs (from nursery records)	$ 98,081
b.	Investment in nursery operation	159,345
c.	Desired rate of return	.10
d.	Investment cost (b × c)	15,935
e.	Annual costs plus investment cost (a + d)	114,016
f.	Square feet of propagation and finishing	43,200
g.	Annual unallocated cost/sq. ft. in propagation & finishing (e ÷ f)	2.64
h.	Weeks in operation (52 if a full year)	52
i.	Unallocated cost/sq.ft./wk., including a return on investment (g ÷ h)	.051

Enter this figure in column 2 for each plant for which a cost will be estimated.

Column 3. Enter weeks to grow each plant to salable size in Colume 3. Include normanl "down time" for cleaning and placing a new crop.

Column 4. Enter the square feet required for individual containers. Enter the number in decimals. For example, if one-half (½) a square foot is required, enter .5; if one and one-half square feet are required, enter 1.5.

Column 5. The unallocated cost per plant is calculated as: Column 2 × Column 3 × Column 4. Enter the unallocated cost per plant in Column 5.

Column 6. Enter the costs that can be allocated to the individual plants. Any cost category allocated should have been excluded from the total annual costs. Common costs that can be allocated are pots and cuttings.

Column 7. Enter the sum of the unallocated cost per plant (column 5) and the allocated cost per plant (Column 6) in Column 7.

Column 8. Enter the percentage of the plants that reach a salable size and quality. Enter the number in decimals. For example, if ¾ of the *plants are salable, enter .75.*

Column 9. The adjusted cost per plant is calculated as Column 7 ÷ Column 8. Enter the quotient in Column 9.

Figure 1. Completed Work Sheet for South Florida Nursery

Column 9. The plant cost adjusted for plant losses is calculated by dividing the amounts in Column 7 by the respective percentages of salable plants in Column 8. The adjusted plant costs are entered in Column 9.

MANAGEMENT USES OF PLANT COST INFORMATION

The plant cost estimates are of little value unless they can be used for management decisions. Simply knowing the cost and returns per plant is useful, but growing plants with the highest returns per plant does not necessarily insure nursery profits. Since plants require differing growing times and spaces, relative profitability of plants have to be compared on a common basis. A convenient basis for comparison is on a square foot per year. This is a three step process (Table 4). First, determine the returns per plant by subtracting the plant cost from the expected selling price. Second, the return per plant is reduced to a common space basis (square foot) by dividing the return per plant by the growing space required. Thrid, the return per square foot for each crop produced is multipled by the number of crops that can be produced in a year.

Table 4. Comparison of expected cost and return for south Florida foliage nursery.

	Unit	6 inch *D. marginata*	10 inch *D. marginata*	10 inch *T. marginata*
Expected				
Selling price	$	1.75	5.75	7.25
Growing & "marketing cost"[a]	$	1.45	4.65	6.19
Return over total cost	$	.30	1.15	1.06
Square foot per plant	square foot	1	2.5	2.5
Return per square foot per crop	$	.30	.46	.42
Crops per year	$	3.5	2.6	2.2
Return per square foot per year	$	1.05	1.19	.93

[a] Marketing cost, in this case is defined to be the additional cost incurred for holding the plant in the nursery during the period after the plant has reached salable size until it is sold. The plant cost, in this case, was re-estimated using the following "growing and marketing" weeks:

6 inch *D. marginata* — 15,
10 inch *D. marginata* — 20, and
10 inch *T. marginata* — 24.

The return per square foot per year for the three South Florida foliage nursery plants range from $.93 for the 10 inch *T. marginata* to $1.19 for the 10 inch *D. marginata*. In this case all

three plants are yielding an acceptable return. The cost and return for other plants grown need to be estimated to gain insight into overall nursery profitability.

Returns above all costs are necessary if capital for expansion, replacement and modernization is to be accumulated. Thus, growing plants and just covering production costs may not be desirable.

ADDITIONAL COMMENTS ON USING THE WORK SHEET

1. The individual plant costs calculated by this method are only approximations of actual costs.

2. The cost per square foot is an average. Using an average implies that all square feet in the nursery are equal in value.

3. The nursery plant costs calculated from last year's records are history. When input prices are increasing, the plant costs estimates should be updated as soon as the appropriate information is available. When large increases in input prices are expected nurserymen may even project their annual costs.

4. The annual production costs should be adjusted for changes in supply inventories during the accounting period.

5. Consider factors in addition to the plant cost estimates when establishing price lists. It may be necessary to grow plants providing lower returns in order to complete a product mix. Competitors price lists might also be helpful in developing price lists.

COLD PROTECTION OF LOW-GROWING PLANTS

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HEAT TRANSFER

In order to make the most effective use of the methods available to us for protecting plants in the nursery, it is helpful to have some knowledge of how heat is transferred. There are 3 ways heat moves — by *radiation*, *conduction*, and *convection*.

Radiant energy is energy in the form of short waves above the visible region of our spectrum. These waves travel in a straight line at the speed of light, 186,000 mps. This energy is not heat as it moves through the atmosphere, and it does not become heat until it strikes a solid object. It is, therefore, not affected by wind. On a cold, calm night a plant loses heat by radiation since any object warmer than its surroundings will lose heat to the colder objects which, in this case, would include the atmosphere. If we could prevent the loss of radiant energy from the plant, it would stay at its same temperature and would not be damaged by the cold. During the day the plant is absorbing radiant energy from the sun. It is protected from overheating by evaporative cooling during the transpiration process through the stomates.

Conduction is the method of transferring heat by actual physical passage of heat energy from one molecule to another. Although the rate of transfer depends on the thickness and chemical nature of the material through which it is moving, probably more important is the heat differential from one side of the layer to the other. When we consider this in relation to greenhouse coverings, we find that we are working within such a narrow range of thickness that the differences in coefficients of heat conduction of glass, fiberglass, and polyethlene are not important. The heat transfer coefficient is so close that we can use the same factor in calculating heat loss through a single layer covering.

Convection is another way we can move heat. Large mass movements of air transfer heat from one area to another. We use wind machines to move heat by convection.

Convection and radiation are the methods by which heat is lost when frost or freeze occurs. We have advective or radiation type freezes. When cold northern air masses move in with winds of 12, 15 or 20 mph, heat is removed by convection. We call this an advective type freeze. If, on the other hand, we have a still night with a cold, clear sky above, plants and other ob-

jects lose heat rapidly by radiation. This is usually a localized situation of extreme cold and is termed frost. It is a radiation type freeze. Even if the weather prediction is for 3° or 4° C (38° or 40°F), it is possible to get severe damage on a still night as plants lose heat rapidly by radiation. Their temperature can easily drop 10 to 12 degrees below the surrounding air.

It is assumed, when speaking to a group of plant propagators, that we will be concerned with cold protection of low growing plants and the primary objective will be protection from cold injury and not ideal conditions for rooting or plant growth. Furthermore, if we assume that the damaging temperature for most succulent plant material is at or near 0°C (32°F), then our main objective is to prevent, for a short period of time, the temperature from going below this point and thus avoid damage.

With this in mind we have a few alternatives open to us that can be employed to prevent damage. Among these are (1) erection of a temporary cover over the plant material under which heat in some form may or may not be supplied, and (2) sprinkling (overhead irrigation).

TEMPORARY STRUCTURES

Since propagation is usually done in beds having side walls of varying heights to hold the media, it becomes very easy to place some sort of temporary superstructure over the beds to support a covering material, which is pulled over the plants on a cold night. It is important that the covering not touch the plants.

There are two things we must keep in mind if this structure is not supplied with supplemental heat. We are trying, first, to stop heat loss by radiation and, second, to trap heat being brought to the surface of the soil by conduction. Since many of the covering materials are permeable to long wave radiation, we can enhance a structure's effectiveness by thoroughly watering the soil prior to covering the plants. This serves two purposes. The air over a wet soil in a closed structure is at or near 100% relative humidity. Thus, when the temperature begins to drop, condensation occurs on the cover, and this becomes a very good inhibitor of radiant heat loss. Contrary to common belief, high humidity does not increase the incidence of disease. The disease was already present. It is true, of course, that moist conditions do provide a good environment for its growth. There is some heat released as a result of condensation, which retards the drop in temperature. Also, wet soils are better conductors of heat than dry soils. Therefore, by wetting the soil, more heat is conducted upward and trapped within the cover. Employing this principle will effectively give you from 5 to 10°F protection

depending on the nature of the cold, whether it's windy or calm, for example.

On a windy night heat loss will be greater from any structure than on a still night. Heat moves across the covering by conduction and is then transferred rapidly by convection, which in turn speeds up the loss through the covering. It is impossible to say specifically how much heat loss can be reduced by any of these methods since it depends on wind velocity as well as other factors such as cloud cover. However, we have found that if we thoroughly wet a cold frame early enough to allow plant materials to dry, then cover the frame, we can maintain temperatures 12 to 14°F above outside air. This technique is used routinely by bedding plant producers.

More protection can be gained if some sort of insulating material can be conveniently placed over the outer cover. This can be straw, leaves or cloth material. If the expected temperature low is below your protection level then a source of heat can be added. This can be provided rather quickly by stringing light bulbs inside the structure. The lights can be connected to a thermostat if desired. An ordinary incandescent light bulb will give off approximately 3.5 BTU's per watt. Thus, a 100 watt bulb will give off about 350 BTU's of heat per hour. You can put 18 of these bulbs (1800 watts) on a 20 amp circuit. Therefore, a string of 18 100-watt bulbs will generate about 6,300 BTU's of heat. In addition there will be some radiant heat emitted from the bulbs. With this system, we have been able to protect tender plant material down to an outside temperature of −8°C (18°).

OVERHEAD IRRIGATION

Another means of frost protection that is usually readily available to the growers, particularly on a small basis, is overhead irrigation. The principle is based on the fact that heat is released when there is a change in phase of water. Thus, when water changes from a liquid to a solid (ice) approximately 144 BTU's of heat are released per pound of water. A gallon of water weighs about 8 lbs. and, therefore, when a gallon of water freezes, 1,152 BTU's of heat are released. On an acre-inch basis this would equal 38,000,000 BTU's of heat. The problem with overhead irrigation is twofold. First, water must be applied at a rate such that there is always liquid water present. As long as there is liquid water changing to ice, the temperature of the plant tissue underneath the ice will remain at 0°C (32°F), or the freezing point of the water. This means then that you must have sufficient water to withstand the low temperature regardless of how low below the predicted minimum it may drop. As soon as

freezing stops, the temperature of the plant drops to that of its surroundings. This implies a system in which the output can be varied considerably. These systems do not exist.

Secondly, the system must be designed in such a way that the water is not blown away from the plants if the cold is associated with wind.

Also, wind increases the evaporation rate of water, which is a heat consuming process. As the wind velocity increases the evaporation rate and the amount of water required also increase.

Another problem with overhead irrigation is that the nozzles freeze, adequate coverage is not obtained, and severe damage occurs.

Thorough and continuous cover of water is essential, for wet plant tissue freezes at a higher temperature than dry tissue. For example, dry citrus leaves freeze around −6°C (21°F) while wet ones freeze at −2°C (28°F). Although I do not know a definite reason for this, it could be because we have filled all the pores with water and have a continuous conductive surface. At any rate, if the wind shifts or the water supply is inadequate so that the freezing action is not occurring, the situation has been made worse by wetting the plants.

In spite of the problems with overhead irrigation, we have successfully protected low growing crops down to a temperature of −9°C (16°F). Thus, it works in both principle and practice.

In using this system, it is a good idea to continue sprinkling until all the ice has melted from the plants. Also, the soil must be very well drained. If it is not, water-logging will occur and plants will usually die.

In summary, then, we can see that a great deal of heat can be retained by using simple measures to reduce radiation loss. Furthermore, there are inexpensive ways to add heat to a protective structure on a short term basis. And, finally, overhead irrigation can help under certain conditions, but liquid water must remain on the plants until the danger is past.

THE MAJOR DISEASES OF HOLLY IN THE NURSERY

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Holly (*Ilex*), species represent one of the most important

groups of woody ornamentals grown in U.S. ornamental nurseries. There are numerous cultivars and hybrids with many different growth forms offered for sale. Hollies have originated in geographical regions with diverse climates and are frequently grown under conditions in the nursery that predispose them to disease. Therefore it is not unusual for disease epiphytotics to occur.

Some of the diseases that have been reported are restricted to a single species of holly (14), whereas other diseases occur on several different species (20). In addition, certain holly cultivars of a species have been reported to be more susceptible than others (5).

Under the intensive culture practices of high fertility levels, frequent irrigation, and high plant density currently employed in the nurseries in the east and southeast, holly is frequently predisposed by conditions favorable for disease development. During a particular year it is not unusual for growers to experience extreme cold, extreme heat and heavy rainfall of several days duration with resulting severe outbreaks of disease.

Foliar pathogens and soil-borne root rot pathogens have been observed to enter the nursery production cycle during propagation. High humidity and temperatures used during propagation are conducive to infection and disease. Some of the infected plants will be eliminated during propagation, but others will survive and serve as a source of infection at a later stage in the production cycle. Pathogens may reside on the leaves and stems, in the rooting medium, and on propagation containers, be splashed or blown up from the soil below the propagation containers, or be present in the water used for misting, or possibly be introduced by unsanitary practices employed by personnel during propagation.

Cooley reported that cuttings of American holly in propagation were infected by *Rhizoctonia*. Defoliation began 2 to 3 weeks after sticking (16). The stems were killed and a zonate leaf spot was characteristic of the disease.

Under culture in the field, holly is susceptible to root rots and parasitic nematode attack. Root rot organisms may be present in the soil in low populations with no apparent effect on plant growth. However, if the fields are not drained well or have impermeable sub-soils, excessively heavy rainfall may result in prolonged saturated soil conditions that favor rapid multiplication of water mold fungi like phytophthora. Plant susceptibility is also enhanced.

Fungi have been reported as pathogens of holly more frequently than any other group of organisms attacking the leaves, stems or roots. Bacteria are reported causing disease in land-

scape holly but have not been particularly damaging under nursery culture (32).

FOLIAR DISEASES

Containers of *I. crenata* grown under tightly crowded conditions of high humidity and temperature are highly susceptible to *Rhizoctonia* web or thread blight. It has been reported that during warm, humid weather, *Rhizoctonia ramicola* attacks the leaves and twigs (*I. crenata*). Dead leaves may be matted together or held suspended from the twigs by fungus hyphae, denser mats of which usually appear at the point of contact of diseases and healthy leaf blades, binding them together (46). Leaves have necrotic spots which may involve the entire blade. At maturity, the tan necrotic centers are surrounded by purplish-brown margins and the affected areas are brittle in texture, cracking and falling away under slight pressure. Diseased plants may be severely defoliated. The lowest and inner leaves and twigs are the most susceptible (Figure 1).

Figure 1. *Rhizoctonia* webblight of Japanese holly. Note dead leaves hanging from diseased twigs.

On Chinese holly, *I. cornuta*, spot anthracnose developed on the upper surface of leaves, producing lesions on the shoots and scabby lesions on the berries (38). Leaf spotting and defoliation of 'Burfordi', *I. crenata*, *I. opaca* and *I. vomitoria* may also be caused by *Cylindrocladium avesiculatum*. Small chlorotic spots appear on the leaves, turning purplish-black and enlarging to form circular lesions 10 to 15 mm in dia. Mature lesions are circular, frequently zonate, 10 to 15 mm on *I. crenata* 'Helleri', *I. opaca* 'Savanah', *I. vomitoria* 'Nana' (20) (Figure 2). English holly plantings in the northwest are susceptible to infection

by a foliar phytophthora (*P. ilicis*) (14). Rust of American holly caused by *Chrysomyxa ilicina* has been reported but is not ordinarily a serious problem (40).

Tobacco ring spot virus was reported in nursery-grown *I. crenata* 'Rotundifolia' (45). Leaves on infected holly plants were permanently distorted although no observable reduction in plant growth occurred. Symptoms on older leaves consisted mainly of irregular leaf margins.

Figure 2. Cylindrocladium leaf spot of vomitoria holly.

CANKERS AND DIE-BACK DISEASES

Canker and die-back were reported on *I. cornuta* 'Burfordii' caused by a *Gloesporium sp.* Stem discoloration on terminal twigs and defoliation occurred. Sunken necrotic lesions were present in the cortical tissues of the twigs (41). We have observed a die-back of *I. crenata* in Virginia especially where heavy pruning for shaping has been practiced.

ROOT ROT DISEASES

Phytophthora cinnamomi was pathogenic on Japanese holly (*I. crenata*) causing dark streaks extending up the crown and lower stem (25). Similar symptomology has been reported on other woody host plants. English holly growing in Virginia in the field under conditions of poor drainage was susceptible to infection by *P. cinnamomi* (27) (Figure 3).

Biesbrock, et al. reported that under conditions of water saturation, *Pythium vexans*, induced root damage in *I. crenata* 'Convexa'. *P. vexans* damage was not much affected by different soil temperatures. In contrast, *Pythium irregulare* was more pathogenic to Japanese holly at certain temperatures (9). Container media containing 100 percent pine bark infested with *P.*

Figure 3. *Phytophthora* root rot of English holly. *Left:* Field soil; *Right:* Pasteurized soil.

irregulare produced larger plants than containers of 100 percent coarse sand infested with *P. irregulare* (22).

