INCREASING GERMINATION RATE AND GERMINATION PERCENTAGE OF SOME KINDS OF SEEDS BY WASHING,DRYING, AND STORING

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INTRODUCTION

Many plants have seeds which are difficult or slow to germinate. When seeds are slow to germinate, and it has been determined that there is no physical barrier to the uptake of water — such as a hard seed coat — then various methods may be used to hasten germination. These methods include the use of gibberellic acid, ethylene, cold stratification, etc.

From the propagator's point of view it is important to have as many seeds germinate as quickly and uniformly as possible.

The technique of hydrating and dehydrating (wetting and drying) offers a simple method which may be used to speed up germination and increase uniformity of germination.

Sen and Osbourne (5) showed that if the embryos of *Secale cereale* were hydrated for 3 to 6 hours, then dehydrated back to their original weight, their germination was more rapid than for untreated seeds when they were re-imbibed. Berrie and Drennan (1) using oats, and Vincent and Carvers (6) using *Rumex crispus*, obtained the same response. All these researchers concluded that seeds which had been hydrated and dehydrated were physiologically more advanced than untreated seeds.

Lush and Groves (2) found that a pretreatment of hydration and dehydration increased the germination rate of annual ryegrass seed. Lush, *et al* (3) found a similar response with *Clematis microphylla*.

Researchers (4,7) working with other plant species have also reduced or broken dormancy in seeds by washing them in running water for various periods of time.

Using running water instead of soaking has certain advantages for hydrating seeds. It removes any substances leached out of seeds, and greatly reduces the growth of bacteria and fungi on the seeds during hydration. These infections can occur quite quickly in water if hydration is carried out by soaking. It possibly also provides a higher oxygen level to the seed, which may be important during the early germination period.

MATERIALS AND METHODS

Several experiements were carried out using two cultivars of *Poa pratensis* (Kentucky bluegrass) — 'Monopoly' and 'Sydsport'; and four species of Australian native grasses — *Poa* sp., *Bothriochloa ambigua*, *Themeda australis*, and *Stipa bigeniculata*.

Seeds were washed in running water continuously for 24 hours and then sown wet — or dried — and stored at 4°C for periods of time ranging from 3 to 28 days.

Germination tests were carried out in petri dishes (100 seeds/dish) using 300 seeds per treatment. The seeds were germinated in cabinets which were illuminated for 8 hours in every 24 with light/dark temperatures of 30°C/20°C, respectively. Germination counts were made daily.

RESULTS AND DISCUSSION

For *P. pratensis* there was a 20% increase in germination after 10 days over the control with washed seed and a 40% increase when the seed was dried and stored for at least 3 days (Figure 1). There was very little further increase in germination when the seed was stored for up to 28 days, but there was no decrease.

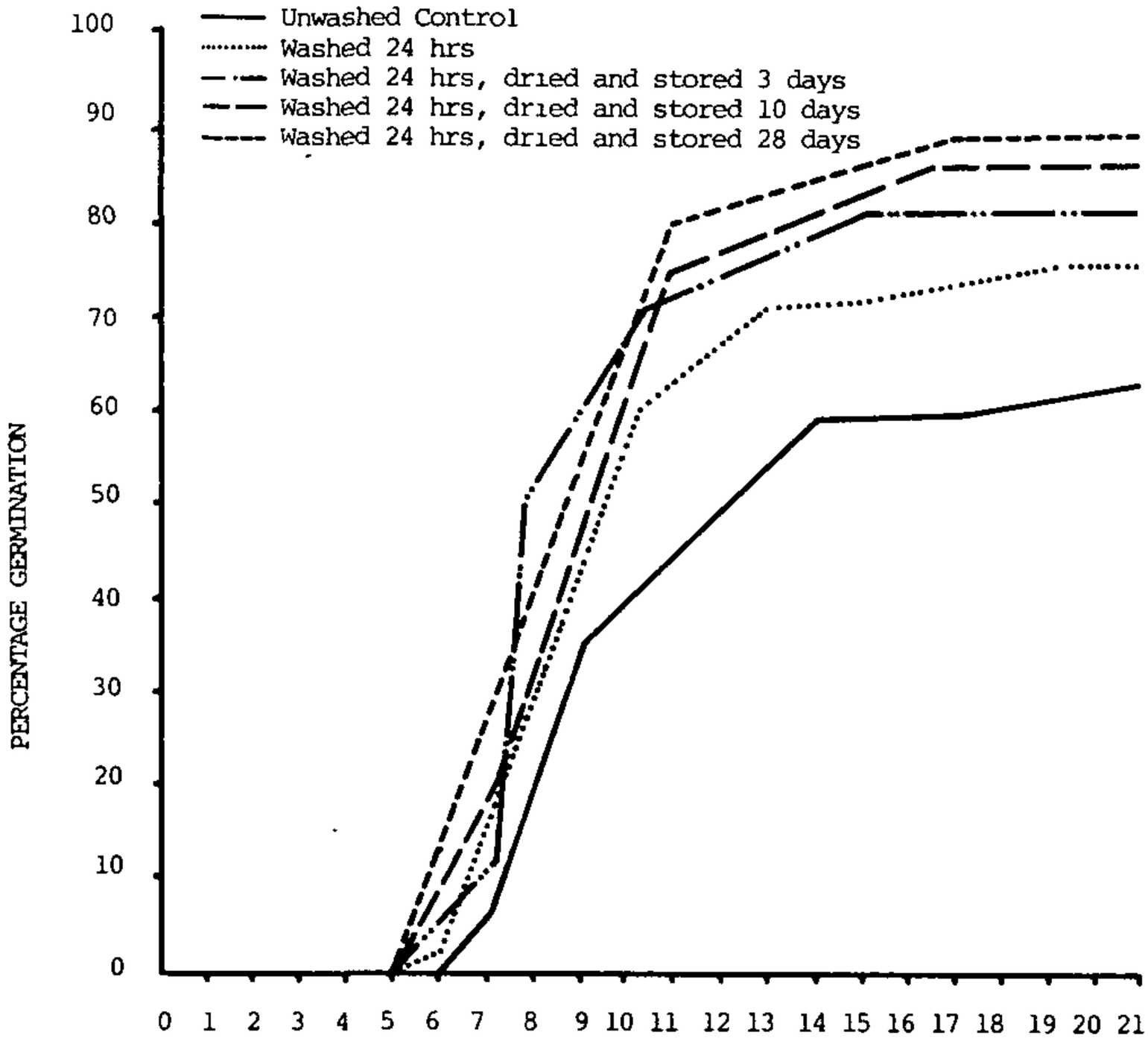

Figure 1. Percentage germination of *Poa pratensis* cv. Monopoly seed washed in running water for 24 hours and then stored for 0, 3, 10 and 28 days, compared with untreated controls.

Figure 2 shows that there was some germination increase after 24 and 48 hours washing in running water, but there was a substantial increase after washing, drying, and storing the seed for 7 days. After 10 days there was an increase from 35 to 95% germination of the washed, dried, and stored seed over the control.

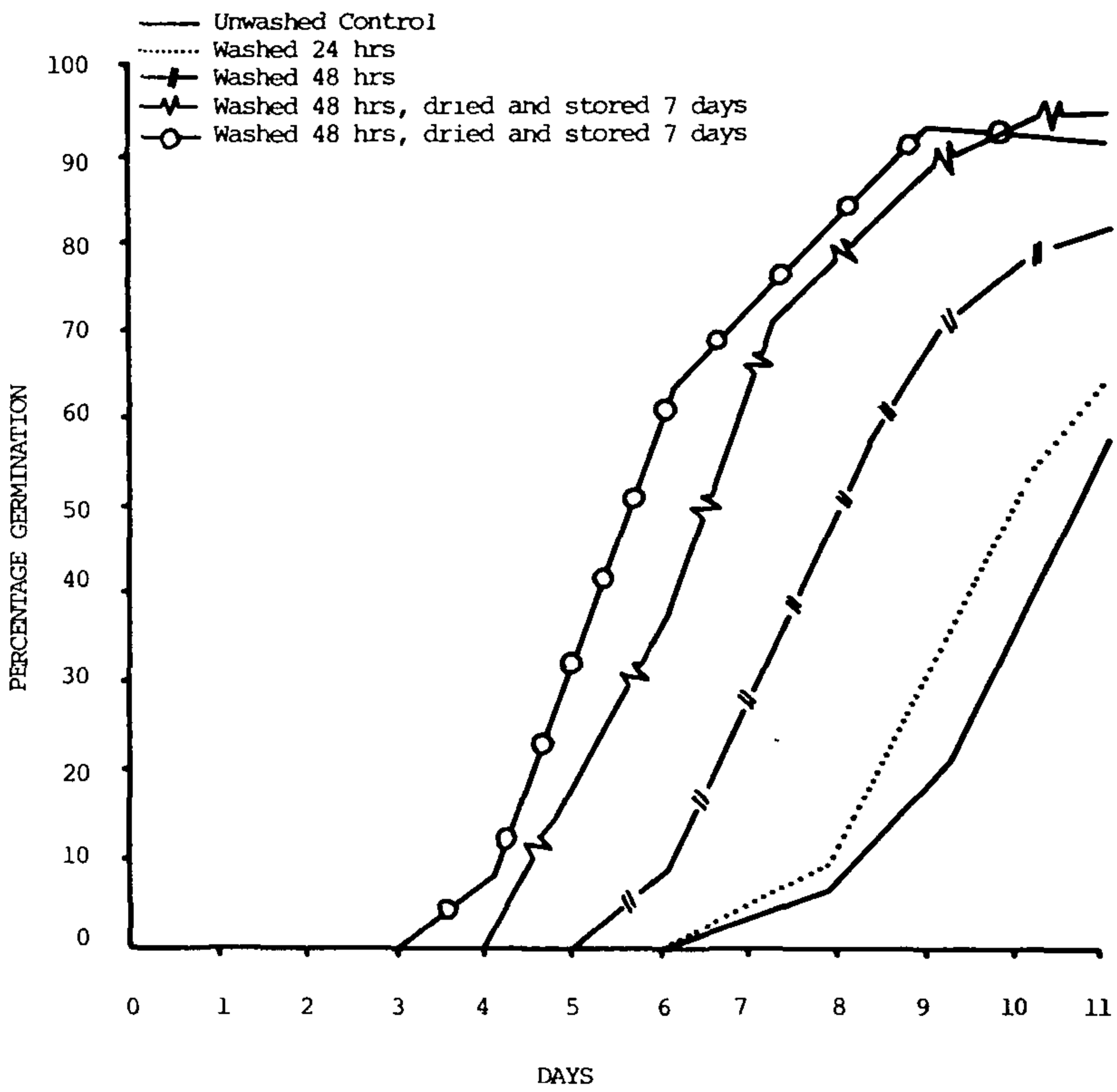

Figure 2. The effect of washing *P. pratensis* cv. Sydsport seed in running water for 24 and 48 hours. Seeds were either sown immediately after washing or sown after drying and storage for 7 days.

From Figure 3 it can be seen that for *Bothriochloa ambigua* there was no difference between germination of seed washed for 24 or for 48 hours, and the untreated control, after 10 days.

There was, however, an increase over the control of 20 to 25% in germination after 10 days for seeds which had been washed, dried, and stored for 7 and for 14 days. There was no appreciable difference between seed stored for 7 to 14 days.

There was no significant increase in germination in *Themeda australis*, *Poa* sp., and *Stipa bigeniculata* seeds that were washed, or washed and stored.

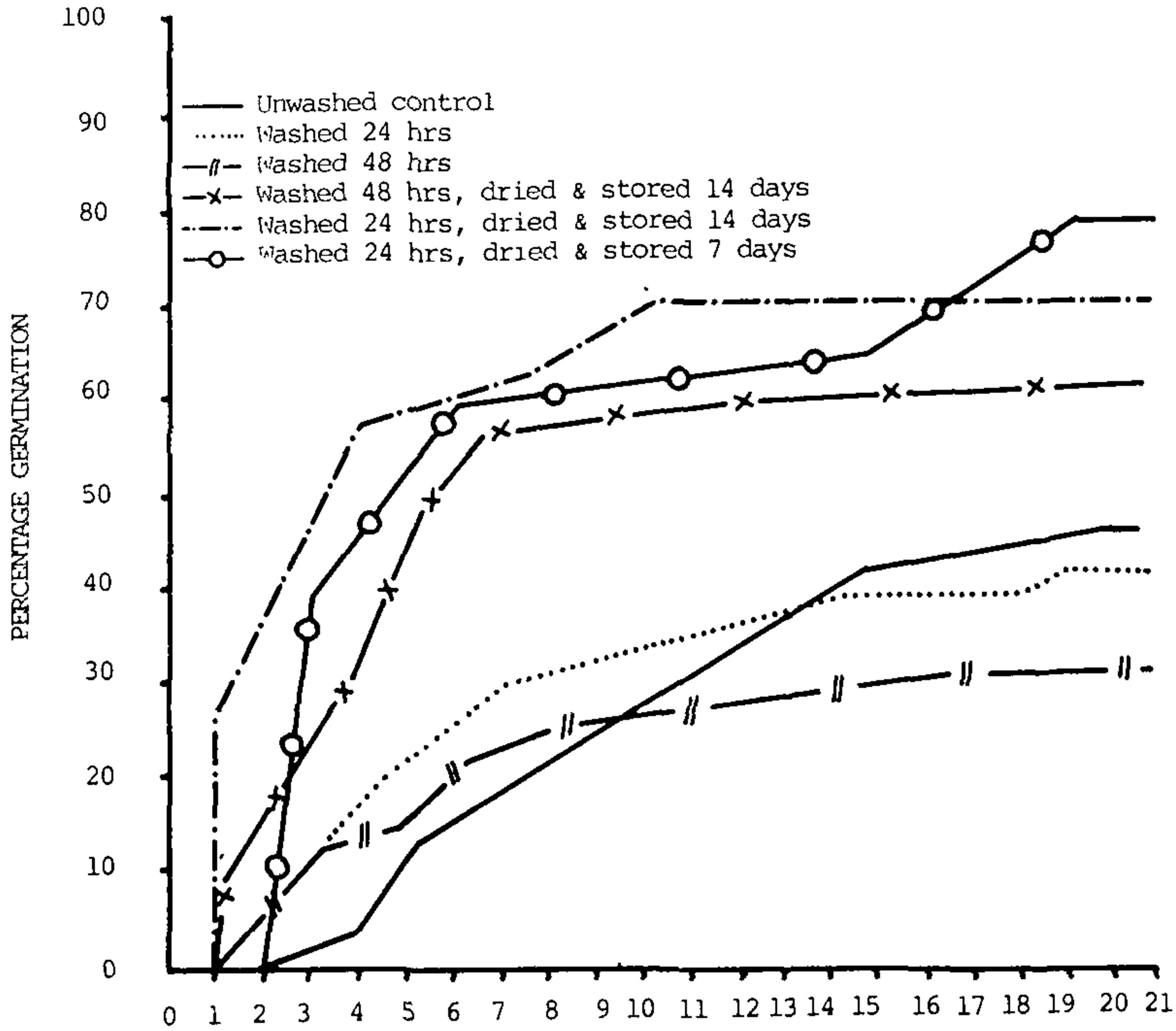

Figure 3. The effect of washing *Bothriochloa ambigua* seeds in running water for 24 and 48 hours. Seeds were sown after washing, and after drying and storing for 7 and 14 days.

The increase in germination rate following hydration and dehydration has a likely explanation in the work of Sen and Osbourne (5). They found that in rye embryos RNA synthesis can be detected within 10 minutes of imbibition, and protein synthesis within 15 minutes. If either newly-synthesised messenger RNA or long-lived existing stored RNA that code for enzymes essential for continued growth, are translated during early protein synthesis, then an embryo that has been previously hydrated and then dehydrated could enter directly into the DNA replicating phase when it is subsequently reimbibed. This would give such seed an advantage over those seeds that had not been treated.

When the pretreatment of hydrating, and dehydrating and storing, produces an increased germination rate it often also produces an increase in the total germination percentage with-

in a normal germination time frame. These increases in rate and in percentage seed germination are of great value to the plant propagator.

It may be of real value to use this method to try and speed up the germination process or to increase the percentage of any seed which are slow to germinate, or have a low percentage germination. In addition, the method is simple and cheap.

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A BRIEF REVIEW OF ETHYLENE IN PROPAGATION

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Abstract. Ethylene is a gaseous plant hormone affecting a wide range of plant growth and development responses It is effective in minute concentrations and is extremely common in the environment It is difficult to avoid exposure of plants to ethylene

There is conflicting evidence of the effects of ethylene in plant propagation and minor changes in conditions appear to alter the response from promoting rooting to inhibiting it In some cases ethylene clearly promotes root initiation, or root elongation Ethylene effects in propagation can be tested by adding it, most conveniently as ethephon, or by removing it with ventilation Its action can be inhibited by silver thiosulphate.

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INTRODUCTION

Ethylene is now generally recognized as a plant hormone. It is commonly known for its ability to stimulate fruit ripening and to induce senescence responses such as abscission or dropping of leaves and flowers but, like other plant hormones, its effects have been documented in relation to a very wide range of plant responses, including:—

Seed Germination — breaking dormancy
— stimulation and inhibition of seedling growth

Growth of Shoots— stimulation and inhibition
— change in nature of growth to short and fat
— a changed angle of growth

Induction of Root Initials — generally promotes induction

Growth of Roots — generally inhibits elongation
— very low concentrations can promote elongation
— promotes root hair formation

Induction of Flowering — in bromeliads, mango, etc.

Control of Sex Expression — promotes femaleness

Fruit Growth — promotes growth of fruit, such as figs

Fruit Ripening — stimulates ripening of climacteric fruits
— degreening of fruits is promoted

Senescense — leaf senescence promoted
— flower senescence promoted
— abscision of flowers, leaves, and stems promoted.

Like other hormones ethylene is effective at minute concentrations, in the part per billion to part per million range, not the percentage range — where it forms an explosive mixture with air.

Ethylene is extremely common in the environment. It arises as an air pollutant, especially from the internal combustion engine; from incomplete combustion of organic materials (i.e. from smoky fires); from the ballasts in fluorescent lights; from plants, particularly stressed plants, whether that be water stress, nutrient stress, physical pressure (e.g. wind, handling, packaging or transport); disease or wounding such as that associated with preparation of cuttings. Consequently it is difficult to avoid exposure of plants to ethylene during propagation or during growth and marketing.

ETHYLENE IN PROPAGATION

The first published report of ethylene stimulation of root formation was by Zimmerman and Hitchcock in 1933 (10). This was a year before auxin was shown to also stimulate rooting (9). There has been a continuing sequence of apparently contradictory reports about the effects of ethylene in propagation since that time. An excellent example of the confusion in the literature is the simultaneous publication of two articles on the effects of ethylene on root formation in 'Berken' mung bean. While there appears to be only minor differences in experimental technique one article (7) claimed that ethylene stimulated rooting, while the other (3) found a decrease in root initiation.

To me the real significance of this is that apparently minor differences in conditions and propagation technique can have a dramatic effect on whether ethylene promotes or inhibits root formation and/or growth. The only way to know how it works in your operations is to try it, and to remember that there are two approaches to use — adding ethylene and removing it.

Examples of ethylene-stimulated root formation are found in the work of Swanson (8) where four out of six species tested, *Prunus tomentosa*, *Amorpha fruticosa*, *Forestiera neomexicana*, and *Cotoneaster racemiflorus*, rooted better with ethephon alone than with ethephon and IBA combinations, or the untreated controls. *Juniperus scopulorum* and *Rhamnus cathartica* rooted best when treated with a combination of ethephon /IBA/NAA.

Maleike (5) showed that spraying coleus and pelargonium cuttings with ethephon promoted rooting. He suggests this as a technique for getting faster rooting and therefore more plants through the facility in a shorter time.

There is evidence of very low concentrations of ethylene promoting root elongation in some plants while higher concentrations inhibit elongation in the same roots (4). In rice, seminal root growth is stimulated by ethylene but crown roots are inhibited, while in barley the opposite applies (6,1). There are also many reports indicating that ethylene stimulates formation of root hairs and the initiation of adventitious roots, while inhibiting the elongation of such roots (6). Timing of exposure to ethylene may therefore be important in that its continued presence after roots have been initiated would be undesirable if it is inhibiting their elongation.

Other workers have suggested that primordia production is blocked by ethylene for the first 24 hours after taking cuttings, but after this phase ethylene promotes root formation (2).

I mentioned earlier that there are two aspects to control of ethylene in propagation — adding it and removing it. Ethylene exists as a gas and it is inconvenient to apply it as such unless the plants can be kept in a relatively sealed environment. It is soluble in water and can therefore be dissolved and applied as a spray. However a more convenient formulation is the commercially available ethephon, which breaks down to release ethylene when diluted or when its pH is raised.

Other ways of effectively applying ethylene are, firstly, to treat with auxin, the traditional root induction treatment. Auxins, particularly high concentrations of auxins, induce plant material to produce large quantities of ehtylene. Another traditional propagation technique that induces massive production of ethylene is wounding of tissue. Wounding is inevitably involved in any preparation of a cutting but the extent of wounding is commonly increased to increase the percentage strike. Increased ethylene production is associated with this treatment. Stress also induces increased ethylene production by the tissue itself whether that stress be water stress, nutrient stress, high or low temperature, or even flooding of tissue.

The simplest way to remove ethylene from a plant environment is by effective aeration. Ethylene can also be removed by a strong oxidising agent and the material commonly used is potassium permanganate, or Condies crystals. For this to be effective a very high exposure of saturated postassium permanganate is necessary.

It is also possible to inhibit the production of ethylene by the plant tissue and this can be achieved by low oxygen concentration. However plant growth would also be inhibited. It is also possible to inhibit the action of ethylene in the plant tissue. High concentrations of carbon dioxide can do this for some ethylene responses, but the most effective technique is to treat the tissue with the silver ion in the form of silver thiosulphate. This material is commonly used to extend the vase life of cut flowers and in treating certain other nursery lines such as *Zygocactus* plants to minimize the dropping of flowers.

Ethylene, like auxins, is one of several plant hormones and all are involved in the control of plant growth and development. So, too, are many other factors such as light, water, mineral nutrients, oxygen, and carbon dioxide. They are all in balance and closely interacting. Altering any one of these many factors alters the plants synthesis of and/or responses to the other factors. It is, therefore, possible to modify plant responses, e.g. initiation of roots, by altering factors other than hormones. We can put too much reliance on hormones as the

controllers of plant responses instead of looking at all of the factors. A ten-fold increase in auxin or ethylene can have dramatic effects on a plant's growth response, but so too can a ten-fold change in water supply or carbon dioxide.

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MICROPROPAGATION OF 'NORTHERN SPY' APPLE ROOTSTOCK

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Abstract. The literature on the micropropagation of apple rootstocks is briefly reviewed. Detailed results are presented on factors affecting the establishment of cultures, shoot proliferation, adventitious root initiation, and growth and establishment in potting medium of the apple rootstock 'Northern Spy.'

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REVIEW OF LITERATURE

Apple trees are normally propagated by budding or grafting the cultivar required (scion) onto a rootstock which is, itself, propagated by seed, cuttings, or from stool beds. The maintenance of stool beds is labour intensive and the production of rootstocks can be expensive.

A less expensive and more efficient method of producing clonal apple rootstocks is by micropropagation. Over the last 5 years there has been considerable progress in the micropropagation of apple rootstocks and scions. A number of commercial laboratories have been established that now specialize in the micropropagation of fruit trees (4,5,27,47). The success of micropropagation for apples is based largely on the finding that the cytokinin, BAP, can stimulate the growth of shoot-tips (18) and induce shoot proliferation (31), and that phloroglucinol can synergise auxins during rooting (21). Further advances have identified that the cytokinin type (28) and concentration (23,25), light levels (12), explant type (12), and agar concentration (34) are important for optimum shoot proliferation.

Recently, considerable attention has been given to studies on root initiation and growth. The stimulatory effect of phloroglucinol was first shown on shoot proliferation with 'M-7' and 'M-26' (19) and on root initiation with 'M-26' (21). Others found that phloroglucinol had no advantage (36), resulting in growth inhibition (45), or variable response, depending on cultivar (50) and concentration and the growth phase of the stock plant (42). Phloroglucinol was included routinely with 'M-9' cultures (16) and, although it had no effect on proliferation, it enhanced subsequent root initiation. The mode of action of phloroglucinol is not known and it has been suggested that it increases root initiation by increasing auxin uptake (15), or as an auxin protector by acting as an alternative substrate for IAA oxidase and/or peroxidase (17).

Investigations of the effect of auxin levels on rooting has led some workers to use a high auxin medium for root initiation followed by a low or auxin-free medium for root elongation (14,16,22,36). Lowering the salt concentration may also be

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Abbreviations:
LS, Linsmaier and Skoog;
2ip, isopentenylaminopurine,
BAP, 6-benzylaminopurine,
IAA, indole-3-acetic acid,
IBA, indole-3-butyric acid,
NAA, αnaphthalenacetic acid;
NOA, β-naphthoxyacetic acid,
PAA, phenylacetic acid,
GA_3, gibberellic acid

necessary for adequate rooting (23,30,36,43). Other factors affecting rooting include agar concentration (43), wounding the base of the stem (36,37), temperature (23), the time shoots are on proliferation medium (17) and the number of time shoots have been sub-cultured (38,40).

The benefits of micropropagation depend on rapid establishment and high survival rates once plantlets are transferred to an external environment in a potting medium. Few detailed studies have been made on this transfer procedure, but the problem areas primarily associated with poor water relations have been identified. There are four major factors. *Firstly*, there is a reduction or absence of epicuticular wax on the leaves of *in vitro* plants compared to glasshouse-grown plants (8,39). *Secondly*, the adequate functioning of stomata is delayed. Leaves of *in vitro* 'Pixy' plum lost more water than glasshouse-grown plants (3), the water loss occurring entirely from the underside of the leaves (6). For the first 3 days after transferring cultured 'Mac 9' apple to potting medium stomatal closure was low and water loss high, and only after 4 days did the stomatal closure mechanism develop (1). Treatments known to induce rapid stomatal closure were not effective with cultured leaves (2). *Thirdly*, high water loss has been attributed to reduced epicuticular wax and incomplete vascular development between the roots and the stem in cauliflower (9). *Finally*, leaf anatomical studies have revealed large air spaces between palisade and spongy mesophyll cells of cultured plants which may result in excess water loss (3,44).

Other factors found important for successful transfer of cultured plants include the use of antitranspirants (41, Hutchinson unpublished), the use of chilling or sprays with GA_3 when post-transfer growth is poor (10), and the incorporation or inoculation with appropriate mycorrhizal fungi (7,29,32,46).

With regard to successful transfer procedures, there are many problems still to be solved and many questions remain unanswered. In particular, the optimum potting medium and transfer environment need to be defined. The interaction of the prior cultural environment on the success of establishment is another area requiring further study. One recent advance is the initiation of roots and establishment of 'M-26' rootstocks combining the features of micropropagation and establishment in a single process (33).

Attention is drawn to more extensive reviews on fruit tree tissue culture (20,35,48), the micropropagation of deciduous fruit and nut species (13,24), and apple tissue culture (49).

The purpose of this paper is to briefly describe some factors which influence the establishment, shoot proliferation,

and root initiation and growth of the apple cultivar 'Northern Spy.' This cultivar was selected because certified virus-tested material is in limited supply, yet it is extensively used as a rootstock in Australia because it has semi-dwarfing characteristics and is resistant to woolly aphid (*Eriosoma lanigerum* Hausm.). Aspects of this work have been published previously (11,12).

MATERIALS AND METHODS

General: The basal medium of Linsmaier and Skoog (26), supplemented with 5 μM l^{-1} BAP and 1 μM l^{-1} IBA was used. Media were gelled with Difco Bacto agar at 0.8%. The pH of all media was adjusted to 5.8 prior to autoclaving at 100 kPa for 15 minutes. Cultures were incubated at 25°C with a 16:8 hour (light:dark) photoperiod under cool-white fluorescent tubes providing 75 μM m^{-2} sec^{-1}. Variations are indicated in the text. Shoot-tips 3 to 5 cm long were collected from the nursery at the Horticultural Research Institute, Knoxfield. They were brought to the laboratory and kept in running water for 1 hour before being sterilised for 1 minute in 70% ethanol containing 0.1% Tween 20 followed by 15 minutes in freshly prepared and filtered 5% calcium hypochlorite (w/v) containing 0.1% Tween 20 after which they were rinsed three times in sterile water. All subsequent manipulations were done in a laminar flow cabinet. After surface sterilization, the apical 3 to 5 mm was dissected out and placed vertically on the medium.