I. crenata is susceptible to infection by *Thielaviopsis basicola* (28). Damage to roots of *I. crenata* is seen as black lesions on the tips of infected roots but may occur elsewhere on the roots. The foliage of infected container grown *I. crenata* exhibited chlorosis and the roots were stunted (Fig. 4). The roots of colonized plants bear conidia and chlamydospores on the surface and in the root tissue. Six cultivars of *I. crenata:* 'Helleri',

Figure 4. *Thielaviopsis* black root rot of Japanese holly. Healthy plant in center and disease plants on right and left.

'Hoogendorn', 'Nigra', 'Green Cushion', 'Mobjack Supreme' and 'Hetzii' are moderately to highly susceptible.

I. vomitoria and *I. opaca* are moderately resistant. *I. aquifolium* and *I. cornuta* are highly resistant (29).

NEMATODE PROBLEMS

I. crenata 'Rotundifolia' was more tolerant than 'Convexa' or 'Helleri' to the root knot nematode *Meloidogyne arenaria.* Soil containing high populations of *M. arenaria* killed Japanese holly (5). In a nematode-host study, Chinese holly (*I. cornuta* 'Rotunda') was seriously stunted by the nematodes, *Meloidogyne arenaria,* and *Tylenchorhynchus claytoni. Ilex vomitoria,* 'Nana' was damaged by *T. claytoni.* However, *I. cornuta* 'Burfordii' was resistant to *M. arenaria* in contrast to *I. cornuta* 'Rotunda' (6).

In greenhouse studies the nematode, *Criconemoides xenoplax* was damaging to *I. crenata* 'Helleri', 'Convexa' and 'Rotundifolia' (2).

Aldicarb and DBCP — two nematicides — controlled nematodes on Japanese holly growing in microplots for up to 12 months after treatment. *Paratrichodorus* and *Meloidogyne arenaria* were controlled up to 8 months in the root zone of Japanese holly with either nematicide. Stunted Japanese hollies infected with *M. arenaria* failed to make significant recovery 12 months after treatment (8).

PROTECTION AGAINST DISEASES

Holly should be propagated from healthy stock plants. The cuttings should be rooted in pathogen-free media, preferably on raised benches. Some fungicide application over the cuttings may be necessary to prevent root, stem and foliar diseases caused by soil-borne fungi like *Rhizoctonia, Pythium* and *Phytophthora.* It may be necessary to treat the propagation and container media with fumigants or heat. Consideration should be given to chlorination of irrigation water if the only water source is pond water that must be recycled. The containers used to propagate or grow in should be new or thoroughly disinfected before using.

Under field culture, poorly drained areas are likely to result in root rots caused by *Pythium* or *Phytophthora spp.* Nematodes are capable of causing severe damage to the roots of holly. Therefore, preplant field fumigation may be feasible to prevent root rots and nematode damage.

Containers in the field should be placed on crowned or well drained beds. Water used to irrigate these containers

should be free of plant pathogens. Close spacing or crowding may create the proper conditions for *Cylindrocladium* leaf spot or *Rhizoctonia* web blight. Providing air movement between the plants will usually alleviate the problem. Foliar fungicides are also suggested in some regions.

Fields with a history of plant parasitic nematodes scheduled to be used for growing holly should be fumigated before planting. Contact-type nematicides should be considered if these are registered.

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QUESTION BOX

The Southern Region Question Box was moderated by Richard Stadtherr and Jake Tinga.

JACK SIEBENTHALER: What is fly ash? Several growers are using it in their media.

JAKE TINGA: It is a slate-like waste product resulting from coal combustion and was formerly readily available.

TED RICHARDSON: Fly ash is still available from coal-burning power companies.

RICHARD VAN LANDINGHAM: Calcined clay is another product that can be used as a medium. It is manufactured by heating clay as is done with vermiculite and perlite. It is then light and sterile and is comparable to perlite.

DON CLAY: The clay is similar to Fuller's earth.

JUDSON GERMANY: We are able to buy styrofoam, which is considerably cheaper than perlite.

PETER GIRARD: It works well and is cheaper than perlite.

JAKE TINGA: It might be possible to use the waste from hot drink cup manufacturing. In addition to improving aeration I have also read a report from Germany that formaldehyde is a

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break-down product, which provides some control of soil pathogens.

S.I. PATEL: We have found that a mix composed of 1 part styrofoam and 1 part peat works well. We also have used fly ash incorporated in sand as a medium.

JAKE TINGA: It is possible to use many different products as media components, including rice hulls, castor bean meal, and peanut shells. All have advantages and disadvantages.

RICHARD SCHNALL: Can cuttings be rooted in fresh pine bark? Is IBA effective in pine bark; that is, is the hormone absorbed on the bark?

FRANK POKORNY: We have rooted quite successfully in 100 percent aged bark. IBA seemed to be effective. The only problem was an initial slow-down due to large size particles. Although we made no attempt to adjust particle size, results were good for most woody plants. Wetting was no problem in aged bark.

CHARLIE PARKERSON: In order to grow a good liner we feel we need more than just bark. The soil column in liner containers is too short to provide good aeration and continued vigorous growth following rooting.

NEWT EDWARDS: Question for Peter Girard. How do you achieve almost 100 percent rooting with deciduous azaleas?

PETER GIRARD: We use a rooting medium composed of ½ Michigan peat, ¼ perlite, and ¼ sand.

We are very careful to use sterilized sand as it often contains a large number of fungi. We make cuttings as soon as shoots are 3 or 4 inches long. They are extremely soft. We remove the lower two leaves and make a ¾ inch cut on the side. We feel this extra wounding provides more area for callusing and gives better rooting. It is important to keep the plants growing; so as soon as they are rooted, cuttings are placed under lights. If they drop their leaves the first winter, plants eventually die even though they have formed good roots. In spring they are placed in number 400 pots using a medium of ⅓ Canadian peat, ⅓ Michigan peat, ⅙ perlite and ⅙ pine bark. Fertilizer and lime are included in the mix. They are liquid fed throughout this time until the following August. We may need to pinch the cuttings twice while they are in the greenhouse. Fertilizer is then withheld and watering is greatly reduced so that the plants will become dormant. As long as they are actively growing, buds will not form. We have also found that in our area (Ohio) we must discontinue the use of Osmocote by July to avoid winter damage. Our fertilizer problems have not been caused by the fertilizer itself but by our not using it prop-

erly. Osmocote gave good results when time was allowed for new growth to harden before winter.

RICHARD STADTHERR: Are you growing under continuous light?

PETER GIRARD: Lights are on 3 minutes every 15 minutes during the dark period. Plants are in 4 foot beds; and lights are 2 feet above them.

BILL CURTIS: What kind of light do you use?

PETER GIRARD: We use clear 100 watt bulbs.

GARY HUTT: Could you just light from 10 till 2 during the dark period?

PETER GIRARD: We have had the best results with the flashing light technique. As days get longer, we reduce the lighting period to 10 p.m. until 4 a.m. During short days we use the intermittent light from 6 p.m. until 6 a.m.

VIRGINIA LASSITER: What temperature do you maintain?

PETER GIRARD: 65°F is the average temperature in our greenhouses. Azaleas do not need to much heat to grow.

TED RICHARDSON: Are you using 1 percent IBA?

PETER GIRARD: Yes. We also add Truban to the IBA. We do not water the cuttings but simply put them under the mist. If the mix becomes soggy, rooting must occur above this overwet area. We like to stay on the dry side and keep the humidity high.

GARY HUTT: What other hormones might be used?

PETER GIRARD: NAA is a possibility, but our standard practice is what I have described.

JAKE TINGA: I like to grow dry in a deep medium, even 12 inches. If the column of medium is only 2 inches, cuttings are wet the entire time.

HENRY NIENHUYS: When do you take your cuttings?

PETER GIRARD: In June or earlier if we have an early season.

RICHARD STADTHERR: Do they wilt? We think results are better if we wait until the hairs on the stem start to turn brown.

PETER GIRARD: They do wilt but recover and root well. We have tried various times and find June cutting the best.

HENRY NIENHUYS: We take our cuttings in February in the greenhouse, then plant them out in May. We can then grow them outside and avoid supplemental lighting.

TED GOREAU: A question has been asked about the propagation of *Juniperus procumbens* 'Nana', dwarf Japgarden juniper.

We grow this plant. In contrast to the method used by Bill Lawson, we do strip our cuttings to the depth that they will be inserted into the medium. We feel that this gives us more uniformity in depth of sticking. We try to get our propagators to grasp the cutting just at the lower remaining leaves, stick the cutting into the medium to this depth, and firm the medium with their two fingers. August and September are good times to take cuttings, but I believe we get our best results with cuttings taken in December, January and February. We have a higher rate of success with *J. procumbens* 'Nana' than with the standard size. In summer we use Hormodin 2, (0.4 per cent IBA), and in winter, Hormodin 3, (0.8 percent IBA). Our medium consists of 1:1:1 peat, perlite, and sharp sand. We feel it is a good mix.

RICHARD VAN LANDINGHAM: We also propagate this plant. We take our cuttings in January and February. They are stripped and placed in a sandy medium. We believe that proper watering is the key to success. It seems the more we water the more problems we encounter. We water only when necessary.

TED GOREAU: I agree that water is the key. We find it is less of a problem in open beds.

CHARLES HENDERSHOTT: There has been a question concerning cold protection when propagating hollies in cold frames. The important point is to wet thoroughly everything except the plant foliage before closing the frame. This gives the added benefit of heat transfer from the soil by the condensation of moisture on the inside. If plants are in pots, it is important to have them in good contact with the soil. Remember, the point is to maintain the plants, not grow them.

RICHARD VAN LANDINGHAM: What effect does plastic on the ground have on heat transfer?

CHARLES HENDERSHOTT: It impedes heat transfer.

S.I. PATEL: How can plants in a slat house be protected? We have tried keeping them sprinkled but have run into problems when plants stay wet for a long period of time.

CHARLES HENDERSHOTT: This is a problem particularly associated with Florida where many plants are grown outside under shade. There is no simple solution. However, one thing that can be done is to place the plants on raised beds and run water in the furrows between the beds. A well-drained soil is essential.

LYNN TABER: Is it helpful to irrigate the evening before a freeze is coming?

CHARLES HENDERSHOTT: It depends on whether the freeze is a convection or radiation type. On a calm night, irriga-

tion is usually beneficial. However, on a windy night evaporation is rapid, and temperatures are lowered due to the absorption of heat during the evaporation process. If it is a windy night, do not irrigate.

STEVE WOODRUFF: Is it possible to use Ronstar in the cutting bed without damage? Also what about a preventative insecticide program?

RICHARD VAN LANDINGHAM: We are using Ronstar successfully with hollies and pyracantha propagated in a shaded poly house. We do not routinely use insecticides.

GARY HUTT: In response to a question about using pond water, I would like to say that we have encountered no problems other than clogging the mist lines.

BILL CURTIS: There may also be algae problems, which chlorine prevents.

JAKE TINGA: Algae growth is worse in white pipes.

GARY HUTT: We have painted ours black.

BILL COLBURN: Iron bacteria also cause clogging, but this organism occurs mainly in well water.

JAKE TINGA: Using pond water in the propagation area is a dangerous practice. It is a source of serious contamination by water molds.

S.I. PATEL: In regard to a question about maximum size of cuttings, I believe that family relationship affects this.

TED STEVENS: We have rooted 5 and 6 foot crape myrtle cuttings.

BILL CURTIS: It is possible to root 3 foot heel cuttings of *Magnolia grandiflora*, but it is uneconomical to do so.

TED STEVENS: I would like to know more about propagation with 100 percent humidity rather than mist.

BRYSON JAMES: Several commercial firms are using this method. I became interested because it has been my observation that most propagation problems are due to improper watering — usually overwatering. Rooting can be done in either beds or containers using a standard rooting medium. A fungicide should be included. Water cuttings in very thoroughly, then cover the structure with a milky white plastic and about 55 per cent saran shade cloth. We find that Monsanto white plastic works well. Seal the plastic and leave from 6 to 8 weeks, depending on the species being rooted. As long as moisture condenses on the inside of the plastic during the hottest part of the day, there is 100 percent relative humidity. There is no need for mist. The only problem is excessive heat buildup. It is essential to use the white poly. However, in one case we registered 118°F

and cuttings were not damaged.

Actually this is an old method. It was originally done using glass sash, which, of course, did not provide 100 percent humidity and required much more attention to ventilation and watering.

QUESTIONS FOR H.A.J. HOITINK:

RAY SELF: How does composting affect bark suppression of pathogens?

HARRY HOITINK: We have found no evidence that composting adversely affects the control of disease by the bark. On the other hand, composting can kill the *Phytophthora* that may be present in some pine trees used for bark.

I might add that many years ago farmers used crop rotation as a major method of disease control. They felt 5 percent organic material in the top soil would control most soil-borne disease problems. The organic material can do the same thing today, and there are many waste products that can be economical bark substitutes. These include sewage sludge and waste from the manufacture of dogfood or any high protein product.

The addition of one bushel of bark to the soil around dwarf apple trees has been found experimentally to reduce the incidence of collar rot, *Phytophthora cinnamomi*, and *Pythium*. Although pine bark helps control the water molds, it seems not to have the same suppressing effect on *Rhizoctonia* as hardwood bark. Most growers have prepared their media by adding peat to hardwood bark. However, *Rhizoctonia* infection increases as the percent of peat increases. Poinsettia growers can control this problem by using not more than 14 percent peat and drenching one time with Benlate. It is not necessary to use Dexon or Truban* for water molds. A bark growing medium also reduces *Fusarium* occurrence in chrysanthemums.

Although it is not necessary to compost pine bark to remove the toxic materials found in hardwood bark, composting does improve wettability and avoids nitrogen tie-up. We have also had fermentation problems with fresh bark that was packed in plastic bags for shipment. Two weeks composting may be long enough for pine bark although a much longer time is needed for hardwood bark. Composting, therefore, serves these purposes: It reduces the amount of wood present and thus helps avoid tie-up; it removes most toxins; it improves wettability; it prevents anaerobic decomposition and fermentation.

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* Benlate; benomyl (DuPont); Dexon; fenaminosulf, (Chemagro Corp.); Truban: terrazole, (Olin Matheson).

CHARLES PARKERSON: Do we get more *Phytophthora* if we add peat?

HARRY HOITINK: Not if peat content is less than 50 per cent and other materials such as perlite or styrofoam are added to lighten the mix.

PHIL BEAUMONT: What can be done if a bark pile has become acid?

HARRY HOITINK: This problem can occur in any organic material and can be difficult to solve. It has been found that 835 pounds of lime were required to neutralize a sawdust pile with a pH of 1.9. We have had hardwood bark brought to our lab with a similar pH level, and it was extremely toxic due to the presence of volatile organic products, probably alcohols. However, one grower received a load of pinebark with pH of about 3.2 that he was able to recover by leaving it for about 6 months, then turning one time.

A simpler technique than turning a pile periodically is to use a fan for aeration. It is easy to lay a drain tile in the pile and connect it to a small ⅓ hp fan set to run 5 seconds per hour.

BRYSON JAMES: Do you lose ammonia by maintaining the high pH level you suggest?

HARRY HOITINK: At about 7.6 ammonia is untied. With 4 pounds urea per cubic yard we do get free ammonia. We try to keep pH lower than 8.5 and try to maintain about 50 percent moisture since drying also promotes ammonia loss. If we windrow compost, we do not worry about high pH. However, high ammonia levels in less well-aerated situations can kill all microflora leaving a sterile bark. This delays composting until all the ammonia evaporates and microorganisms active in composting return.

RICHARD SCHNALL: How does the use of bark affect the activity of growth regulators, especially those used in propagation?

HARRY HOITINK: Both growth regulators and fungicides are absorbed by bark. It has also been found that the pH level of hardwood bark affects the activity of the growth regulators used in poinsettia growing. However, I do not have any information on the rooting hormones.

WILL WITTE: The active ingredient is ancymidol* is tied up by pine bark also, at least when the bark is fresh. However, the reaction is not consistent.

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* Ancymidol: A-Rest, (U.S. Rubber Co.).

JIM PERRY: Dr. Hoitink, could you characterize the difference between aged and composted bark?

HARRY HOITINK: At the present we really cannot as unfortunately we know very little about the chemistry of organic materials during degradation. During decomposition pH reaches neutrality — 6.8 to 7.2.

QUESTIONS FOR C.H. HENDERSHOTT:

RICHARD AMMON: Some of the nurserymen in the north are putting barrels of water in their plastic houses. Is this an effective way of storing heat?

CHARLES HENDERSHOTT: The principle behind this practice is easier to discuss if we remember that a BTU is the amount of heat required to raise the temperature of water 1°F. Eight BTU's per gallon are released each time the temperature in the barrels drops 1° because each gallon of water weighs 8 pounds. From each 50 gallon drum 400 BTU's are released per degree until the temperature reaches freezing. It is only when water at 32° changes to ice at 32°, that we can get 1,152 BTU's of heat per gallon.

TED RICHARDSON: If the vapor condensate on the inside of the greenhouse freezes, is its effectiveness changed?

CHARLES HENDERSHOTT: Yes. In the first place, heat is released as the water changes state. It will also be an even more effective barrier against radiant heat loss. Ice may also slightly reduce loss by conduction to the plastic covering.

TED RICHARDSON: Would the frozen condensate reflect the radiation to any greater extent than does water in liquid form?

CHARLES HENDERSHOTT: Probably not. It impedes transfer but probably does not reflect radiation to any great extent.

BILL ADAMS: It might be helpful for nurserymen to know that here in Florida charts are available that tell how many inches of water should be applied to protect plants under given wind conditions.

QUESTIONS FOR ROBERT HARE:

JAKE TINGA: What time of year do you girdle the trees?

ROBERT HARE: Early spring, or when the hardwoods have fully expanded leaves. We have good success in June.

DON SHADOW: Have you tried *Fagus*?

GERALD SMITH: Or southern magnolia?

ROBERT HARE: I have not tried either of these species. However, we have been quite successful with Formosan sweetgum (*Liquidambar formosana*). We have been interested in this

tree since it can provide needed fall color in our area. For the past 10 years we have been selecting for color and now have several clones that can be easily propagated by modular air layering.

I would like to reemphasize that there are two advantages to modular air layering, as compared with conventional dry girdling. These advantages can make the method commercially feasible. The first advantage is the increased rooting success obtained by using certain chemicals and maintaining moisture. The second advantage is that mist can be discontinued within a few days after removing the shoot and containerizing. The 2 minutes required, when all materials are ready, is not excessive if high percentages of rooting and survival are possible.

QUESTIONS FOR WILLIAM H. CRIBBS:

BRAD MAY: Is anyone using the Georgia and north Florida peat?

BILL CRIBBS: Yes. Some people are using it. Obtaining the peat is difficult and requires a large commercial enterprise. There are several large deposits in northern Florida, and some peat is now being used from about six of these, including one in the Lake Apopka area. This peat also makes good fuel, so growers may in the future find competition for its use for this purpose.

TED RICHARDSON: Is there any difference between peats from south and north Florida?

BILL CRIBBS: Those I have analyzed from south Florida are not significantly different if conditions of formation have been the same. Peat from a shallow bog undergoes alternate wet and dry periods. Decomposition is much more rapid, and we get inferior peat with a high salts content. By a deep bog we mean one that never completely goes dry. Peat from these is of much higher quality.

GARY HUTT: What is the pH?

BILL CRIBBS: The north Florida peats are very acid in spite of the fact that they are formed in limestone areas. I might add that nutrient content is good. Copper is the only micronutrient that must be mixed with the peat.

HARRY HOITINK: If these peats are fibrous, as are the Canadian and German peats, I believe they will make excellent growing media. The problem we have with Michigan peats, is that they are fine, and do not provide the porosity and aeration needed to control *Phytophthora* and *Pythium*.

A REVIEW OF CONTAINER-GROWN GRAFTLINGS, AS PRACTICED BY SUNRAYSIA NURSERIES

PETER B. SMITH

Sunraysia Nurseries,
Gol Gol, New South Wales

Until recently our nursery's production of all grafted subjects was conducted in the traditional manner of lined out field rows. Inspired by a paper presented at our inaugural I.P.P.S. meeting held at Leura in 1973, presented by Mr. Roy Rumsey, "The Propagation of Container-grown roses," we determined to apply similar techniques to our crops.

As with all differing techniques, there are inevitably disadvantages and advantages when comparisons are made. In the transition from field-produced graftlings, to container-grown graftlings, we believe the advantages far outweigh the disadvantages.

Disadvantages:

Higher production costs due to controlled environmental structures, our current capital costs being: —

1) propagation (controlled environment) house, $150.00/sqm bed space.
2) seedling production polyhouse @ $9.00/sqm bed space.
3) grafting and training shadehouse @ $7.65/sqm bed space.
4) "Hardening Off" open modules @ $1.35/sqm bed space.

Higher transport costs if graftlings are shipped in containers.

Consumer Advantages.

Superior fibrous root system.
No transplanting shock — no reduction in root area or leaf area.
Extended transplanting period.
Pathogen-free potting media.
Reduced period between transplanting and subject maturity = quicker cash returns.
Reduced losses at transplanting.

Nursery Advantages.

Superior working conditions; broader spectrum of skilled craftsmen.
Superior environmental conditions = reduced losses.
60% greater density of plants per unit area.
Extended sales season.
Reduced production period = less man-hours and production closer to market demands.
Superior product = increased good will = increased sales.

PRODUCTION METHODS FOR SPECIFIC CROPS

Over the past five years we have grafted grapevines, citrus, avocados, olives, chinese gooseberries (kiwifruit), pistachio, *Prunus* spp., *Fraxinus, Koelreuteria,* and *Hibiscus;* we are currently extending our techniques to all graftlings grown at our nursery.

Grapevine graftlings. Nematode and phylloxera-resistant stocks — 'Salt Creek,' (Ramsay), 'Dog Ridge,' 'Harmony,' 'Schwarzman,' 'Teleki,' R99, 'So4,' 'K 51-32,' 'K 5 B.B.,' have all been worked to some 40 different *Vitis vinifera* cvs. Stock and scion cuttings are collected during dormancy and dipped in 0.1% "Chinasol", a surface sterilant, for 15 hours. They are stored in plastic bags at 1° to 2°C. Stocks are cut to 36 cm in length and graded into 12 grades from 5 to 15 mm in diameter. Scions are cut to single bud lengths and graded similarly. Stock and scions are bench-grafted (32 cm in length from cutting base to graft union).

Scion and union are wax covered and the cutting base dipped in 2,000 ppm IBA for five seconds. Bench grafts are packed in callusing boxes and cool stored at 1° to 2°C until required for growing on.

During spring callusing boxes are placed on heated benches in the propagating house for 7 to 28 days, depending upon stock cultivar. After root initation, callusing, and bud burst have occurred the graftlings are potted up to 3″ propagating tubes. These are placed under plastic covers, with mist, in the propagating houses for 14 days. They are then weaned from mist and hardened for a further 14 days and moved to the tube house of 75% shade. Once the graftlings are self supporting in late spring to early summer, they are moved to poly plant bags in full light. Graftlings are sold the following winter. In our own vineyards we have transplanted Doradillo/Harmony grafts in September with spring growth 15 cm to 25 cm long, trained them to vineyard trellis in the first season and cropped them at 12.5 tonnes per hectare in the second growing season, a feat certainly not possible had the graftlings been field-grown. This result is due directly to the superior container-grown root system and no transplanting check to growth.

Citrus. Stocks in current demand by our citrus industry, sweet orange, citrange, *Poncirus trifoliata,* citronella, Cleopatra *mandarin,* Rangpur lime, and *Citrus celebica* × *C. grandis* ? *(C. macrophylla)* (Alemow) have all been worked to some 38 scion cultivars with equal success.

Seed is harvested autumn to winter as it matures and is hot water treated at 52°C for 10 mins. It is cool stored at 1° to 2°C

until required for spring planting. Seed is direct sown into 3″ propagating tubes in early spring and grown on in poly houses until early summer. Tubes are potted on to 3 liter poly plant bags and put down under 50% shade.

It is imperative that seedlings are culled during this operation for "bench roots" and off type "sexual embryo" seedlings. Also the tap root must be severed to induce a fibrous branching root system, thus avoiding root binding.

The seedlings are autumn budded with dormant micro buds and grown on the following season. Stocks are cut back to the bud in late winter and scion growth is trained under 50% shade. The trees are moved to full light in early autumn for hardening off. Sales commence 19 months from seed sowing.

Bench grafting of citrus stock cuttings is a very simple operation and produces a saleable tree in the same period as seedling budding. However, the production of large quantities of graftable stock cuttings is more costly than seed production. Bench grafting is a technique which could be used to increase production in the event of late orders for certain stock and scion combinations where seedling grafts do not meet the demand.

The tops of late summer micro-budded stock can be cut off in the autumn and used as stock cuttings. These are bench grafted with whip or cleft grafts on the day of gathering, bound with budding rubber, waxed and set in 75 mm tubes, under mist. Stocks and scions unite as rooting occurs. The grafts are weaned from mist after 24 days and held dormant over winter in the tube house under 75% shade, then potted on to 3 liter poly plant bags in July and trained under 50% shade in the ensueing season. They attain saleable size simultaneously with micro-budded seedlings.

Great regard for the possibility of virus transmission should be taken if this technique is to be employed. We recommend the use only of scion material of the same parentage as that budded to seedlings from which stock cuttings are taken.

Avocado. Both Guatemalan and Mexican rootstocks have been worked to twelve scion cultivars, again with good success.

Seed is harvested autumn to winter as it matures. It is hot water treated at 50°C for 30 minutes and planted immediately in heated propagating houses. As germination commences, seedlings are transplanted to 3 liter poly plant bags and moved to poly houses. Scions are collected in a dormant state from late winter to early summer and stored at 1° to 2°C until required for grafting.

Grafting commences late winter and is completed by early

summer. Once scion growth commences and callus is evident, graftlings are moved to 50% shade for training. Sales commence 18 months after seed sowing.

Chinese Gooseberries. (Kiwifruit) New Zealanders appear to have a preference for 'Bruni' stock. For this reason we are currently using 'Bruni' seedlings; however, we have used seed of most other cultivars and successfully grafted eight scion cultivars to all seedling stocks.

Seed is harvested late winter and sown immediately after extraction in trays placed in propagating houses. Seedlings are pricked out to tubes and grown on in the tube house in 75% shade. Tubes are potted on to 2½ liter poly plant bags in early summer and grown on in poly houses. The seedlings are top-grafted by the whip or cleft graft the following winter. They are moved to 50% shade as soon as union is completed and trained. Sales commence 18 months after seed is sown. All other subjects referred to have been similarly worked with great success, using either seedling or cutting stocks budded or top-worked as with citrus production.

Conclusion. As with all nursery products, the market place dictates the terms. The demand for our container grown graftlings is ever increasing to the extent where we no longer produce any of the above mentioned crops in our field nursery.

SETTING UP A MIST PROPAGATION SYSTEM

ROB VAN DER STAAY

P.O. Box 181, Moonah, Tasmania 7009

The basic concept of any type of propagation system is to induce roots on a cutting in the shortest possible time. This is usually achieved by subjecting the cutting to an environment conducive to rooting, i.e. high humidity, low light, and zero stress. How one achieves this is left to your imagination, but I would like to discuss just one possible system. I will indicate some of the factors one should consider in the construction of a heat mist propagation bed. Construction of such a bed is relatively simple and usually gives very good results.

Site. Choice of a level site for the construction of a propagation house of any size is important. The major reasons for this are ease of construction and level installation of mist lines, reducing possible drip. General house construction may be of light-weight bubble or igloo design, or a more substantial glasshouse which has been adequately protected from corrosion.

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Water Quality. A major concern of any mist system is an adequate quantity and quality of water with sufficient pressure to operate mist correctly. Many problems have occured where water quality has been poor due to both salt and disease problems. Dissolved solids in water used for mist systems should be low for two reasons: (1) high salt water will leave a deposit on the surface, thus reducing the photosynthesis rate (very important for adequate root development), and (2) high salt levels are injurious to young roots. High salts also cause marginal burn of foliage of many crops and suppress growth. To overcome these salt problems, a relatively small desalination unit may be installed to clean up your water. Since mist systems use only a small total amount of water, a relatively small unit will often suffice. However, the unit must be large enough to prevent flow restriction when misting is in operation.

Disease pathogens in water supplies can result in almost total destruction of a crop or, at best, spread a disease throughout the nursery. To overcome this a chlorination plant should be installed. This is best sited at the source of water, i.e. at the pumping site or incoming water from main supply. A sufficiently large unit should be installed to ensure treatment of all the water used on the nursery site.

The problem of algal growth has become very noticeable with the introduction of PVC pipes. Chemicals available for control often adversely affect plants. Algae may be controlled with the use of micro-pore filters down to 5 microns. There are several types of filters, including throw-away cartridge types used in homes. Three filters in series may be needed to clear-up the algae. Larger reusable filters are also available. Filter choice should be dictated by maximum water flow required, not necessarily by volume of water used. Mist systems require large volumes of water for only 10 to 15 seconds, so the chosen filter must allow this water to flow easily. If the flow is restricted improper misting will occur.

Controller. From experience the time clock system appears to be the best form of mist control. Electronic leaves are generally unreliable at present but improving technology may change their status.

The controller will regulate the amount and frequency of water applied through the mist nozzle so it must be geared to the cutting requirements. Under hot, dry conditions high mist frequencies are required, and vice-versa. It is often better to have high misting frequency and short actual mist time, rather than the opposite. This is because one wants to keep the leaf surface moist, reducing transpiration of cutting rather than watering the cutting.

Mist Heads. Mist heads should be chosen keeping in mind the following conditions:

(1) an inbuilt filter, easily cleanable
(2) adequate coverage
(3) even mist

There are many kinds of nozzles on the market at present which do the job satisfactorily provided the correct water pressure is applied. If pressure is too low, the nozzle will not give adequate coverage. The mist will not be fine enough and will result in dry edges. If pressure is too high the mist may be too fine resulting in cloud formation, again resulting in dry spots. Mist nozzles should thus be chosen to match the water pressure on site or a pump should be used.

The use of the inbuilt filter helps prevent blockage of very small orifices in mist nozzles. This is important in filtering out any additional algal growth which may occur in the mist line.

The mist line should be level to ensure even misting. Water will find its own level and will flow to the lowest point. This means that the mist line will tend to drain itself at the lowest point during misting interval. Thus, to avoid this the line must be level. Misting times will also vary considerably if the water line is empty. It will take some time for the water line to refill before proper misting will occur over the total length of the line. This leads to longer misting times at one end and shorter at the other end, giving a wet and a dry end. Levelling the line obviates this.

There are many factors which can cause problems with insufficient water supply. This mist system supplies a large amount of water in usually a few seconds, i.e. 15 to 20 seconds. An average line probably uses approximately 9 to 13.5 l of water during this time, which is about 27 to 54 l per minute. Thus, to ensure sufficient water at the mist nozzle, feeder line size must be relatively large, e.g. 25 mm.

In the case of larger areas, more than one solenoid may be required to give an adequate mist system. Lines may be controlled independently with each line having its own controller, or electronically operating a tripping sequence of each solenoid with one controller.

Mist head spacing is very important. For a mist nozzle which has a 1.8 to 2.1 m spread, the nozzles should be placed 0.9 to 1.2 m apart. This ensures good overlap and adequate coverage.

Bench Heating. Rooting times and percentage strikes are dramatically improved by keeping the temperature of the rooting medium at 23 to 25°C (70 to 75°F). This can be achieved

either by using hot water pipes or electric cables buried in sand or concrete blocks, or directly in the rooting medium.

The amount of energy required to heat a misting bench is approximately 15 watts/square foot or 56 BTU/square foot. For example, a bench 30 × 1.8 m (100 × 6 feet) requires approximately a 34,000 BTU heater or 9 KW heating cable to hold the bench at 25°C (75°F). For a bench which does not have mist, the energy requirement is approximately half; i.e. 30 BTU/square foot or 8 watts/square foot. The figures are approximately the same for sand and cement benches. The temperature in the bench is controlled by a thermostat which turns the heat on or off as required to maintain soil temperature. To check the temperature at differing positions on the bench simply insert a thermometer into the soil mix and read the temperature.

Technical information is usually available from suppliers of mist equipment.

CAMELLIA PROPAGATION

G.K. MELDRUM

Sandy Bay, Tasmania

There are many references in the literature to the vegetative propagation of various species of plants by cuttings. In my observation the majority of these articles assume that the effect of treatment on all plant materials which can be broadly claimed as similar, will be comparable irrespective of the species. For example, commonly used commercial rooting powders are available in three strengths to meet the needs of all cuttings within the broad classifications of softwood, semi-hardwood and hardwood. I believe that such an assumption is unlikely to be valid and advance the view that there is need for further specific studies on the rooting behaviour of cuttings of various species.

This is particularly true with camellia in which root formation is so slow that the cutting may expend its store of energy, or for some other reason, die before developing a root system of its own. Such an eventuality is less likely in kinds of cuttings that root quickly. Unlike some plant species which initiate roots in cuttings through apparently intact bark, the camellia only does so through a callused wound. The propagator's success is in some measure a reflection of the speed with which callusing can be induced.

My procedure in the treatment of camellia cuttings is the consensus of opinion from the many articles available on the

either by using hot water pipes or electric cables buried in sand or concrete blocks, or directly in the rooting medium.

The amount of energy required to heat a misting bench is approximately 15 watts/square foot or 56 BTU/square foot. For example, a bench 30 × 1.8 m (100 × 6 feet) requires approximately a 34,000 BTU heater or 9 KW heating cable to hold the bench at 25°C (75°F). For a bench which does not have mist, the energy requirement is approximately half; i.e. 30 BTU/square foot or 8 watts/square foot. The figures are approximately the same for sand and cement benches. The temperature in the bench is controlled by a thermostat which turns the heat on or off as required to maintain soil temperature. To check the temperature at differing positions on the bench simply insert a thermometer into the soil mix and read the temperature.

Technical information is usually available from suppliers of mist equipment.

CAMELLIA PROPAGATION

G.K. MELDRUM

Sandy Bay, Tasmania

There are many references in the literature to the vegetative propagation of various species of plants by cuttings. In my observation the majority of these articles assume that the effect of treatment on all plant materials which can be broadly claimed as similar, will be comparable irrespective of the species. For example, commonly used commercial rooting powders are available in three strengths to meet the needs of all cuttings within the broad classifications of softwood, semi-hardwood and hardwood. I believe that such an assumption is unlikely to be valid and advance the view that there is need for further specific studies on the rooting behaviour of cuttings of various species.