RESULTS AND DISCUSSION

Culture Establishment

a) *Time of year.* The effect of time of the year was studied by collecting shoot-tips in mid-spring, mid-summer, mid-autumn, and mid-winter.

Cultures could be established at any time during the year although contamination was least, tissue browning less of a problem, and growth more rapid if explants were collected in mid-spring or mid-summer. Explant browning was a significant problem with material collected in mid-autumn or mid-winter (Table 1).

Table 1. Effect of time of year on establishment, explant browning, and contamination

Time of year	Established	Explant browning	Contaminated
mid-spring	80%	15%	5%
mid-summer	90	10	0
mid-autumn	45	30	25
mid-winter	20	60	20

Medium LS with 5 μM l^{-1} BAP, 1 μM l^{-1} IBA and 1 mM l^{-1} phloroglucinol
n = 20

b) *Role of phloroglucinol.* The role of 1 mM l^{-1} phloroglucinol was studied on the establishment and following 5 sub-cultures using explants collected in mid-spring. The control medium had phloroglucinol omitted.

Phloroglucinol was effective in establishing proliferating cultures and more than doubled the number of shoots produced in each of the first two sub-cultures; however, by the fourth sub-culture phloroglucinol did not result in increased shoot number (Table 2). With these experiments phloroglucinol may be aiding in the uptake of cytokinins resulting in increased shoot proliferation.

Table 2. Effect of incorporating 1 mM l^{-1} phloroglucinol on shoot number for five sub-cultures

Sub-culture number	Plus phloroglucinol	Minus phloroglucinol
1	4.0	1.9
2	8.1	2.4
3	9.4	5.9
4	8 9	7 9
5	10.0	9.6

Medium: LS with 5 μM l^{-1} BAP and 1 μM l^{-1} IBA n = 20

Shoot proliferation

a) *Type of explant.* Five explant types from aseptic cultures were compared. Proliferation of the commonly used shoot-tips was compared with other explant types: i) single nodes placed vertically, ii) two nodes placed horizontally, iii) two or three shoot-tips resulting from stem fasciation and, iv) the basal mass material remaining after the removal of tissue in i) to iii).

All explant types were suitable for shoot proliferation. Vertical nodes and basal mass explants were better than single shoot-tips, clusters of two to three shoot-tips, and horizontal nodes (Table 3). The majority (63%) of single shoot-tips produced up to 6 shoots. The spread of shoot numbers was less and the nodal number was greater from clusters of two to three shoot-tips, greater again from single nodes, and even greater from basal mass explants. With nodes placed horizontally, 28% of the cultures produced single shoots and about 30% produced 10 to 16 shoots. The proliferation obtained with other explant types other than shoot-tips is interesting although not unexpected considering they contain dormant buds. What is unexpected is that shoot-tips are not the best type of explant to use to maintain cultures as the majority produce relatively few shoots. This allows other explant types to be used for routine proliferation and shoot-tips to be used immediately for root initiation, reducing further the time to obtain plantlets.

Table 3. Effect of explant type on shoot proliferation.

Explant type	Shoot number	Number of cultures examined
Single shoot tips	9 5 ± 0.5*	234
Clusters of 2-3 shoot tips	9.5 ± 0 4	146
Single nodes (vertical)	12 4 ± 0.4	129
Two nodes (horizontal)	8.3 ± 0 7	72
Basal mass	12 4 ± 0 5	32

Medium LS with 5 μM l^{-1} BAP and 1 μM l^{-1} IBA
*Standard error of mean

b) *Cytokinins.* Three concentrations (1, 5, and 10 μM l^{-1}) of each of four cytokinins (BAP, 2iP, kinetin, and zeatin) in factorial combination with light at five levels (25, 50, 75, 100, and 125 μM m^{-2} sec^{-1}) were evaluated. Single nodes and single shoot-tips were both tested as explant types.

Of the cytokinins tested BAP was by far the most effective for inducing shoot proliferation from both nodal buds and shoot-tips. For both explant types there was an increase in shoot number with increasing BAP concentration up to a light level of 75 μM m^{-2} sec^{-1}, after which it becomes supra-optimal, reducing proliferation. While proliferation was greatest at 10 μM l^{-1} BAP, the shoots were usually less than 1 cm tall and difficult to sub-culture, whereas with 1 or 5 μM l^{-1} shoots were between 1.5 and 2.5 cm tall and able to be readily sub-cultured. Kinetin, zeatin, and 2iP at, any concentration or light level, failed to induce any growth with nodal explants, whereas kinetin and zeatin were slightly promotive at 10 μM l^{-1} with shoot-tips (Tables 4 and 5). Single shoots with about 6 nodes developed with 2iP from shoot-tips. Since it was shown that BAP was suitable for inducing shoot proliferation in apple (31) it has been the most widely used cytokinin. These experiments confirm the results of Lundergan and Janick (28) which showed that BAP was superior to either kinetin or 2iP. With nodal explants BAP also has the advantage of breaking dormancy, whereas zeatin, kinetin, and 2iP are not.

Table 4. Effect of light level and BAP on shoot number using nodal explants

	Light level (μM m^{-2} sec^{-1}				
BAP concentration (μM l^{-1})	25	50	75	100	125
1 0	1.0	3 5	5 2	4.6	2.6
5.0	2 5	6 5	10.8	8.9	6 5
10 0	5 0	7 0	19 8	10.7	10.1

Basal medium LS with 1 μM l^{-1} IBA

Table 5. Effect of light level, and cytokinin type and concentration on shoot number, using shoot-tip explants

Cytokinin concentration (μM l^{-1})		Light level (μM m^{-2} sec^{-1}				
		25	50	75	100	125
Kinetin	1 0	2.1	1.0	1 0	1 0	1 0
	5 0	2.2	0.9	1.1	1.0	1 0
	10 0	4.0	3.5	3.5	3.5	1 2
Zeatin	1.0	1 5	1.1	1.8	1.4	1.5
	5 0	1 6	2 4	2 6	1 8	1 5
	10 0	6.1	4 8	4 6	4 5	1 5
BAP	1 0	4.0	4 2	4 4	4 3	4 3
	5 0	4.7	10.0	10.1	9 6	6 0
	10.0	4 9	16 0	17.1	16.8	9.8

Basal medium LS with 1 μM l^{-1} IBA

Root initiation and growth

a) *Auxins.* Three concentrations (1, 5, and 10 μM l^{-1}) of each of five auxins (IAA, IBA, NAA, NOA, and PAA) were tested in factorial combination with light at levels as for shoot proliferation.

Of the auxins tested, only IAA and IBA at 1 or 5 μM l^{-1} were suitable for root initiation. Both NAA and NOA tended to produce callus at the base of the stem with roots emerging from the callus but with no vascular connection between the roots and the stem. Phenylacetic acid was unsatisfactory as an auxin, with only about 20% root initiation at 10 μM l^{-1}.

b) *Salt concentration and physical support.* The effect of half and full strength LS salts (with organic addenda at normal concentration), and 1 and 5 μM l^{-1} IBA were tested in factorial combination with nine physical supports: agar, perlite, vermiculite, perlite:vermiculite (1:1), peat moss, coarse sand, peat moss:coarse sand (1:3), filter paper bridge, and liquid rotated medium (1 rpm).

Half-strength salts with 1 μM l^{-1} IBA was generally better than other chemical combinations, with high percentage root initiation in agar, perlite, coarse sand, and liquid rotated medium; however root number and length were low in agar and in perlite, compared to coarse sand and liquid rotated medium. This increase with coarse sand may be due to better aeration of the medium. Better aeration coupled with a greater absorptive area may be why a liquid rotated medium is so good; however, the resulting plantlets are fragile and translucent, making them difficult to establish in a glasshouse environment. The physical properties of vermiculite and peat moss are satisfactory for root initiation *in vivo* but may be unsuitable in this situation because of pH. These results support the finding that low salt concentrations are beneficial (23,36,43)

but only if used with low IBA concentrations and suggest that, depending on the choice of physical support, a one-step procedure may be suitable for both root initiation and elongation.

Establishment in potting medium

The influence of potting media was tested by evaluating mixes of peat moss:coarse sand (1:3), or perlite:vermiculite (1:1), with 5 sec. misting each 15 min. for 14 days. In addition, the effect of the same potting media were tested but with two applications of the anti-transpirant, Folicote® at 5% (v/v), one at the time of transfer and another 5 days later.

It is possible to transfer and establish rooted plants in potting media. Of those tested, a mixture of vermiculite:perlite was better than peat moss:coarse sand, if misting was used. Poor survival with peat moss:coarse sand may have been due to poor drainage. If anti-transpirants were used there was no difference between potting media (Table 6). Regenerated plants have shown no morphological differences to conventionally propagated plants.

Table 6. Effect of potting medium, misting, and anti-transpirant on survival percentage

Potting medium	Mist	Anti-transpirant	Control
Vermiculite perlite (1:1)	80	80	0
Peatmoss:coarse sand (1:3)	50	85	0

CONCLUSIONS

Aseptic cultures of 'Northern Spy' can be established at any time during the year although mid-spring and mid-summer are best. Shoot proliferation is maximum using nodal explants from aseptic cultures with 10 μM l^{-1} BAP and a light level of 75 μM m^{-2} s^{-1}, but the shoots are dwarfed and difficult to sub-culture. Better quality shoots, suitable for root initiation, were obtained when BAP concentration was reduced to 5 μM l^{-1}. Half-strength salts and 1 μM l^{-1} IBA result in maximum percentage root initiation and, if used in combination with a number of different physical supports, allowed control over the number and length of roots formed. Plantlets can be established in potting medium with a mixture of vermiculite-perlite, and either intermittent misting or sprays with an anti-transpirant.

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PROPAGATION OF *CAMELLIA JAPONICA* USING HORTICULTURAL ROCKWOOL

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Our nursery has been experimenting for the past 5 years with various rooting media for camellia propagation. In the spring of 1982 it was suggested to us that we try Rockwool as a medium. The nurseryman making the suggestion had experienced great success in its use for the propagation of miniature roses. We purchased from the manufacturer of Rockwool, approximately 10,000 blocks measuring 38 × 38 × 40 mm. These blocks came in sheets of 28 units measuring 266 × 152 × 40 mm.

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The sheets of Rockwool were laid on a sand bed in a glasshouse, the bed being heated by an electrical cable and maintained at 21°C. Intermittent mist was used on a time clock system, misting occuring for 10 sec every 10 min during daylight hours. The Rockwool sheets were placed on the bed dry and then thoroughly watered 2 or 3 times to ensure that they were wet through. Gloves were used with the dry sheets as the fibre can affect sensitive skin.

Cutting preparation began the first week of January (midsummer), 1983. The 10,000 blocks were used, along with approximately 100,000 tubes containing our usual medium. The cuttings were semi-mature new growth approximately 100 mm long. Some cultivars were longer and some shorter. They were dipped in "Rite Gro" Striking Powder No. 4, the active ingredient being 16 gms/kg indolebutyric acid. The cuttings were inserted in the Rockwool on the glasshouse bench and thoroughly watered.

Watering was continued by hand only rarely as the mist kept the cuttings sufficiently wet. Spraying with a combined fungicide of Benlate and Dacinal was done every two weeks. Cuttings were checked frequently — the beginnings of callus was noted after about 2 weeks. Roots started to appear in 5 weeks, and the cuttings were ready for potting in 8 to 10 weeks.

The first batch of cuttings gave a strike of about 90%. This far exceeded our expectations and the 65% strike in our usual medium. The Rockwool cuttings were potting in 100 mm pots and later into 150 mm pots for sale in autumn, 1984. The tube cuttings were moved into 125 mm pots and by autumn, 1984 were still not as well established.

During the summer of 1984 we propagated our entire crop of camellias in 57 mm deep, Rockwool blocks. These deeper blocks were treated in the same way as the shallower size used in 1983. They were thoroughly hand-watered 2 or 3 times and used in the same way as outlined for the first experiment.

We cannot give a rooting percentage for 1984 at the time of writing but the results look very encouraging.

The only problem we have encountered so far is in the control of green algae, which grows rapidly on any area of Rockwool exposed to sunlight. The area covered by leaves is unaffected by algae.

One conclusion we have reached, when using Rockwool for propagation, is that you must be prepared to pot as soon as the plants are rooted. If the plants are left for any extended time after rooting they can deteriorate rapidly. The use of

liquid fertilizer regularly can help, but the sooner they are potted the better.

As we grow about 150 *Camellia japonica* cultivars we are likely to have difficulties with some.

We have found that only one or two *C. japonica* cultivars have failed to root; it will take a number of seasons to determine if this is due to the use of Rockwool or to the cutting material used. We also experimented with two cultivars previously discarded because of propagation difficulties and found them to strike very well using Rockwool as a medium.

An advantage of using Rockwool is the speed with which it can be handled. There are no pots to fill and no trays or baskets to pack and the medium requires no sterilization. The potting stage is facilitated by planting the entire material; there is no "knocking out" and no empty tubes to store. Sheets of Rockwool can be picked up wet if handled carefully; alternatively a bricklayer's trowel can be used.

Our use of Rockwool in 1983 resulted in a 25% better strike and saved considerable time and labour. Potting, however, must be carried out quickly after rooting to preserve the strike. A solution to the green algae problem must be found.

ENCLOSED MIST SYSTEM FOR PROPAGATION OF BROAD-LEAVED EVERGREENS

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The first requirement in any propagating system for leafy cuttings is to conserve water in the cutting, which no longer has access to a free water supply from a root system. While some water can be absorbed through the cut base of the cutting, this is generally insufficient to replace water loss from transpiration. This water loss occurs because the humidity of the air around the cutting is lower than the humidity of the air inside the cutting. If the temperature of the air around the cutting increases, the relative humidity decreases; if the leaf temperature rises the vapour pressure inside the cutting increases, both lead to increased water loss from the cutting. Plants will endeavour to regulate this water loss in two ways: some have evolved structural forms of stomata which restrict rate of water transfer, while all plants will tend to close the

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stomata as water stress occurs. The extent of stomatal closure has a profound effect on CO_2 uptake.

The second requirement is to provide an environment in which the leaves can continue to photosynthesize during the process of root formation. Few leafy cuttings, when taken, have adequate reserves of carbohydrates to provide both the energy and the raw material required for root initiation and development. These two requirements are diametrically opposed; because photosynthesis requires that the leaves be exposed to light, and light falling on the leaves will raise the leaf temperature, with consequent increase in potential for water loss.

The traditional approach to propagation by leafy cuttings was to enclose them in a relatively small structure, e.g. closed frame, or polythene tent, usually inside a greenhouse. In such a small structure it is possible to maintain a higher level of atmospheric humidity than in an open, ventilated greenhouse. While these structures were an advance in their time they had a severe weakness. Light entering the structure caused a considerable increase in air and leaf temperature and consequently the cuttings would transpire rapidly, diminishing their potential to form roots.

To overcome this problem it was normal practice to reduce the amount of light by shading; this reduced photosynthetic activity and hence also reduced the potential to form roots. The art of the propagator was to juggle these two factors, sometimes referred to as the "propagators' dilemma".

The introduction of the intermittent mist system seemed to have overcome this problem. Cuttings were planted in open benches and sprayed with water in an endeavor to maintain a film of water on the leaves. This would have two effects — evaporation of water from the leaves would reduce leaf temperature, and simultaneously would raise the humidity of the air immediately surrounding the leaves, hence reducing the potential for transpiration. Because of the leaf cooling effect the leaves could be exposed to much higher light, and thus be more effective in photosynthesis. The intermittent mist system has been widely used, and is generally accepted as superior to the polythene tent, but recent studies have shown it to be less effective than we have previously thought it to be.

The disadvantage of intermittent mist systems is that, in fact, the relative humidity of the air varies from about 100% following a burst of mist to much lower values between bursts, as less humid air in the ventilated greenhouse mixes with the air around the cuttings. Furthermore, the irregular pattern of the leaf canopy makes a uniform distribution of

water to all leaf surfaces impossible. Because of these two factors, some cuttings may be subject to periods of water stress, even in a system which appears to be working satisfactorily.

The practice of combining the two systems, using mist inside a polythene tent, has been provided by Loach (1,2) at the Glasshouse Corps Research Institute in Britain. The advantage of this "enclosed mist" system is that it combines the effect of reduced leaf temperature and consequent reduction in leaf vapour pressure with increased humidity around the leaf because of the enclosed atmosphere inside the tent. Although air temperatures inside the tent rises above the ambient temperature of the greenhouse, leaf temperature does not rise to the same extent, so that transpiration is reduced. Measurements have shown that in an enclosed mist system the potential transpiration may be only about 60% of that in an open mist bed.

The New Zealand Nursery Research Centre (3) has carried out trials with enclosed mist systems, in comparison with open mist systems, over the last three years. This was done by erecting a rectangular section metal frame, 0.4m high, over half of each of two mist benches inside a greenhouse. Polythene film was draped over this frame to give an enclosure, although no attempt was made to ensure that it was 100% airtight. Some typical results are shown in Table 1.

Table 1. Percentage of cuttings rooted under two different kinds of mist systems

Species	Open mist	Enclosed mist
[*Azalea kurume* 'Kirin'][2]	98a[1]	100a
Boronia heterophylla	44b	74a
Boronia megastigma	69a	26b
Daphne odora 'Rubra'	56b	95a
Nandina domestica 'Pygmaea'	70b	100a
Rhododendron 'Ivery's Scarlet'	34b	60a

[1] Numbers followed by the same letter are not significantly different at the 5% level.

[2] *Rhododendron* (Kurume) 'Kirin'.

In general the rooting of the broadleaved cuttings in the closed mist was either improved, or equal to that of the open mist, but in one case, *Boronia megastigma*, it was significantly reduced. It is likely that the greatest benefits of enclosed mist will be found in cuttings whose resistance to transpiration is low, and the least in cuttings which are easy to root in almost any conditions. It has been found that conifer cuttings are generally inhibited from rooting in an enclosed mist system. One theory (1) is that in conifers the stomata are generally

grouped in deep pits, which would easily be blocked by water, thus depriving the leaf of CO_2. Similar conditions may well occur in other fine-leaved evergreens, e.g. *Boronia megastigma*.

Successful use of the closed mist system depends upon careful attention to two factors. The first is aeration of the propagation medium and drainage, since there is a high level of water entering the system, water must be able to drain freely from the propagation medium and bench. The system in use at NZNRC uses a peat/pumice (1:2 v/v) mixture in trays on a heated, drained capillary bench to ensure that these conditions are met. The second is the need for careful weaning of cuttings from the system. This has been accomplished with most species by gradual removal of the polythene cover over about 7 days, coupled, if possible, with a gradual reduction in misting frequency toward the end of this period.

The enclosed mist system is still in relative infancy and much more remains to be found out in the light of experience. No doubt, in the process of gaining that experience we will find further modifications being developed, meanwhile it offers a new opportunity for cuttings which have problems in water economy.

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COLLECTING, SELECTING, AND PROPAGATING AUSTRALIAN PLANT INTRODUCTIONS

W. RODGER ELLIOT

Australian Tube Plants,
Montrose, Victoria.

The Australian flora is often referred to as being unique, but this is not an accurate description, as most of our Australian plants belong to families that are widely distributed throughout other parts of the world.

The Australian flora is closely linked with the world flora, and the endemic species have evolved since the continent was isolated. The flora can be roughly divided into three main elements:

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The Australian flora is closely linked with the world flora, and the endemic species have evolved since the continent was isolated. The flora can be roughly divided into three main elements:

1. *Asian*. Many species from the Kimberleys, Western Australia, Northern Territory, northern and eastern Queenland, coastal New South Wales and far eastern Victoria have links with the Pacific and Asian region, especially those found in rainforest areas.
2. *Antarctic*. The relationship with New Zealand, sub-antarctic islands, and South America is obvious in south-eastern Australia, especially Tasmania.
3. *Australian*. The unique development of endemic plants has occurred since isolation, especially in Western Australia, due to the dry barriers of central Australia and the Nullarbor Plain.

The Australian flora is currently recognized as containing about 20,000 species, but it is projected that a final total will be in excess of 25,000 species (2).

It is at the genera and species levels that we find there is a high degree of endemism. About 30 to 40% of Australian genera are endemic. At the species level, about 75 to 85% do not occur outside this continent (5).

HISTORY OF CULTIVATION

Australian plants have been cultivated since the 17th century, when Dampier visited the western Australian coast. After the visits by Banks and Solander during the 18th century the botanical and horticultural worlds showed immense interest in the curious and diverse flora of Australia. They found the world's tallest flowering plants, as well as minute ephemeral herbs.

Australian plants grown in England prior ot 1788 inlcude *Acacia verticillata*, *Allocasuarina torulosa*, *Eucalyptus obliqua*, and *Leptospermum lanigerum* (4). Thus was the beginning of a tremendous upsurge of interest in the introduction and cultivation of Australian plants. The garden fashion of that era was to grow as many rare plants as possible, and this gave the wealthy of the day an opportunity to achieve their goal.

It is interesting to delve into horticultural publications of the early 18th century and find the following:

Boronia pinnata, (hawthorn-scented boronia). Greenhouse shrub from Australia, introduced 1795. Flowers from March-May, pink. Cultivation sometimes makes a plant valuable or otherwise, so it is with this little odoriferous shrub. If sparingly watered, kept at all times under glass, and thoroughly drained, it will usually florish (3).

Selections of *Epacris impressa* seedlings were at their peak

during the 1870's with over 70 highly valued varieties under greenhouse cultivation.

Much cultivation, selection, and propagation has been done since that time, with an ever-growing interest in the cultivation of Australian plants. Considerable credit must go to the Parry family of "Floralands" Gosford, New South Wales; George Althofer, then of Nindethana Nursery, Dripstone, New South Wales; the Boddy family of Eastern Park Nursery, Geelong, Victoria; and to Alf Gray, who spent many years collecting in Queenlands, New South Wales, Victoria, South Australia, and Western Australia. All these and other enthusiasts have contributed greatly to the ongoing domestication of Australian plants.

Current exploration and collection is leading to the discovery of more species, and many of these are being introduced to cultivation by botanic gardens, nurseries, and enthusiasts.

It is difficult to state an exact figure for the number of Australian plants that have been introduced to cultivation. Current research by D.L. Jones and the author leads us to believe it to be well over 8000 species.

COLLECTION AND SELECTION

What are the criteria for collection and selection? Basically these are the same for all plants, whether they be chance seedlings, sports, or plants developed through breeding programs. The following criteria are extremely important, and must be kept uppermost in one's mind if we are involved in introducing new plants to cultivation.

1. **Is it an endangered species?** The cultivation of endangered species is paramount, provided every precaution is taken to ensure that the natural population is not further endangered by our eagerness to bring it into cultivation. Experience gained in the propagation and cultivation of endangered plants may help us to understand the needs of such species, and thus provide the basis for an adequate management program to ensure the continuity of the species in its natural habitat. It is worth mentioning here that there are inherent problems with the introduction of plants from the wild. A major problem is that collectors are often too eager for their own interests, and do not take into account the need for conservation values.
2. **An assessment of overall aesthetic quality** — especially as a mature plant. Your personal choice is often biased, but hopefully others will agree with you.

3. **Proposed or suitable uses.**

a) In amenity horticulture —

i) As a home garden plant

ii) As a container or pot plant (for local sales and export.)

iii) For broad landscape planting.

iv) As an indoor plant.

b) Has it potential for any other specific uses?

As a windbreak and shelter plant, for use in the control of salinity, waterlogging or soil erosion, for food, cut flower or drug production, for timber products, or for wildlife conservation value.

c) Will the selection prove adaptable to a wide range of conditions, or will it have specific requirements? This consideration is of utmost importance, and can include aspects such as tolerance to drought, waterlogging, frost and smog. Features such as fire retardant properties may also be of considerable significance in assessing the proposed uses for a species.

4. **It is likely to become a weed once introduced to cultivation?**

This is often a difficult question to answer, but we should be guided by how related species or genera have behaved, once grown away from their natural habitats. People responsible for the introduction of plants should never underestimate the importance of whether a plant has the potential to become a noxious weed.

5. **How is the selection going to adapt to nursery production?**

This involves several aspects including ease of propagation and the good development of young plants to the point of sale. The final answer to this question may not be gained until thorough trials are undertaken.

COLLECTION OF PROPAGATION MATERIAL

Basically there are three alternatives from which to choose.

1. **Seed.** Seed is often difficult to collect unless you happen to be in an area where mature seed is present on plants. Many species will shed their seed on maturity, e. g. *Acacia*, *Anigozanthos*, *Grevillea*, *Hakea*, and *Kunzea*. There are, however, others that usually retain mature seed, e. g. *Banksia* (most species), *Callistemon* (most species), *Calothamnus*, *Eucalyptus*, *Isopogon*, *Leptospermum*, *Melaleuca*, and *Regelia* (1).

2. **Cuttings.**

Collection: Collection of initial propagation material

can pose problems. Undoubtedly many people here today have experienced the frustration of trying to collect good quality cutting material from wild plants. In some cases it is nearly impossible to gain even a few suitable sprigs.

It is often a case of gathering from what is available and hoping that some success in rooting will eventuate. If you have easy and regular access to wild material a judicious pruning program can help to rejuvenate the plant. The resultant new growth can then be used, and success is much more likely to be achieved.

Storage: It is elementary that cutting material must be kept in first rate condition. The material should be kept at a low temperature, and with a small amount of moisture to maintain humidity.

Some collectors use plastic bags which are tied securely. Others wrap the cutting material in moist newspaper and then place the bundles in a plastic bag. ONE WORD OF CAUTION — Some people place cuttings in portable refrigerators, or in the small units that are commonly used in caravans. These can be very efficient refrigerators and temperatures can drop to below 0º C. In such an event the damage can be irreversible.

One good practice is to place bags of cutting material in the open air during a cool night. Of course, this is not recommended if frosts are imminent. Placing the cuttings in a protected situation so that they will not be subject to the early morning sun is also important.

Excess moisture and high temperatures provide optimum conditions for the development of pathogens and sweating can also occur, thus damaging the plant material.

The storage of material in tight bundles is to be deplored, especially if it is despatched in that manner from far-away regions. Usually after arrival most of the material is best thrown straight into the rubbish bin.

Despatch. It is most important to use the fastest method of getting the material to its destination, so it can be processed as soon as is possible. Australia Post now offers a service that can have packages delivered to a destination within 24 hours from many parts of Australia.

3. *Division of live young plants.* Similar coments as stated under *Cuttings* are relevant here.

PROPAGATION

The results of propagation from cuttings collected in the wild is usually most variable. Some species will root in a

couple of weeks, whereas others will take more than 12 months before there is any evidence of roots.

At our nursery, propagation methods and structures are relatively simple and unsophisticated. There is not a great reliance on so-called high technology. We find that we get excellent results wih most species under the existing conditions.

The greatest step to success in propagation from cuttings is to use material that is in top condition. If you can choose the right material you have a much better chance of gaining roots on the cuttings.

The *propagation medium* which we find satisfactory is
10 parts coarse granitic sand.
1 part good quality mountain loam.
2.5 parts peat moss.

Each cutting is dipped in a hormone powder (0.3%IBA or 0.8%IBA) and placed in a separate 5 cm tube.

Our *propagation structures* are polythene tunnel houses. The single skin coverings are not taut, thus producing air movement in the tunnels when the skin moves. The tunnels are on a slightly southward slope, which also means that air movement is activated by the hot air being released from the northern end, and thus fresh air enters from the southern end.

Trays of cuttings are placed at ground level on a 15cm bed of crushed rock, which also acts as a heat bank.

Watering is through coarse misting nozzles, which are opeated by an Irri-Trol MC-4R irrigation control unit. During mid-summer watering occurs at hourly intervals over the hottest part of the day. Hand watering helps to overcome any dry spots.

EXAMPLES OF SELECTIONS PROPAGATED AT AUSTRALIAN TUBE PLANTS NURSERY

The majority of these selections have been introduced by us, whilst others have proved troublesome to propagate for many years. The species and cultivars listed below are chosen not merely because we were involved in their introduction, but because of our first-hand knowledge of their performance under propagation and cultivation.

Commersonia pulchella (Sterculiaceae)

A lovely dwarf shrub from north of Perth, Western Austrlia. It produces its small, white flowers for most of the year. Plants can sucker lightly and this material is ideal for propagation.

Conostylis bealiana (Haemodoraceae)

A tufting perennial herb from Western Australia, with brilliant golden yellow tubular flowers produced from autumn to late winter. Propagated by division of rhizomes, best done during April to July.

Dampiera linearis forms (Goodeniaceae)

Presently we are studying various forms of this wonderful blue-flowered species. Other *Dampiera* species are also propagated. Suckering growth is found to produce best results.

Epacris impressa (Epacridaceae)

We have been involved in a limited selection program with this show species. A naturally occurring form from the Grampian mountains, Victoria, 'Spring Pink' produces masses of small pale pink bells during spring.

Another selection tentatively known as 'Bushy Pink' is a garden seedling which develops much bushier growth than most forms cultivated. It has deep pink flowers.

Best results are gained using soft new growth. This also applies to most Epacridaceae species.

Eriostemon australasius (Rutaceae)

A highly sought-after New South Wales species. We propagate from a clone introduced to cultivation many years ago. Many propagators experience problems in rooting this species. Most of our stock plants are grown in 20 cm pots and kept hard-pruned and well fertilized so that vigorous growth is promoted. We have found it best to use this growth while the tips are still floppy.

Hibbertia longifolia (Dilleniaceae)

This small clumping species from hear Herberton, Queensland, show great potential with its large yellow flowers, slight suckering habit, and reddish winter foliage. Suckering growth roots readily.

Leptospermum lanigerum 'Pendulous' (Myrtaceae)

A garden cultivar with arching branches and greyish foliage. It becomes covered with white flowers in early to mid-spring. No problems in propagation.

Persoonia pinifolia (Proteaceae)

For many years propagators have tried to produce plants of this most attractive New South Wales species. Personally, many cutting batches ended in failure until cuttings were taken from young seedlings. The seedlings germinated after a parent tree had died in a suburb of Sydney. This led to the establishment of stock plants which are now pruned severely to produce flushes of new growth. This very soft new growth

is used without removing the floppy top growth. With the tip growth removed we experienced dieback which ran rampant through the cuttings. Cuttings can produce roots within 4 weeks, but is more common for roots to appear after 10 weeks, with the majority rooted within 20 weeks.

Prostanthera lasianthos 'Kallista Pink' (Lamiaceae or Labiatae)

This deep, pink-flowered form originated on a property at Kallista in the Dandenong Ranges, Victoria. It presents no propagation problems.

Rhododendron lochae 'Mt. Bartle Frere' (Ericaeceae)

This form has more vigour and paler coloured flowers than the typical form from Mt. Bellenden Ker in Queensland. It strikes well without retaining a node at the base of the cutting.

Thomasia pygmaea (Sterculiaceae)

This species occurs naturally near the Stirling Range in Western Australia. It is a delightful species that is becoming increasingly popular in cultivation as it is proving adaptable to a wide range of soils and climatic conditions. The new growth becomes firm very quickly, and is best collected for propagation before this occurs.

Thryptomene saxicola 'Mingenew'

Various forms of *T. saxicola* are well known in cultivation. This selection from near Mingenew (north of Perth), Western Australia, has a compact arching habit and larger flowers. Propagates well from semi-hardwod cuttings.

CONCLUSIONS

Our Australian flora has tremendous potential for cultivation. Without being biased it is recognized by many people both within Australia and from overseas that Australian plants will become amongst the most popular plants in cultivation over the next decade. People are beginning to realize that the diverse and curious flora of this continent is different in so many ways from the plants of other regions. They are, therefore, eager to be involved in the cultivation of these species.

There is also a greater awareness now of the importance of using indigenous plants in their local areas, and this opens a further horizon regarding the cultivation of Australian plants. To date little selection work has been undertaken in this regard, but some important work is being done by a commercial organization, "Ecological Horticulture".

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RECENT DEVELOPMENTS IN THE PROPAGATION AND ESTABLISHMENT OF PLANTS FROM SEED.

TONY BIGGS

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Investigations dealing with horticultural seeds continue to occupy growers, researchers, educationalists, and others all over the world. The range of topics being investigated becomes wider each year and over the last four years more than 2000 abstracts on seeds have been cited in Horticultural Abstracts. This review paper looks at some of the recent work in the areas of dormancy and germination inhibition, and also considers developments in seed treatment.

DORMANCY AND GERMINATION INHIBITION

The effects of low temperatures during seed stratification on breaking dormancy have been investigated extensively with many fruit and ornamental plants. Work with peaches (27) has confirmed the effect of the endocarp (stone) and testa on dormancy. Stratification for 12 weeks at 4.4°C was required to break dormancy of seeds within uncracked endocarps, whereas removal of the stone before cold treatment reduced the period to 4 weeks. Cold treatment of excised peach embryos overcame dormancy in only 2 weeks. Leaching unstratified excised embryos in water stimulated germination even more rapidly. The endocarp inhibits germination by preventing water uptake and also interferes with the leaching of inhibitors from the testa and embryo.

Indian workers (9) demonstrated that lignins extracted from the bark of a number of trees will inhibit germination of lettuce very effectively. On the same topic, workers in Japan (10) isolated and identified phenolic compounds as germination inhibitors in beetroot seed clusters.

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There has been increased interest in the effect of saline soil conditions on seed germination of vegetable crops in particular. Work with brassicas, capsicums, onions, and tomatoes has shown that germination percentages fall with increasing sodium chloride concentrations in the soil solution. Concentrations between 0.05% and 0.5% NaCl significantly reduced germination in these vegetables. On the other hand, it was found that soaking seeds in sodium chloride solutions of up to 3% for 12 hours before sowing into non-saline soils had no affect on germination. Further work demonstrated that cultivars differ in their behavior in saline soils.

Work with pecans (11) showed the interaction between abscisic acid (ABA) and gibberellic acid (GA) in germination inhibition. Before cold stratification at 4°C there were low levels of GA-like substances and high levels of ABA. During stratification the positions were reversed, with GA reaching the highest level after 6 weeks of stratification. Soaking seed in water for 24 hours after 2 to 3 weeks of stratification caused more rapid disappearance of ABA, while soaking in GA, at 1000 ppm for 24 hours after 6 weeks of stratification improved germination significantly. Work in Germany with mustard seeds (21) has reinforced the importance of abscisic acid as a germination inhibitor. It was shown that ABA reversibly stopped embryo development at the brink of radical growth initiation by inhibiting the water uptake which accompanies embryo development. Subsequent removal of the ABA allowed seeds to take up water rapidly and continue to germinate.

SEED TREATMENTS

Aeration and oxygenation. Tomato seeds were aerated for 24 hours with air or oxygen in water at 20° to 25°C before sowing (22). This treatment converted complex storage chemicals into simple utilisable materials and improved germination from 77% to 92%. Similar improvements have been obtained with melon seeds (19) following a 24 hour soak in aerated water. Russian workers (14) soaked tomato seeds in 0.2% to 0.6% solutions of hydrogen peroxide for 2 to 4 days and then held them for 6 to 18 hours in temperatures alternating between +21°C and -1°C. The composite treatment advanced emergence by 7 to 8 days when seed was sown in the field and crop yield was increased by approximately 25% over controls.

Seaweed extract soaking (30). Beetroot seeds soaked in a 1% (v/v) solution of seaweed extract prepared from various species within the families Laminariacae and Fucuceae showed superior germination to seeds soaked in water. The improvements were attributed to the cytokinin-like properties of the extract.

Organic solvent soaking. (26). Surrounding layers of seeds frequently contain and exude germination inhibitors and germination may be improved by totally or partially removing these layers. Manual removal may not be practical, however, and benefits have been demonstrated with cashew by soaking seeds for 2 hours in chloroform or acetone. The solvents removed the waxy pericarp layers and facilitated water imbibition and phenol exudation. The treatments hastened and partially synchronised germination and advanced field emergence.

Growth substances. Germination improvements have been demonstrated with a large number of species following treatments with gibberellic acid (GA) and cytokinins. Frequently there are interactions between the growth substance treatments and species/environment factors.

Work with celery (4) demonstrated that gibberellic acid and cytokinin treatments, separately, allow seeds to germinate at higher temperatures. Mixtures of GA with ethephon (Ethrel) or some cytokinins [especially benzylamino purine (BA)] produced even more effective germination promotion.

Low temperature treatment (1.5°C for 4 weeks) and/or GA_3 treatment (500 mg./litre for 24 hours) were compared on freshly harvested (27 species) and stored (23 species) seeds (2). Low temperature and GA treatments both improved germination in all fresh seed but GA treatments were more effective on stored samples. Species varied in behavior but it was recommended that a combined treatment of 24 hours in 500 mg./litre of GA_3 followed by 4 weeks at 1.5°C could be successful when exact requirements are not known. Work in California with Valencia orange (7) confirmed that seed taken from fruit harvested early in the season did not germinate. Storage of those seeds at 3°C to 4°C for 21 days produced 100% germination. Similar germination improvements were shown by seeds from fruits which remained on trees and received approximatley 100 hours below 3°C to 4°C. Gibberellic acid (GA_3) treatments overcame the cold requirement to some extent and produced 55% germination in seeds which received no low temperature treatments.

Germination of sour orange seed in Texas was delayed and reduced when seed was air-dried for more than 24 hours (8). GA_3 seed soaks reversed these effects of air drying and also produced taller seedlings. The adverse effects of air drying were not reversed by either stratification or water soaking treatments.

Other interactions with gibberellic acid were shown in treatments of sour orange, rough lemon, and *Poncirus trifoliata*

seed used for producing citrus rootstocks (1). GA soaks for 16 to 30 hours gave best results with seed of low vigour. With *P. trifoliata*, the best results were obtained when seeds were extracted just before treatment from fully ripe fruit.

Gibberellic acid and kinetin have been compared on scarified apricot stones and on lime seeds *(Citrus aurantifolia)* (3). GA at 500 ppm or kinetin at 5 or 10 ppm gave the best results with apricot, but a lower (100 ppm) concentration of GA was most successful on lime. Gibberellic acid and kinetin treatments also improved seedling growth.

Germination of Alexandra palm *(Archontophoenix alexandrae)* seed was shown to be accelerated by soaking for 24 to 72 hours in water before sowing and further accelerated by soaking for 72 hours in 100 ppm or 1000 ppm solutions of gibberellic acid (18).

The effect of gibberellic acid on excised embryos was demonstrated by work with *Camellia japonica* (13). Untreated fresh seed gave 48% germination after 12 days, but treatment with 1000 ppm GA for 24 hours increased germination to 84%. Treatment of excised embryos with a solution of 1000 ppm GA for 24 hours gave 100% germination in 6 days.

Germination of fresh, untreated seed of American horn beam *(Carpinus caroliniana)* was only 24%, but this was improved by stratification for up to 21 months (5). Further improvements resulted from combined treatments of stratification and gibberellic acid soaks, but the best results were obtained following scarification and GA soak treatments (up to 500 ppm) when good germination was obtained without stratification.

General germination stimulation has also been reported for medicinal plants (15), where 24 hour soaks of GA_3 at 100 to 1000 ppm gave improvements with *Lavendula spica, Atropa belladonna*, and *Hyoscyamus niger*, and *Primula* × *polyantha* (16), where a soak of 250 ppm GA_3 stimulated germination to 88% compared with 55% for untreated seeds. In this case there was no improvement to seeds of *Primula vulgaris*.

Irradiation with gamma rays. Gamma ray irradiation has been used on seed for many years in attempts to induce genetic mutations, but more recently the effects on germination have been studied.

Work with cucurbits has shown crop yield increases following irradiation of seed at 300 and 500 rad. (33). These increases were demonstrated in the crops grown immediately from irradiated seed and also in the following season with crops grown from seed saved from the first plants. Higher

levels of irradiation (500 to 100 rad.) on cucumbers also accelerated plant development, increased the number of female flowers and produced yield increases (6).

Ghanian workers (31) irradiated oil palm seeds with levels between 1 and 140 K.rad. The highest rates produced high germination percentages within 2 to 5 weeks of the treatment but untreated seeds did not germinate. Unfortunately the irradiation treatments retarded further plant growth.

Irradiation of poppy seeds with 150 to 10,000 rad. reduced the morphine content of seed capsules, with the highest irradiation levels causing the greatest reduction (20).

Further work with carrots (24) using seed irradiation of 2000 rad. produced crop yield increases of 17% to 20%, more uniform plant stands, and improved root quality. Higher irradiation rates on calendula seed (5000 to 10,000 rad.) caused advancement of flowering, increases in the number of double flowers, and productivity improvement (25). Finally, there are indications that onion plants produced from gamma-irradiated seeds showed less infection by white rot *(Sclerotium cepivorum)* (28).

Osmotic pre-treatment. Soaking carrot seed in a mixed salt solution of KNO_3 and K_2HPO_4 at -5 bars reduced the time between sowing and emergence from 16.6 days to 11.3 days (29). Microscopic examination showed good correlations between embryo length in the seed and earliness of emergence. Osmotic pre-treatment with polyethylene glycol (PEG) allowed carrot seed to be stored up to 20 months without any reduction in seedling emergence.

Treatment of impatiens seeds with polyethylene glycol at −7.5 bars for 10 days resulted in 80% germination within 24 hours of subsequent sowing. Seedlings were more advanced after 5 days and flowering occurred earlier (23).

Anti-bacterial treatments. Previous seed treatments to eliminate brassica black rot *(Xanthomonas campestris)* have had mixed results. Hot water treatments often do not eliminate the pathogen but do reduce germination. Low concentration thiram soaks (0.2% w/v) are more successful and also eradicate canker *(Phoma lingam)* without reducing seed germination. Bactericide soaks using 500 μg/ml. of terramycin or streptomycin solutions for 1 to 2 hours, followed by a water rinse and a 30 minute soak in 0.5% (w/v) sodium hypochlorite, have eradicated black rot with no phytotoxicity to developing plants (12). Non-use of the water rinse and hypochlorite soak did cause subsequent phytotoxicity.

Bacterial spot of pumpkin *(Xanthomonas cucurbitae)* was eliminated from seed taken from infected plants by soaking for

60 minutes in a 1 : 20 solution of commercial hydrochloric acid in water with 1% non-ionic spreader added (17). Hot water or sodium hypochlorite treatments only reduced the incidence of bacterial spot and the disease developed rapidly on seedlings and young plants.

Biological control of soil-borne diseases (32). Moist tomato seeds coated with *Trichoderma viride*, *Streptomyces griseus*, or *Bacillus subtillis* were sown in soils infected with *Phytophthora parasitica*, *Pythium debaryanum* or *Fusarium oxysporum*. The antagonistic activities of the bacteria significantly reduced the incidence of damping-off diseases.

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PROPAGATION OF DESSERT PEACHES AND NECTARINES FROM LEAFY CUTTINGS FOR COMMERCIAL CLOSE-PLANTED ORCHARDS

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We have a 32 hectare irrigated fruit farm at Woorinen, near Swan Hill on the Murray River. The climate is rather severe with temperatures ranging from 0°C in the winter to 45°C in the summer. These conditions, however, combined with our heavy clay loam soil, are ideal for the cultivation of stone fruits.

Five years ago, in 1978, we decided to reorganise our plantings using the "Tatura Trellis" (an intensive planting method) and trickle irrigation, for the following reasons:

a) To increase production without increasing the size of our holding.

b) New cultivars of stone fruits were becoming available.

c) Cost efficiency was necessary for picking and pruning and in the use of tractors for spraying and cultivation.

d) Earlier yields were available from intensive planting systems.

e) Water and land costs were rising at an alarming rate.

By using the "Tatura Trellis" we were able to plant 1600 trees per hectare instead of 300 using the old method. Thus production could be increased threefold without increasing the area or working costs.

The decision to construct a "Tatura Trellis" arose from the observation of the experiments which had been carried out at Tatura Irrigation Research Institute, Tatura, Victoria, by Bass Van den Ends and Leigh Issell for the cultivation of canning peaches in the Goulburn Valley, Victoria. With their cooperation we were confident that crop yields obtained in their area could be duplicated with dessert stone fruits.

One of the major problems faced was to obtain cheap trees in great numbers. The major cost of any intensive fruit tree system is the initial cost of the nursery tree: Issell had researched the propagation of canning peach cultivars from leafy cuttings and we decided to use this method but with emphasis on dessert cultivars of peaches and nectarines.

A low cost polyethylene igloo (11 metres by 3 metres) was installed with a canopy of 70% shade cloth, to help combat the high summer temperatures, in which a misting system was installed.

The following propagation method was used:

a) A suitable young, healthy tree was selected from which to take cuttings. These were taken early in the morning — 6.30 a.m. to 10 a.m. to avoid the heat, or until 12 noon if the weather was cool.

b) The cuttings were prepared in the orchard as they were taken from the tree, sprayed with water and stored in a polystyrene box before being taken to the propagation house.

c) The shoots were cut flush from the growing point, leaving a small amount of old wood at the cutting base. The soft growing tip was removed and three or four leaves were left which were cut in half.

d) In the propagation igloo, the cuttings were dipped in IBA (1000 ppm) for about 10 seconds.

e) They were then firmly placed in plastic seedling trays in a medium consisting of equal parts of perlite, vermiculite, and polystyrene beads.

f) The mist duration was 5 seconds every five minutes during the day and 5 seconds every 60 minutes during the night.

g) Roots appeared after 20 to 25 days and the cuttings could be weaned after 35 days.

h) Weaning was conducted over 4 to 5 days with complete denial of mist after the fifth day.

i) The trays of cuttings were then placed in a double shade cloth area and hand-watered for two days. They were then potted into 180 mm pots and protected from direct sun until the initial shock had been overcome.

RESULTS

These cuttings grew into 40 cm trees by winter when they were planted in the orchard. They were small but sturdy plants with a good fibrous root system. They developed rapidly in the spring and one year after propagation were one metre high. Records of rooting percentages were not kept, but from observations over the past five years the following points can be made:

a) Some cultivars were more easily propagated by this method than others, in particular the low-chilling Florida peach cultivars, such as 'Florida Sun', 'Orion' and 'Albatross'. With nectarines greater success was achieved with 'Phripp', 'Sunglo', and 'Sunred' than with 'Nectared' series.

b) Flexibility was needed in the control of the misting and weather conditions had to be watched at all times.

c) Cuttings were more successfully rooted when taken from young trees — up to 5 years old.

d) The time of greatest danger was in the weaning process, where the cuttings must be subjected to only one shock at a time.

It should be emphasised that we are orchardists rather than nurserymen and this system of propagation was used to propagate cheap, healthy trees for our own use because of our particular requirements.

It has been successful because:

a) Large quantities of stock were available close to the propagation centre.

b) Trees were being produced on their own roots at a reduced cost.

c) The method was relatively simple and did not require expensive equipment or great expertise.

PREPARATION AND USE OF LIQUID ROOTING HORMONES

PETER B. MAY
Victorian College of Agriculture and Horticulture
Burnley, Victoria

The auxin group of plant hormones were identified in the 1930's. By the late 1940's they had shown activity in a number of different horticultural applications, including the rooting of cuttings. The discovery that basal application of auxins to cuttings improved their strike rate had a major impact on commercial nursery practice, greatly increasing the range of plants which could be propagated by cuttings..

A number of naturally occurring and synthetic auxins have been used to induce the rooting of cuttings but only two are in common use. These are indole-3-butyric acid (IBA) and 1-naphthaleneacetic acid (NAA). Rooting hormones are generally applied to cuttings as either powders, using talc as a carrier, or in solution. Hartmann and Kester (4) offer some arguments in favour of the use of hormone solutions.

Early experiments with hormone solutions used relatively dilute solutions (0 to 200 mg/litre), in which the cuttings were soaked for periods up to 24 hours. This technique has largely

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Early experiments with hormone solutions used relatively dilute solutions (0 to 200 mg/litre), in which the cuttings were soaked for periods up to 24 hours. This technique has largely

been replaced by the quick-dip method where more concentrated solutions (500 to 10,000 mg/l) are used. Higher concentrations than these have been successfully used on difficult-to-root plants. Chong (1) describes the use of IBA solutions of 40,000 mg/l. Howard (5) suggests that for the quick-dip technique, a shallow 5 second dip is adequate.

Purchase and Storage of Hormones. If you wish to prepare your own rooting hormone solutions and be able to prepare the largest range of working concentrations, then purchasing the pure forms of IBA and NAA will be the most satisfactory. Most suppliers of laboratory chemicals carry a range of auxins.

In the solid form both IBA and NAA are relatively stable but IBA is best stored at temperatures between 0 and 5°C. NAA is quite stable at room temperature (3).

Preparation of Stock Solutions. In order to have the maximum flexibility in the preparation of rooting hormone solutions, prepare concentrated stock solutions of each hormone you intend using. These stock solutions can then be diluted to working strength concentrations as required. The stock solution will have to be more concentrated than the strongest working strength solution you are likely to need. As a guideline, a suitable stock solution concentration would lie between 10,000 and 20,000 mg/l. The procedure for preparing a stock solution is as follows.

a) Calculate mass of hormone needed; e.g. to prepare 500 ml of 20,000 mg/l IBA you will need 10,000 mg IBA (10 g).
b) Weigh out the hormone crystals. If you do not have access to accurate balances your local pharmacist may be willing to assist.
c) Dissolve the crystals in 50% (v/v) alcohol. The auxins are only very slightly soluble in water and alcohol can be used as a solvent. Methylated spirits is also suitable (7). For the preparation of stock solutions more concentrated than 20,000 mg/l you may need to use 95% (v/v) alcohol as the solvent to prevent the hormone from precipitating out at low storage temperatures (1).

In recent years, some attempts have been made to find better solvents than alcohol for rooting compounds. Interest has particularly focused on solvents which might give better hormone penetration of stem tissue. Products have been marketed in the U.S.A. using dimethyl sulfoxone (3) and dimethyl formamide (9) as solvents.

Storage of Stock Solutions. In concentrated solutions both IBA and NAA will be stable but storing them in brown glass

bottles in a refrigerator or some other cool area is a worthwhile precaution (2).

Preparation of Working Solutions. Once stock solutions have been made up, the preparation of working strength solutions is relatively simple. If you are intending to prepare slow-dip solutions (0 to 200 mg/l) then stock solutions can be diluted using water. For quick-dip solutions (500 to 10,000 mg/l), 50% (v/v) alcohol is used as the dilutent (4).

To calculate the amount (ml) of stock solution required you will need to know the concentration of the stock solution (mg/l), the concentration of the working solution you wish to prepare (mg/l), and the volume (ml) of working solution you intend to prepare.

Fit these values into the following formulas:

$$\text{volume of stock solution} = \frac{\text{volume of working solution (ml)} \times \text{concentration of working solution (mg/l)}}{\text{concentration of stock solution (mg/l)}}$$

$$\text{volume dilutent needed} = \text{total volume of working solution} - \text{volume of stock solution}$$

A working example is given below:

Concentration of stock solution: 20,000 mg IBA/l

Concentration of working solution to be prepared: 5,000 mg IBA/l

Volume of working solution to be prepared: 100 ml

$$\text{Volume of stock solution needed} = 100 \times \frac{5{,}000}{20{,}000} = 25 \text{ ml}$$

Volume of dilutent (50% alcohol) needed = 100 −25 ml
= 75 ml

IBA/NAA Combinations. If you wish to make up working solutions containing two or more active components, for instance IBA and NAA combinations, then the rules to follow are essentially the same. First, calculate the volume of each hormone stock solution needed to give the correct hormone concentrations in the working solution. Use exactly the same formula as given for single hormone solutions. Then, to calculate the volume of dilutent required, add together the two stock solution volumes and subtract this total volume from the volume of working solution you wish to prepare. A worked example is given below:

Stock solutions: 10,000 mg IBA/l
8,000 mg NAA/l
Working solution to be prepared: 1,000 mg IBA and
500 mg NAA/l
Volume of working solution to be prepared: 250 ml
Volume of IBA stock solution required = $\frac{250 \times 1{,}000}{10{,}000}$
= 25 ml
Volume of NAA stock solution required = $\frac{250 \times 500}{8{,}000}$
= 15.6 ml
Total stock solution volume = 40.6 ml
Volume 50% alcohol required = 250 — 40.6 ml
= 209.4 ml

A point worth remembering here is that where IBA/NAA combinations are being prepared, your stock solution concentrations may need to be higher. Stock solutions of 20,000 mg/l of hormone will allow you to make working solutions up to 10,000 mg/litre, which will cover most requirements.

Use of Hormone Solutions. Soak solutions, because they are dilute, are likely to be unstable and can become ineffective after a few days due to microbial destruction of the hormones (4). Because these solutions are made up in water they can also spread pathogens if hygiene is not good (6). However, the 50% alcohol used to dilute the quick-dip solutions will kill microbial contaminants and thus quick dip solutions are more stable and do not present the same potential for spreading disease (4). Use of quick-dip solutions in very hot weather may result in increased hormone concentration through loss of solvent but, with IBA at least, there is a reasonable tolerance of plant response to auxin concentration (3).

If the propagator wishes to use a fungicide treatment of the cutting in addition to the auxin treatment, cuttings are best dipped in the fungicide as a separate treatment after the auxin has dried (4).

A quick check for the activity of auxin preparations can be made using leaves of tomato as a bioassay material (4).

Safety. As with the use of any chemical, some caution should be exercised when handling preparations of potentially toxic materials. In one sense the liquid preparations of auxins are safer to use than powders because the risk of inhaling dust is reduced, but when we look at available toxicological data the risks do not appear to be great. NAA, for instance, has an acute oral LD50 for rats of 1000 mg/kg body weight (8). Extrapolating this data to the human, an assumption that is not

entirely valid, a 75 kg propagator would need to ingest something of the order of 75 gm of NAA to reach this dose. Made up as a 1000 mg/l solution he or she would have to drink 75 litres of solution. The rooting hormones deserve to be treated with respect but seem not to present any great danger to the careful user.

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SOME PRINCIPLES OF GRAFTING FOR THE PRODUCTION OF WEEPING TREES

NELSON R. WILSON

Wilson's Nursery
Wandin North, Victoria

Plants may be grafted in a multitude of ways for many different reasons, but grafting is usually employed for one of the following reasons:

a) To propagate plants which are difficult to propagate by cuttings;

b) To join plants, the roots or shoots of each being selected for special purposes such as disease resistance and/or adaptability to special conditions such as soil or climate;

c) To invigorate weak plants, or repair damage;

d) To allow one root system to support more than one cultivar;

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c) To invigorate weak plants, or repair damage;

d) To allow one root system to support more than one cultivar;

e) To produce clonal material usually on more vigorous rootstocks than itself; and

f) To eliminate problems of structure, growth, and disease.

Grafting is widely used for the commercial production of fruit trees and a variety of other ornamental nursery lines derived from clonal selection. These include flowering fruit trees, elms, ashes, liquidambar, etc.

Grafting is also widely used to create "special effect" plants that could not otherwise be grown to display their best features. These "special effect" plants include most of the weeping trees. Most of the weeping trees can be readily grown from cuttings or seed but produce plants with a prostrate or near prostrate habit. By grafting these prostrate plants onto upright stems (standards) of varying heights, plants with weeping habit can be produced which can cater for a variety of landscape situations.

The production of rootstocks for weeping trees should be given careful consideration. The practice of using seedling-grown plants as rootstocks for weeping trees does not always give the expected results when grafted to cultivars of the same species. The reason for this can often be traced back to incompatibility with some of the seedling rootstocks. There are many examples of this where seedling rootstocks grafted to another cultivar will behave quite differently. When only small numbers of grafts are made in one season the reasons for these failures are often obscured, being attributed to faulty techniques or bad seasonal conditions. The reasons are usually more apparent when large numbers of grafts are made.