This is particularly true with camellia in which root formation is so slow that the cutting may expend its store of energy, or for some other reason, die before developing a root system of its own. Such an eventuality is less likely in kinds of cuttings that root quickly. Unlike some plant species which initiate roots in cuttings through apparently intact bark, the camellia only does so through a callused wound. The propagator's success is in some measure a reflection of the speed with which callusing can be induced.

My procedure in the treatment of camellia cuttings is the consensus of opinion from the many articles available on the

subject. Cuttings are taken when the new spring wood hardens to a degree that it will snap when bent and when it changes colour from green to light brown. This normally occurs in Hobart, Tasmania, in mid-summer. Cuttings are ideally 10 to 15 cm long and cut from the parent plant at the leaf axil from which the growth originated. The lower 1 to 2 cm of the cutting is wounded by slicing the bark sufficiently deep to expose the cambium. The prepared cutting is dipped into a suspension of Captan, approximately 5 g to 500 ml of water. Until 1978 all cuttings were then treated with a commercial rooting powder named as appropriate for use with semi-hardwood cuttings. They were planted some 4 to 5 cm deep into a medium consisting of 75% coarse sand and 25% peat. As is the usual practice, they are then held in a glasshouse on a sand bed heated to 22°C and under an automatic misting system.

Using this technique approximately 65% of all cuttings set reached maturity as viable plants after one year. No reference can be found in the literature to the percentage of cuttings that a propagator might reasonably expect to raise to maturity, but the 65% achieved is not accepted as satisfactory.

Several factors which might limit the success of the operation could be recognised, but the most important probably related to the inadequacy of the glasshouse. Great difficulty is experienced in maintaining the ambient temperature in the house sufficiently low to meet the percept that the cuttings should have "warm feet and cool heads".

In 1979 two experiments were initiated with cuttings collected under conditions similar to the previous years. In the first experiment a total of 1,440 cuttings of *Camellia japonica* or *C.* × williamsii cultivars were selected at random from 128 different cultivars. After preparation these were stood for 24 hours prior to planting in a 20 ppm aqueous solution of indole-3-butyric acid (IBA) as recommended by Hartmann and Kester (3).

The cuttings were divided into four unequal groups and placed into the following media as listed in Table 1. All groups were, as usual, held in the glasshouse on a sand bed heated to 22°C and under automatic mist.

Heat and misting were discontinued after 100 days and the cuttings examined after a further 80 days (Table 1.). The bottom heat was discontinued at 100 days due to the operator's absence. If the heat had continued longer, the percentage rooted in all groups should have improved, though the relative efficiencies of the various media would probably have been similar.

The anticipated percentage of cuttings surviving to viable

Table 1. The effect of media composition on the rooting of camellia cuttings treated with 20 ppm aqueous IBA

Rooting Medium	Number of Cuttings	Number Rooted at 180 Days	Number Callused but Without Roots at 180 Days	Percentage Rooted at 180 Days	Anticipated Percentage Surviving at 365 Days
GROUP I 75% Fine Sand 25% Peat	292	20	57	7%	13
GROUP II 50% Fine Sand 25% Polystyrene 25% Peat	537	245	85	46	51
GROUP III 75% Vermiculite 25% Peat	323	220	25	68	73
GROUP IV 50% Fine Sand 25% Perlite 25% Peat	288	76	30	26	33

plants at 365 days was calculated from previous experience which showed that of cuttings well callused but not rooted at 100 days, approximately 66% subsequently rooted.

It should be stated that the fine sand used in these mixtures was much finer than that used in previous years and complied with the specifications for sand used in the U.C. System for Container Grown Plants (1). The very poor results achieved in Group I may indicate the transcending importance of a medium which will allow adequate aeration of the cutting. In retrospect, it is unfortunate that a group of cuttings was not included using the type of coarse sand tested in previous years. The results in Group III, where the cuttings strongly rooted, suggest that this medium is worthy of further investigation.

The second 1979 experiment involved 120 *C. reticulata* cuttings drawn from 10 different cultivars. This material was divided into 4 groups each containing 30 cuttings and comprising 3 cuttings from each cultivar.

Hormonal treatments were applied as listed in Table 2. Apart from the hormonal treatment, all cuttings were treated similarly to those in Group 1 of the first experiment. The results are summarised in Table 2.

Table 2. The effect of hormonal preplant treatments on the rooting of camellia cuttings.

Hormone Treatment	Number of Cuttings	Number Rooted at 180 Days	Number Callused but Not Rooted at 180 Days	Percentage Rooted at 180 Days	Anticipated Percentage Survival at 365 Days
GROUP A 20 ppm IBA for 24 Hours	30	7	10	23%	47%
GROUP B 100 ppm Ethrel for 2 hours	30	3	11	10	33
GROUP C 400 ppm IBA in 50% ethanol for 5 seconds	30	7	14	23	53
GROUP D 1000 ppm IBA in lanolin	30	6	12	20	47

The only specific reference known to me concerning hormone concentration in the rooting of camellia cuttings is that used in Group A as given by Hartmann and Kester, (3). Jacobs and Steenkamp (4) state that the method of application of IBA as detailed in Group C gave satisfactory results in the propagation of proteas. Also, Fordham (2) in propagating mountain laurel experimented with a wide range of concentrations of IBA from 500 to 80,000 ppm and recorded success throughout the whole of the range, particularly when NAA was included.

The results achieved in Group C suggest that further observations with high concentrations of IBA in the rooting of camellias are required.

The use of Ethrel in Group B follows a suggestion made by Menary (5). This compound has been shown to stimulate the synthesis of endogenous auxins. It was suggested with the thought that the plant might synthesise endogenous rooting hormones in response to ethylene.

It seems remarkable that Group A in the second experiment should have rooted so much better than Group I in the first experiment, as both received identical treatment, and Group A was of a species normally regarded as difficult to strike. It is suggested that this reaction is probably related to differences in water management between the two groups and, if so, again emphasises the critical importance of the micro-environment in the rooting media.

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5. Menary, R.C. 1978. Personal Communication.

USE OF HARDWOOD BARK IN COMPOSTS

BRUCE TIBBALLS

Montrose, Tasmania

Eucalypt bark is being composted by ponding it for 3 to 6 months and storing from 12 to 18 months prior to use. More research is needed, however as there are still a few problems to be sorted out, the method of composting and the time required being the most important.

Mr. Stan Clark, who is composting and marketing the material, believes a period of 20 to 24 months is essential to completely break down the solid particles of bark. He has found that after 18 months considerable heat returns to the stockpile if it is turned over. This pile should consist of at least 75 m^3 to get 55 to 60°C temperatures for pathogen control. This is achieved without the addition of any form of nitrogen. However, small trials in compost bins with chemicals added only gave 43°C for a period of eight days, but this then dropped back to 15.5°C.

Partly composted materials also create a problem with earthworms. They chew it up and almost completely empty tube stock, not leaving enough medium for the plant to exist on. Some toxins do remain and adversely affect growth. However, this can be improved by the addition of a nitrogenous fertilizer. Osmocote is very effective.

With some plants, particularly in the Primulaceae family, growth is excellent with rapid root penetration. We grew the best crop of polyanthus in 20 years with 100% bark, plus Osmocote, with a small amount of superphosphate added.

In the case of eucalypts and Australian natives large white roots can appear in a matter of three weeks in 12 cm pots. This

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In the case of eucalypts and Australian natives large white roots can appear in a matter of three weeks in 12 cm pots. This

can affect replanting in some cases as the root system does not always bind into the bark and tends to fall away when repotting.

There is almost complete absence of damping-off in shrub seedlings using straight bark compost provided the amount of water can be controlled. Mr. Clark is now getting almost 100% germination and growth on shrub seedlings that were previously impossible to grow. Water-holding capacity is excellent and plants do not wilt during hot weather.

The compost is weed-free but weeds do appear at a very rapid rate where seeds are introduced by physical means and, with the addition of fertilizer, their growth is even more rapid. Due to the pugginess of the material when subjected to very wet conditions, current experiments involve the addition of sand to the mix. Proteas and banksias seem to benefit more than others, but mixing sand with bark does necessitate sterilization unless it can be blended prior to composting and heated in the heap. The nitrogen requirement for hardwood bark is greater than that required for softwood bark due to a faster rate of decomposition in the hardwood.

We have used Osmocote slow-release fertilizer after composting and have found it to be very efficient although recent tests with ammonium nitrate also seem very promising.

After extensive tests in the neat bark, there were no detectable toxins present. There seems to be some evidence of antagonists as reinfection by *Pythium* and *Phytophthora* is minimal. The use of fresher bark during winter months is also advisable due to the more fibrous nature of the material.

Another problem we encountered was the fungus gnat. This pest breeds in winter months under glasshouse conditions and the control used was regular spraying with Dichlorvos. The ideal treatment would have been a drench, but growing indoor plants, we did not think that this was advisable so we gradually

Table 1. Analysis of worm casts and eucalypt bark as obtained by the Tasmanian Department of Health Services.

	Worm Casts	Eucalypt Bark
	Reaction (pH)	
	7.4	6.2
Inorganic materials	per cent	
Total soluble salts	0.11	0.10
Sodium chloride (NaCl)	0.11	0.04
Total nitrogen (N)	0.26	0.32
Total phosphorus (P)	0.08	1.03
Total potassium (K)	0.18	0.12
Total calcium (Ca)	0.69	0.68
Total magnesium (Mg)	0.16	0.17
Total sodium (Na)	0.11	0.12

diminished the problem by eliminating the adults.

Table 1 shows an analysis of eucalypt bark and of worm casts.

In conclusion, eucalypt bark can be expected to be of considerable benefit to the nursery industry in the future, particularly with the price of peat moss escalating at a very rapid rate.

USE OF SIERRA BLEND PLUS 100-DAY OSMOCOTE ON NATIVE PLANTS

GORDON LAMB

Grove Nursery,
Wattle Grove, Western Australia

When Sierra Blen Nursery Mix (19-6-10 + iron) was initially marketed in Perth, Australia it was inferred that we need not use a primary souce of nitrogen to counteract drawdown on a sand and sawdust mix. We decided to conduct our own trials to determine if this was the case, using 160 plants in 8 groups:

Group I. 4 pounds U.F.38 lime, trace elements, 5 pounds 280-day Osmocote. (Control)
Group 2. 4 pounds U.F. 38 lime, 5 pounds Sierra Blend
Group 3. 4 pounds U.F. 38 lime, 4 pounds Sierra Blend, 1 pound 100-day Osmocote
Group 4. 4 pounds U.F. 38 lime, 3 pounds Sierra Blend, 2 pounds 100-day Osmocote
Group 5. 4 pounds U.F. 38 lime, 4 pounds Sierra Blend, 2 pounds 100-day Osmocote
Group 6. 4 pounds U.F. 38 lime, 2 pounds Sierra Blend, 2 pounds 100-day Osmocote
Group 7. 4 pounds U.F. 38 lime, 2½ pounds Sierra Blend, 2 pounds 100-day Osmocote
Group 8. 4 pounds U.F. 38 lime, 1 pound Sierra Blend, 2 pounds 100-day Osmocote

The plants selected for experimentation were *Grevilea biternata, G. robusta, G. rosmarinifolia, Eucalyptus lehmannii,* and *E. platypus*. Four of each type were used in each of the eight treatments. Plants were propagated in a soil-less mix combining 1 part German peat, 1 part bluemetal and 1 part perlite with 5 pounds of 100 day Osmocote to the cubic yard.

Our normal potting mix, 2 parts sawdust : 1 part white washed sand, was used for growing on, together with the components listed above.

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The trial was conducted in late summer (February-March) when we had fairly high temperatures, 37° to 40°C, for sustained periods of up to one week. The plants were watered overhead for a period of 45 minutes once a day, with an additional late afternoon irrigation for 30 minutes on extremely hot days.

After a period of 6 weeks the plant in the 2 pounds 100 day Osmocote, 3 pound Sierra Blend group were visibly much larger and healthier than plants in any of the other groups. Plants growing in Group 2 appeared to be lacking nitrogen, and plants growing in Group 5 appeared to have their growth retarded by the additional amount of fertilizer. The growth of plants in the other groups appeared to be related to the increased amount of Osmocote and Sierra Blend.

Since these trials we have used the best formulation on several other genera and achieved favourable results with most. There were problems with bottlebrush species and some species of melaleuca.

In conclusion, under our conditions at Grove Nursery, using our water supply and Jarrah sawdust, we found that Sierra Blend did not contain sufficient primary nitrogen to counteract nitrogen drawdown. However, when we used 3 pounds per yard^3 in conjunction with a mixture of 4 pounds U.F.38 lime, additional trace elements, and 2 pounds 100 day Osmocote, Sierra Blend proved to be a satisfactory addition to our soil mix.

SOME TASMANIAN PLANTS WORTHY OF CULTIVATION

ALAN M. GRAY

Hobart, Tasmania

There are many Tasmanian endemic plants which would make admirable specimens in any garden or park. Unfortunately, most are either unknown or unavailable to the commercial nursery trade, and hence to the general public. Many of these plants are easily propagated, establish readily, and require little special attention. Some, however, do present problems in propagation and, as such, are a challenge to the amateur and professional plant propagator alike.

I have selected some species which I believe have considerable merit and the potential to become desirable ornamentals. Not only is it desirable to introduce and produce these plants on account of their unquestionable aesthetic value but, surely, as our natural forests and bushlands are being decimated at an

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increasing rate it is vital that we make the effort to preserve some of these plants for posterity.

It has been my frustrating experience that many commercial nurseries are reluctant to undertake the propagation and production of native plants — especially Tasmanian natives. It seems that this is due to two main reasons. Firstly, there is the mystery surrounding many of the aspects of the presumed special treatment required by natives. Native plants respond to the same methods and principles as are used with the large majority of well-established popular exotic species. All that is required is the willingness on the part of the nurseryman to experiment a little.

The second reason that so few natives are propagated and presented to the public appears to stem from the fear of being "stuck" with a slow or non-selling line. The nursery, having propagated and offered for sale a "new" plant that has taken considerable time, (hence money) to produce, may not be able to confidently promote to the public all relevant facts relating to the plant's requirements and likely performance. This is often due to a lack of willingness on the part of the nurseryman to undertake a little research or study. The solution is obvious.

Personally, I believe that the nursery trade in general should make greater efforts in the advertising field and, as well, take a far more active role in the research, propagation and promotion of novelties.

It is not my business to attempt to change the attitudes of nurserymen toward their production and sales approaches. Rather, I am intending to illustrate a number of Tasmania's more spectacular plant species, point out their intrinsic attractions and, hopefully, win some of you in their favour. Relevant details of each species, e.g. natural habitats, propagation techniques, cultivation and any other necessary details are outlined below:

1. *Prionotes cerinthoides*. EPACRIDACEAE. climbing heath. An epiphyte. Summer hardened tips. Light appl. hormone. Sand/peatmoss 2:1. Bottom heat 15 to 18°C. Mist, Rich leaf mould and humus. Well drained but adequate summer watering. Semi-shade.

2. *Bellendena montana*. PROTEACEAE. mountain rocket. Small alpine shrub to 1 m. Summer hardened tips, cut to a node. Hormone application essential. Sand/peatmoss 2:1. Bottom heat 15 to 18°C. Mist. Light clays with plenty of humus mixed. Well drained. Full exposure, very hardy. Seed germination very difficult.

3. *Telopea truncata*. PROTEACEAE. Tasmanian waratah.

Tall subalpine shrub to 5 m. Seed the only practical method of propagation. Sand/peatmoss/leaf mould, 3:1:1, and *STERILIZE*. Cover with maximum of 1.0 cm mix. Cool, well ventiliated area for germination. Damping-off often a problem, may require treatment with fungicide. Well-drained clay soil. Full exposure. Hardy. Can grow 50 cm/year. There is also a rare yellow form in cultivation, which has the advantage of being vegetatively propagated.

4. *Agastachys odorata*. PROTEACEAE. white waratah. Tall, subalpine shrub; does best on heavy but well drained, acid peat/humus. Cuttings. Light application hormone. Bottom heat 12 to 15°C. Mist. Potting soil and planting out situation; must have leaf mould and a pH of approximately 4.5 to 5.5. Rapid growth under ideal conditions.

5. *Eucryphia lucida*. EUCRYPHIACEAE. leather wood. The source of the famous, distinctive Leatherwood honey. Cutting or seed, (if available). Cuttings do well in 2:1 sand/peatmoss mix. Bottom heat not essential. Mist recommended. Deep rich humus — rich soils for maximum development. Rapid grower; may flower at a very early stage. Should be more widely planted in plantations to ensure continuation of nectar supply. Forestry operations are gradually limiting the natural range of the species.

A small alpine variety, *E. lucida* var. *milliganii*, is also worthy of attention. There is a pink form of this currently under cultivation.

A variegated form of this plant is now in cultivation and has been registered as cultivar, i.e. *Eucryphia lucida* cv. 'Leather-wood cream'.

6. *Anopterus glandulosus*. ESCALLONIACEAE. native laurel. Dense shrub with large, glossy leaves and large spikes of delicate white or pinkish flowers. Cuttings. Hormone. 2:1 S/P mix. Bottom heat, 12 to 15°C. Mist. Deep, moist, slightly acid soil. Faster grower in good conditions. Some shelter desirable.