One method that overcomes these failures is to use an intermediate stock which has proven to be compatible with both rootstock and scion.

The usual rootstock is planted then grafted with the intermediate stock of a selected proven clone which is grown for one season or until the desired height is obtained. It is then grafted or budded with the prostrate or weeping clone. This method has proved very satisfactory and, provided care is taken with the grafting, 100% success can be achieved.

By using the intermediate stock system to produce stocks for some species of weeping trees it is possible to obtain a good straight stock 2 to 3 metres high without bends or knots in one growing season. This total approach has allowed salable plants to be produced 12 to 18 months earlier than by using the conventional method.

When carrying out the actual grafts it is best to use graft-

ing knives of the highest quality kept as sharp as possible at all times. Whenever a knife is felt to "drag" or leave marks on the cut surface it should be re-sharpened. I find the most useful grafting knives are the ones with slightly curved edges.

With most types of deciduous weeping trees I use the "whip and tongue" graft. The length of the flat sloping cut is made approximately six times the thickness of the scion. The cambium layers of at least one side of the graft should be perfectly aligned. The grafting tape is left on the graft until the scion has shoots 5 to 8 cm long. This will usually be two to three weeks after bud burst.

Plants grafted in outdoor situations are usually staked with a small stake tied to both stock and scion to provide protection from wind.

Many interesting plants can be produced by grafting and the current work being carried out in the production of weeping grevilleas illustrates this.

TRANSFERRING TISSUE-CULTURED PLANTS — IN PARTICULAR GREVILLEAS — TO THE NURSERY ENVIRONMENT

ADRIAN BOWDEN

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When plants propagated by tissue culture are transplanted from the sterile high humidity conditions of the tube or jar to the nursery environment, the results are often very disappointing. When evaluating these results we should not look at transplanting as a single process, but rather as a chain of events with conditioning of plants for transplanting; the actual transplanting; the media; temperature/humidity; and hygiene, all being links in this chain. If we then learn to understand each link and understand how it fits into the chain, results will improve.

It should be pointed out that tissue-cultured plants differ physically from similar sized plants grown conventionally, e.g. under mist from cuttings. When first removed from sterile culture their leaves are thinner, they have less cuticle and are less waxy. They are less functional, as their stomates do not respond as efficiently to stressful conditions. Often instead of closing rapidly they remain open. These factors cause the

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young plant to dehydrate more quickly than would be normally expected.

Roots are often not as functional as they appear, and sometimes are not connected in the normal way, thus greatly reducing their effectiveness. After 7 to 10 days new leaves and roots have been produced and from that time on the task becomes a lot easier as the plants begin to function normally.

Let me now make the point that the following plants produced by tissue culture have proved easy to transplant for us: Most house plants, including gloxinia; *Nephrolepis; Syngonium; Spathiphyllum; Saintpaulia; Anthurium, Ficus; Davallia; Dionaea; Cephalotus; Begonia*, and *Cordyline*. In fact, losses in any of these can generally be put down to causes such as insect or fungal attack, or overwatering.

When one starts to transplant perennial and woody plant material, however, it becomes a whole new learning experience. Gerberas and roses, for example, have not proved very difficult to transplant providing the material is in good condition at the time of transplanting. Results in excess of 90% have been achieved.

Gypsophila has proved difficult unless exactly the correct type of material is used for planting out.

Grevilleas, of which we grow several cultivars, have proved to be one of the most difficult, but we have achieved results of 80 to 90% by using the following methods:

Pre-conditioning: Plants in the laboratory are generally subjected to low light, even though this may not appear to be so. It is usually about 1000 lux. These plants are then exposed to higher light — 3000 to 10,000 lux — for up to two weeks before planting out, to prepare them for the harsher conditions in the glasshouse. When the plants are placed in the glasshouse they are put in a shaded area, in light conditions similar to those used for growing ferns.

Temperature/Humidity. Over a period of approximately three years we carried out a comprehensive study of temperature and humidity using a thermohygrograph. This information was correlated with plant survival and losses. During this period the outside conditions varied greatly. In winter the humidity averaged between 50 and 70% and the temperature between 10°C and 20°C. In summer the humidity averaged between 10 and 30% and the temperature between 15°C and 30°C.

From the above trial we were able to conclude that for the successful transplanting of grevilleas, the humidity needs to be 85% plus, while the temperature is held between 15°C and 25°C inside the house for the first three to four weeks.

How high humidity is achieved will vary from place to place. In some operations plastic sheeting is placed directly over the plants for seven to ten days. Others use plastic cling film (Gladwrap®). Others, in areas where outside humidity is low and temperatures are high, use mist or tents with mist inside them.

We use as a guide the following — if you can take a photograph inside your transplanting area, without the lens fogging up, the humidity is too low.

Media. Over the same three-year period trials were also carried out to select the ideal medium. Mixtures of sand, peat, foam, perlite and crushed rock were used.

One of the best was found to be a coarse sand with about 25% air space. There was a direct link between air space in the medium and plant growth. Generally the plants which had proved to be the most difficult to transplant in our conventional medium of peat, foam, and perlite (used for hardwood cuttings) grow much better in coarse sand. This produces some problems, however, when these plants are being freighted out by air.

Controllers. We have preferred to use mist timers rather than sensitive leaf controllers. Whatever controller is used it is wise to have a back up controller on hand as well as spare solenoid valves. When tissue-cultured hardwood plants are first put out you can be sure that everything that can go wrong will go wrong.

Fungal Attack. Fungal attack can be prevented by using steam sterilized media, clean containers, and by spraying immediately after planting out with a fungicide. We use Previcur (70% propamocarb) at the rate of 15 mls/10 l product, with a follow-up application 10 to 14 days later of Rovral (iprodione 50%) at 1 g/l wettable powder.

The Stage Plants Have Reached at Transplanting. This is of major importance and has a large bearing on the number of transplants that become saleable plants later on.

Our approach has been to mostly plant out unrooted material that has callused and is just starting to root. The reasons for this are faster planting speeds and a resultant higher percentage of successful plants. If rooted plants are transplanted a lot of roots are broken off if worthwhile planting speeds are maintained.

In conclusion, if proper care and attention is given to all the aspects of conditioning and transplanting of woody tissue-cultured plant material, the results can be commercially successful.

MECHANISMS OF HORMONE ACTION IN PLANTS

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Botanists have recognised for over one hundred years that plant growth and development are controlled by chemicals produced within the plant. Today there are five groups of widely known and used hormones (Figure 1). These are the auxins, the gibberellins, the cytokinins, abscisic acid, and ethylene (10). It is unfortunate, however, that the definition of a plant hormone was borrowed from the definition used by zoologists.

> "an organic compound synthesised in one part of a plant and translocated to another part, where in low concentrations it has a controlling or regulatory effect — it causes a physiological response" (1).

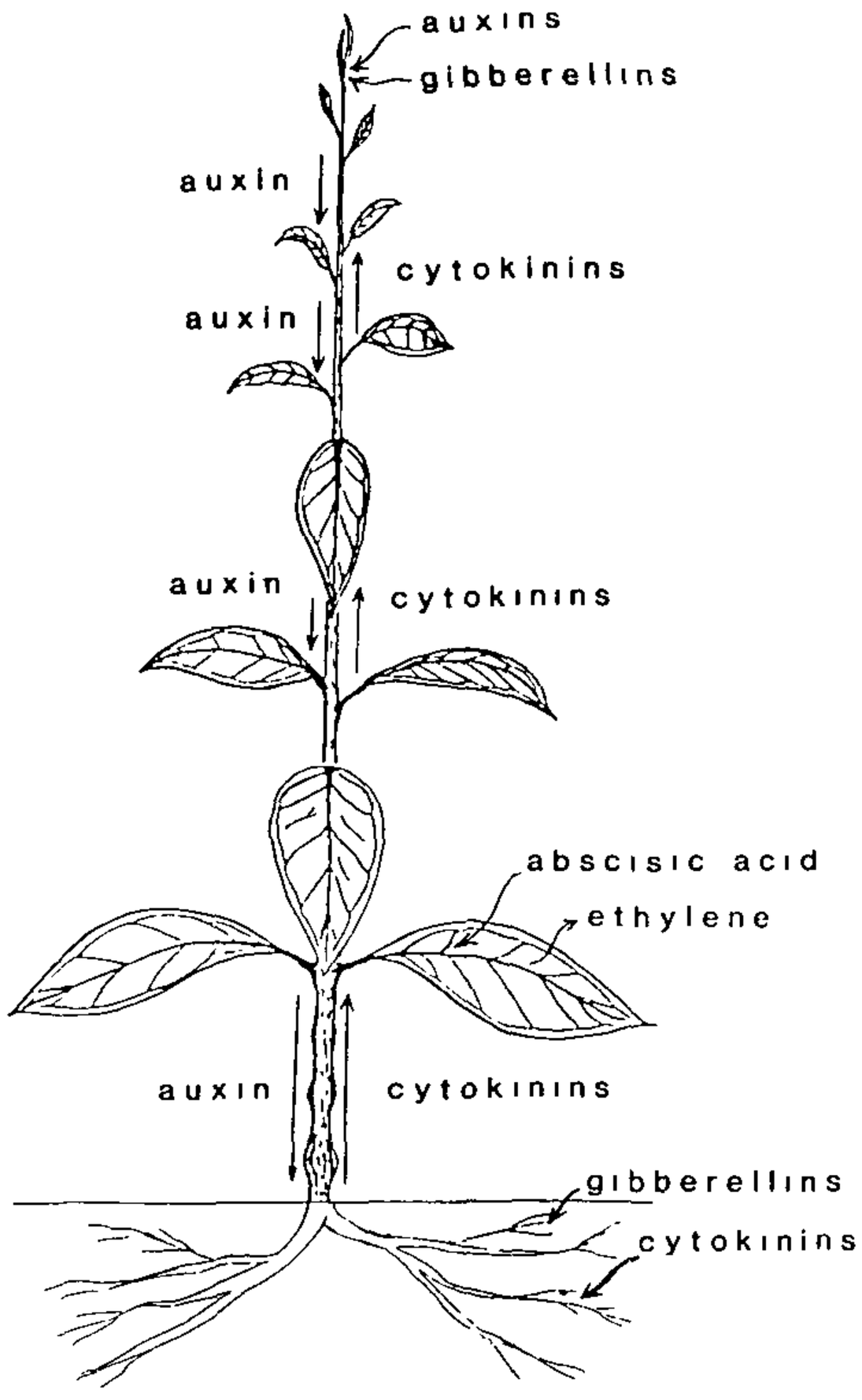


Figure 1. Major hormones and their sites of synthesis.

The definition is fine for an animal where the sites of synthesis and response are separate but in plants synthesis, response, and transport may all occur in the same tissues (8). Many chemicals that affect plant growth and development but *do not conform to the definition, are called plant growth substances* (Figure 2).

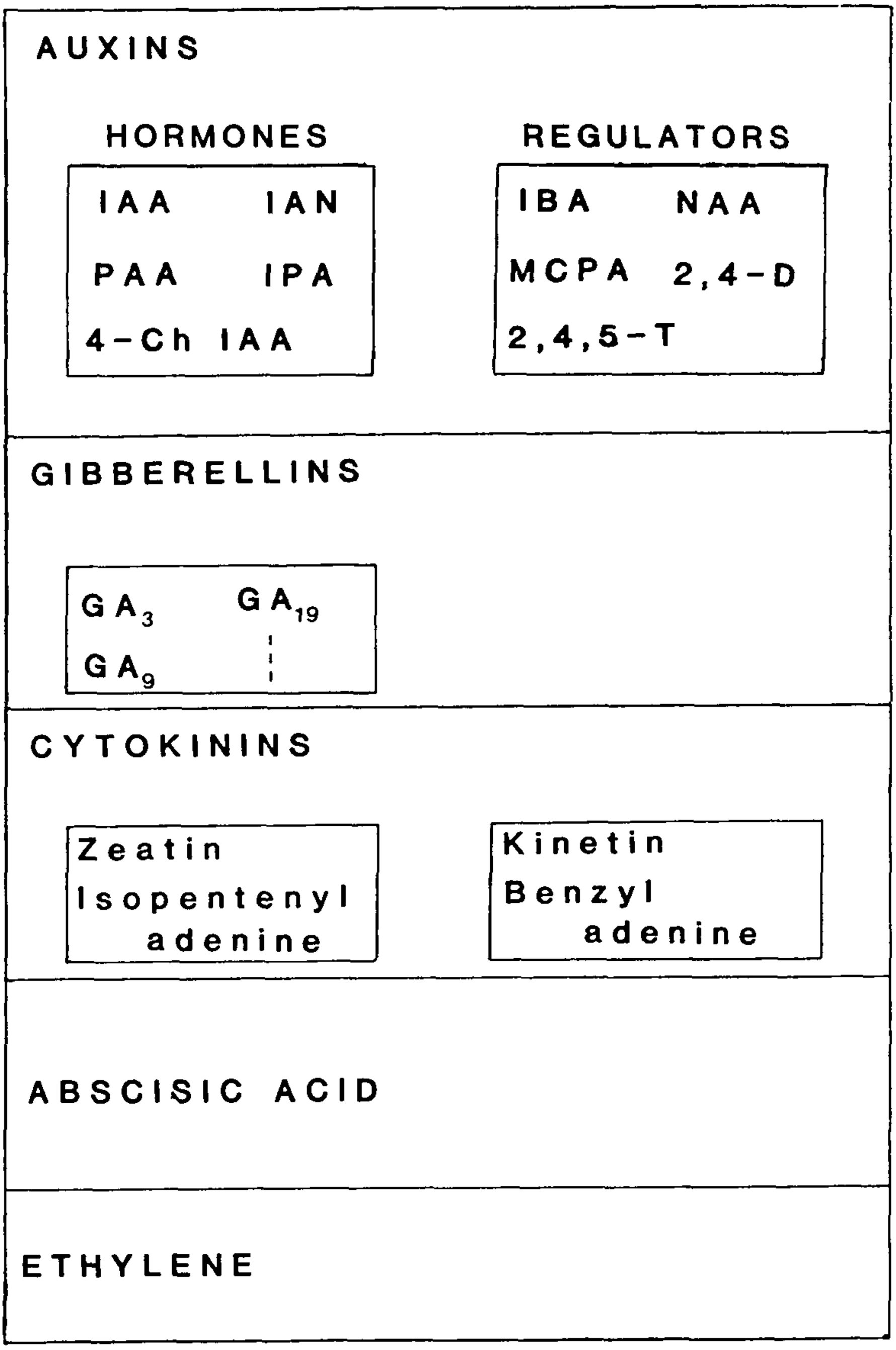


Figure 2. Hormones and plant growth regulators.

A further complication that arises is whether five groups of hormones can control the large number and diversity of activities that are involved in plant growth and development. Although there is still some debate (3), it does appear that the hormones can control many of the plant's activities through a complex set of interrelationships that involve the hormones and the plant tissues themselves. The variables involved in these relationships include:

1). Different hormones affect different tissues.

2). Different hormone concentrations can cause different responses in the same tissues.

3). Different levels of interaction between two or more of the hormones can stimulate different responses.

4). The physiological state of the tissues can alter their responses to hormones.

The combination of these variables gives almost infinite variation and so offers the possibility of controlling the plant's activities.

MECHANISMS OF HORMONE ACTION

Because hormones cause so many plant responses, only the major effects of each of the groups will be considered. Practical applications of the hormones in plant propagation will be discussed.

AUXINS

The study of auxins was begun in 1880 by Charles Darwin, but it was the work of Went in 1928 that showed their importance in plant growth. The most common and best known hormonal auxin is indoleacetic acid (IAA), but it is not the only naturally-occurring auxin (Figure 3). Phenylacetic acid (PAA) and indolepropionic acid (IPA) appear to be present in many plants, while 4-chloroindoleacetic acid (4-chl-IAA) is found in legumes and indoleacetonitrile (IAN) is present in members of the Brassicaceae (12). IPA is about twice, and 4-chl-IAA about four times as active as IAA itself. In most plants the ratio of PAA to IAA is about 1:4 or 5, and PAA is found only in association with IAA.

Many of the synthetic auxins are well known to horticulturists. Naphthaleneacetic acid (NAA) and indolebutyric acid (IBA) are structural analogues of IAA, while 2,4,5-T and MCPA are analogues of PAA.

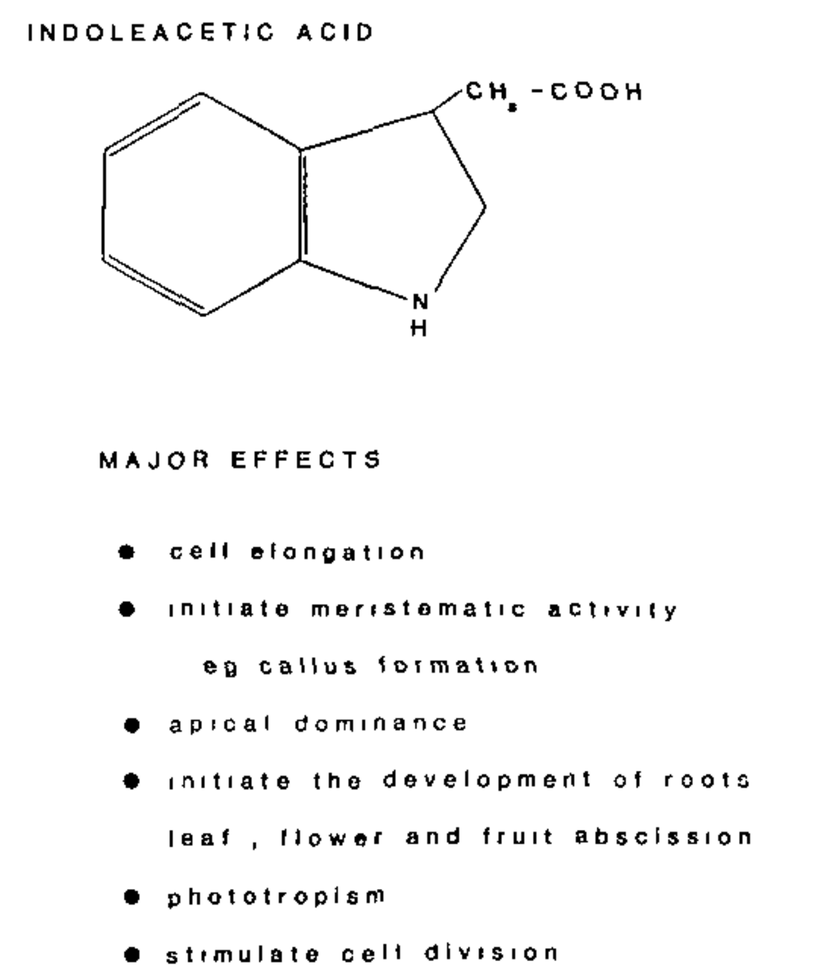


Figure 3. Auxins.

Effects of Auxins. The most obvious effect of auxins is the promotion of cell enlargement and in the cambium they can stimulate cell division as well. They are also responsible for the inhibition of lateral buds in stems, where they are produced in the apical meristem. It also appears that auxins have a role in leaf abscission but other hormones may also be involved.

Auxins can stimulate root elongation but only at extremely low concentrations (10^{-7} to 10^{-13}M); at higher concentration root growth is inhibited. The development of root primordia, however, may be stimulated by high concentrations of auxins. This stimulation may involve the activation of preformed root primordia or it may initiate the formation of adventitious roots. The range of concentrations over which root development is promoted is very wide, ranging from about 10^{-2} to 10^{-4}M, or 20 to 2000 ppm, depending upon the plant and the method of auxin application (5).

Auxins influence much of the plant's growth and development but how they affect plant tissue is uncertain. It has been suggested that auxins trigger enzyme activity by acting as coenzymes, or by stimulating RNA production that, in turn, produces more enzymes. It may also be that auxins alter the cell membranes, and this then allows cell enlargement and the other effects that have been observed (10,11).

Auxins and Plant Propagation. Auxins have been widely used by plant propagators especially for the promotion of root initiation in cuttings. The auxins that have been used are usually the synthetic auxins, IBA or NAA. These can be applied in various forms and concentrations (6) but are usually applied as a powder or liquid dip. The concentration used

depends upon the duration of auxin application. The use of auxins at the appropriate concentrations is essential because the wrong concentration can turn an intended promotion into a complete inhibition of the tissues treated.

Attempts have been made to use auxins for the promotion of callus formation in budding and grafting operations, but the results have been disappointingly inconsistent. The use of auxins, in conjunction with cytokinins, has been the basis for the successful tissue culture of most plants or plant parts. The use of synthetic auxins as herbicides has also been very successful. They appear to kill plants by interfering with the normal production of enzymes and are more effective against broadleaf plants in which they are more readily absorbed and translocated than in grasses.

The synthesis of IAA in the meristematic regions of roots and stems is to be expected, because the enzymes necessary for the manufacture of IAA are most active in these tissues. The plant and many micro-organisms, such as bacteria, possess enzymes that degrade auxins. IAA can be degraded quite rapidly but the process is retarded by refrigeration. Light degradation of IAA can also occur and the hormone should not be exposed to bright sunlight. The synthetic auxins such as IBA and NAA are less prone to light and biological deterioration and may be kept for longer periods of time.

GIBBERELLINS

Gibberellins were first discovered in Japan as a result of studies on a fungal disease that caused rice plants to grow very tall. The active compound was isolated and identified in the 1930's, but was not widely-known in other countries until after the war. All of the gibberellins are variations of the organic acid, gibberellic acid (Figure 4). At present there are 53 gibberellins, of which about 40 are known to occur in plants (8,9). Most plants contain only a few of the gibberellic acids (GA), and the most commonly occurring GA is GA_3, which is also the one most readily available (7).

Like IAA, GA is produced in young, actively photosynthesising leaves. Some GA is also synthesised in the roots and appears to move from the roots via the xylem into the stem. Other parts of the plant, such as embryos, seeds, and fruits are known to contain GA, but it is uncertain whether they actually synthesise it. GA is more readily transported through the plant than auxin, and can act over long distances to control various processes. Not all of the reponses due to GA, however, occur over long distances.

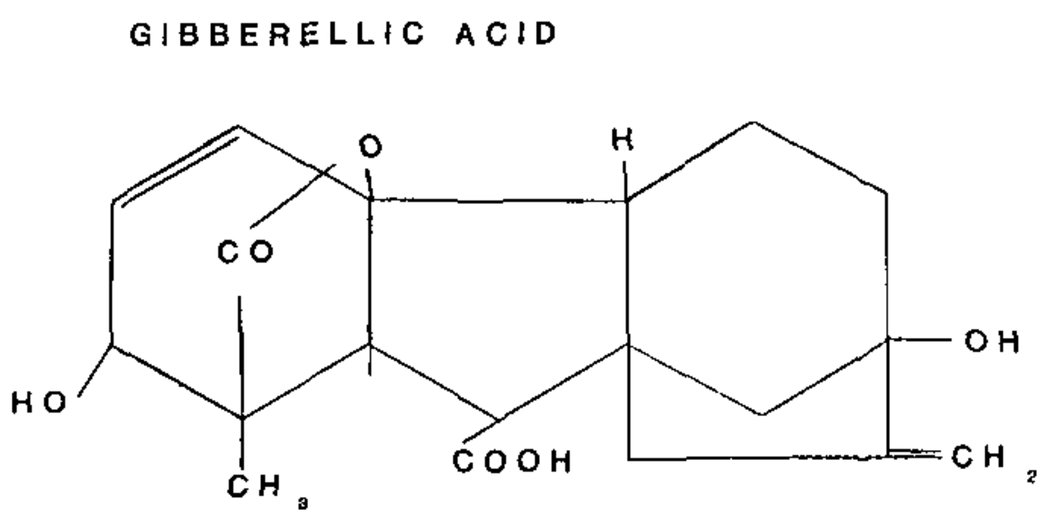


Figure 4. Gibberellins.

Effects of Gibberellins. The most spectacular effect of gibberellins on plant rowth is their ability to stimulate stem elongation in intact plants. Most plants show some response to applied gibberellin and in many short-stemmed or dwarf plants the effect may be striking. In this respect gibberellins appear to affect plant growth in a manner opposite to the auxins. The stem elongation is usually due to an increase in internode length that is due to the expansion of cells caused by enhanced water uptake. Often the dry weight of the plant is unaltered by such changes in growth.

Like auxins, gibberellins appear to influence plant metabolism in several ways. They are capable of stimulating cell division apparently by enhancing DNA and RNA synthesis. Gibberellins also hydrolise starch into sugar which not only provides energy, but promotes water uptake by the cells, which causes cell expansion. The gibberellins may also increase cell wall plasticity. Any or all of these properties may give the stem elongation that is observed or the increases in the sizes of leaves, flowers, or fruits.

Both auxins and gibberellins can induce similar physiological responses in many plants. However, gibberellins appear to be more effective on whole or intact plants, where many of the auxin effects are for excised organs or sections of plants. It is clear that there is a major interaction between these two common and important groups of hormones that influence many facets of plant growth and development. Knowledge of gibberellins is not sufficient as yet to be certain of their mode of operation and research into the active forms of GA is continuing.

Gibberellins and Plant Propagation. Gibberellins have been used to promote the germination of dormant seeds. This occurs in cereals because gibberellin induces the production of enzymes that digest the endosperm and provide energy for the growth of the embryo. The concentrations of GA used for such treatments can range from 10^{-3} to 10^{-1}M, or 100 to 10,000 ppm. The seed coat often has to be removed from the seed to allow the GA to penetrate for the treatment to be effective. The GA actually breaks the dormancy of the seeds in many species, overcoming the need for environmental cues.

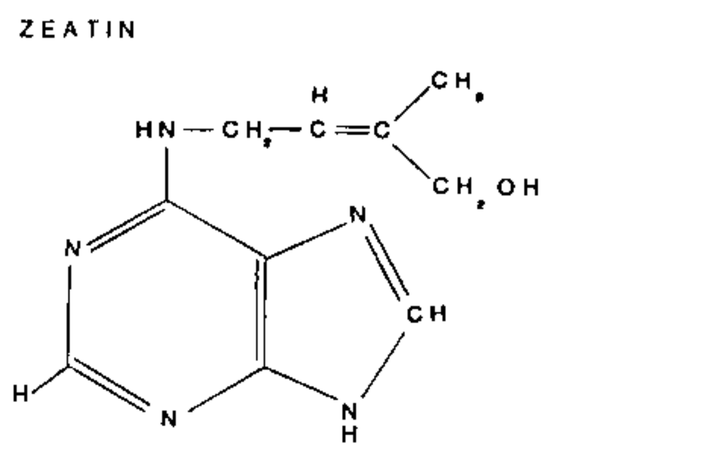
Gibberellins appear to be more stable compounds than the auxins. They are not so sensitive to light, nor are they degraded so easily biologically. Careful storage, however, is still advised and the habit of keeping hormones in a darkened refrigerator is to be encouraged. The high cost of GA is explained by the fact that it is still produced biologically using *Gibberella* fungi. There is no economic, synthetic manufacturing process.

CYTOKININS

As early as 1913, it was known that substances present in the vascular tissues of some plants could stimulate cell division (cytokinesis). The first of these compounds to be identified was kinetin (Figure 5), which had been isolated from the DNA of fish sperm. Kinetin has not been found in plant tissues, although some researchers believe it is present in very low concentrations (8). Other compounds that stimulate cell division have been found in plants and these are called cytokinins.

The first cytokinin isolated from plant tissue was zeatin, which has been found in peas, spinach, wheat, potato, maize and other plants. It is found associated with RNA and is a modification of adenine, one of the components of RNA. Other cytokinins include ribosylzeatin, isopentenyladenine, and benzyladenine. Both kinetin and benzyladenine are synthetic substance that have cytokinin activity. Most of the angiosperms contain cytokinins and a few gymnosperms are known to contain them.

Cytokinins are most common in young leaves and in root tips but also occur in young fruits and seeds. Cytokinins do not appear to be readily transported through the plants and their effects are often especially localised. Transport of cytokinins from the root tip to other tissues appears to be likely. The high concentrations of cytokinins in young tissues may be due to the xylem transport into these young active parts.