7. *Geum talbotianum*. ROSACEAE. Geum. Densely tufted alpine ground cover. Large wrinkled leaves, exquisite white flowers. Divisions, seed. Supply of each would need to be investigated or arranged. Damp soaks among clefts in rocks. Rich leaf mould. Tolerates much exposure.

8. *Dacrydium franklinii*. PODOCARPACEAE. Huon pine. A large but very slow-growing tree in nature; develops rather more rapidly in a garden situation provided the soil is deep, fertile and constantly moist. Cuttings extremely easy to strike. Pure sand or just a little peatmoss. No hormone. Mist and, for faster results, bottom heat, approximately 15°C. Pot into 1:1 sand bush leaf mould. Fairly sheltered location in garden; deep,

constantly moist soils. If cuttings are stored in the refrigerator crisper the root number increases by 50%.

9. *Microcachrys tetragona*. PODOCARPECEAE. Creeping pine. This is not a "pine"; however, it is a true conifer. An alpine species which may cover areas of more than 4 to 6 m on some Tasmanian mountains. It rarely grows more than 4 to 8 cm in height and is commonly observed creeping over rocks and draping down banks. Tolerates extreme exposure and low temperatures. Cuttings easy although a little slow. Bottom heat and mist greatly assist. No hormones. Excellent rockery plant or potted specimen. Heavy soil with much humus, constant moisture.

10. *Microstrobos niphophilus*. PODOCARPACEAE. A miniature conifer from the Tasmanian mountains. Grows to 3 m. Cuttings slow but with high strike rate. No hormone. Heavy humus, moist but well-drained. Good hedge or tub specimen.

11. *Diselma archeri*. CUPRESSACEAE. cheshunt pine. Very similar, superficially, to the last. The leaves and fruit differ. The shrub may reach 4 to 5 m high and with similar spread. The habit is also a little more "formal". Cuttings and similar treatment as for *Microstrobos*; a little easier to strike. Birds eat the berries and regurgitate the pellets containing seed which then germinate well.

12. *Athrotaxis selaginoides*. TAXODIACEAE. King Billy pine. *A. cupressoides*. pencil pine. *A. laxifolia*. loose-leaved pine. These three species are often large, majestic forest trees, but all three make magnificent garden specimens and grow considerably faster than in the wild. Cuttings or seed. Cuttings callus easily but may take some time to root; roots are fragile. Bottom heat (15 to 18°C) and mist greatly assist. Sand/peatmoss, 2:1. Seed must be fresh, sown thinly and covered no deeper than 5 to 8 mm, moist but never saturated. Care must be taken to avoid damping-off with young seedlings. Trees tolerate exposure. Deep, humus-rich, moist soils. Growth can be surprisingly rapid: 2 to 3 m in 10 to 12 years.

13. *Nothofagus gunnii*. FAGACEAE. tanglefoot. Australia's only truly winter deciduous tree. Subalpine, a magnificent display of golden-bronze leaves in autumn. Seed only. Must be fresh; 4:1 sand/peatmoss. Sow thickly, little heat. Moist but not saturated. Stratification, 8 weeks at 2 to 3°C (after sowing) can be advantageous. Pot as soon as possible after seed germination. Leaf mould and peat moss with a little light clay in the proportions of 4:2:1 is ideal. Cool root-run is essential; moist, well drained site. Ideal for tub planting or miniaturizing. Grows best

at high altitudes, e.g. 3000 ft.

14. *Senecio centropappus* (Syn.: *S. brunonis*). ASTERACEAE. tree groundsel. Occurs naturally only on Mt. Wellington, near Hobart. Cuttings have not yet been successful as far as is known. Seed is easily collected and germinated. Sand/peatmoss mix, 2:1. Does best in clay soils. This beautiful plant is a rapid grower.

15. *Richea scoparia*. *R. dracophylla*. EPACRIDACEAE. Two spectacular heaths from the mountain regions of Tasmania. Propagation from cuttings has, so far, proven almost impossible. Seed is produced in enormous quantities, however the length of viability is very short — perhaps one or two days; seedlings are minute. The propagation of *Richea*, (there are 10 species in Tasmania and one in Victoria, New South Wales and the Australian Capital Territory) poses a very interesting challenge.

16. *Cyathodes* species. EPACRIDACEAE. cheese berry, pink mountain berry. These spectacular "berries" have yet to be produced from seed, the technique for success still eludes the plant propagator. Cuttings are difficult and very slow. The *Cyathodes* plant is yet another challenge.

17. *Gunnera cordifolia*. HALORAGACEAE. A prostrate subalpine plant. Spreads rapidly by long runners. The plant is easily propagated by divisions. Will grow in wet, boggy situations and, thus, makes an excellent ground cover in such conditions. One plant may cover 1-2 m^2 in area.

18. *Leptospernum humifusum* (Syn.: *L. rupestre*). MYRTACEAE. creeping ti-tree. A high altitude plant, usually creeping over boulders and mounds but occasionally ascending up to 1 to 2 m. Very hardy and easily propagated from seed or cutting. Cuttings taken from a prostrate plant will grow accordingly; seedlings might be prostrate or erect. Sand/peat moss, 3:1 for seed or cuttings; sow seed thickly, but shallowly.

Problems and challenges for the plant propagator:

Bellendena montana	seed
Telopea truncata	cuttings
Nothofagus gunnii	cuttings
Senecio brunonis	cuttings
Richea species	cuttings (seed viability problems)
Cyathodes species	seed (need a more efficient cutting method)

NUTRIENT FILM CULTURE

RON RICHARDS

Department of Agriculture, Tasmania

The nutrient film culture (N.F.T.) method of growing plants was devised by Dr. A.J. Cooper of the Glasshouse Crops Research Institute, Littlehampton, England. Basically it consists of growing the plants with their roots contained in a narrow channel and moistened with a warm flowing nutrient solution only a few millimetres in depth. Deeper solutions are being used in some situations with reasonable success but are not truly N.F.T. and will not be considered in this paper.

All the essential chemical elements needed for plant growth are contained in the flowing film of nutrients. Following uptake of nutrients, the acidity varies, and adjustments are made with phosphoric or nitric acids. The depletion of nutrients may be measured electrically and adjustments made using specifically formulated "top-up" solutions.

In Tasmania six commercial enterprises are currently using N.F.T. to produce crops of tomatoes, and experiments are in progress with cucumbers, carnations and chrysanthemums. Although package equipment is available from commercial firms, most growers have decided to develop their own systems of channels and ancillary equipment. All are growing on polythene film, folded into triangular shape and either resting on sloping soil or supported above the ground on wooden or steel structures.

Why should growers be interested in growing plants by this different technique? Elimination of costly and tedious soil sterilization and the promise of improved yields motivate most. To date, most growers are well pleased with the results, even though most admit some mistakes in operation and acknowledge that improvements in technique are needed. Most intend enlarging the installation next year.

What are the possibilities of this technique for the nurseryman? One suggestion has been for slow-growing plants. Growth obtained in one year of N.F.T. has been equal to that obtained in three years by conventional methods, mostly as a result of the warmer solution and optimum nutrient concentration.

The plants would need to be potted on and allowed to develop soil roots before sale. The possibility exists for the development of special rooting solutions for cuttings. The solutions could initially be enriched with callus-inducing growth substances. These cuttings could be supported in special re-

moveable racks facilitating inspecting at different stages of growth with minimal shock to the plants.

Whether N.F.T. continues to expand will depend on its competitiveness with conventional methods of cultivation. It is significant that this is the only form of hydroponic growing that has made significant progress in established growing areas.

REFERENCES

Cooper, A. "Commercial Applications of N.F.T." Grower Books, 49 Doughty St., London.

Cooper, A. "The A.B.C. of N.F.T." Grower Books, 49 Doughty St., London.

pH AND SALINITY DEMONSTRATION AND INTERPRETATION

ROB VAN DER STAAY

P.O. Box 181
Moonah, Tasmania 7009

pH MEASUREMENTS

There are many forms of pH meters available today. These range from pH soil testing kits for less than $10 in garden shops to very expensive and elaborate units found in research laboratories costing in excess of $600. Meters available for soil testing can be reasonably priced at about $200 and give very reliable and accurate results. The only reliable measurement of pH is via what is called a glass bulb pH electrode. When purchasing such a pH unit or electrode, get what is called a combination electrode, as it has its reference and pH electrode built in one; pH electrodes require what they call a reference electrode, but purchase of a combination electrode will not necessarily mean a purchase of another electrode.

Measuring pH is relatively simple in soil. A simple procedure is to take a sample of soil in a clean cup or beaker and add sufficient water to make up a paste rather like a sloppy mud-pie mix. Mix well and allow to stand for approximately 15 to 20 minutes. Mix again and simply insert the electrode into the mixture. Read the pH on the scale of the meter. After reading, wash the electrode down with clean water; store in clean water when not in use. The pH meter must be calibrated before use and this can only be done by immersing the electrode in a standard pH solution. Adjust the pH on the scale to the known value of the standard and you have just calibrated your instrument.

Temperature is important when measuring pH because it

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Temperature is important when measuring pH because it

varies with temperature. Usually you can correct for temperature by a setting on the temperature control knob on the pH meter.

SALINITY

Measurement of salinity in soil is slightly more difficult. The pH sample you have prepared can again be used for salinity reading. Now we must extract the water from the paste, using a vacuum pump and filter. A simple water pump can be used for this. After extracting the liquid, salinity measurement is easily done by simply inserting a conductivity electrode in the solution and reading the meter.

For water samples, little preparation is required. Simply, insertion of the electrode and reading the meter is all that is required.

However, there are some problems with salinity including what do these readings mean and what type of instrument to purchase? Let's deal with the latter point first. The salinity meters vary considerably in appearance but they are all basically the same. The thing you must watch in the purchase of a meter is the type of units the meter reads. All the salinity information of any consequence is given in a unit called micro-mho or milli-mho. 1 m−mho = $10^3\mu$−mho. Again, the choice of electrode is important. Since soils and irrigation water have relatively low salt levels, before damage is done to crops, a cell constant (K) of 1 should be purchased. This enables you to directly read your meter without having to worry about correction factors.

Salinity or conductivity meters measure the conductance of a solution which, in turn, is a measure of the number of cation or anions in solution; i.e. how much dissolved salts are present in solution.

For water, a conductivity range in irrigation water has been developed over the years and follows something like this.

Low salt water	< 0.75 m−mho
Mod. salt water	0.75 - 2.0
High salt water	2.0 - 3.0
Very high salt water	< 3.0 - causing severe problems.

For soils, using the above technique for determination, the following ranges apply:

0 - 2	Salinity effect mostly negligible
2 - 4	Yields of very sensitive crops may be restricted
4 - 8	Yields of many crops restricted
8 - 16	Only tolerant crops yield satisfactorily
>16	Only a few very tolerant crops yield satisfactorily

Most crops grown in nurseries are found to grow best when

soil salinity is below 4, otherwise salt problems do occur. Salt levels can be controlled by leaching or high frequency irrigation if saline water is used for irrigation. With the installation of liquid feeding using very soluble fertilizers; these fertilizers add to the salinity problem. For example, if we use 2 lb ammonium nitrate to 1,000 gallons you add approximately 0.4 to your conductivity reading. If you add, say, 1 lb potassium nitrate per 1,000 gallons also you, in effect, add 0.33 to your reading, giving you an overall salinity addition of 0.73 m mho. These levels can be very important if you already have high salt water levels. So to reduce the effects of salt, care must be taken in the selection of fertilizers and quantities used under liquid feed programmes.

CONTROL SYSTEMS FOR PROPAGATION

PENELOPE ROSE and LYNNE TWENTYMAN

Forest Native Nursery
Sydney, New South Wales

A "system" may be defined as a method for the collection and presentation of facts. Its only product is information. Information collected from the system enables decisions to be made which, in turn, improve efficiency by allowing the maximum use to be made of resources and labor.

While the various operating areas of a nursery are intimately related, each one can be considered as a separate entity from the point of view of a systems design (Figure 1).

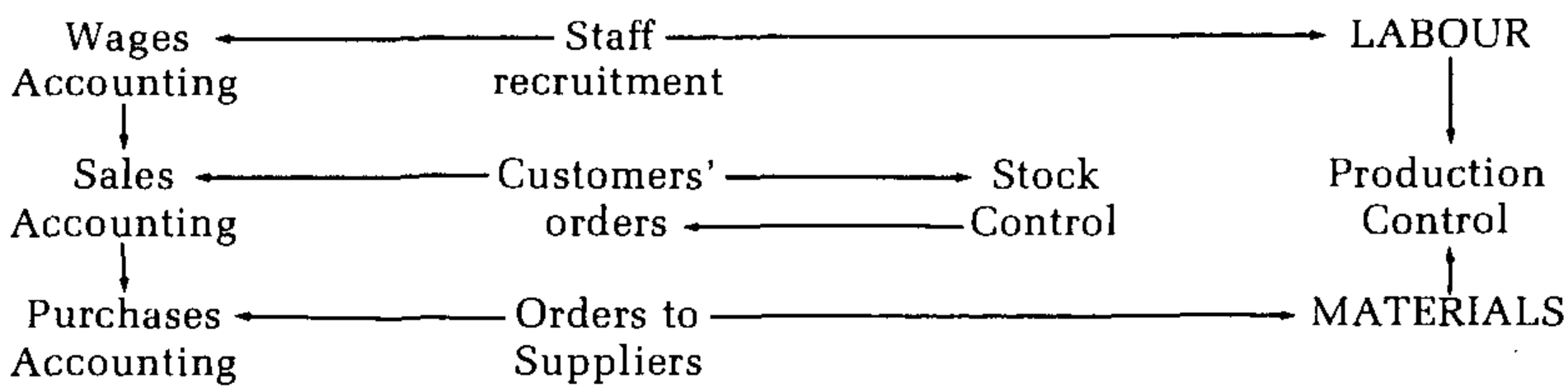

Figure 1. Interrelationships of Various Information Systems in the Nursery

It is readily accepted that every nursery has some kind of "system" for accounting, and within this system, separate methods for processing of wages, sales and purchases. It is not so readily accepted that every nursery should have a system for the control of its stock and production. Before proceeding to designing the system it is necessary to consider fundamental requirements for any system. These are:

1. It must be cost efficient. This means that it must not

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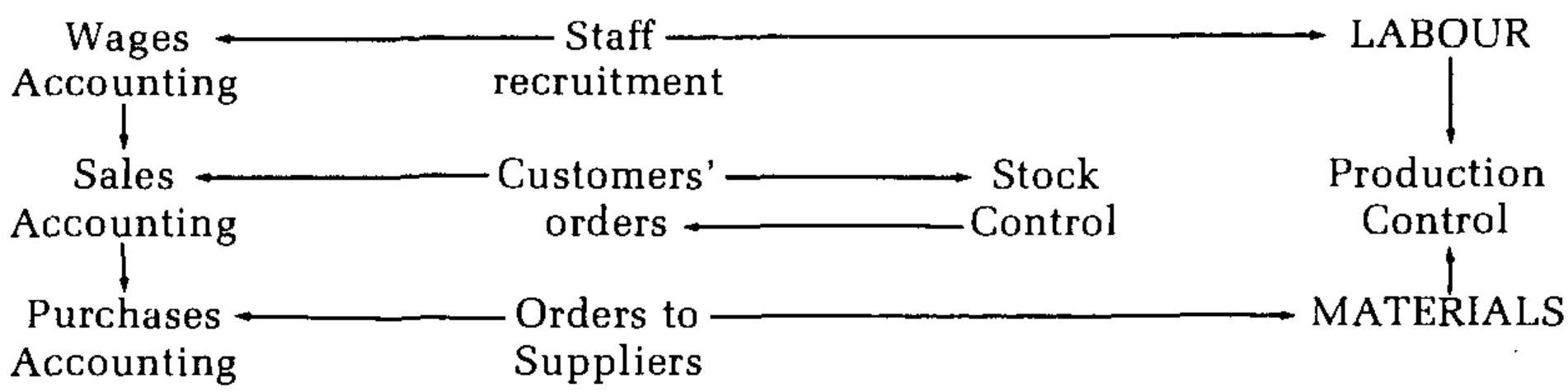

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1. It must be cost efficient. This means that it must not

demand more in time and effort than it returns in effective, useful information.
2. It must be capable of being used over a long period by competent but average intelligence personnel.
3. It must be flexible, that is, capable of coping with changes in the operation and also of being expanded or even absorbed into a larger and more comprehensive system.

The first step in systems design is to investigate fully the requirements of the operation for which it is to be used. To illustrate this, we propose to consider the design of a low-level or manual system for the control of seedling production for eventual sale in containers (Figure 2).