MAJOR EFFECTS

- stimulate cell division
- retard senescence
- replace light requirement for germination in some seeds
- overcomes apical dominance
- may delay abscission
- produce seedless fruits

Figure 5. Cytokinins.

Effects of Cytokinins. Like the auxins and gibberellins, cytokinins have many effects on plant growth and development. They have an effect on cell division and a role in callus formation. They appear to promote cell expansion especially in the leaves and cotyledons of dicotyledonous plants. They may also participate in the development of the embryo during seed formation. Cytokinins may also initiate growth in inactive lateral buds, but growth often does not continue.

Perhaps the most spectacular effect of cytokinins is the retardation — almost reversal — of senescence. Not only is pigment degradation in an aging tissue delayed, but re-greening may also occur. In addition, raw materials are transported to the treated tissue via the xylem system, and protein may be synthesised. Abscission of cytokinin-treated fruits, flowers, and leaves may also be delayed as a result of the increased metabolic activity.

Although cytokinins induce a variety of plant responses it is possible that all result from a single initial reaction. The similarity of cytokinin structure to adenine suggests that there may be an effect on RNA which, in turn, may influence the level of protein synthesis. There is often an increased enzyme activity after cytokinin treatment which may explain some of the observed rejuvenation phenomena. A cytokinin influence on ribosomes, the sites of protein synthesis, cannot be discounted (10).

Cytokinins and Plant Propagation. Much of the knowledge that has been gained of cytokinins has come from studies of tissue culture and callus formation. The interaction of cytokinins and other hormones, especially auxins, is the basis of aseptic plant propagation and regeneration from callus. Many synthetic compounds, most of them analogues of adenine,

have been used in various plant tissue culture experiments, but kinetin and benzyladenine have proved to be the most useful.

Kinetin has been used to stimulate germination in some seeds, such as lettuce. Benzylaminopurine (BA) and some other compounds are more active cytokinins than kinetin in many plants (5). Such treatments may overcome the environmentally-induced dormancies that occur in some seeds (2). Storage lives of vegetables may be prolonged by spraying with cytokinins but this is not legally accepted at the present time.

ABSCISIC ACID

Abscisic acid (ABA) is a hormone that has been known for about twenty years. It was identified during research into fruit abscission, hence the name. It appears, however, that abscisic acid plays more important roles in dormancy and stomatal behaviour. ABA is a single compound (Figure 6) but there are similar compounds present in some plants, such as phaseic acid, which appears to be inactive, and xanthoxin which has some of the properties of ABA. Synthetic ABA is commercially available and has been used in many physiological studies.

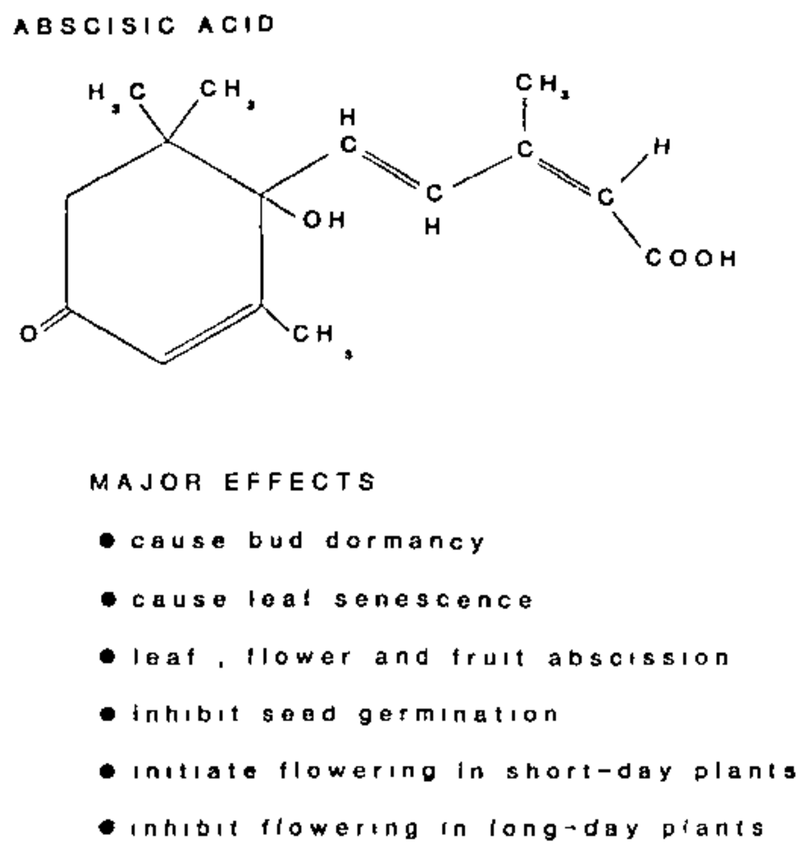


Figure 6. Abscisic acid.

Effects of ABA. In general, ABA appears to be an inhibitor of plant growth. As such, it is involved in bud dormancy and the abscission of fruits and leaves. ABA also appears to have a significant role in the senescence of leaves. Many of these inhibitory effects can be reversed by the presence or application of hormones, such as auxins and gibberellins. The dormancy of many seeds can also be attributed to the high levels of ABA present.

The mechanism of ABA action is still uncertain but alteration of cell membrane permeability, especially to cations, is involved in the effects on stomata. ABA also inhibits RNA and protein synthesis which may interfere with enzyme activity.

Such inhibitions may explain some of the longer term effects such as abscission or senescence.

ABA and Plant Propagation. Since ABA generally inhibits plant growth, it is not widely used in plant propagation. The major significance of ABA is that its effects must be overcome if many plants are to be propagated. Treatment with cytokinin often overcomes seed dormancy due to ABA, and cold temperatures may have a similar effect.

ETHYLENE

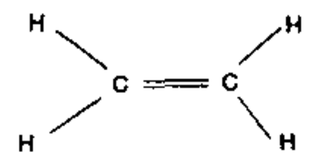
For a long time it has been known that ripening fruit produces ethylene. It is an unusual hormone because it is a volatile gas, not a compound in solution. Some researchers do not regard ethylene as a hormone but as a plant growth regulation. Since ethylene is produced in plant tissues — flowers, leaves, fruits, stems, seeds, and roots — it does appear to be a natural and active plant hormone (8). The production of ethylene by plant tissue is often stimulated by other hormones, such as auxins.

Effects of Ethylene. Ethylene appears to induce flowering in mangos and many of the bromeliads, but on other plants it has an inhibitory role. Ethylene may also inhibit the elongation of roots, stems, and leaves by causing a stunting and thickening of the cells. The inhibitory effect may also be involved in the epinasty that ethylene sometimes causes. Ethylene is also produced in response to the wounding or infection of many plant tissues.

The more significant effects of ethylene involve its role in the abscission of flowers, fruits, leaves, and stems, and its interaction with other hormones in the senescence of plant tissues. Practical implications for fruit storage have resulted from the knowledge of these processes where storage and then ripening can be manipulated by changing the levels of oxygen and ethylene.

Ethylene and Plant Propagation. Although ethylene has been widely used in horticulture for its effects on fruit storage and flower induction, it has not been widely used for plant propagation. However, ethylene does stimulate germination of seeds in some species and may prove commercially viable. Ethylene may also cause development of latent roots of willows and mung beans (5) and in proteas, rooting of cuttings can be enhanced (4).

ETHYLENE



MAJOR EFFECTS

- cause fruit ripening and senescence
- cause abscission of fruits , flowers and leaves
- cause leaf epinasty
- may overcome geotropism
- may enhance root initiation

Figure 7. Ethylene.

HORMONE INTERACTION

Although the major effects of the plant hormones have been discussed, the importance of their interactions must be emphasized. It is the complementary and sometimes antagonistic effects of the various hormones that causes normal plant growth and development. Such interactions may be complicated, especially when there are more than two hormones involved. Although tissue culture has revealed the interaction between cytokinin and auxin in the differentiation of callus the interactions within a plant may be far more complex.

Many of the hormonal interactions that control plant growth are poorly or only partly understood. One of the best known set of interactions involves leaf abscission. Although not fully understood, at least four different hormones may be involved. It is the interaction of hormones that enables the regulation of so many diverse aspects of plant growth and development by a relatively small number of compounds. The regulation can be precise, affecting only a single facet of plant metabolism and coordinated with overall growth.

CONCLUSIONS

Although hormones have been recognized for their effects on plant growth and development, their horticultural potential has yet to be fully realised. Their wider use is limited both by an incomplete understanding of their function and, in most instances, their expense. Both of these restrictions should soon be overcome, encouraging the use of hormones in many areas of horticulture.

Hormones are outstanding horticultural tools. Every aspect of horticulture affords some opportunity for hormonal manipulation. Hormones are used in plant propagation, in the control of plant growth, form, and development, in the regulation of flowering, and in harvesting and storage. We must, however,

understand how hormones influence plant growth and development and use them wisely.

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AVOIDING PROBLEMS IN SEEDLING AND BUDWOOD SELECTION IN CITRUS

IAN S. TOLLEY

Box 2

Renmark, South Australia

There are many criteria that can be used to select good propagation material. For everyone I might suggest, there will be many more you can add which are of a specific nature to the plants you are propagating.

Let me use two examples to illustrate the difference between areas of decision and happenstance in propagation.

Seedlings for citrus come from a wide range of seed sources, many of which were, and still are, chosen for their

understand how hormones influence plant growth and development and use them wisely.

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Let me use two examples to illustrate the difference between areas of decision and happenstance in propagation.

Seedlings for citrus come from a wide range of seed sources, many of which were, and still are, chosen for their

ease of growing by the propagator, but not necessarily the best material needed by the end user.

An example is the use of Rough lemon as a rootstock. It is a proven poor performer in the field, and has long since been supplemented by much improved rootstocks, but it is still being used today. It is marvelous stock to propagate but should not the main aim be to reflect the needs of the end user?

If seed is the product then great care needs to be exercised to harvest it fresh from the tree to avoid soil contaminants. Heat treatment has to be done accurately and an understanding of the requirements of fungicide protection is also necessary to provide an ongoing repetitive production of reliable seed.

There is always a chance that mistakes will occur but if good records are kept, then when they do occur, they can be more easily traced and analysed. This improves the service to the end user.

Many seed sources are fortunately true to type, exhibiting an acceptably high proportion of nucellar uniformity. Culling processes in these stages are not difficult *but beware if seed has been taken from seedling trees and mixed*. How then can you tell which plant is true to type or which is zygotic?

If you are producing seed for your own use or for sale, then propagate a line of vegetatively produced mother plants from your best selection, and be assured that future grafting and selection of seed or cuttings will be uniformly achieved.

For example, in the citrange group of hybrid rootstocks Troyer and Carizo are popular selections. We find it essential to cull at least 30 to 40% to achieve visual uniformity and reduce to an acceptable level the chance that the end user may have a seedling stock which does not have the performance characteristics expected of the particular clone.

Once the scion has been budded to the particular seedling it is doubtful if anyone will know if the combination is faulty, and the grower may well blame his management for the poor growth performance, never knowing that it may well have been an initial lack of culling by the original propagator.

A further area worthy of intensive effort is to take whatever steps are necessary to achieve rapid, and even more essential, uniform germination. This may entail structural considerations and the use of bottom heat, controlled watering, etc.

But what concerns me more is the treatment of seed prior to sowing. There are many ways to improve this vital area:

1) Improving uniformity — selection of the largest seeds in the batch.

2) Seed coat treatment and removal.

3) Pre-germination.

Any of these will lead to more uniform germination in the shortest period of time, and enable you to improve the selection process of seedlings produced, since you will have removed some of the major variables which undoubtedly contribute ongoing problems to the final stages of a usable plant.

The Selection of Budwood and Cutting Material. This is recognized by most propagators as an important skill developed by experience and training — but how many propagators spend as much time preparing the mother trees or plants for budwood or cutting collection?

How many use leaf analysis as a regular tool to ensure the propagation material is not deficient in one nutrient or another and, as a consequence, blame poor strikes or poor budwood takes on the season?

How many propagators manipulate fertiliser regimes on a seasonal basis to ensure that the primary plant material is in prime condition?

How many are actively training mother plants using techniques which can include leaf removal and hormone spraying to control the quality of the propagation material for the time you wish to propagate?

I have found that when we have poor results in budding it can almost always be traced back to mother trees in poor condition, producing poor budwood.

It is so easy to concern ourselves with the immediate reasons — it was too hot or too cold, or the stocks needed extra water before, during, after the budding, etc.

I suggest, however, that looking into the background may show more productive areas for improving propagation techniques and results. I am sure that most of us share the frustrations of using the best available propagation material at the time. Many times we know it to be second rate but it is all that is available.

In an endeavour to control some of the factors associated with getting the best budwood at the right time we have experimented with growing mother plants in macro-pots. These macro-pots are made with a wire mesh frame, lined with black polythene, placed on small wooden pallets covered with shade cloth. These macro-pots are filled with our standard potting mix. With an irrigation system and a controlled

fertiliser program we have achieved a reliable method of controlling growth. We have developed this system over a period of 5 years.

With a spacing of 800 macro-pots per acre one can imagine how little area is required to provide a substantial, if not total, supply of all the propagation material required. The material is on site and ready when you need it.

FROM TISSUE CULTURE TO FOREST TREES

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Abstract. Micropropagation of eucalypts and many other kinds of forest trees is now technically possible. There are several methods available to reduce the cost of producing plants by micropropagation and there is potential for integrating tissue culture techniques into nursery systems developed for seedlings. However, the largest cost in micropropagation is the labour and time entailed with manual subculturing techniques. Automatic, intelligent machine systems could overcome this restriction and revolutionize clonal forestry.

INTRODUCTION

Clonal plantations of forest trees are now a reality in many parts of the world. It is the main method of establishing plantations for species that can be easily propagated vegetatively, like poplars. Even for species that are more difficult to propagate, such as the eucalypts, clonal plantations are being established on a large scale: Brazil plants more than 10,000 ha per annum (3), the Congo over 6,000 ha (6) and France plans 2,000 ha (14). Most of these plantations are established from rooted cuttings of hybrid eucalypts. This development in forestry is not surprising since it enables clones to be planted which are adapted to specific sites or management objectives. Such clones might have been selected for maximum growth or adaptation to harsh environmental conditions such as mining dumps or saline soils. Clonal forestry also allows hybrid vigour to be exploited.

When we examine the methods of propagation of commercial plant species we find that vegetative propagation is the preferred method for most of the high-valued horticultural plants, e.g., perennial fruit crops and ornamentals. However, broad-acre crops, such as annual cereals, forage crops, and vegetables, are usually propagated by seed because each plant

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When we examine the methods of propagation of commercial plant species we find that vegetative propagation is the preferred method for most of the high-valued horticultural plants, e.g., perennial fruit crops and ornamentals. However, broad-acre crops, such as annual cereals, forage crops, and vegetables, are usually propagated by seed because each plant

has a low value and the present techniques of vegetative propagation are too labour intensive and expensive to produce clones in large numbers.

Forest trees fall in between the horticultural crops and the broad-acre crops. On the one hand, forest trees are similar to horticultural fruit trees, being perennial; seed improvement programs are both difficult and slow. For example, each cycle of selection in *Pinus radiata* takes about 15 years. On the other hand, forest trees are similar to broad-acre crops as each tree has a low value at the time of planting (approximately $0.05 for bare-rooted *Pinus radiata* and up to $0.90 for large container-grown eucalypts). Forest trees are also required in large numbers (millions per annum) over a short planting season and many are difficult to propagate vegetatively.

COMMERCIAL MICROPROPAGATION OF FOREST TREES

A joint project between CSIRO's Division of Forest Research and Alcoa of Australia is examining whether micropropagation could be used as a method of producing clones for forestry plantations. If this is to become a reality it will be necessary to overcome a number of problems which are commonly found in commercial micropropagation laboratories and to reduce the costs of plants produced by micropropagation.

Micropropagation has the advantages over cuttings of a much higher multiplication rate, a greater degree of control and small space requirement. Media have been developed for the propagation of many forest species and small-scale commercial operations are being undertaken with eucalypts in our laboratory (10) and for *Pinus radiata* (1) and poplars (4) in New Zealand.

Salinity is an enormous problem world-wide (15) and a large and increasing problem in Australia where about 43 million ha are affected (5). During the CSIRO/Alcoa project emphasis is being placed on the micropropagation of salt-tolerant eucalypts. These clones (Table 1) were selected at the University of Melbourne (17), the Forests Commission of Victoria (16), and the Forests Department of Western Australia (2) by subjecting seedlings to an increasing salt stress in hydroponic growing systems.

Field trials are being established in Australia and overseas to determine which clones are most suitable for particular locations and to determine the role of such trees in reclaiming salt-affected areas.

Table 1. Salt-tolerant clones of *Eucalyptus*. All clones tolerated a NaCl concentration above 640 mmol l^{-1} under laboratory conditions.

Species and Clone No.**	Locality name+	Location of original seed source* Lat. (°S′)	Long. (°E′)	Alt. (m)
E. camaldulensis				
41	Umberumberka Creek, NSW	31°55′	141°14′	230
42	Wiluna, WA	26°34′	120°03′	490
43	Victory Creek, WA	28°31′	120°59′	400
44	Wooramel River, WA	25°45′	114°16′	11
45	Gum Creek, WA	26°31′	120°02′	490
46	Wooramel River, WA	25°45′	114°16′	11
47	Irwin River, WA	29°16′	115°00′	20
48	Wooramel River, WA	25°45′	114°16′	11
49	De Grey River, WA	20°11′	119°11′	46
52	Umberumberka Creek, NSW	31°55′	141°14′	230
73	Finke River, NT	24°30′	133°15′	550
74	No location given	—	—	—
77	Minilya River, WA	23°49′	114°01′	10
78	Pentecost River, WA	15°48′	127°53′	30
79	Swanport Bridge, SA	35°07′	139°17′	8
82	Umberumberka Creek, NSW	31°55′	141°14′	230
83	Victory Creek, WA	28°31′	120°59′	400
84	Victory Creek, WA	28°31′	120°59′	400
85	Wiluna, WA	26°34′	120°03′	490
87	Wilpena Creek, SA	31°29′	139°21′	95
88	Wooramel River, WA	25°45′	114°16′	11
89	Wooramel River, WA	25°45′	114°16′	11
93	De Grey River, WA	20°11′	119°11′	46
94	De Grey River, WA	20°11′	119°11′	46
95	De Grey River, WA	20°11′	119°11′	46
96	Gum Creek, WA	26°31′	120°02′	490
97	Gum Creek, WA	26°31′	120°02′	490
125	Swanport Bridge, SA	35°07′	139°17′	8
126	Lake Hindmarsh	36°03′	141°53′	72
127	Wilpena Creek, SA	31°29′	139°21′	95
128	Lake Agnes, VIC	35°26′	141°56′	55
129	Swanport Bridge, SA	35°07′	139°17′	550
130	Finke River, NT	24°30′	133°15′	550
131	Hamilton, Vic.	37°24′	142°02′	250
E. macarandra				
61	No location given	—	—	—
E. spathulata				
72	No location given	—	—	—
E. wandoo				
123	No location given	—	—	—
124	No location given	—	—	—
250	No location given	—	—	—
251	No location given	—	—	—
252	No location given	—	—	—
253	No location given	—	—	—
254	No location given	—	—	—
255	No location given	—	—	—
256	No location given	—	—	—
257	No location given	—	—	—

* Clones were derived from individual seedlings of a particular seed source.
** CSIRO Division of Forest Research
\+ NSW (New South Wales); NT (Northern Territory); QLD (Queensland); SA (South Australia); WA (Western Australia).

REDUCING THE COSTS OF COMMERCIAL MICROPROPAGATION

1) The largest cost of producing plants by micropropagation is the labour involved in transferring shoots from one medium to another. Labour costs are about three times the cost of all other parts of the micropropagation procedure. Methods of reducing labour costs are:

a. Reduce the amount of time spent on each container. For many species it is possible to cut the shoots randomly into small clumps rather than dissecting out small individual shoots.

b. Reduce the number of steps for propagation. Shoots of some clones can be rooted directly as miniature cuttings thus avoiding the transfer step to a sterile rooting medium. However, this may increase the risk of plant loss, a factor which has to be carefully considered when a large number of plants are involved. Rooted plants can also be hardened in the same containers used for rooting. This may enable a higher success rate on transferring plants to a potting mixture and ultimately to the field.

c. Micropropagation could be integrated into an automated nursery system. We are at present evaluating the use of a seed-chain for root formation, hardening, and automatic transfer to larger pots (18). This system has been developed for automatic seeding and sorting of germinated seedlings at very high rates (thousands per hour). There is no inherent reason that it could not be adapted to micropropagation.

   Alcoa has developed a vacuum-operated device to enable rapid transfer of the rooted plants from agar-solidified medium to a seedling tray.

d. Sets of instruments can be pre-sterilized and so reduce the considerable time involved in flaming instruments in the sterile transfer chamber.

2) The time taken in media preparation and the cost of media can be reduced if the plants can be grown in liquid rather than an agar-based medium. Most of the eucalypts we have in culture grow better on a liquid rather than an agar-solidified medium.

3) Space can be saved in the growing room by culturing in stacks of containers. The stacks can also serve as part of a batch processing system where the stack of containers is handled as a unit for media preparation, for sterilization, in the growing room, and for despatch.

4) The cost of cleaning containers and removing labels can

be eliminated by culturing in cheap disposable containers such as polypropylene (autoclavable) take-away food containers.

5) Slow-growing, systemic contaminants are a serious problem and their elimination and detection may be a large cost in commercial micropropagation (12,13). Most of the rapidly-growing microbial contaminants are readily detected in tissue culture and such cultures are discarded. However, we have found that some of our cultures, and cultures from other laboratories, have deteriorated for no apparent reason. Some of these cultures contained a slow-growing bacterium which was not apparent on the plant medium for several months. It could not always be isolated on a number of microbial media, suggesting that it may be systemic or not uniformly distributed throughout the plant. The significance of such organisms as plant pathogens has not been determined but in some cases they may be very important (7).

The usual solution to the problem of systemic pathogens is to devise detection procedures, especially for the initial explants, and then to discard all contaminated cultures. This method is reliable but it may represent a large cost to a commercial laboratory when it finds (say through improved detection procedures) that hundreds of containers may be contaminated.

Antibiotics have not been generally successful as they often only retard the growth of the micro-organisms or severely inhibit plant growth. Further studies are required using systemic fungicides (9) and other anti-microbial agents in tissue culture.

6) Record-keeping and checking for errors is a major task if a laboratory is handling many clones; the maintenance of accurate records for the identity of clones (such as certified cultivars) is vital. In our laboratory we are handling about 200 clones, a minimum of 20 containers per clone on a 3-weekly subculturing interval. This represents over 130,000 records per year.

To reduce the labour and errors with record keeping we have developed an interactive data base system which gives details of each clone (such as its original source, salt tolerance, etc.) and maintains a complete history of all subculturing operations for each clone (19). The basis of the system is to keep track of sets of numbered containers, what medium is in the container, which clone, when it is due for subculturing, where it is located in the culture room, etc. Comprehensive error-checking is also performed and the information can be interrogated in many ways.

However, even when all of the above problems have been solved we still have a major hurdle to overcome if micropropagation is to play a role in clonal forestry. This problem is the large number of plants required over a restricted planting season. Each operator in the transfer chamber can place about 1,000 shoots per day onto an agar based rooting medium, as well as maintain the clone on shoot-multiplication medium. Compare this rate of production to the annual planting rate of forest trees in Australia; about 40 million trees (8) (assuming a planting density of 1,000 trees per ha). Even if only 10% of this area was planted to clones it represents 4 million plants which is equivalent to 4,000 days of subculturing (or 15 operator-years of subculturing, assuming 1,000 plants per day). Clearly, this is a large task if the clones have to be produced over a restricted planting season.

Apart from having a large number of operators working in sterile transfer chambers, one solution to this problem is to store either rooted plants or shoots as cultures in cool storage. This enables the work-load of producing plants to be spread over a longer time period. A more satisfactory solution to this problem is to develop machines that can duplicate the repetitive operations of the human hand in dissecting shoots and transferring these to a sterile medium. The Centre for Research on Intelligent Systems at Deakin University, Victoria, is developing a microprocessor-controlled machine to do such a task. A prototype is being developed which will have a production rate of 1 plant per second (85,000 plants per day or 1 million in 12 days). Such developments are essential if micropropagation is to play a significant role in producing clones for forestry plantations, or for broad-acre crops.

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OUTDOOR PROPAGATION ON HEATED BEDS

KEVIN G. STEVENS
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Canning Plant Farm has about 6.5 hectares of container-grown nursery stock in Perth. Like most nurseries we used to do the cutting propagation in glasshouses and polyhouses.

Whilst in America we noticed that at some of the large nurseries a great amount of cutting propagation was being carried out in the open under mist. The material appeared to be in good condition with no sign of disease. Upon arriving home we decided to try this method.

The selection of the site was most important as we soon found out, as under our conditions the winds were quite severe. The hot Western Australia summer also caused some problems.

It was necessary to choose a site which was well protected

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The selection of the site was most important as we soon found out, as under our conditions the winds were quite severe. The hot Western Australia summer also caused some problems.

It was necessary to choose a site which was well protected

from wind. We chose one which was occupied by an existing tunnel, which proved to be ideal. It was protected from the wind by a fence on one side and another tunnel on the other. The plastic and shade coverings were removed from the tunnel but the frame was retained.

Bottom heat was provided by laying 25 mm poly-pipe along each bed 450 mm apart. These were then covered with 14 mm diameter blue metal to a depth of 50 mm. This provided a well-drained even base for pots and trays. Hot water was circulated through the pipes at 60°C, giving a temperature in the trays of 20 to 25°C.

A mist system was installed by suspending 25 mm plastic pipes from the tunnel frame. The misting nozzles were drilled directly into the pipe at 1.2 m intervals. This system gave a very good coverage. During the hotter months of summer the frame is covered with 70% shade cloth.

The mist was controlled by a time-clock, which is considered better than a system controlled by moisture sensors, etc. The time-clock has to be adjusted for cloudy, wet, or exceptionally hot days. One of the main advantages of having to reset the clock, or at least check it, means you also inspect the cuttings every day which, of course, is essential. This was also the experience of Monrovia Nursery in California where the system was first observed.

A large range of shrub cuttings have been struck on these beds. These include natives, such as grevilleas, and exotics such as azaleas. Success has also been achieved with some of the hardier indoor plants in summer.

Currently cuttings are being struck from April right through the winter without any protection. The bottom heat appears to prevent any damage from frost and general cold. The greatest benefit gained over glasshouse propagation has been the lack of disease. There has virtually been no disease problems. This method of cutting propagation has meant the costly overheads of glasshouses have been eliminated.

EFFECT OF INDOLEBUTYRIC ACID, MEDIUM COMPOSITION, AND CUTTING TYPE ON ROOTING OF *GREVILLEA JOHNSONII* CUTTINGS AT TWO BASAL TEMPERATURES

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REVIEW OF LITERATURE

Grevillea johnsonii is a most attractive species. An upright shrub with fine, slender, deep-green foliage on reddish stems, it is quick growing and forms a more compact and neater shrub than the closely related *G. longistyla*. Occurring naturally in the Rylstone area of the central tablelands of New South Wales, *G. johnsonii* has proved frost hardy in Canberra and plants at the National Botanic Gardens have reached 4 m × 3 m in five years. The orange to pink flowers are borne in loose clusters in the upper leaf axils from late winter to early summer.

Vegetative propagation of *G. johnsonii* is considered difficult (4,10) although grafting onto *G. robusta* has proved successful (2,4). Generally, the use of soft cutting material taken from hard-pruned stock plants maintained in active growth by the regular application of nitrogenous fertilizer is recommended for the propagation of grevilleas (1,2). Hellriegel (10), working with *Grevillea* 'Ivanhoe', obtained superior rooting with tip cuttings compared with basal cuttings. In contrast Dupee and Clemens (4) obtained the opposite result with the difficult-to-root *Grevillea* 'Robyn Gordon'.

The use of a rooting hormone is generally recommended with *Grevillea* species (1,2) for which indolebutyric acid (IBA) has been shown to be superior to naphthaleneacetic acid (NAA), or an IBA/NAA combination in stimulating rooting (6,8).

A number of rooting mixes have been used successfully for *Grevillea* cuttings (1,2,4,6,10). Ellyard (6) employed a sand: sieved-German peat: perlite, 1:1:1 v/v mix, although recent observations suggest that a mix of higher air porosity might be more appropriate. In this regard the sand: sieved-German peat: perlite 2:1:1 v/v mix recommended by Hellriegel (10) is of interest.

Temperature has a definite effect on the rooting of cuttings. Difficult-to-root species appear to respond more to increased basal temperature than easily-rooted species (4,7,11,12). Increased basal temperature, however, can increase callus development (13), a finding relevant to many *Grevillea* species which consistently over-callus.

In the experiment reported here the effect of indolebutyric acid concentration, cutting type, and rooting medium on rooting and callus development of *Grevillea johnsonii* at two basal temperatures was investigated.

MATERIALS AND METHODS

The two cutting media used in this study were sand: German peat: perlite (1:1:1 v/v) and sand: German peat: perlite (2:1:1 v/v). The physical properties of the two media are given in Table 1. The percentage air-filled and water-filled pore space was determined by the method of Buscher and Van Doren (3), modified in that the pots were drained for 3 hours on sand (bottom heat, 24° ± 1°C) under mist prior to determining the drained weight. The medium pH was determined by both a 1:2.5 v/v dilution of soil in 0.01 M Ca Cl_2 and a 1:2.5 v/v dilution in distilled water.

Table 1. Physical properties of rooting media.

Particle Size (mm)	Percentage distribution 1:1:1 v/v medium	2:1:1 v/v medium
< 0.25	4.3	3.6
0.25-0.50	11.2	12.0
0.50-1.0	41.3	41.7
1.0 -2.0	35.8	36.1
> 2.0	7.4	6.6
pH in 0.01 M $CaCl_2$	3.5	3.7
pH in water	4.2	4.4
Air porosity (%)	28	27
Water porosity (%)	30	23

Cutting material was collected from a seven year old cultivated plant on 14 October, 1982, and two types of cuttings were prepared immediately. Terminal cuttings consisted of nodes 1-4, node 1 being that closest to the apex with a near

fully extended leaf. The basal cut was made 1 cm below node 4 and the leaves were removed from nodes 3 and 4. Stem cuttings consisted of nodes 5-8. The basal cut was made 1 cm below node 8 and the leaves removed from nodes 7 and 8 and reduced in area at nodes 5 and 6.

Auxin (in 50% ethanol) was applied as a 5-sec. quick-dip to the basal surface of the cutting and excess liquid allowed to evaporate before the cuttings were inserted into the cutting medium in 100 mm × 100 mm × 80 mm deep plastic pots (8 cuttings/pot).

The cuttings were placed on a sand bed under mist in a glasshouse (light transmission 25%). The mist was controlled by an electronic leaf set to maintain a relatively dry environment around the cuttings. Bottom heat was provided by electric cables buried in the sand bed. Two basal temperatures, 30 ± 1°C and 24 ± 1°C were used. The cuttings were treated regularly with a captan/benomyl fungicide mix. All cuttings were harvested at 12 weeks and the number of rooted cuttings/replicate and the number of roots/cuttings recorded. Each cutting was also rated on a 3 point scale with regard to the amount of callus present (1 = no or little callus, 3 = heavy callus). The experiment was designed to test the effect of four IBA levels, two cutting types, and two rooting media at two temperatures (not replicated) on the rooting of *G. johnsonii*. At each temperature the experiment was a 4 × 2 × 2 factorial set up in a randomized complete block design. Each treatment was replicated six times with 8 cuttings per treatment replicate.

RESULTS

At the basal temperature of 24°C both medium composition and auxin concentration had a highly significant effect on the percent rooting of *Grevillea johnsonii* (Figure 1 and Table 2). Of the two media, the sand:peat:perlite, 2:1:1 v/v, medium proved the superior. In this medium optimum rooting was obtained at 4000 ppm IBA; 8000 ppm IBA proved detrimental to rooting. In the sand:peat:perlite, 1:1:1 v/v medium a different rooting pattern was obtained, resulting in a significant difference in percent rooting in the two media at 4000 ppm and 8000 ppm IBA (Table 3). Cutting type had a significant but lesser effect on rooting. Calculation of LSD (0.05) showed the difference in the percent rooting of terminal compared to stem cuttings to be significant only in the sand:peat:perlite, 1:1:1 v/v medium at 2000 ppm IBA.

Table 2. Significance levels for struck cuttings and callus formation on *Grevillea johnsonii*.

Comparison	Significance levels (P)[2] 24°C	30°C
No. of Struck Cuttings		
Blocks	**	**
Medium	***	N.S.
Cutting type	*	N.S.
Auxin	***	**
Medium × Cutting type	N.S.	N.S.
Medium × auxin	*	N.S.
Cutting type × auxin	N.S.	N.S.
Medium × cutting type × auxin	N.S.	N.S.
Callus formation		
Blocks	N.S.	N.S.
Medium	***	N.S.
Cutting type	***	***
Auxin	N.S.	*
Medium × cutting type	***	N.S.
Medium × auxin	N.S.	N.S.
Cutting type × auxin	***	***
Medium × cutting type × auxin	N.S.	N.S.

[1] This analysis was undertaken on $\sqrt{x} + \frac{1}{2}$ transformation of rooted cuttings/replicate date

[2] * = $P < 0.05$. ** = $P < 0.01$ *** = $P < 0.005$ N.S. = Not significant.

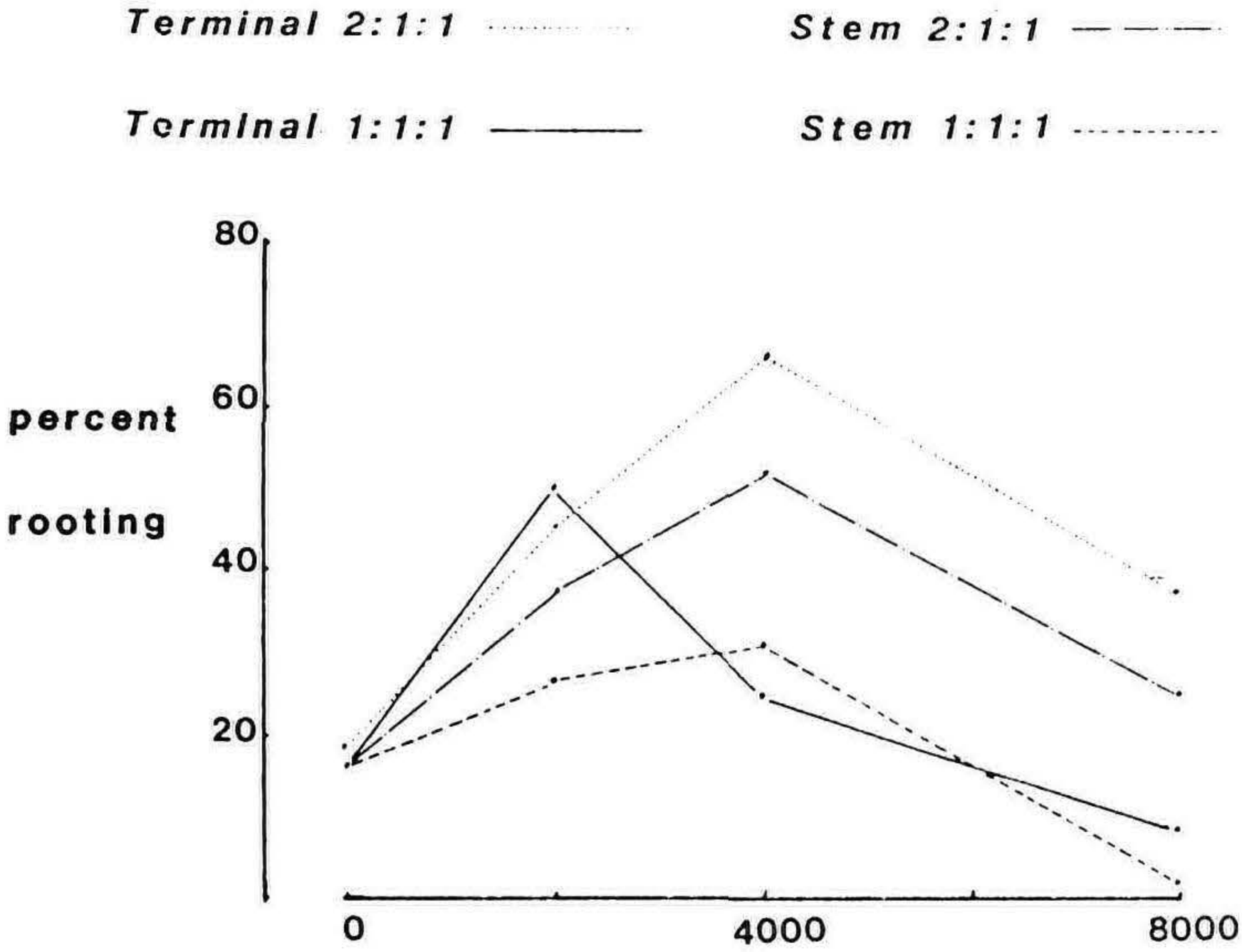

Figure 1. Effect of indolebutyric acid on the percent rooting of terminal and stem cuttings of *Grevillea johnsonii* propagated in sand:peat:perlite 2:1:1 v/v and sand:peat:perlite 1:1:1 v/v medium at a basal temperature of 24 ± 1°C.

Table 3. Significance levels for the effect of media at 24°C on percent rooting at four auxin levels.

IBA Concentration	Significance of medium effect
0 ppm	N.S.
2000 ppm	N.S.
4000 ppm	**
8000 ppm	**

At the basal temperature of 30°C auxin application had a significant effect on percent rooting (Figure 2). High auxin concentrations appeared less detrimental to rooting than at 24°C. In contrast to the results obtained at 24°C, medium and cutting type were without significant effect on percent rooting.

No significant treatment effect on number of roots per rooted cutting was evident at either basal temperature.

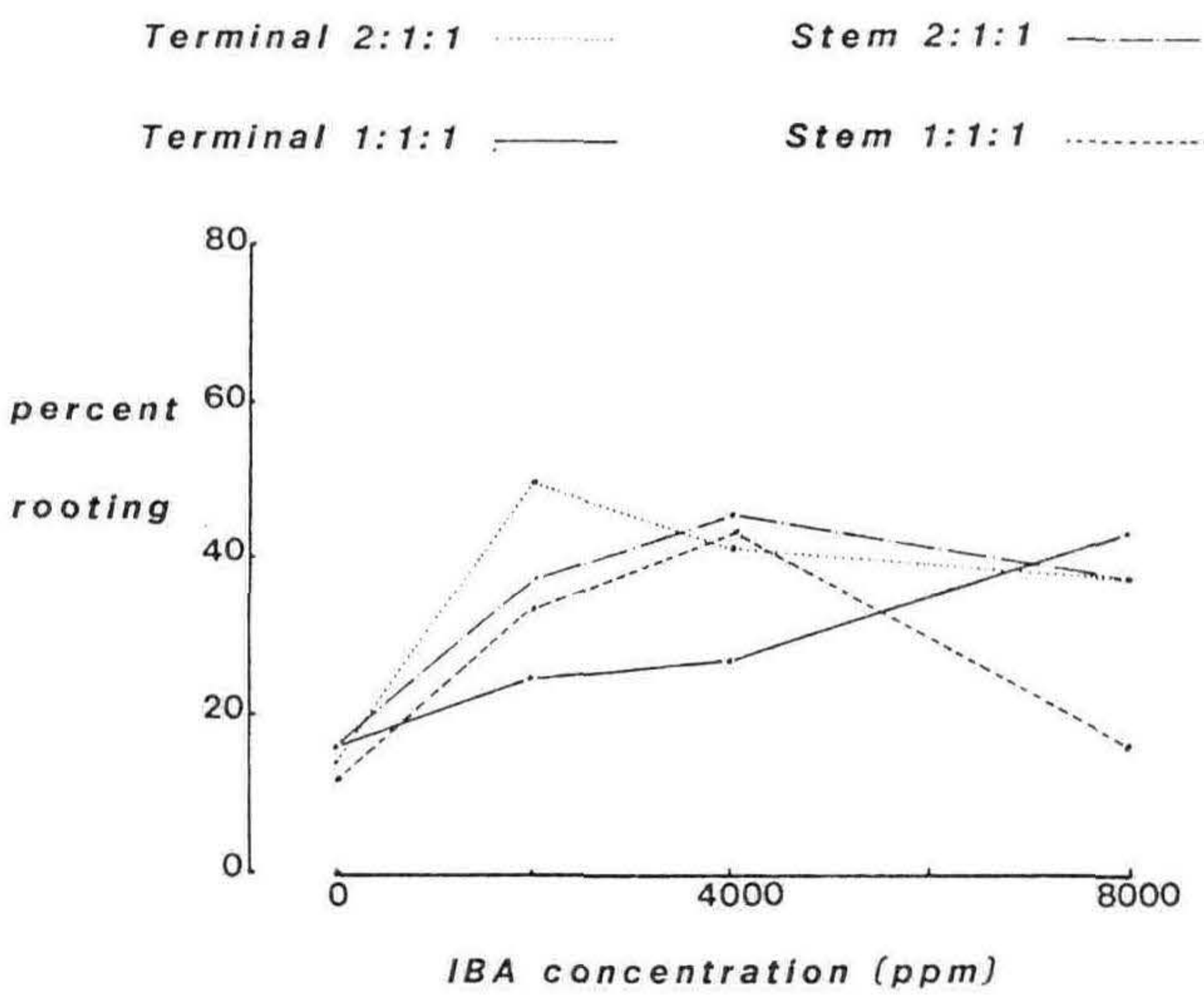

Figure 2. Effect of indolebutyric acid on the percent rooting of terminal and stem cuttings of *Grevillea johnsonii* propagated in sand:peat:perlite 2:1:1 v/v and sand:peat:perlite 1:1:1 v/v medium at a basal temperature of 30 ± 1°C.

At both temperatures stem cuttings produced more ($P < 0.001$) callus than did terminal cuttings (Figure 3). This excessive callus production was often associated with considerable stem dieback which was not apparent on terminal cuttings. With terminal cuttings at 24°C, medium had a significant effect on the amount of callus produced, with the greatest callus production in the sand:peat:perlite, 1:1:1 v/v medium. No significant medium effect was evident with stem cuttings at 24°C, or with either terminal or stem cuttings at 30°C.

With regard to callus production stem and terminal cuttings responded differently to increasing auxin concentration at both basal temperatures. The increased callusing of stem cuttings with increasing auxin concentration was not evident with terminal cuttings.

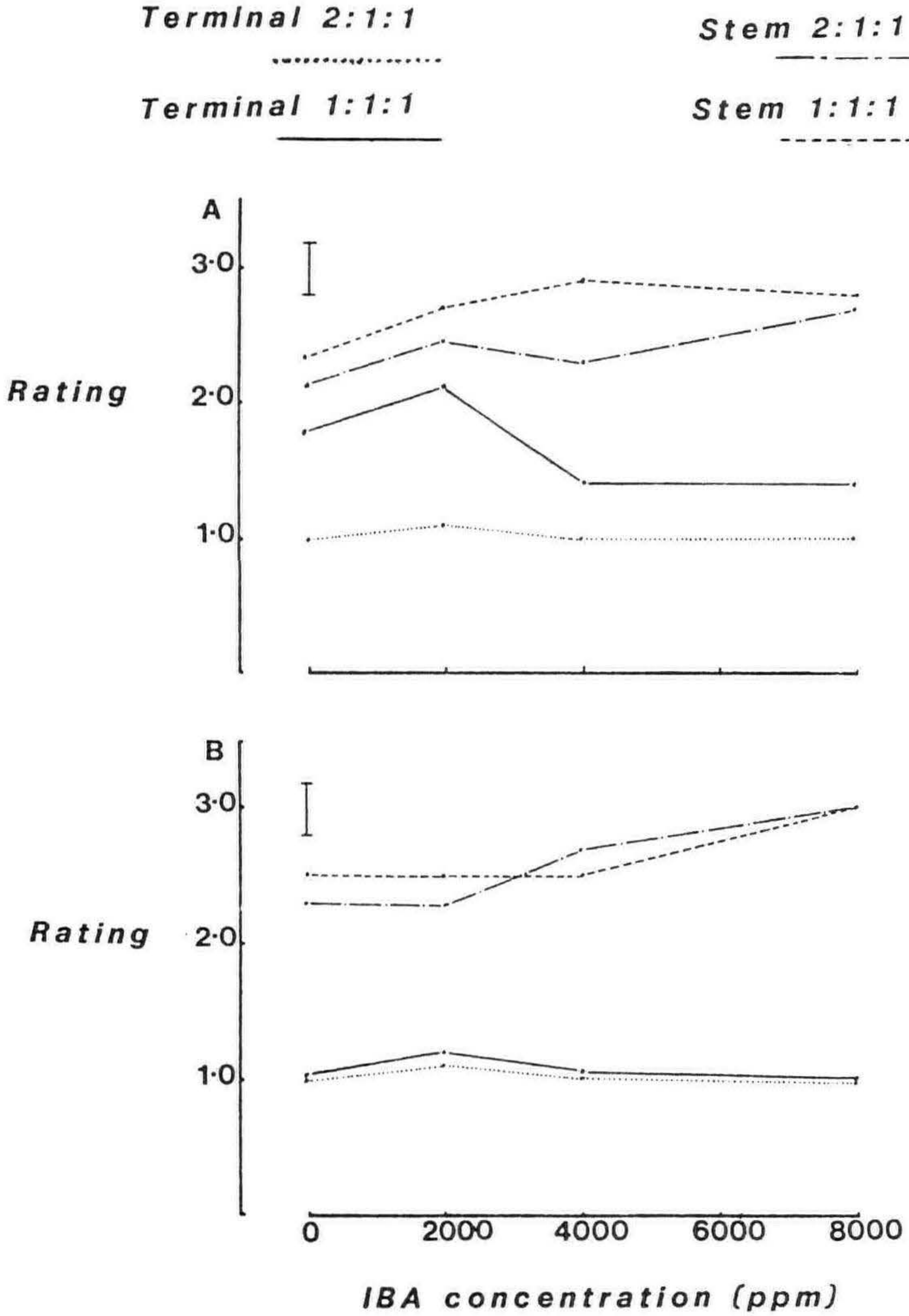

Figure 3. Effect of indolebutyric acid on the formation of callus on terminal and stem cuttings of *Grevillea johnsonii* propagated in sand:peat-:perlite 2:1:1 v/v and sand:peat:perlite 1:1:1 v/v medium at a basal temperature of 24°C (A) or 30°C (B). Cuttings were rated on a 3 point scale: 1 = no or small amount of callus, 3 = large amount of callus.

DISCUSSION

The results clearly show that under the right conditions a good rooting response can be obtained with *Grevillea johnsonii* cuttings. Other work (6,8) with a range of *Grevillea* species suggest that better rooting may be obtained with autumn cuttings.

The sand:perlite:peat, 2:1:1 v/v/v medium, as recommended by Hellriegel (10), with its lower water retention, is obviously the superior medium, particularly at the lower basal temperature.

The results suggest that the water content of the medium is very important in the rooting response. The 1:1:1 v/v/v medium at 24°C would seem to retain too much water for a good rooting response. At this temperature the 2:1:1 v/v/v medium is very significantly superior. At the higher basal temperature of 30°C, at which both media could be expected to dry out more and therefore retain less moisture, no significant medium effect was evident.

The results suggest that the water content of the medium also influences callus production since, as with the percent rooting data, the medium had a significant effect at 24°C but not at 30°C. This would seem to be in agreement with the finding of Bunker (1), who observed with tip cuttings of *Grevillea* 'Robyn Gordon', that a wet medium could lead to excessive callus production. In contrast to the percent rooting data, however, cutting type had the greatest effect on callus production. Hellriegel (10) who has made a similar observation with *Grevillea* 'Ivanhoe', suggests that the tendency for stem cuttings to over-callus is due to a change in the carbon/nitrogen ratio of the plant material and the lignification of cell walls which occurs during secondary growth.

High concentrations of IBA would appear to be more detrimental at 24°C than at 30°C, particularly in the more water retentive medium. Grange and Loach (9) have shown that water uptake by cuttings is directly proportional to the water content of the medium. Increased water uptake could be expected to result in increased auxin uptake. It is possible, therefore, that the decreased rooting percentage observed at 8000 ppm IBA in the 2:1:1 v/v/v medium and at 4000 ppm and 8000 ppm in the more water retentive 1:1:1 v/v/v medium at 24°C may result from the uptake of supra-optimal amounts of auxin. At 30°C basal temperature the media could be expected to be drier and therefore the cuttings subjected to less water and consequently less auxin uptake.

The relationship between auxin concentration, medium,

and temperature and their effect on rooting is obviously complex and will require further investigation in the future.

Acknowledgement. The excellent technical assistance of J. Groves is gratefully acknowledged.

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HORTICULTURAL DEVELOPMENT OF AUSTRALIAN PLANTS

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Abstract. The potential of Australian native plants is examined over a broad spectrum of horticultural applications. The history of the development of this potential is traced and the future direction to which research should be aimed is proposed. The flora is examined for its potential in such categories as garden subjects, cut flowers, dried flowers, amenity plants for arid areas, forage plants for arid areas, indoor plants, and economic plants.

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INTRODUCTION

. The Australian angiosperm flora has been variously estimated at upwards of 20,000 species. This rich resource of plant material is distributed over a vast continuum of climate and soil type resulting in a flora that has potentially valuable components for almost every horticultural purpose.

From the alpine areas of the south-east of the continent to the humid tropical rainforests of the north; from the floral wonderland of the southwestern sandplains, with their Mediterranean climate, to the immense arid centre, we have a variety of plants of which even the average Australian is unaware.

Despite the early effort of botanical collectors in the early and mid-nineteenth century when many Australian plants were being brought into cultivation in Great Britain, it is only in the last 25 years that increasing local interest has been shown in the cultivation of native plants. Several reasons may be suggested for this revived interest in the flora.

Firstly, a sense of nationalism and an increasing awareness of the environment began to develop in the '50's and '60's and the trend is still with us. People became conscious of the shrubs and trees around them and realised that they had a place in the man-made environment as well as in nature.

Coincident with this trend, the Society for Growing Australian Plants was formed in the late '50's and very soon became the largest horticultural society in the country. Native gardens became popular and a near-fanaticism developed among some members, claiming that "natives" were right and "exotics" were wrong. In 1959 the Society launched a full-colour quarterly journal "Australian Plants". It has continued to be produced and has become an important horticultural periodical with circulation to many overseas countries.

Finally, the establishment of the National Botanic Gardens in Canberra which was officially opened in 1970, and King's Park & Botanic Garden, Perth, (1965) has contributed much to the horticultural knowledge and the popularisation of Australia's floral heritage.

POTENTIAL

Of the 20,000+ species of plants in the flora, many have little or no value for ornamental purposes. Some of these "ugly ducklings" however, may have use as,

i) forage plants in arid areas, e.g. several species of saltbush, family Chenopodiaceae.

ii) sources of pharmaceutical compounds, e.g. *Solanum*

aviculare and its tetraploid form, which is often called *S. laciniatum*, as a source of solasodine for cortisone and other steroid drugs.

iii) economic crops, e.g. *Macadamia integrifolia* and *M. tetraphylla* for edible nut production.

It is now proposed to briefly examine some elements of the flora to indicate their potential in various categories.

Ornamental plants

(a) *Garden subjects.* Some years ago the average retail nursery stocked half a dozen or so species of native plants and buyers had to search for the few specialist nurserymen who stocked an extensive range. Today the story is very different as most general nurserymen have a large section set aside for native plants. The range is still limited in terms of the potential that exists but a definite trend is in evidence.

There is a need, however, for nurserymen to improve their knowledge of native plants and to understand how a certain species performs in their area. Much misinformation is being passed on and many species are being stocked which are unsuitable for the local area. As mentioned earlier, there is a range of species available for each climate and soil type but it is important for the correct selection to be made and for the right advice to be given to potential buyers.

There are probably between 7,000 and 10,000 species of ornamental native plants currently being cultivated in Australia. Many of these are still in very short supply but the figure indicates the potential.

(b) *Cut-flowers.* The cut-flower trade is big business in Europe and the United States. Old established blooms, such as roses, carnations, and chrysanthemums are favourites and are among the top sellers. There is a demand, however, for different species and for long-lasting flowers and the Australian flora has much to offer in these categories.

Some years ago the Israelis were quick to see the potential of many Western Australian native plans and farming of a number of species for the European market became well established. Plants such as Geraldton wax flower (*Chamelaucium uncinatum*), kangaroo paws (*Anigozanthos* spp.) and *Banksia* spp. found their way into large selling enterprises such as Aalsmeer in Holland. The Americans, too, were experimenting with banksias and other proteaceous plants in Hawaii.

In Australia, however, several Western Australian companies have employed licensed pickers and the majority of cut-flowers which have appeared on local and overseas markets have been from this source. In 1980-81 the export value

of cut-flowers (not all Australian natives) from Australia was approximately $1.2 million. The wholesale value of Western Australian cut-flowers (local and export markets) for the same period was $1.5 million.

Australia has a major marketing advantage with respect to exporting of cut-flowers because of the different flowering seasons to the northern hemisphere and once these species become well-known the market is bound to increase.

Recently, the Western Australian Government has announced incentives for farming wildflowers in that State and also the funding of research into their cultivation. Although these measures should have been taken some years ago, it is encouraging that they have eventually been initiated. Farming of a number of Western Australian proteaceous plants has been progressing well in South Australia for several years.

Although emphasis has been placed on Western Australian wildflowers, such species as the New South Wales waratah (*Telopea speciosissima*), Christmas bells (*Blandfordia* spp.), flannel flower (*Actinotus helianthi*) and N.S.W. Christmas bush (*Ceratopetalum gummiferum*) have equal potential as cut-flowers.

(c) *Dried flowers, fruits and foliage.* Many Australian native plants perform well as dried plant material. Most of these belong to the families Asteraceae (Compositae) and Proteaceae but several Myrtaceae genera are also gaining favour.

Everlasting, or paper daisies, from the genera *Helipterum* and *Helichrysum* have been well-known for this purpose for many years and, in fact, many colour forms of *Helichrysum bracteatum* were developed in Europe and seed of several species of paper daisies has been available from European seed companies for some years. *Ixodia achilleoides*, another composite, is marketed in large quantities after drying.

Of the Myrtaceae genera, *Agonis*, *Thryptomene*, and *Scholtzia* have considerable potential in the field.

A large export market and a substantial local market exists for dried material and companies have been established in Western Australia and South Australia to cater for it.

Plants for Arid Areas

(a) *Amenity plants.* Middle Eastern countries in recent years have used their petrodollars to improve their arid environment by the addition of plants. It has been found that many Australian plants adapt well to these climates and delegations from Australia have been successful in opening markets for the export of Australian species for use in amenity horticulture.

(b) *Forage plants.* In addition to ornamental plants, Australia's great arid heart has evolved some excellent forage plants. Research in this field is still young but Central Africa, the Middle East, and India, where an arid climate is often associated with saline soils, are all potential users of Australian plants as forage.

(c) *Firewood.* Firewood is a diminishing resource in many tropical countries, where thoughtless clearing without replanting has occurred for many years. Fast growing eucalypts are being used for this purpose in India and South America.

Indoor Plants

(a) *Foliage Plants.* Most of the plants that we know so well as reliable indoor foliage plants have their origin in the world's rainforests. Australia's own rainforest flora has been barely tapped for this purpose. With exception of species such as *Schefflera actinophylla* (umbrella tree) and *Grevillea robusta* (silky oak), few have been used to grace our living rooms and office buildings. European countries are keen to expand their range of plants and have demonstrated a keen interest in plants from Australia.

(b) *Basket Plants.* The basket plant market is expanding in Europe and the United States and the quest for new species is continuing. The Australian flora has rarely been used for this purpose and yet many of our low-growing, spreading plants are emminently suitable.