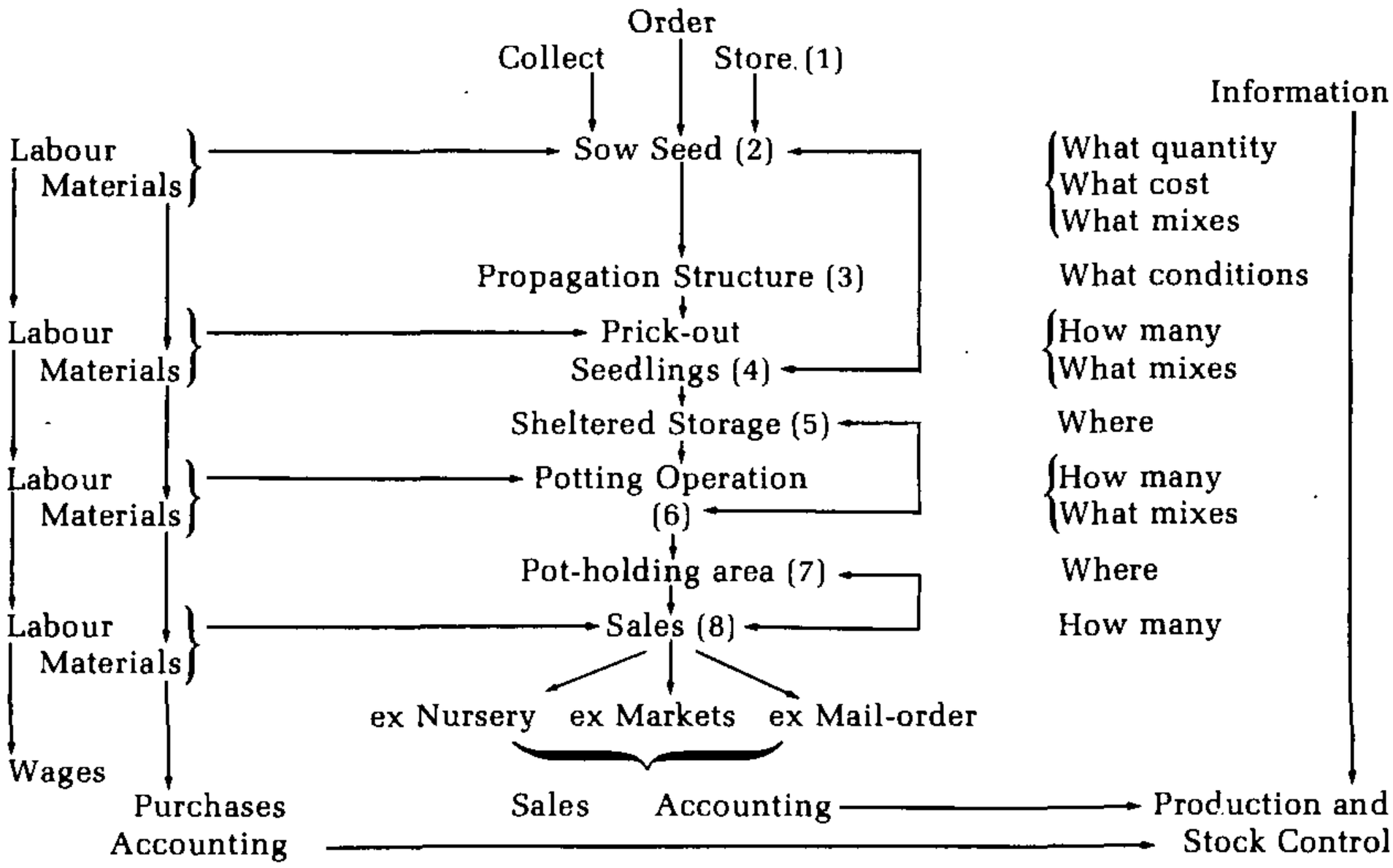

Figure 2. Design of a Seedling Production System.

This operation involves eight steps. At each stage of the production chain there are labour and materials inputs (left-hand side, Figure 2) and these reflect through the accounting system. Accepted standards control the rates of potting and tubing. We shall concentrate on drawing up a comprehensive checklist of all other facts to be collected at each stage of the operation (right hand side, Figure 2). These will relate to mixes, environmental conditions, quantities and timing.

The next step is to ensure that the information required is really necessary. Some facts will be relevant to batches individually and some to batches of the one species. Some information will be of interest only to the propagator (such as the amount of seed required to produce a set number of seedlings) and some will also have importance beyond the propagation section (quantities in production will affect forward sales planning,

label, pot ordering, etc.).

In this nursery we have adopted a simple visual system for monitoring the progress of seedlings and plants. This involves the use of T-shaped cards which are slotted into a special display unit, so that the head of each card is clearly visible. Cards are available in several different colours so there is scope for display arrangements to suit a number of different requirements.

The front of the card is used to record static information for each particular species. Such information includes plant name, its target (the number of plants to be produced during the year), yield (plants/g), ideal mixes, special treatments for seed, etc., as shown in Figure 3:

S O N D J F M A M J J A

PLANT GENUS & SPECIES Target 5,000

Seed in boiling water: soak overnight 25g/1000
Sand 1: Peat 2: Perlite 1

Seed Orders: Smith & Co. 441-8764
Jones Bros. 203-1148
Brown P/L 337-5764

24.5.78	100g	Jones 1	10.6.78	$3
14.9.78	100g	Jones 2	19.8.78	$3
30.11.78	50g	Brown 1	19.8.78	$3

Figure 3. Front of Stock Control Card.

This card is also used to record orders for seed. Included is the date of order, quantity of order, supplier, and on its receipt, date received and cost. A coloured indicator is placed at the left hand side of the T piece whether seed is on order (blue) or on hand (green).

The back of the card records details for each batch (Figure 4). This includes date sown, number of trays (or seeds if more appropriate), quantity sown and source (to tie in with front of card). When the seedlings are pricked out the date is recorded together with the number, which, allowing for a loss factor, should tie in with the target. A special notation is made to give an indication of yield, especially in cases where this is in excess of the target. A reference is also made to storage location.

12.6.78	1T	50g	J1	19.8.78	1859	no Xs	B17
20.8.78	2T	75g	J1/J2	1.10.78	2540	no Xs	A43

Figure 4. Back of Stock Control Card.

Entries collected in this manner allow comparisons to be made between batches. Information is obtained on yields/cost

for seed sources, optimum sowing times, etc. which can eventually be recorded as static information on the front of the card.

Control of the production depends primarily on the target figure assigned to the particular line. This target figure prevents overproduction of a low demand species and shifts the responsibility for providing sufficient quantities of other lines to the propagator.

Control also relies heavily on information collected during a lead-in period. It is not possible to control the operation so that production coincides with peak selling times such as spring or Christmas if, for example, the time it takes between the sowing of seed and the plant being ready for sale is not known.

Other factors to be considered in planning control are:

1. Whether starting points are determined by internal or external factors; that is, does the operation rely on an outside source for seed supply or is seed on hand.

2. Are the deadlines absolute or relative? The starting date for a batch will be absolute if it is to be ready for a given peak period but other operations in the chain will be relative to those preceding them.

3. Can the activity be cycled to advantage with greater or lesser frequency? In other words, should a hypothetical target of 5,000 plants of the species for a year be obtained from only one or from more sowings in that year?

To draw attention to the various operations (seed sowing, seedling transfer, and potting) we use a series of colored indicators along the top of the T-piece. The top edge is marked for the 12 months in the year in such a manner that operations earmarked for any particular month all fall one below the other.

However, this system is only as good as its operators. If they do not look at the cards, if they do not use and move the indicators, or if they do not keep accurate records, it all falls down.

A master record is also kept, noting those entries from the propagator's cards which are of general relevance. Information on potting from the Production Day Book is added to complete the picture (Figure 5). This master record allows anybody to

PLANT GENUS and SPECIES — Target: 5,000

Date Sown		Date Tubed	No.	Loc'n	Date Potted	No.	Location
12.6.78	1T	19.8.78	1859	B17	10.11.78	1823	41A
20.8.78	2T	1.10.78	2540	A43			

Figure 5. Master Sheet Entries at 1.12.78.

check on the progress of any line grown in the nursery.

The system has proved quite adequate for the needs of a small nursery but as we have expanded and speed of turnover has increased a number of frustrations are creeping in. We are not able to keep track of plants sold from a batch — that is, how long the 1823 plants in location 41A have taken to sell out. It is often necessary to pay a visit to this location if someone other than sales personnel wishes to know the exact numbers remaining, and often a second batch may not be potted in time to follow on from the previous one. In other words, as we grow so does the gap in communication between Sales and Production.

The ultimate system would tie in all the functions of the nursery, from wages, purchases, stock and production control to sales. This is theoretically possible with the system described but to do so would break the first fundamental requirement for system efficiency: the time and effort required would prove too costly. However, the system described here will evolve fairly readily to a higher level system such as provided by a computer. Whether the information generated by electronic data processing is worth the cost of installing a computer-based system is a decision for each individual nursery. However, computers are here to stay and propagators as well as nurserymen in general should be willing to investigate further their potential.

GRAFTING MAPLES

ARNOLD TEESE

Yamina Rare Plants Nursery
Monbulk, Victoria

Although taxonomists have divided the genus *Acer* into 13 or more sections this is not always a true guide to compatibility. The species, *A. pseudoplatanus is compatible with a consid*erable number of species which are botanically well outside their own section; also the cv. *Atropurpureum* which has a purple coloring on the reverse of the leaf seems to be more compatible with other species. *A. platanoides* can be grafted onto *A. pseudoplatanus* 'Atropurpureum' quite readily but with difficulty onto the common form. *A. pentaphyllum*, not yet placed taxonomically but is superficially similar to the *Trifoliata* section, is compatible with *A. pseudoplatanus*, as are *A. saccharum* and *A. pensylvanicum*, each in different sections. *A. palmatum* is also reasonably wide in compatibility,

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particularly with some of the "snake bark" group, e.g. *A. laxiflorum*, etc. There is still room for considerable study in this field.

Although many maples can be budded or even grown from cuttings — and some are better propagated this way — we find that in a nursery where most plants are container-grown that grafting fits into our schedule much better than cutting propagation. Any type of graft can be used but beware of cultivars having pithy wood, these are not very successful when using whip and tongue or cleft grafts. Overall we have found the veneer type graft most successful; we only make the cut bark-deep on both stock and scion. A short top is left on the stock until the scion has started growth. Contrary to most plants, maples should not show excessive sap flow at the time of grafting, or budding for that matter, as this tends to "drown" the scion. We use plastic ties and no grafting wax. Ties must be cut as soon as a reasonable take is assured as excessive callus often forms under the plastic, particularly with small scions, causing binding. An interesting method of grafting is used by some Japanese nurserymen. They make a T cut in the bark (as for budding) make a long angle cut on the scion — on one side only — then insert the scion and tie; the stock is then cut off close to the top of the tie.

The advantages we see in the veneer and in the Japanese methods are that the greatest possible width of cambium is exposed, so that success is more likely. These methods are also more suitable where scions are very small and stocks are quite large — e.g. in some forms of *A. palmatum*. Many of the maples have very thin bark and cambium so that every attempt should be made to improve the chances of success.

Although grafting can be done outside we have better results in a glass or plastic covered house where water can be kept off the point of union until callusing occurs. In Australia we find early August (late winter) a very suitable time but have had even better results in late summer or early autumn. For late winter grafting we place stocks in the glasshouse for about four weeks to start a gentle sap flow and store scions in a refrigerator if we are forced to be a little late — otherwise we pick the scions as required. With late summer grafting we remove all leaves from the scions and place grafted plants in a plastic-topped frame in the glasshouse for approximately eight weeks. They can be overwintered outside in our comparatively mild climate. Although the ties should be cut at this time the excess stock can be removed any time before spring. For most tree and shrubby-type maples we graft as near to the ground as practicable but for weeping forms and horizontals we vary the height

up to 2 m to suit a variety of purposes.

First or second year seedlings are usually used for the rootstocks. Seed of most species should be sown as soon as ripe in the open ground or in deep boxes. Cover seed 1 to 2 cm with sand. If seed has dried out soak it in warm water for several hours, then mix with moist peatmoss, place in a tight plastic bag, and store in the bottom of a refrigerator for 6 to 10 weeks. Inspect each week and plant immediately if any sign of germination is seen. Some species, such as *A. griseum*, may take two or even three years to germinate but the majority come up quite well in the first spring if picked and planted immediately.

THE IMPORTANCE OF THE ENVIRONMENT IN GROWING AFRICAN VIOLETS

ROBERT KASTEEL

Kasteel's Nursery
Duffy's Forest, New South Wales

African violets are one of the most specialized of ornamental crops. They are easily propagated from seed or leaf cuttings. Fully matured leaves from the outside of flower stalks are preferred for propagation. Adventitious buds are rapidly formed and develop into plantlets.

African violets are not a difficult crop to grow if you understand them and their conditions. The important environmental considerations are as follows:

Light. The emphasis is on light intensity rather than daylength. The optimum solar radiant flux density is 1100 ft. candles. Extensive yellowing occurs in the foliage of African violets which are exposed to radiant energy levels above 1200 ft. candles. This is due to chlorophyll destruction by the radiant energy. Light intensty above 1100 ft. candles reduces the number of flowers per plant in some cultivars. More commonly, the initiation of flowers by African violets is seriously limited at radiant flux densities below 300 ft. candles. A radiant flux of 100 ft. candles for 12 hours per day is enough to produce satisfactory plants with good formation and foliage color, but is insufficient for appreciable flower production.

With sunlight the optimum radiant flux for both vegetative growth and flowering is 1100 ft. candles for a minimum of 7 hours per day. However, radiant energy from "daylight" fluorescent lamps at 500 ft. candles for 12 to 18 hours a day

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produces a better growth and more flowers than a higher solar radiant flux. The uniform radiant flux that can be maintained for long periods is responsible for this difference in plant response.

Temperature. African violets grow best and flower most profusely when the night temperature is 20 to 30°C (68 to 73°F) and the day temperature is 14°C (57°F). Growth is vigorous even at a day temperature of 10°C (50°F) if the nights are warm. This thermoperiodic behavior of the African violet is very unusual, considering that night temperatures higher than day temperatures do not occur naturally anywhere in the world. African violets are also atypical in that they have a higher optimum radiant flux density at lower temperatures, whereas most plants respond to an increase in temperature with a higher radiant energy requirement. The optimum irradiance for growing African violets with light from electric lamps is 500 ft. candles at 23 to 26°C (73 to 79°F) and 1000 ft. candles at 14°C (57°F). High temperatures may cause dropping of immature flowers. It may also cause blasting of buds or small flowers of poor quality.

Water. Water applied to the leaves of African violets may cause the development of white or cream colored spots, streaks or rings on the upper surface. This physiological problem, commonly referred to as "Ring Spot" occurs when a difference of 17°C (30°F) between the leaf temperature and the water temperature exists. The presence of water on the surface of the leaf is not a factor in the development of "Ring Spot". Any substance that is 17°C warmer or colder than the leaf will cause spotting. An ice-cube wrapped in plastic and held against the leaf will produce spots that are identical to those that occur when the foliage is sprinkled with cold water. If the temperature of the water used to irrigate African violets is similar to the leaf temperatures, it may be applied to the leaves without concern about "Ring Spot", provided account is made for the evaporative cooling of the water if the humidity is too low.

The presence of water moving into the palisade cells that are warmer or colder than adjacent leaf cells causes the cells to collapse. Chlorophyll is destroyed and the cells turn white or yellowish-brown. The best indicator we have to tell us whether a plant has too much or too little water is the plant itself. Unfortunately, however, by the time the plant shows symptoms of either too much or too little water, much harm has come to the plant.

If we are to realize optimum plant growth one must look at watering systems such as capillary sand irrigation, constant water-level systems, capillary mats and the tube irrigation systems. Basically, soil contains three types of water . . . bound,

available and free.

Bound water is that which surrounds, in a thin film, the soil particles. It is so tightly held that the plant roots cannot extract it.

Available water is most important to plants. It is not held tightly like bound water, but it will not move out freely as free water. It is held in the small pores of the soil by capillary forces.

Free water is held in the larger open spaces or larger pores of the soil and is free to move by drainage. It is therefore important to have a mix with a high water potential and good drainage.

Soil. A desirable potting mix for African violets requires a total pore space of 70%, consisting of 35% air-space and 35% water-retention space. The volume, shape and drainage of the pot will affect this ratio.

The ingredients shown in Tables 1 and 2 were selected as being satisfactory.

Table 1. Potting mix ingredients for African violets and their characteristics.

	Total Pore Space	Water Retention Space	Air Space
Sphagnum peat moss	84%	59%	25%
Rice husks (moist)	73	3	70
Sawdust ready mix (4 parts sawdust, 3 parts pinebark, 3 parts sand)	45	38	7

Our mix consisted of 2 parts sawdust, 1 part rice hulls and 1 part peat, giving a total pore space of 67%, a water-retention space of 33% and an air space of 34%.

Table 2. Nutrients added to mix (per m^3).

500 g potassium nitrate	250 g iron sulphate
1 kg lime	100 g Esmanel
3 kg dolomite lime	500 g single super phosphate
1.25 kg blood and bone	

After potting, liquid fertilizer is applied through the watering system. To 200 l water are added 20 kg potassium nitrate, 10 kg ammonium nitrate, 10 kg diammonium phosphate and 300 g "Librel" (iron chelates). This gives a solution with 21.2% total nitrogen (9.7% as ammonia and 11.5% as nitrate nitrogen); 5.9% phosphates and 19.3% potassium. This solution is then diluted 1:300 in a G.E.W.A. System and gives a final ratio of 140 ppm nitrates, 40 ppp phosphates, and 130 ppm potassium.

Pests and Diseases.

Cyclamen Mite attacks the young tender growth of the crown, distorting the plant, causing growth in general to be dwarfed. Plant hairiness is more pronounced and leaves tend to be quite brittle and to cup upwards.

Treatment — Plictran or Temik when infestation evident; plants are generally beyond sale at this stage.