Economic Plants

(a) *Pharmaceuticals.* Mention was made earlier of two *Solanum* spp. that have been used commercially for pharmaceutical production. Many other species have been used for the production of alkaloids used for various purposes, such as the control of uterine spasms, anti-cancer activity, anti-bacterial activity, ophthalmology, etc.

Duboisia myoporoides and *D. leichhardtii* have been collected from the field for many years in N.S.W. and Queensland for the extraction of scopolomine and hyoscyamine but now, a hybrid has been produced which gives better results. This cultivar is being grown commercially in Queensland.

Medical research work is continuing to uncover more pharmaceutical uses for Australian plants and it is important that such screening has as wide a coverage as possible. The conservation of our flora is thus vital so that the full potential of native plants for this purpose can be realised.

(b) *Timber, honey, fruits, etc.* The timber industry has been well-established in Australia for many years but unfortunately the control of timber cutting has left much to be desired. The

sad history of red cedar (*Toona australis*) logging is now legend and the total banning of rainforest logging in N.S.W. is the result of ruthless cutting without thought of re-establishment for future use.

Attempts are currently being made on the mid-north coast of N.S.W. to establish red cedar plantations. This should be extended to other timbers such as rosewood (*Dysoxylum fraserianum*), Queensland maple (*Flindersia brayleyana, F. pimenteliana*), etc.

The honey flora of Australia is well documented and this country is now fourth in the world in terms of honey production, with an annual yield of approximately 20 million kilograms.

Specialty products, such as leatherwood honey from the Tasmanian rainforest tree, *Eucryphia lucida*, have a unique flavour and are favoured by connoisseurs.

Australia is not generously supplied with plants that have edible fruits and nuts and that are considered palatable to the European taste. There are some, however, and perhaps with a little research some could be developed to commercial status. The macadamia nut has already been mentioned and many hectares of this tree have been planted in northern N.S.W. and southern Queensland.

Eremocitrus glauca (desert lime) and *Santalum acuminatum* (quondong) are two desert plants which have potential for dry area production, the latter having already attracted some research attention. The rainforests also yield plants that may have commercial potential with appropriate selection and breeding. Such species include *Pleiogynium timorense* (Burdekin plum), *Tetrastigma nitens* (a native grape), *Microcitrus inodora* (a native lime), and several *Antidesma* spp.

HISTORY OF HORTICULTURAL DEVELOPMENT

As Australians we have been slow to embark on research programmes aimed at the horticultural development of our flora and to date more work has been done outside the country than within. Brief mention has already been made of some of this work and it is proposed to concentrate, here, on local developmental work.

Selection and breeding. Selection, of course, is the prerequisite of any development programme and from early plantings and descriptions of native plants sent back to Great Britain, it was apparent that some of the early plant collectors made collections of superior forms of natural species. Unfortunately, many of these forms have died out and have been lost to

horticulture. Some fine forms of the Victorian heath (*Epacris impressa*) were in this category.

The commonly cultivated, long-flowering form of *Grevillea banksii* is one such selection and although its origin is uncertain, it is vastly superior to the common form of the Queensland southern and central coasts which flowers for only a few weeks.

During the last 20 to 25 years, interested amateurs, enterprising nurserymen, and some institutions have deliberately sought superior forms of species and brought them into cultivation. The National Botanic Gardens, Canberra has carried out extensive field work with this in mind. An outstanding selection in recent years was *Grevillea obtusiflora* 'Little Thicket', a vigorous, suckering plant which has value as a ground cover.

Selections have been made for frost resistance, colour, flower size, shape of bush, multi-petalled forms, etc. but little has been done towards the next step of development of breeding programmes using these selections. This work has been hindered by lack of staff and funds.

Most of the cultivars that have reached the market are the result of chance hybrids and many have little more to offer than either of their presumed parents. Some exceptions exist and such plants as *Grevillea* 'Robyn Gordon', *Grevillea* 'Poorinda Royal Mantle' and *Grevillea* 'Sandra Gordon' show the flora's potential. If well-designed, scientifically based breeding programmes are used, then even greater results are possible.

These techniques have been used with the kangaroo paws (*Anigozanthos* spp.) and such outstanding cultivars as *Anigozanthos* 'Dwarf Delight' bear witness to the value of well considered aims and objectives.

Nutrition. Nutrition of native plants was poorly understood for many years and led to statements that native plants must not be fertilized.

Much of Australian soil is low in phosphorus and the flora has adapted accordingly. Thus when high phosphorus fertilizers were applied to native plants they usually responded by dying. More recently it has been conclusively shown that a positive response can be obtained by application of low phosphorus fertilizers and much work has been carried out in this field by both institutions and study groups formed by the Society for Growing Australian Plants.

Tissue culture and embryo culture. Tissue culture techniques have advanced tremendously since they were used in the early 1960's to produce virus-free carnations and orchids.

Considerable work was done in the 1970's at the National Botanic Gardens, Canberra to expand this technique to propagate kangaroo paws. This is now being done commercially. The propagation of woody plants by this method is still in its infancy but some success has been achieved and some *Grevillea* cultivars are being produced commercially.

The related technique of embryo culture has been used at the National Botanic Gardens to propagate Sturt's desert pea (*Clianthus formosus*) and the beautiful but rare plant, *Hibbertia miniata*. This latter species is endangered in its limited habitat and the application of embryo culture techniques permits many plants to be grown without reducing the wild population.

Grafting. Grafting is not a new technique when applied to native plants, as it was used in Great Britain during the last century in the propagation of Sturt's desert pea. Rootstock of *Colutea arborescens* was used in this case.

Little further work was done with grafting of native plants until the technique was revived by the National Botanic Gardens in 1971. Problems were being experienced with the short life of *Prostanthera* spp. (mint bushes) in cultivation. This was due to the root system being attacked by the root rot fungus, *Phytophthora cinnamomi*.

A satisfactory rootstock was found in *Westringia fruticosa* and the life of prostantheras was substantially extended. Further work with other genera followed and other institutions and interested amateurs began experimenting and extending the range of grafted plants. The technique is not yet being used commercially to any extent.

Export of native plants. In 1979, the Federal Government sponsored an investigation of the potential markets for Australian plant material in the Northern Hemisphere. The results of the investigation were published as a report in 1982 and indicated that an export market existed for potted plants from Australia but the recommended list was small and included only one species from mainland Australia, a palm, *Carpentaria acuminata*. It was also recommended that further study be carried out into the development of native plants from two families, Myrtaceae and Proteaceae. The findings of this report were disappointing and showed a lack of knowledge and appreciation of the flora and its true potential for the export markets. Other surveys have been undertaken to Middle Eastern countries but the export market is still limited and the number of species under consideration for export is still small.

THE FUTURE DIRECTION

Much hard work lies ahead if we are to exploit the full horticultural potential of the Australian flora. Government funding on both a State and Federal level is essential to embark on the research programmes necessary to achieve this.

Continued selection. The flora still conceals many superior forms of species which have not yet been brought into cultivation. Extensive field work is required to seek these clones and allow them to be cultivated in botanic gardens where they will be available for future breeding programmes.

Propagation. A great deal has been done in this field in recent years but still many problems beset us. Seed dormancy is not fully understood and until a species can be grown from seed, plant breeding programmes are impossible. Reliable seed germination still eludes us for *Lechenaultia*, *Persoonia*, *Conospermum*, *Verticordia*, and many other genera, all of which have considerable horticultural merit. Propagation from cuttings is also unreliable for some genera and where clonal characteristics need to be maintained this method must be used unless tissue culture techniques are available. Grafting of many Western Australian species may be the only way that these plants can be grown in the eastern states. More work has to be done to finesse technique, determine optimum timing, and to ascertain the best rootstocks. Tissue culture for woody species, we have said, is still in its early days. This technique may eventually be the final solution to clonal reproduction but many thousands of hours of research will be necessary to determine media composition and type of tissue required for each species involved.

Nutrition and photoperiodism. Further research is necessary, not only to determine the nutrient regime required for optimum growth, but also that required for maximum flower yield. Photoperiodism has been seldom examined for Australian plants but for basket plant production this factor must be considered so that proper controls over flowering may be exercised.

Plant breeding. While further selection, propagation, and nutritional research are basic for continued plant breeding programmes, sufficient material is now available to undertake extensive breeding trials. Efforts should be directed towards the extension of flowering periods, the development of more durable flowers, the production of longer stems, etc., etc.

Farming techniques and disease control. With the practice of field harvesting blooms for the cut-flower market having a limited future from the points of view of quality and conservation, attention must be given to farming techniques. Suitability

of soil types and climate must be determined as well as the previously mentioned nutritional requirements.

Quality of flower and foliage for the export market must be first class or the market will not persist. Leaf-eating insects, leaf-distorting insects, fungal spots on leaves — all must be controlled so that the final product is blemish free. Little is known about the control of pathogens which cause leaf blemishes and much research will be required to overcome this.

Screening for pharmaceutical value. While pharmaceutical screening is not horticultural research, it should be carried out in liaison with the horticulturalists. It is obviously important that when positive reactions are obtained from screening analyses, that this species can be brought into cultivation and preserved for further examination.

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MICROPROPAGATION OF JAPANESE PERSIMMON *(DIOSPYROS KAKI)*

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Abstract. A micropropagation method for Japanese persimmon, *Diospyros kaki*, is described. Of a range of cytokinins tested, only zeatin (Z) supported good shoot growth. Adenine sulphate (AdS) at 40 mg/l improved shoot growth in the presence of Z at 1 mg/l, but indolebutyric acid (IBA) had no effect at 0.1 mg/l and was deleterious at 1.0 mg/l. Best shoot growth occurred with Murashige and Skoog minerals. Rooting of shoots approximately 2 cm long was induced by dipping shoot bases into 1000 mg/l aqueous IBA before placing them in fine pumice. Bottom heat (26°C) and intermittent mist (2 sec/30 min) in a high humidity tent resulted in 80% rooting. Rooted cuttings became dormant or died when disturbed. The use of Rootrainers is being investigated to improve shoot growth following rooting.

Japanese persimmon (*Diospyros kaki* L.f.) is extensively grown in Japan and there appears to be good prospects for off-season production of this fruit in New Zealand. New selections are being tested for suitability to New Zealand growing conditions, but propagation using conventional methods has been slow. Attempts to root cuttings from adult trees have been unsuccessful. Seedling rootstocks of *D. kaki* take 2 to 3 years to reach graftable size.

Yokoyama and Takeuchi (7) reported callus and root and shoot induction from young embryos of *D. kaki*. Roots and abnormal structures, but not shoots, arose from cambial callus on mature twigs (8).

There did not appear to be any reported attempts to micropropagate this species. A micropropagation study was undertaken in an attempt to improve the rate of multiplication of new selections.

MATERIALS AND METHODS

For preliminary experiments, shoots were collected from field-grown plants of the cultivars Fuyu and Okame. All subsequent work used greenhouse-grown grafted plants of the following cultivars: Fuyu,, Gailey, Hiratanenashi, Izu, and Maekawa Jiro. To surface sterilize the shoots, leaves were removed and the shoots were dipped in 95% ethanol, followed by immersion in a solution containing 0.5% sodium hypochlorite with 0.05% multifilm X77 wetting agent for 30 min. For bud dissection the shoots were then rinsed in 95% ethanol and air dried before dissection of buds 0.5 to 2 mm long. For nodal

explants the shoots were rinsed with sterile distilled water and cut into single node sections approximately 15 mm long.

Dissected buds were placed into petri dishes, and nodal explants into 100 ml jars, both containing 20 ml of medium. Plates containing dissected buds were wrapped in aluminum foil for the first 2 to 3 days of culture. Buds and explants were grown at 25°C with 16 hours of light, 8 hours of darkness, using cool white fluorescent tubes at 5 μE m^{-2} sec^{-1} for the first month and thereafter at approximately 35 μE m^{-2} sec^{-1}.

Rooting experiments were conducted either *in vitro*, or by dipping shoots into hormone solutions or powders before placing them into a variety of potting media. In some experiments, trays containing microcuttings were placed in high humidity chambers under 70 μE m^{-2} sec^{-1} fluorescent lights at 26°C. In other experiments, trays were placed in high humidity tents in a shaded greenhouse with bottom heating of 26°C with or without intermittent mist.

RESULTS AND DISCUSSION

Preliminary experiments using dissected buds from field-grown plants compared shoot development on media containing either benzyl adenine (BA) or isopentenyl adenine (IPA). On the medium with BA the agar turned brown and the buds died, whereas on IPA buds began to expand and small leaves grew. However, black callus developed at the bud base, which eventually almost enveloped the explants. Explants also died on the media used by Yokoyama and Takeuchi (7,8).

Cytokinin Response. Cultures were established on IPA-containing media from greenhouse-grown shoots of 'Gailey' and 'Fuyu'. A trial was then set up comparing shoot growth induced by the cytokinins Z, kinetin (K), and benzyl-tetrahydropyranyl-adenine (SD8339), at 1 mg/l and IPA at 5 mg/l. Zeatin resulted in the best shoot development. Some elongation occurred with IPA, but a large basal callus developed and phenols leached into the medium. In the presence of other cytokinins the explants blackened and died.

Addition of adenine sulphate (AdS) at 40 mg/l to Z at 1 mg/l appeared to improve shoot growth. Increasing AdS to 80 mg/l was deleterious, so 40 mg/l has been adopted as a standard addition to all media.

An experiment was set up comparing growth on Z at concentrations ranging from 0.01 mg/l to 10 mg/l with either small whole shoots or single nodes as explants. At both 0.01 and 0.1 mg/l Z all explants died. At 1 mg/l Z all whole elongated, but no axillary buds developed. Single nodes pro-

duced vigorous single shoots. At 10 mg/l Z shoot elongation was markedly suppressed and a number of small axillary shoots grew at the base of the original shoot or, in the case of single nodes, at the base of the new shoot.

In a further experiment, growth was compared using Z at 1 mg/l and 3 mg/l. The results are shown in Table 1. No significant difference in response between 1 and 3 mg/l was found. However, using small whole shoots as explants, a multiplication rate of 1.6-fold was attained compared with a 3.5-fold increase when single nodes were used.

Table 1. Effect of zeatin concentration and explant type on multiplication of 'Gailey' persimmon after six weeks.

Zeatin concentration	Whole shoot explants[1] No. shoots/shoot	Single node explants[2] No. nodes/node	No. shoots/shoot
1 mg/l	1.55 ± 0.13[3]	3.72 ± 0.35	4.25 ± 0.25
3 mg/l	1.66 ± 0.16	3.25 ± 0.31	4.38 ± 0.38

[1]32 shoots per treatment.
[2]32 nodes from 8 shoots, per treatment.
[3]Mean ± standard error.

Zeatin is a very expensive cytokinin, so experiments were set up to determine whether part of the zeatin could be replaced with IPA. Although 1 or 10 mg/l IPA with 0.1 mg/l Z stimulated shoot growth, shoots equivalent to those which developed on 1 mg/l Z were not achieved.

In all subsequent experiments, single nodes have been used as explants (Figure 1) and 1 mg/l Z as the standard shoot growth medium.

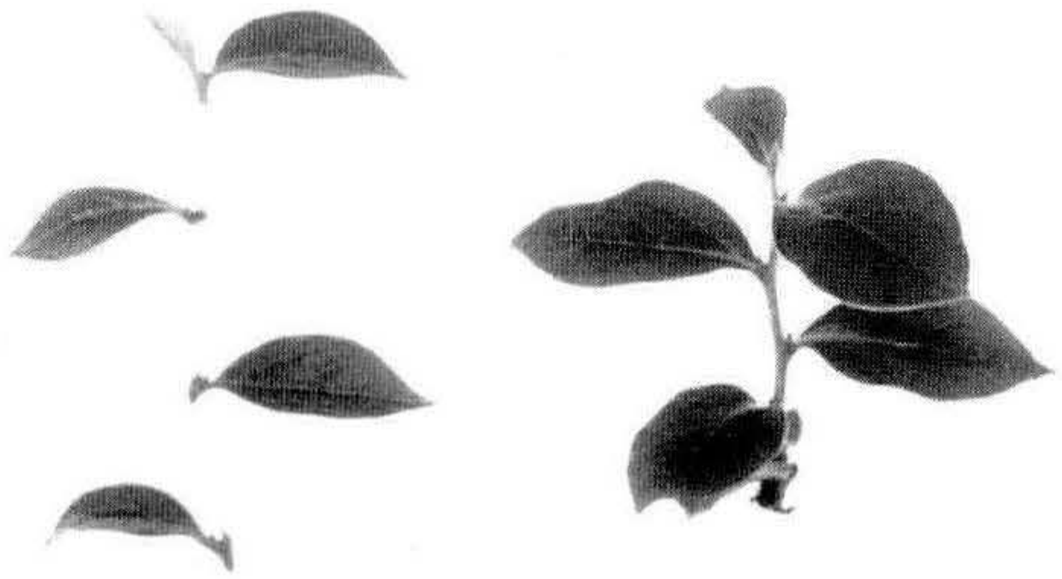

Figure 1. Single node explants (left) and shoot development after 6 weeks (right) on medium containing zeatin (1 mg/l).

Auxin Response. The effect of indolebutyric acid (IBA) at 0, 0.1, or 1 mg/l was checked in the presence of 1, 3 or 5 mg/l Z and 40 mg/l AdS. IBA at 1 mg/l was very inhibitory to shoot

growth, whereas at 0 and 0.1 mg/l growth was not significantly different.

Mineral Requirements. Up to this time all experiments had used either full or half strength Murashige and Skoog (MS) minerals. Shoot growth on these media were then compared with growth on a range of media which have been used for woody plant micropropagation in our laboratory (Table 2). Best growth occurred on the full MS medium. On 'Le Poivre', elongation was also good, but leaves were pale, narrow and small. Growth on B5, Knops, WPM, and ½MS was very poor (Figure 2).

Table 2. Comparison among inorganic salt formulations[1,2].

	MS	½MS	Le Poivre	B5	WPM	Knop
Composition in mg/l						
NH_4NO_3	1650	825	400	—	400	—
$(NH_4)_2SO_4$	—	—	—	134	—	—
KNO_3	1900	850	1800	2500	—	250
$K72SO_4$	—	—	—	—	990	—
$Ca(NO_3)_2.4H_2O$	—	—	1200	—	556	1000
$CaCl_2.2H_2O$	440	220	—	150	96	—
KH_2PO_4	340	170	270	—	170	250
$NaH_2PO_4.H_2O$	—	—	—	250	—	—
$MgSO_4.7H_2O$	730	185	360	—	370	250
H_3BO_3	6.2	3.1	6.2	3.0	6.2	6.2
$MnSO_4.4H_2O$	22.3	11.2	1.0	13.2[3]	29.4[3]	22.3
$ZnSO_4.7H_2O$	8.6	4.3	8.6	2.0	8.6	8.6
KI	0.83	0.42	0.08	0.75	—	0.83
$Na_2MoO_4.2H_2O$	0.25	0.13	0.25	0.25	0.25	0.25
$CuSO_4.5H_2O$	0.025	0.013	0.025	0.025	0.25	0.025
$CoCl_2.6H_2O$	0.025	0.013	0.025	0.025	—	0.025
$FeNa_2EDTA$	40	40	40	40	40	40
Balance of macronutrients (mM)						
NH_4^+	20.6	10.3	5.0	2.0	5.0	—
NO_3^-	*39.4*	*19.7*	*33.0*	*25.0*	*9.8*	*10.9*
Total N	*60.0*	*30.0*	*38.0*	*27.0*	*14.8*	*10.9*
K^+	20.3	10.2	19.8	25.0	12.7	4.2
Ca^{++}	3.0	1.5	10.2	1.0	3.1	4.3
Mg^{++}	1.5	0.8	3.0	1.0	1.5	2.0
PO_4^{3-}	1.5	0.8	2.0	1.1	1.3	1.8

[1] All formulations used with MS vitamins, 30 g/l sucrose, 1 mg/l Z and 40 mg/l AdS.
[2] References for media. MS (6), Le Poivre (5), B5 (3), WPM (4), Knop (2).
[3] The original recipe specified $MnSO_4.H_2O$ and the amount of $MnSO_4.4H_2O$ has been adjusted accordingly.

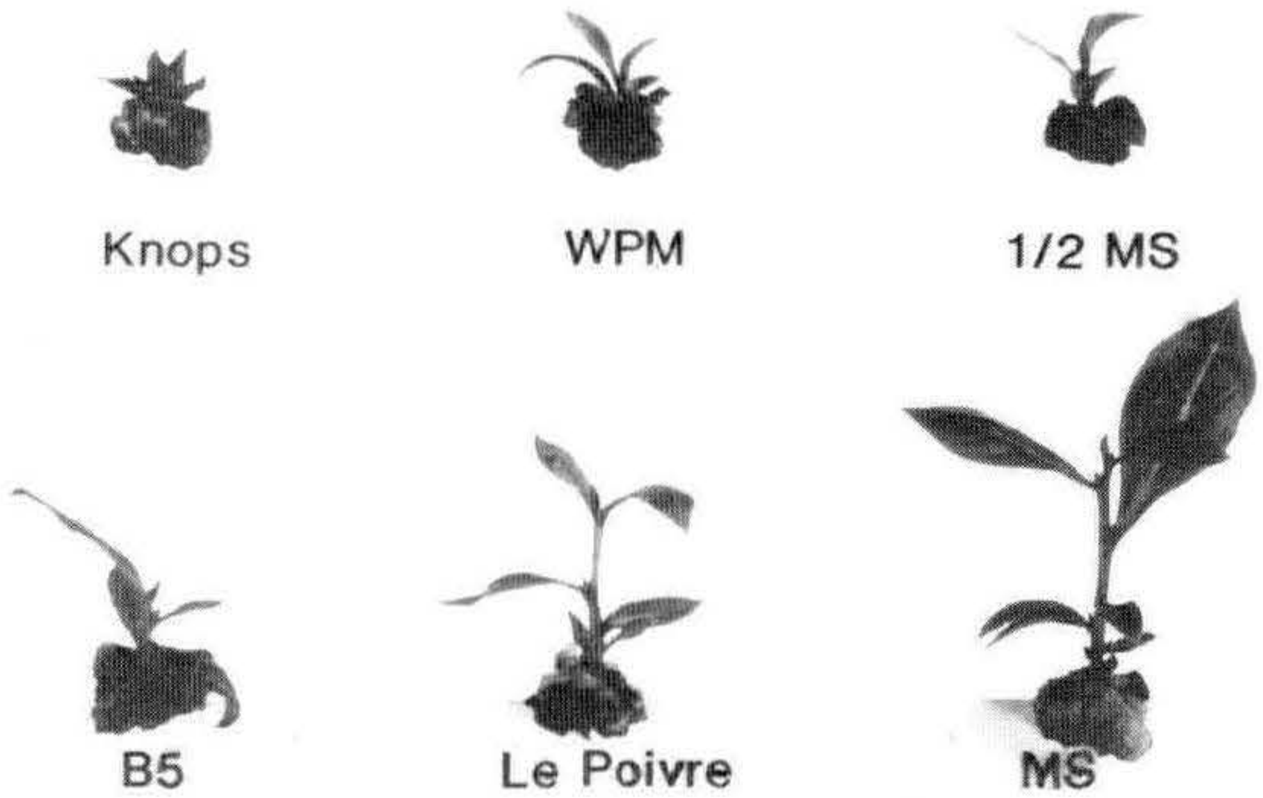

Figure 2. Representative shoots developing from nodal explants grown for 4 weeks on different media.

Shoot Water-soaking. Water-soaking or vitrification of shoots (1) was a problem in some experiments, particularly at levels of Z above 1 mg/l. This was overcome by increasing the agar concentration from 6 to 8g/l of Davis bacteriological agar, which did not reduce shoot growth. Davis agar at 8 g/l gave a firmer gel and less water-soaking than Difco Bacto agar at 8 g/l.

Cultivars. Clear differences in the response of different cultivars have been noted. Excellent shoot growth has been achieved with 'Gailey', 'Fuyu' and 'Maekawa Jiro', with multiplication rates of 4- to 6-fold every four weeks. Under similar conditions, multiplication of 'Hiratanenashi' has been approximately 2-fold, while growth of 'Ize' has been very poor.

Rooting. Attempts were made to root shoots *in vitro* using IBA or NAA at a range of concentrations from 0 to 10 mg/l in the presence or absence of zeatin. This always led to either heavy callus formation and/or senescence of the shoot. With other plants, the addition of charcoal to media often reduces callus formation and improved leaf expansion. With persimmon cultures, charcoal at 2.5 or 5.0 g/l led to leaf drop and death. Only one shoot has been rooted *in vitro* and this subsequently died.

Attempts were also made to root shoots directly into peat:pumice potting media following treatment with either hormone powders (Seradix 1, 2 and 3; May and Baker Ltd.) or a quick dip into aqueous auxin solutions. Using hormone powders some shoots formed roots but results using aqueous IBA at 1000 mg/l were more encouraging, with 66% rooting in one experiment. At 500 mg/l IBA or NAA less than 10% rooting occurred. Concentrations above 1000 mg/l IBA showed no

further stimulation. However, results were variable. The base of many of the cuttings collapsed and it was suspected that there might be something toxic in the peat:pumice medium used.

A comparison was made among different potting media in an attempt to improve overall rooting percentages and cutting survival. The results are shown in Table 3. After seven weeks, the fine pumice medium gave best results. It was apparent that wherever peat was present many cuttings turned black at the base and rooting percentages were lower (14%) than when peat was absent (61%).

Table 3. Effect of various potting media[1] on the rooting of 'Gailey' persimmon after seven weeks[2]; 12 cuttings per treatment.

Potting medium	pH	Rooting (percent)	Stem black (percent)	Death (percent)
Fine pumice	5.5	83	0	0
Coarse pumice	5.8	58	42	17
Sand	6.0	42	58	8
Peat	4.6	8	92	8
Peat:sand[3]	5.1	0	100	75
Peat:pumice[3]	5.1	33	58	8

[1] All potting media were sterilized.
[2] In high humidity chambers at 26°C, 70 μE m^{-2} sec^{-1} for 16 hours.
[3] 50:50 v/v.

Softwood cuttings from seedling persimmons root well using bottom heat of 26°C with air temperatures reaching 40°C (B. McKenzie, pers. comm.). This tolerance for high temperatures was also observed using tissue-cultured material. Shoots continued to grow and rooted well in the shaded (80%), high humidity tent with 26°C bottom heat, intermittent mist (2 sec/30 min), with air temperatures often up to 38°C in the afternoon.

Subsequent Growth. Persimmons are particularly prone to transplantation shock. When rooted shoots were transplanted to new potting media they usually went dormant or died. To overcome this problem, rooting directly into Rootrainers has been carried out and current trials are investigating the requirements for maintenance of shoot and root growth.

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IMPORTANCE OF EARLY NUTRITION IN PLANTS

BRIAN C. HANGER

Department of Agriculture, Horticultural Research Institute, Knoxfield, P.O. Box 174, Ferntree Gully, 3156, Victoria

Abstract. Three studies were conducted to demonstrate the importance of nutrition on the growth and development of young seedlings and rooted plants from cuttings. Seedlings of four Curcurbiataceae species were grown in rockwool without nutrient for 14 days from sowing and then given one application of nutrient. Strong growth responses occurred within 3 days of nutrient application, an indication that the internal nutrient reserves had become exhausted even before the appearance of visual deficiency symptoms. *Gerbera jamesonii* seedlings were fed weekly for 10 weeks from sowing with nutrient solutions of different strength. Optimum growth was achieved when solutions had electrical conductance values between 2 and 3.9 mS cm^{-1}. *Daphne odora* cuttings were taken from mother stock of different vigour and struck in rockwool blocks, with and without nutrients. They were grown-on in rockwool then transplanted into scoria and grown hydroponically for one growth cycle. Absence of nutrients in the rockwool caused the production of very long roots which were prone to damage on transplant. After one growth cycle, best plants were from cuttings taken from strong healthy mother stock and supplied nutrients throughout.

INTRODUCTION

Plant propagators hold many opinions on the need to supply nutrients to newly germinated seedlings and cuttings prior to or at time of rooting. Some hold the view that the early application of nutrients is unnecessary because the internal reserves in the seed and cutting are adequate to fully sustain early stages of growth. Also, without nutrient application, algal

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growth is suppressed and possible damage from excess salts is avoided. Propagators who do apply nutrients to the medium are often uncertain about what nutrients to apply, how much, and in what form.