Broad Mite causes the foliage to curl down more than usual, with a general look of debility. No noticeable increase in hairiness.

Treatment — Plictran, Temik.

Nematodes — cause loss of vigour and general debility; foliage loses its good green to become pale and dull; outer leaves droop. Young leaves emerge already damaged. Flowers are few. Roots have knots or sizeable pulpy enlargements.

Treatment — Nemacur, Temik.

Foliage Mealy Bug — cause plants to look dusty. Flower stems and leaves have a greyish webby appearance. Deep in the crown and on the underside of the leaf, cottony clusters are visible.

Treatment — Insectigas, Temik.

Soil Mealy Bug — cause a plant to look wilted as with Crown Rot or Root Rot; dull appearance of leaves, and plant becomes small in centre.

Treatment — Nemacur, Temik.

Thrips — cause whitish spots, blotches and dead looking areas along the edges of the flower petals. There will be malformation and premature fall of blooms and buds.

Treatment – Insectigas, Temik.

Botrytis — infects dead or dying plant parts; e.g. dropped or damaged flower petals, and spreads to cover the infected area with a woolly grey growth. The fungus is common and is airborne.

Treatment — Rovral, Benlate.

Powdery Mildew — causes white to greyish spots on the surface of the host plant part, which ultimately become brown with black spots.

Treatment — Benlate, Daconil.

Crown Rot — causes rotting of the growing point of the plant, and has symptoms similar to cyclamen mite.

Treatment — Terrazole.

All of the above insects can be controlled by Insectigas, al-

though it may be necessary to use Temik if an infestation is already present.

CAPILLARY WATERING

JACK PIKE
Pike's Nurseries
Rydalmere, New South Wales

In discussing capillary watering it is first necessary to see how it fits in with the different classes of water. Soil moisture has been classified into three categories (3) as illustrated in Figure 1.

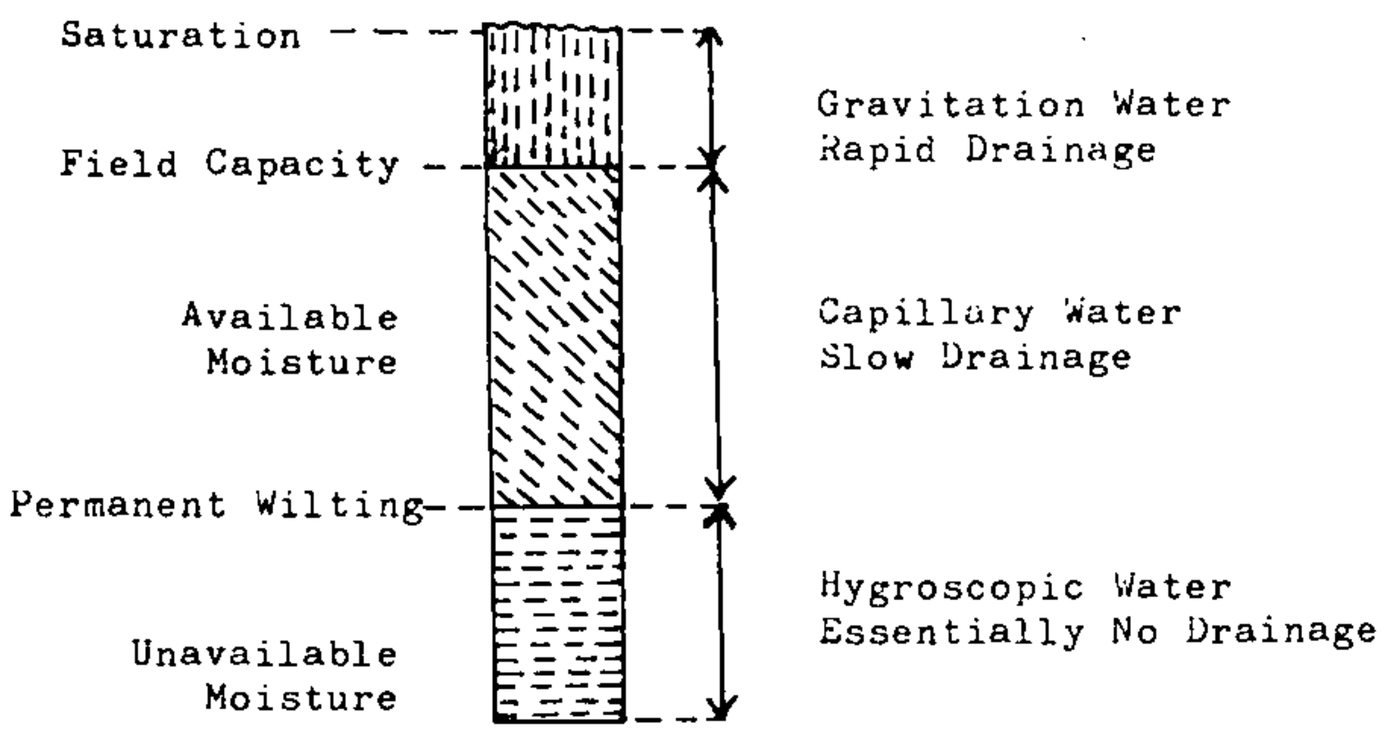

Figure 1. Classification of Soil Moisture. From "Irrigation Principles and Practices" 3rd Ed., Israelson, O.W. and Hansen, V.E. (3).

Excess or gravitational water will rapidly drain from the soil under the forces of gravity. This water lies in between the saturation and the field capacity points.

Available or capillary water is the free water available to the plant, held in the soil by capillary forces and thus drainage is very slow. It lies between the field capacity and the permanent wilting point.

Unavailable or hygroscopic water lies beyond the permanent wilting point. Unavailable water is held too tightly in the soil by the capillary forces and surface tension and is not accessible to the plant roots.

The phenomenon of capillary rise of liquids is a familiar concept. The liquid wets the surface of a capillary tube and due to the pressure difference between the capillary liquid and air, the liquid in the capillary will rise until equilibrium is met. It would be desirable to have capillary or available water constantly and evenly at the plants disposal, and to make use of the phenomenon of capillary rise of water. These features have been incorporated in plant culture systems for many years and is

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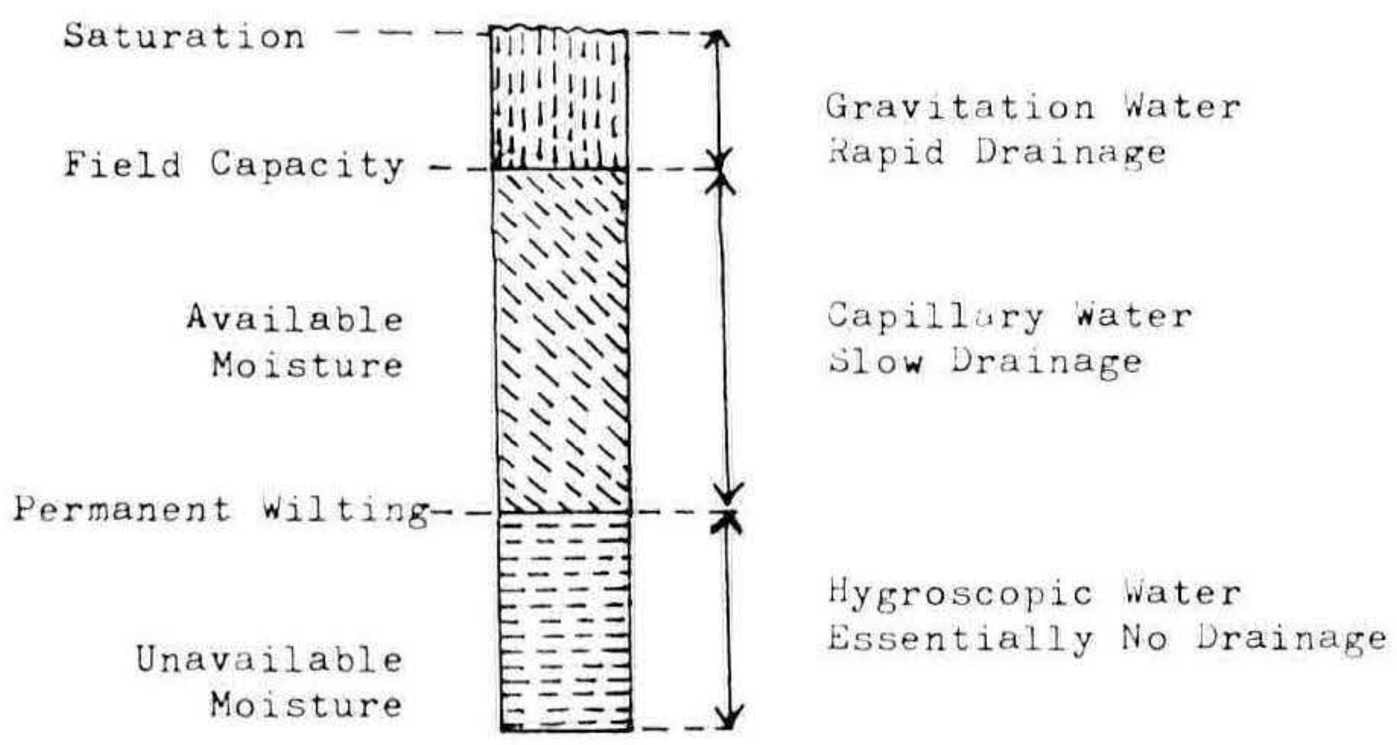

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known as sub-irrigation or capillary watering. In Europe the capillary sand bed has been used extensively over the years, but its installation and cost have been major factors in its slow adoption in other countries. Of the several systems developed I shall concentrate on the commercially available capillary matting system.

Types of Matting. There are several types available. In New Zealand a felted mat is available but its lasting qualities under some conditions may not be very long. In Australia the most widely available is the vilene capillary matting. It is a polyester fibre which lasts for years under most conditions. It is readily available in 1 and 2 m widths and up to 30 m in length; custom made widths and lengths are also available. It is not critical that beds be level, as in sand beds, and conversion of most types of benching is a relatively inexpensive proposition. It is desirable to have a slight fall on the bench either in length or width and to have a surface suitable for laying black polythene film on. If the bench has more than a 4 cm fall the matting should be cut at this point to stop the water draining to one end too fast.

Advantages. The system offers a "uniform supply of water and nutrient with economy of fertilizer" (9). It requires little attention and is suitable for pots ranging in size from 10.6 to 22.9 cm in diameter and up to 30 cm deep. In comparison hand watering has a high labour cost and is subject to human error. Hand watering and overhead irrigation can over or under-water and leach the nutrients from the soil (8). They also splash the soil and expensive top-dressing from the pots, and the excessive damping of the foliage and flowers can aid in the growth of pathogens.

Only one initial watering from above is needed to establish capillarity, or the water column as it is sometimes called. The water level is then maintained by means of a float (8). Less fertilizer is required, thus reducing the possible harmful salt accumulation (9). "Sub-irrigation with a dilute (0.06%) nutrient solution has enhanced root production in *Lonicera japonica* and *Myrtus communis*" (11).

Patel and Tinga (8) feel that it may be beneficial for a wide variety of plants and cultural conditions since it provides a precise amount of water at all times. Capillary matting has been used to grow African violets, calceolarias, cyclamens, chrysanthemums, poinsettias and many other types of foliage plants. Many types of watering systems have been devised for watering the matting but the main object is to wet the matting easily and with little labour usage.

Disadvantages. One of the main problems associated with capillary matting is the growth of algae on the surface of the

white matting that is used as the water reservoir.

Murray Richards, Director of the New Zealand Nursery Research Centre at Massey University has found chemical control to be unsatisfactory but experimentation with the colour of the matting showed that a purplish-brown shade markedly inhibited algae.

Another problem with capillary matting is that the potting mix is sometimes spilt from the containers and thus necessitates cleaning down of the benches between every crop. To minimize this problem black plastic film has shown promising results. It is 30 microns thick with a number of small slits placed so that at least one slit occurs under each container. The weight of the container on the plastic exerts pressure on the felt underneath and the water comes up to the surface of the plastic under each container thus establishing capillarity. The presence of the plastic surface enables the spilt media to be removed with the squirt of a hose.

There is the argument that white capillary matting reflects light thus increasing photosynthetic effectiveness of plants and that with the use of black polythene you would lose this effect. This argument will soon be tested with the use of film which is white on one side and black on the other.

It has always been considered that *Pythium* and *Phytophthora* would be a problem with capillary watering. Experiments have shown that because root hairs do not dry out and become damaged the entry of harmful pathogens is miminized. The use of an algacide is currently being investigated and promises to be of use in controlling algae both under the benches and on the matting.

In conclusion, capillary water systems are a practical and commercial means of completely automatic watering of many plants.

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FUNGAL DISEASES IN PLANT PROPAGATION

IAN D. GEARD[1]

Department of Agriculture
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A number of plant disease problems can be encountered in plant propagation but two of the most important, "damping off" and "root rot", can be used to illustrate some of the main principles of avoiding disease.

Consideration of disease can be based on what is sometimes called "The Disease Triangle" (Figure 1). It is self evident that to have disease there must be a *host* and a *pathogen* but the mere presence of these two does not necessarily mean that a disease problem will result. There are few, if any, fungi encountered in nursery propagation which are so virulent and so infectious that their presence is a virtual guarantee of disease. The influence of the third element of this triangle, the *environment*, is vitally important in determining the outcome and whether or not disease results.

This Disease Triangle represents the three important elements in the natural situation but in crop production generally, and in nursery production in particular, there is another important factor which influences all three and the interaction between them. This is Man or Management (Figure 2). Management can be used to affect these factors to push the outcome in the desired direction, toward good plant growth and low levels of disease.

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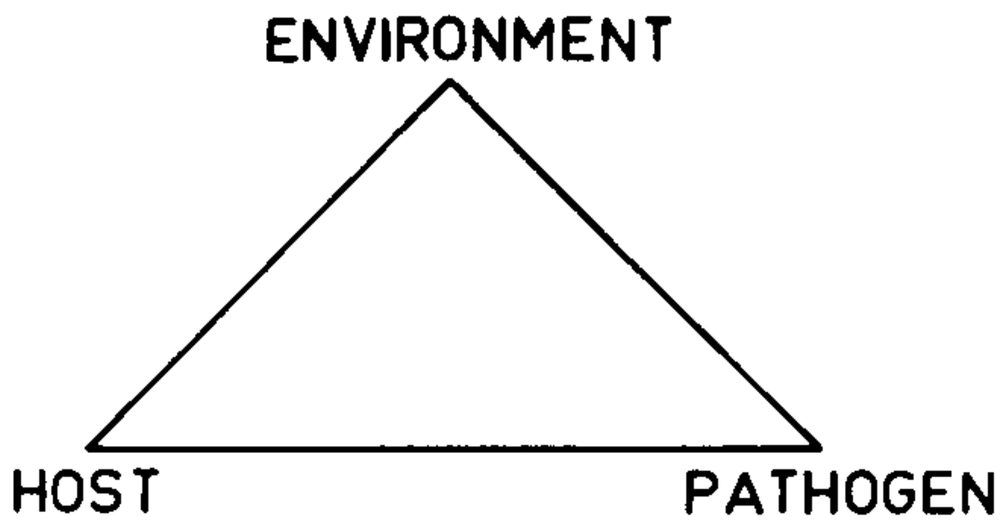

Figure 1. The Disease Triangle.

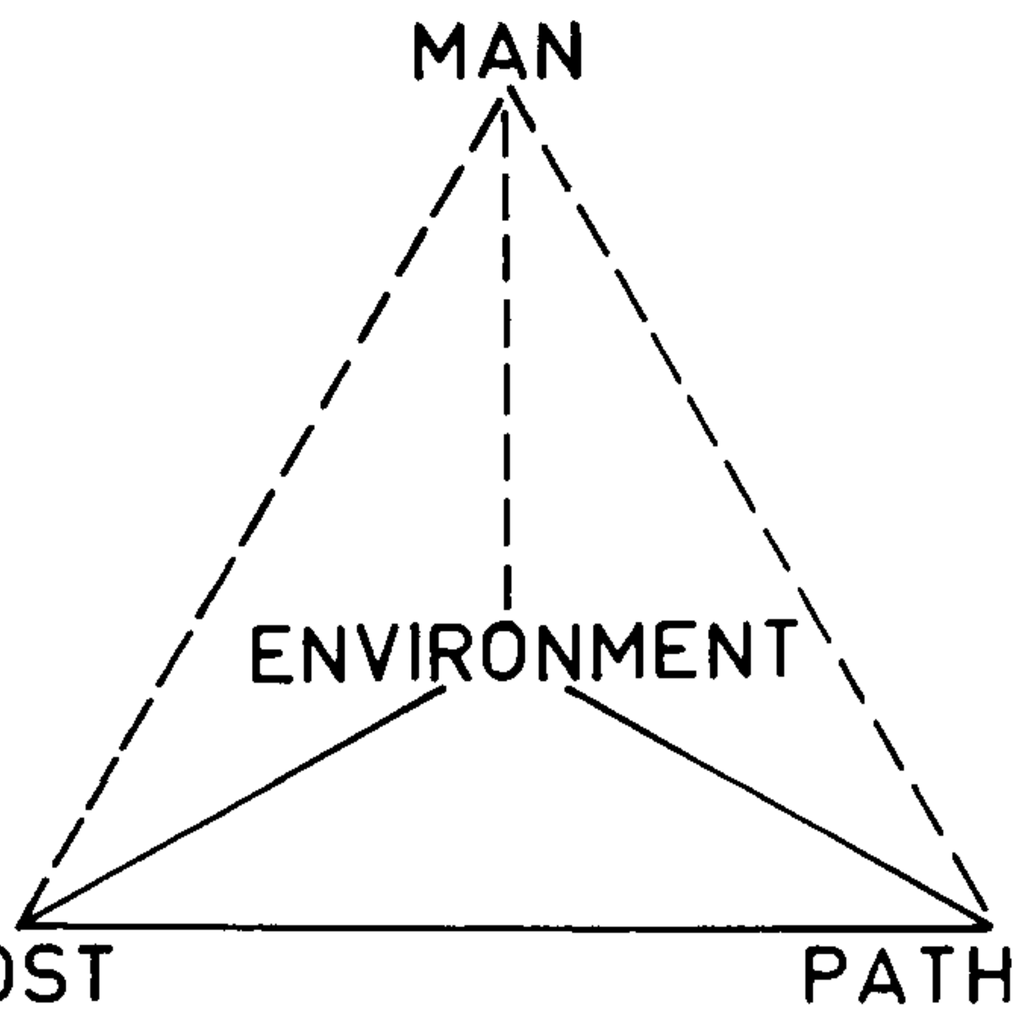

Figure 2. Man can affect each element in the Disease Triangle.

The *host* can be influenced by, for instance, the selection of species and cultivars; other things being equal, resistant cultivars will be used in preference to susceptible ones. The *pathogen* can be influenced very greatly by *hygiene*. The *environment* can be influenced in many important ways. Temperature and humidity are influenced by heating, cooling and ventilation. Soil moisture is under management control by drainage, watering regime, and choice of soil or potting mixture.

The "damping off" problem can be used to illustrate the importance of some of these factors. "Damping off" is due to attack by a fungus — usually a *Pythium* species. Those essentials of the life cycle of *Pythium* necessary to illustrate the points are represented in Figure 3. It consists of two interlinked cycles, the upper, non-sexual reproductive cycle, and the lower, sexual cycle. The common point is the hyphae or fungal threads which ramify through the plant tissue causing rotting and death (Figure 4). In the asexual cycle swellings on these hyphae (called

sporangia) germinate to form thin-walled sacs into which their contents migrate and segment to form a mass of zoospores which are released into the soil (Figure 5). These zoospores are equipped with fine whip like "paddles" or flagellae which enable them to swim in the films of water around the soil particles. After a period of free swimming they lose their flagellae, and encyst. This is followed after a rest period by germination and fresh infection of new roots and the production of hyphae to complete the cycle.

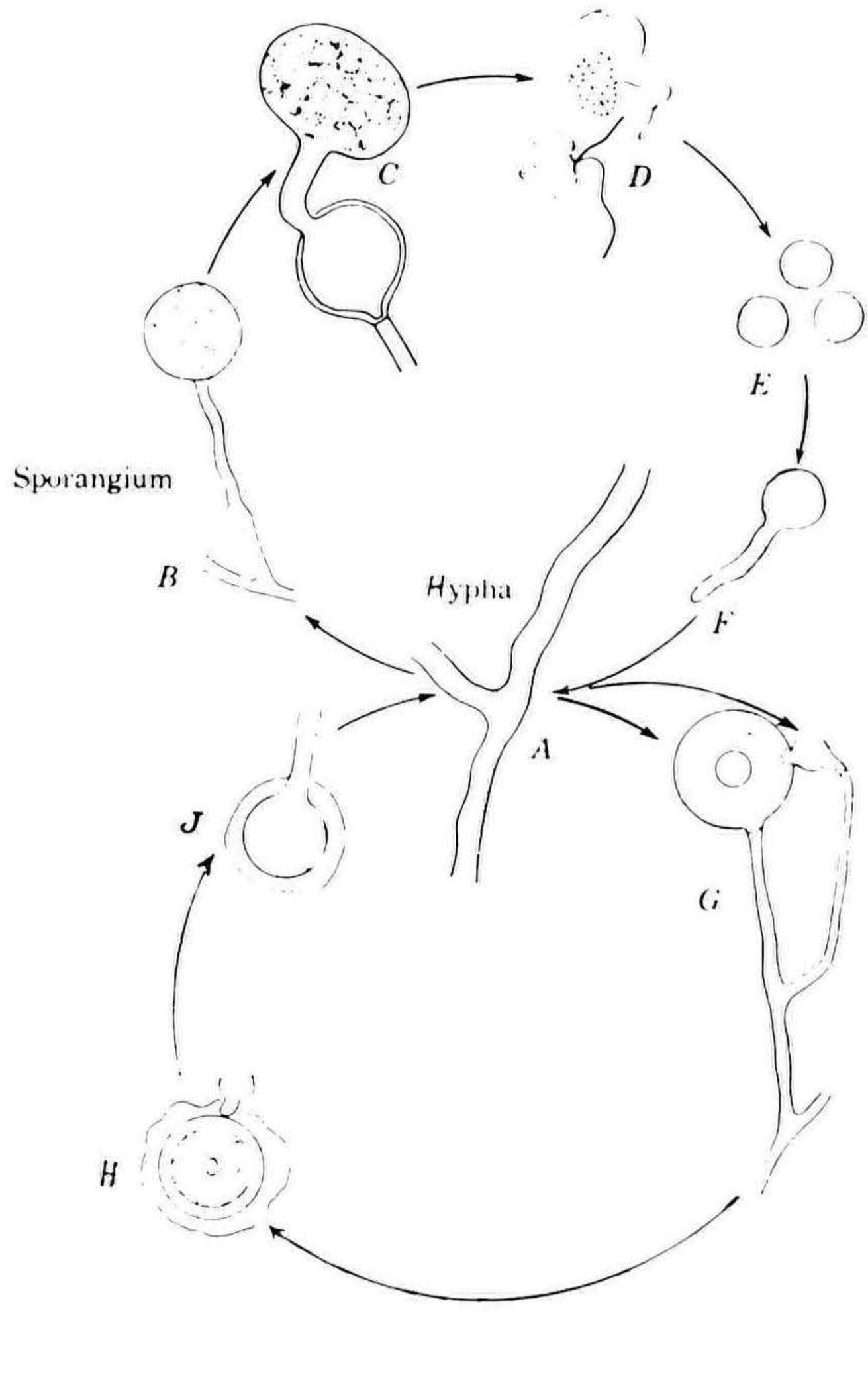

Figure 3. The life cycle of *Pythium*. Above: A to F — The non-sexual cycle. The sporangium (B), germinates to produce a vesicle (C), from which the zoospores (D) are released. After encysting (E) they germinate (F) to produce new infections.

Below: A to J — The sexual cycle. An egg cell (G) is fertilized to produce the thick-walled oospore (H) which can survive for long periods before germination (J).

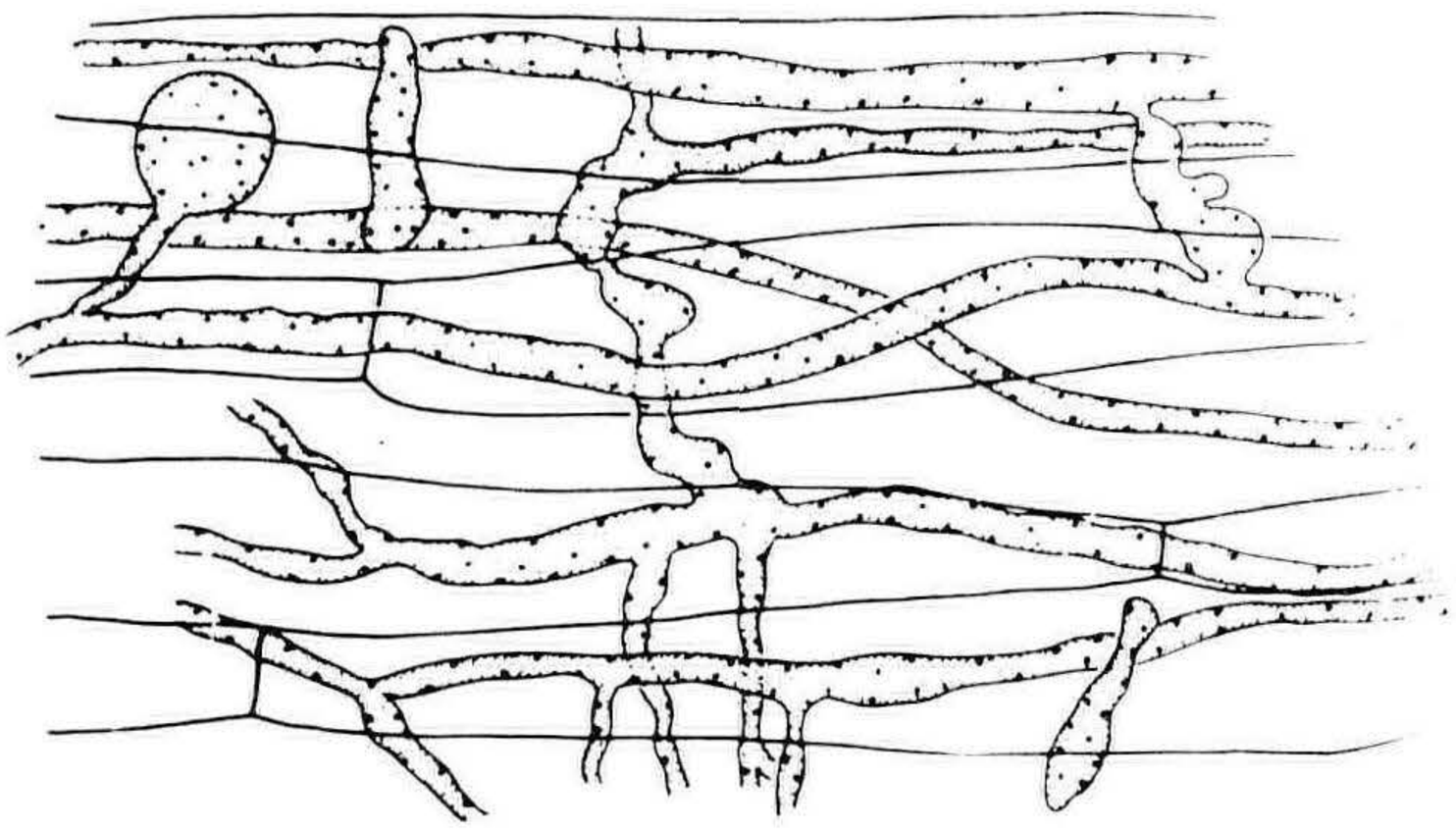

Figure 4. The hyphae or fungal threads of *Pythium* ramifying through plant tissue.

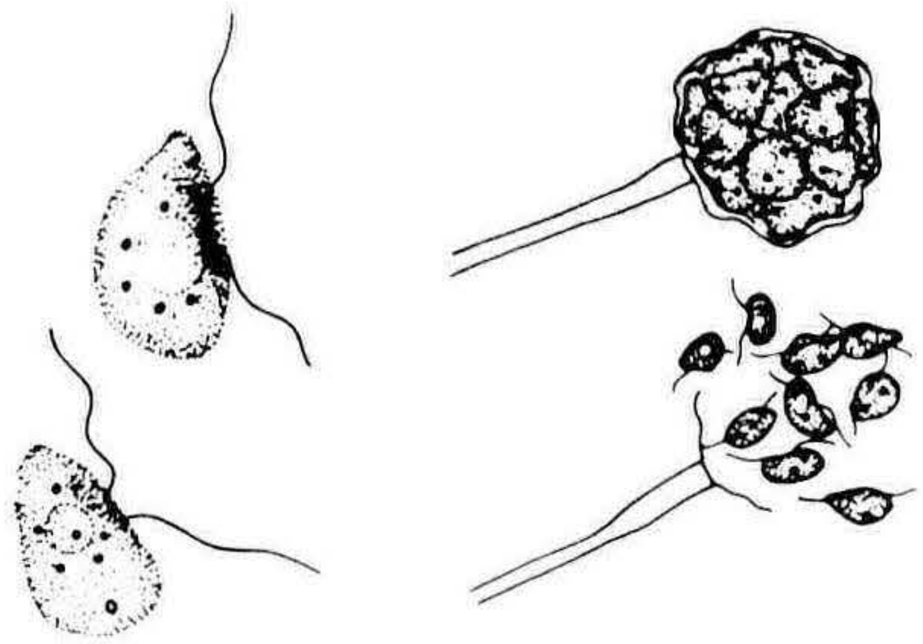

Figure 5. Production and release of the flagellate zoospores of *Pythium*.

In the context of nursery management of the environment the important aspect of this life cycle is the production of the specialized swimming spores which enable the fungus to spread rapidly and infect new roots and new seedlings. This process is greatly favored by wet soil conditions and the aim of management must be to ensure adequate soil moisture for plants while avoiding excess water which will be unduly favorable to the fungus.

Unfortunately this is not the complete answer since while there is enough water for plants to grow there will be enough for slow spread. It is therefore much better for the soil to be free of the fungus in the first place. In Figure 3 the lower circle shows the sexual cycle of the fungus. The important feature of this cycle in the context of avoiding disease in the soil, is the very thick walled "egg spore" or oospore (Figure 6). These spores are produced in large numbers and are capable of long survival in soil irrespective of conditions. When conditions are favorable they germinate to produce hyphae and the asexual cycle of zoospore production occurs with consequent disease risk in plants.

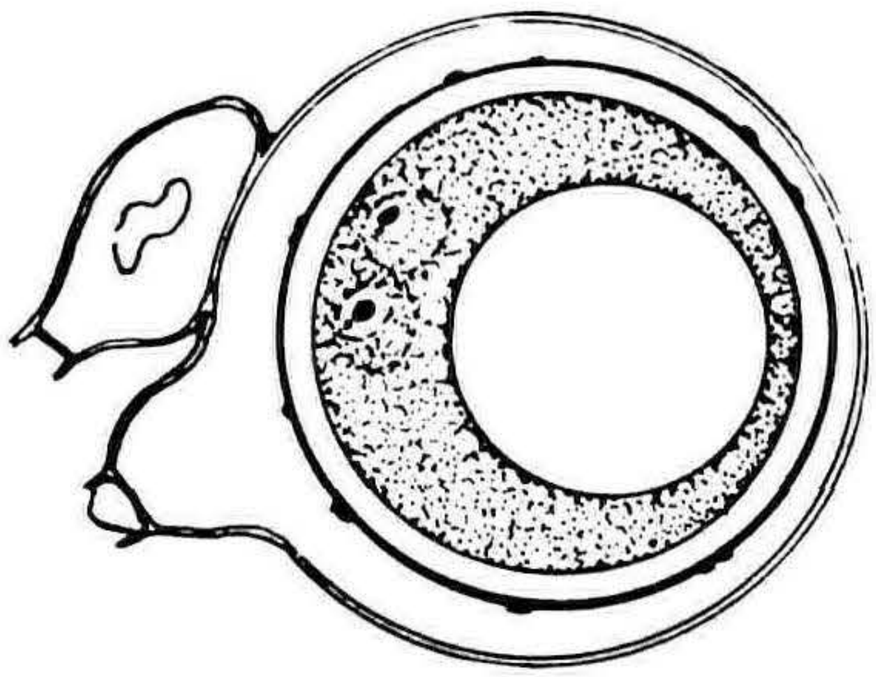

Figure 6. A thick walled resistant oospore of *Pythium*.

The answer to protection of young plants from this risk lies in soil pasteurization followed by hygiene. These two features, soil pasteurization and hygiene go hand-in-hand — soil pasteurization without hygiene is useless; hygiene without soil pasteurization may be little better.

The choice of methods for soil pasteurization is a wide one and some possibilities with their advantages and disadvantages are shown in Table 1.

Once soil is pasteurized by one of these means the reintroduction of contamination must be guarded against by the practice of rigorous hygiene. The tools, containers, working and growing surfaces used in conjunction with pasteurized soil must all be themselves clean and sterilized.

Any contaminated soil from these or any other sources will serve to reintroduce infection and quickly undo the benefits of pasteurization.

The two aspects of the life cycle of *Pythium* which are important in the above considerations i.e. the swimming zoospores and the thick-walled resistant oospores, also occur in the life cycle of *Phytophthora cinnamomi* the fungus which has caused much concern in nursery propagation, particularly of many native species in Australia in recent years. The key to its control

Table 1. Methods of Soil Pasteurization.

		Advantages and Disadvantages
Heat	Dry Heat	Difficult to apply and likely to ruin soil structure
	Steam	Very effective but expensive and some danger to operators. Any recontamination spreads quickly. Induction of toxicities e.g. ammonia and manganese is common.
	Steam/air	Equally effective, less expensive, safer. Retains antagonistic fungi and bacteria which restrict spread of recontaminants. No toxicity problems.
Chemicals e.g. Methylbromide Chloropicrin Dazomet Methyl isocyanate Formalin		Less extensive capital outlay required but restricted range of action, very careful soil preparation required; very temperature-dependent for effectiveness and dissipation of phytotoxic chemicals. Toxicities are quite common. Varying degrees of danger.

is management to eliminate the long lived oospores from the soil by pasteurization; to prevent recontamination from implements, containers and growing surfaces; and to maintain moderate soil moisture levels which favor the plant without being excessively favorable to the spread of zoospores.