Many studies on the nutrition of seedlings and cuttings have demonstrated immediate and long term (9,12) responses to early application of nutrients. However, it has also been found that such responses may be influenced and modified by many factors such as the age and status of the mother stock used for cuttings (9,16,19), the method (3) and rate of nutrient application (12,15,18), effects of individual or certain combinations of nutrients (4,8,16), seasonal and environmental factors, and response differences among plant genera and species (2). This variability in response to nutrition probably contributes to much uncertainty as to any benefit to be gained in feeding very young seedlings and pre-rooted cuttings.

The movement and distribution of nutrients in plants. A knowledge of the basic principles of the movement and distribution of nutrients in plants can help in the evaluation of the nutritional requirements of very young seedlings and cuttings. Sixteen elements are required for normal plant growth and development. Carbon, oxygen, and hydrogen are normally derived from water and the atmosphere, and the remainder from the root medium. Six (nitrogen, potassium, phosphorus, calcium, magnesium, and sulphur) are required in relative large amounts, while the others (iron, manganese, boron, zinc, copper, molybdenum and chlorine) in micro quantities. Each of these elements has distinct and specific functions if the plant is to grow normally. A shortage or an excess of one or more will cause disturbances in the metabolism and function of the plant which results in the development of distinct and recognisable visual symptoms.

The long distance transport of nutrients and water in the plant takes place via two major pathways. One, the xylem, is a system of rigid interconnected dead cells which carries water and nutrient from the roots to the tops. Flow is mainly directed to areas where water loss is high (e.g., transpiration from the leaf surface), but there is considerable leakage along the way into surrounding tissue. The xylem is non-selective in what nutrients are carried. The other system, the phloem, is composed of living cells and is very selective in what nutrients are carried. It is the major pathway for the movement of sugars produced by photosynthesis, and some inorganic nutrients from mainly leaf tissue to other plant parts such as the roots, fruit, and storage organs. Lateral movement also occurs across the cell walls into surrounding tissue and the xylem.

The different selectivity properties of the xylem and the phloem influences the distribution pattern and mobility of each inorganic nutrient in the plant. Nitrogen, phosphorus, potassium, sulphur and, to a much lesser degree, magnesium, move in the phloem, and are therefore freely mobile throughout the plant. If root uptake of any one of these nutrients is reduced, they can be withdrawn from old and storage tissues and redistributed to the young tissue under stress. Therefore, with these nutrients, deficiency symptoms develop in old tissue — not the young. Also, with the onset of senescence, the mobile nutrients are moved out of senescent tissue to other parts of the plant for use or storage. In contrast, calicum, iron, and a number of the micronutrients have a limited mobility in the phloem, and tend to accumulate in older tissue with time. In time of nutrient stress, they are not withdrawn from the older tissue and, as a consequence, deficiency symptoms develop in young tissue (e.g., the growing points).

The nutrient content of a plant organ is influenced by the pathway through which the nutrients are imported. For example, the major pathway into fruit is via the phloem. At maturity, seeds have relatively high reserves of essential nutrients per unit mass compared with other plant organs except for calcium and iron, which are relatively low. Chemical analysis of seed from five Proteaceae species (14) showed nitrogen, phosphorus, zinc, and copper to be highly concentrated compared with mature leaf tissue. Potassium, sulphur, magnesium, and manganese accumulated to a lesser degree, but calcium and iron were low.

When seeds germinate, the internal reserves must be mobilised to sustain early seedling growth. For example in peas in the first 4 weeks, 82% of the potassium was withdrawn from the cotyledonary leaves into the seedling, but only 26% of the calcium (7). There is very little information available on the length of time seed reserves can fully sustain seedling growth without an external supply. What is available suggests calcium to be the most critical nutrient. Krigel (13) found that subterranean clover seedlings required an external calcium source within 7 days of germination, phosphorus in 10 days, nitrogen and magnesium in 14 days, and potassium 21 days. With pecan seedlings (17), 82% died within one month of germination with no external calcium supply, and 23% died when there was no boron.

A cutting must draw on internal nutrient reserves stored in the stem tissue until roots have been initiated and become functional. Those nutrients which are readily mobile in the plant can be redistributed within the cutting to the zone of

root initiation, but those of limited mobility, e.g., calcium can not. Therefore, it is important that nutrients should be present in the rooting medium for immediate uptake by the roots.

The nutrient reserves in the cutting material is directly related to the nutrient status of the mother stock. The fertiliser regime used on the mother stock can, therefore, have important effects on the growth of cuttings. For example, cuttings taken from nitrogen-deficient carnations were found to produce few breaks and were slow to start growth (9). Over-fertilisation, or a nutrient imbalance of the mother stock, may also have adverse effects on rooting and growth of cuttings.

Mist applications, used for the maintenance of high humidity around the cutting during root initiation, can leach nutrients from the cutting and result in the appearance of deficiency symptoms (5). The periodic application of nutrients through the mist can compensate for nutrient leaching and improve production of roots and growth break (20). However, some plants have been shown to be sensitive to nutrient mists, e.g., azalea (11), with the occurrence of leaf burn. Also nutrients encourage algal growth.

Experimental objectives. Three studies were conducted to demonstrate various effects of early nutrition on the growth and development of seedlings and cuttings. In two studies with seedlings, one objective was to show that young seedlings respond rapidly to an early application of nutrients grown under conditions in which an external nutrient supply was limited. For this study, four Cucurbitaceae species were used of variable seed size. The second objective was to demonstrate that seedlings require an optimum nutrient supply, outside of which growth is restricted. Seedlings of *Gerbera jamesonii* were used for this study. The third study was conducted with cuttings of *Daphne odora;* the objective was to show that the mother stock vigour and early nutrition influence the rooting behaviour of the cuttings and subsequent growth of the plants.

MATERIALS AND METHODS

Study A: Cucurbitaceae seedlings. Seeds of 4 Cucurbitaceae species (Table 1) were sown in plastic-wrapped rockwool cubes (75 × 75 and 65 mm high) presoaked in water. Two types of cubes were used: one had a circular well (33 mm diameter, 40 mm deep) cut into the top surface. This well was filled with a 50:50 mix by volume of perlite:vermiculite, and two seeds were sown to a depth of 25 mm. The other type had no well, but the seeds were pushed down between the vertical fibres of the rockwool to the same depth. Each treatment (4 species and 2 types of cubes) were replicated ten times. Four-

teen days later, when the majority of seedlings had emerged to the first true leaf stage, each treatment was divided into two; half the number of cubes were continued on water, while the others were thoroughly soaked with a complete hydroponic nutrient solution. The solution was made up from premixed salts which, when used at the rate of 1.75 g l^{-1}, gave a solution with the following composition: 10.4 mM NO_3-N, 1.1 mM NH_4-N, 7.3 mM K, 1.1 mM P, 1.0 mM Mg, 4.1 mM Ca, 3.5 mM S, 0.03 mM Fe, 0.02 mM B, 6.7 μM Mn, 0.5 μM Cu, 0.9 μM Zn, and 0.1 μM Mo. This solution was also used for the other studies. Seedlings were thinned down to one per cube. All seedlings were harvested five days later. Growth parameters measured for each plant were hypocotyl length, area of cotyledonary leaves, and total area of plant tops.

Study B: *Gerbera jamesonii* seedlings. *Gerbera* seed (Pan American Company) were sown singly into rockwool propagation blocks (approx. 40 mm cubed). Each seed was inserted vertically to a depth just below the top of the block. The nutrient solution was applied weekly in sufficient volume to thoroughly saturate the blocks and induce leaching. Light applications of water were also applied between nutrient feeds if required. The premixed nutrient salts were used at six strengths; nil, 0.5, 1, 2, 4, and 8 g l^{-1} (Table 2). Each treatment contained 30 plants. Seedlings were harvested 35, 52, and 69 days from sowing. At the first harvest, 14 plants were sampled; at the other two harvests, 8 plants each. Growth parameters measured for each plant were: total leaf area, number of emerged true leaves, and dry weight of tops.

Study C: *Daphne odora* cuttings. Shoot tip cuttings, 3 cm long, were taken from relatively weak mother plants grown in the open in soil, and from strong plants grown in hydroponics in a greenhouse. Each cutting was trimmed to 3 to 4 newly-expanded leaves and inserted in rockwool blocks (40 mm cubed) to a depth of approximately 15 mm. Two treatments were applied: the blocks were either soaked in water, or in the complete hydroponic nutrient solution of normal strength (1.75 g l^{-1}). The cuttings were held under a plastic tent in an environmentally controlled greenhouse, and on day 74 were assessed for percentage rooting, total number of roots visible in the walls of the rockwood block, the length of the longest root which protruded from the block, and whether the terminal bud had commenced active growth. Rooted cuttings, undisturbed in the rockwool blocks, were transplanted into larger rockwool cubes (75 × 75 mm, 65 mm high with a well in upper surface) presoaked with either water or nutrient solution. The earlier two treatments were split to give four treat-

ments (Table 4). Water or nutrients were added to the cubes as required and, after 64 days, the number of roots which protruded from the walls of the cube was recorded. All rooted plants were transferred undisturbed in the rockwool cube to scoria in 17 litre black-wall bags and grown hydroponically for 10 months (late winter to late autumn) in a greenhouse. At the end of the period, total shoot growth was measured.

RESULTS AND DISCUSSION

Study A: Cucurbitaceae seedlings. All seedlings emerged within nine days and made rapid growth. At the time of nutrient application, there was no visual evidence to suggest that the absence of nutrients in the rockwool had had any detrimental effect on growth and development. However, within three days of the nutrient application, the treated plants showed a strong visual growth response which was confirmed by the growth measurements taken on the fifth day (Figure 1). In five days, total surface area of the seedlings fed nutrients increased by between 68% for zucchini to 142% for cantelope over the water-fed controls (Table 1). This growth response by all species to nutrients indicated that the seedlings by the 14th day, and irrespective of their initial seed size, had exhausted their internal nutrient reserves sufficient to restrict further organ growth but not to induce visual foliar symptoms. Growth retardation also occurred in the cotyledons which indicated that these relatively mature organs are also subject to nutritional stress if an external supply is limited in the early stages of seedling development.

Seeds sown directly into the rockwool fibre instead of the open-structured perlite:vermiculite mix produced seedlings with shorter hypocotyls. The two largest seed species experienced the greatest impedence to hypocotyl growth (Figure 1). There was no evidence to suggest that this impedence had any effect on subsequent seedling growth. Because of the relatively firm fibrous structure of the rockwool cube, any hole made to hold a seed must be of adequate dimensions to allow the seedling to emerge without hinderance.

Table 1. Average seed weight and percentage increase in total surface area of Cucurbitaceae seedlings five days after application of nutrients to the growing medium.

Species	Cultivar	Common name	Average fresh wt per seed (mg)	Nutrient response Percent increase in total surface area over water controls
Cucurbita moschata	Triamble	pumpkin	294	93 2
Cucurbita pepo	Blackjack	zucchini	179	68 2
Cucumis sativus	Crystal Apple	cucumber	31	104 3
Cucumis melo	Sweet and Early	cantelope	21	141 9

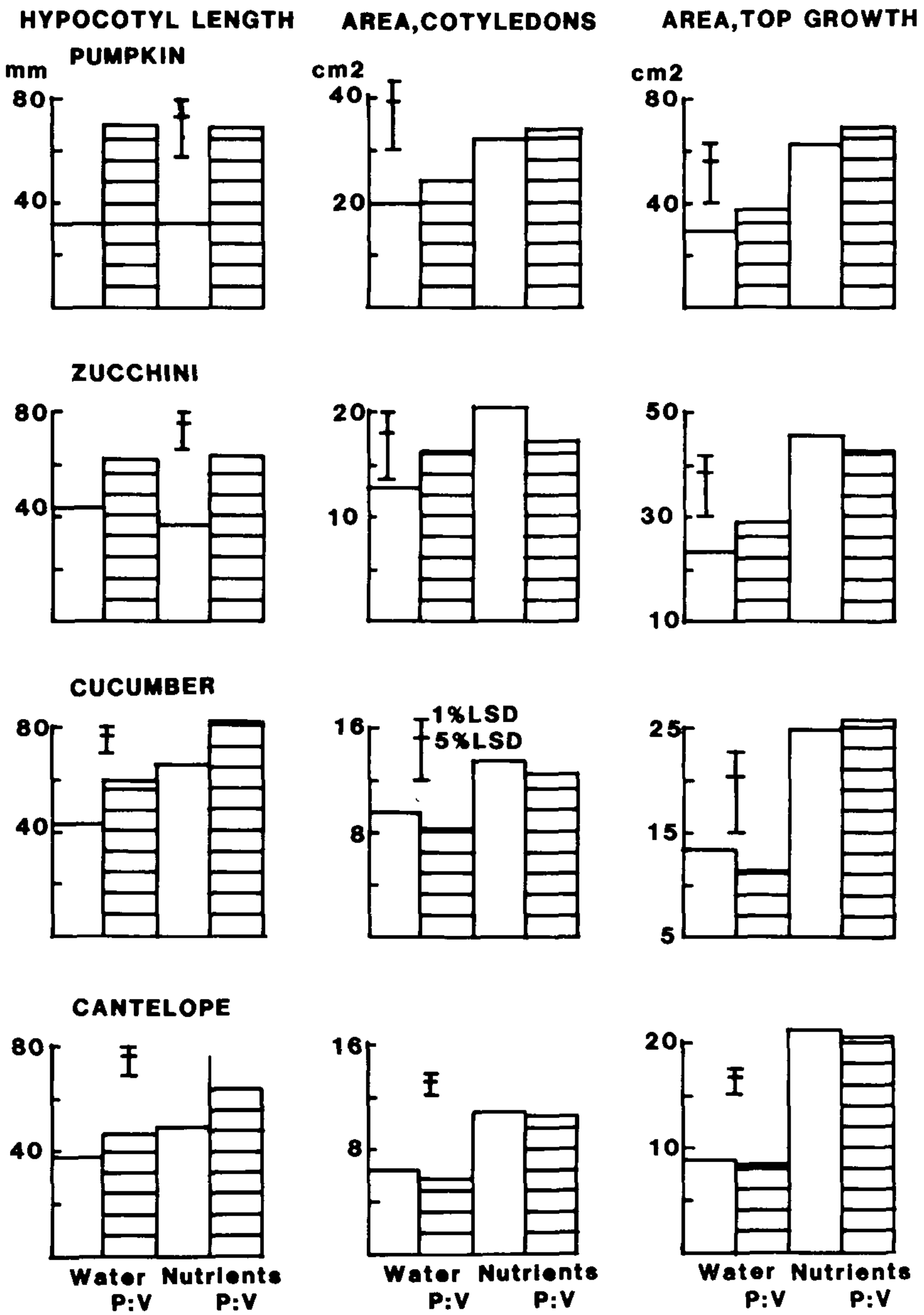

Figure 1. Effect of early nutrition (water vs nutrient) and planting method into rockwool blocks on growth of seedlings of four Cucurbitaceae seedlings P V = 50 50 perlite-vermiculite mix

Study B: *Gerbera jamesonii* seedlings. Seedling emergence began on Day 4. By Day 35, those receiving no external nutrient supply had developed symptoms typical of nitrogen deficiency. Plants fed at 4 g l^{-1} or above were very dark green, and at 8 g l^{-1} leaves were slightly puckered. At the final harvest on Day 69, the nil plants were stunted, pale green and

with a pinkish colouration. The strength of 8 g l^{-1} proved toxic. It suppressed growth, induced leathery-type leaves, tip necrosis of new foliage, and death of a number of plants. Seedlings of best appearance were those at strength 2 g l^{-1}. Dry weight of tops and total leaf area (Table 2) showed that optimum seedling growth occurred at nutrient strengths 2 and 4 g l^{-1}. This effect was evident by Day 35, and became more pronounced at later harvests as the depressive effects of the nil, and strength 8 g l^{-1} became more restrictive on growth. Strengths of 1 g l^{-1} or less were insufficient to sustain maximum plant growth. Plant development (i.e., leaf number, Table 2) was delayed at nutrient strength of 0.5 g l^{-1} or less.

This study demonstrated the need for the grower to determine the optimum fertiliser programme for the particular culture method used. Otherwise seedlings may be grown under nutritional conditions which superficially appear adequate but do not permit maximum growth to occur. If the regular application of a balanced nutrient supply is suboptimal (e.g., 1 g l^{-1} or less in the above study) seedling growth will be progressive but never at its maximum potential.

A deficient nutrient supply is relatively easy to define compared with an excess, because seedlings of different species, and cultivars within a species vary in their response and tolerance to high total salt levels in the medium (18). *Gerbera* appears to be more sensitive to high salts in the medium than chrysanthemum (1). Thus the problem for the propagator is to know the upper and lower nutritional parameters for the plants under cultivation.

Table 2. Effect of nutrient solution strength on the growth (dry weight, leaf area and leaf number per plant) of *Gerbera* seedlings harvest 35 (H_1), 52 (H_2), and 69 (H_3) days after sowing.

Nutrient solution			Top dry weight (mg) per plant			Total leaf area (cm_2) per plant			Leaf number per plant		
g l^{-1}	mS cm^{-1}	pH	H_1	H_2	H_3	H_1	H_2	H_3	H_1	H_2	H_3
Nil	0	5 6	12	13	16	5 3	7 0	6 4	1 5	1 6	1 9
0 5	0 6	6 2	21	38	80	10 0	18 6	31 8	2 1	2 9	4 1
1 0	1 1	6 2	25	56	163	14 0	26 0	60 6	2 5	2 9	5 9
2 0	2 0	6 0	35	89	274	18 1	40 5	89 4	2 7	4 3	5 7
4 0	3 9	5 5	29	71	240	14 2	36 5	84 8	2 8	4 6	5 4
8 0	6 9	5 2	20	21	40*	9 3	9 3	15 2*	2 3	4 1	4 0*
LSD	0 05		14	31	70	3 4	11 7	23 4	0 5	1 1	1 5
	0 01		19	41	94	4 5	15 6	31 5	0.7	1 5	2 1

* Many plants dead Omitted from statistical analysis

Study C: *Daphne odora* cuttings. The vigour of the mother stock, and the nutrient status of the rockwool propagation block had strong effects on strike rate, root growth, and subsequent growth of the grown-on plant.

All cuttings from the greenhouse-grown stock produced roots, whereas the strike rate for cuttings from the weaker outside stock was less than 80% (Table 3). In addition, greenhouse cuttings produced more roots, and some bud burst occurred. The nutritional status of the rockwool affected the root system in that the strike rate of outside cuttings were lower, but this may have been from damage caused by insects attracted by algal growth. With nutrients in the rockwool, fewer roots protruded from the walls, and these were relatively short (Table 3). Such cuttings were less prone to root damage when transplanted. A change in the nutrient treatment of the rooted cutting on transfer to the larger rockwool cube altered root growth behaviour in the same way as already described (Table 4).

The growth of plants 10 months after transfer to scoria and on completion of one growth cycle, reflected both the vigour of the mother stock and the influence of early nutrition on the rooted cutting (Table 4). Overall, plants from outside stock made poorest growth and had the highest mortality rate. Cuttings taken from greenhouse stock and provided with an early nutrient supply yielded the largest plants with the highest survival rate. Many of the plant deaths were from *Botrytis* following infection of senescent flowers.

Table 3. Effect of mother stock and nutrient treatment of rockwool on strike rate, root growth, and bud burst of *Daphne odora* cuttings

Source of mother stock	Rockwool treatment (rooting)	Strike rate percent	Number of roots protruding from rockwool	Length longest protruding root (mm)	Bud burst percent
Outside plants	Water	78 6	7 0±1 8*	5 3±0 6*	0
	Nutrients	51 7	2 9±0 6	1 4±0 3	0
Greenhouse plants	Water	100	19 3±1 1	15 6±1 0	21 4
	Nutrients	100	11 3±1 3	4 1±2 1	57 1

* Standard error of the mean

Table 4. Effect of mother stock and nutrient treatment of rockwool on the growth of rooted *Daphne odora* cuttings before and after 10 months in hydroponics

			After 10 months in hydroponics		
Source of mother stock	Rockwool treatment (for rooting)	(for growing on)	Number of roots protruding from rockwool	Mean percent plant survival	Mean shoot length/plant (mm)
Outside plants	Water	Water	11 0±2 4*	20	195
		Nutrients	1 7±0 4	66 7	206
	Nutrients	Water	15 8±3 7	25	150
		Nutrients	2 3±0 9	50	188
Greenhouse plants	Water	Water	15 4±2 4	71 4	351±59*
		Nutrients	3 4±1 3	57 1	443±87
	Nutrients	Water	46 4±4 7	85 7	518±78
		Nutrients	23 9±5 8	85 7	637±102

* Standard error of the mean

CONCLUSIONS

No evidence supported the view that nutrient supply in the medium is not required at the early stage of seedling growth and rootstrike of cuttings. All studies showed the importance of early nutrition, and that a restricted external nutrient supply in the first few weeks after seed germination hindered growth of seedlings of all four Cucurbitaceae species, irrespective of initial seed weight. The heavier seeds with larger reserves were equally incapable of sustaining seedling growth when the external nutrient supply is limited, probably because the seed reservoir had to support structurally larger seedlings.

The study of *Daphne odora* cuttings showed that a shortage of nutrients in the medium modifies the root system which develops, and that plants never recover from the effect of poor nutrition at the cutting stage. Careful selection of the mother stock is very important. Cuttings taken from weak mother plants had lower strike rates, and good nutrition was unable to fully compensate the rooted plant for the initial lack of vigour.

There is need for the propagator to determine the optimum nutritional requirements of the plants being propagated. If nutrient supply is inadequate optimum growth and development is not achieved. An over-supply of nutrients can be equally counter productive.

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GRAFTING AUSTRALIAN NATIVE PLANTS

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This paper deals with the results of a large number of experimental grafts using Australian native plants. (Tables 1, 2, and 3). Because of the large number of grafts made, methods were adapted or developed to produce grafted plants as quickly as possible. The three main methods involved used very young seedlings or tender shoot growth. The advantage of these methods was that an adequate supply of relatively homogeneous scion material was easily produced or gathered.

The three grafting methods were:

1. **Grafting at the Cotyledon State.** The method described by McKenzie (2) for grafting *Clianthus* spp. was used. When grafting Proteaceae spp. special care had to be taken to observe strict hygiene as these plants were very susceptible to fungal disease in the first few months.

Grafting at the cotyledon stage was possible with some Myrtaceae plants. Some species produce a hypocotyl (tissue below cotyledons above soil surface) which is sufficiently robust to graft if care is taken. Some *Eucalyptus* species, most *Eremaea*, *Beaufortia*, and *Regelia* species produce quite sturdy and relatively thick hypocotyls.

The two species *(Kunzea ambigua* and *Leptospermum phylicoides)* used as stock for the above genera are, by contrast, rather thin and spindly when very young. They, therefore, have to be grown to a much larger size (60 to 80 mm) to obtain stem diameters which match the scions, and are at the semi-mature stage when grafted.

Teflon tape was used as a grafting tape in all three methods. It was strong, easily torn longitudinally into strips 1 to 3 mm wide, did not need to be tied, and was cheap. It was, however, somewhat difficult to handle.

After the graft was made, the plants were kept in a humid atmosphere for up to 5 weeks. This was achieved by covering each plant with a small throw-away plastic medicine glass. These were quite inexpensive and, being translucent, allowed plenty of light to reach the newly-grafted plants. The medicine glasses were changed daily.

Mist was used for some species without ill effect after the first week. The grafts were finally unwrapped and slowly hardened off.

2. **Grafting Growing Tips.** Stock plants were grown in separate tubes to the required stem diameter. An actively-growing green tip was taken from the other plant and the scion was shaped to a wedge. A top wedge graft was made and the graft was bound with Teflon tape. The plants were then treated in the same way as those above.

3. **Cutting-Grafts.** The method used was a side cutting-graft, an adaptation of the method described by Burke (1). A side wedge graft was prepared and bound with Teflon tape. This was buried in the cutting medium so that the graft itself was covered, but the leafy tops of both the scion and stock were above the medium.

The cutting-grafts were placed under mist until the stock had rooted. The young plants were then potted into individual pots so that the graft union was well clear of the soil.

In all three methods the material used was small and quite difficult to handle. It was found that a large lens on a stand or a jewellers binocular loupe worn over the eyes was most useful in cutting and positioning the scion.

RESULTS AND DISCUSSION

The following points have become evident (Tables 1, 2, 3):

(a) Many combinations of stock/scions proved to be unsatisfactory as grafted plants. For a plant to be useful the growth rate should be similar or better than the normal rate attained by the scion growing on its own roots. A number of grafted plants survived for some time but their growth was extremely slow — these were marked x on the tables.

(b) The classic symptom of incompatibility — a clean break at the graft union — can occur at quite a late stage, sometimes several years after grafting.

(c) Using juvenile material, incompatibility may be suppressed for a time. It may then show up as one or more of the following symptoms, months or even years later:

(i) Clean break at the graft union.
(ii) Slow or stunted growth, or general malaise.
(iii) Gross disparity between stock and scion stem width.
(iv) Tendency of stock to produce shoots continually.
(v) Abnormalities in the union, in particular a furrow appearing right around the stem bark at the graft union, indicating discontinuity of growing tissue beneath the bark.

In general, the following combinations look very promising.

TABLE ONE PROTEACEAE

STOCK SPECIES	SCION SPECIES	NUMBER GRAFTED	NUMBER SURVIVING	AGE OF OLDEST PLANT	COMPATIBILITY
Banksia ericifolia	*B coccinea*	1	0	4	X
	B.nutans	1	1	36	+?
	B.violacea	1	1	48	+?
	B.occidentalis	4	0	6	X
	B.sphaerocarpa	2	0	18	X
	Dryandra praemorsa	1	0	6	X
	D.polycephala	2	0	6	X
Banksia integrifolia	*B.baxteri*	4	0	4	X
	B.benthamiana	3	1	48	+?
	B.brownii	10	5	55	+?
	B.burdettii	2	0	10	X
	B.coccinea	2	0	10	X
	B.grandis	2	2	36	+
	B.laevigata subsp.laevigata	1	1	42	+?
	B laevigata subsp.fuscolutea	13	7	45	+?
	B.lanata	2	1	18	?
	B.laricina	24	1	22	X
	B.lehmanniana	2	2	40	+
	B.leptophylla	2	1	18	?
	B.lindleyana	1	0	8	X
	B.littoralis var. littoralis	3	1	36	?
	B.littoralis var. seminuda	3	3	24	?
	B.media	1	0	30	X
	B.micrantha	1	0	18	X
	B.occidentalis	35	30	48	+
	B.oreophila	1	0	5	X
	B.pilostylis	4	1	38	?
	B.praemorsa	2	0	24	X
	B.prionotes	2	0	12	X
	B.scabrella	9	1	18	X
	B.speciosa	7	0	18	X
	B.sphaerocarpa	2	0	18	X
	B.telmatiaea	2	0	12	X
	B.verticillata	3	3	39	+
	B.victoriae	3	3	60	+?
	B.violacea	3	3	24	+
B integrifolia	*B.sceptrum*	4	0	9	X
	B.solandri	20	18	18	+
	Dryandra polycephala	8	0	15	X
	D.praemorsa	2	0	8	X
	D.speciosa	2	0	5	X
Banksia lehmanniana	*B.burdettii*	1	0	4	X
	B.oreophila	1	0	4	X
Banksia marginata	*B.grossa*	1	1	18	?
	B.lanata	3	2	18	?
	B.laricina	3	1	18	?
	B.nutans	1	0	12	?
	B.oreophila	2	0	5	X
	B.praemorsa	1	0	4	X
	B.sphaerocarpa	1	0	6	X
Banksia saxicola	*B.scabrella*	2	1	24	?
	B.leptophylla	5	2	24	?
	B.incana	1	0	12	?
Banksia robur	*B.oreophila*	2	0	5	X
Banksia serrata	*B.baueri*	1	0	12	?
	B.baxteri	2	0	5	?
	B.burdettii	38	15	36	?
	B.caleyi	1	0	18	?

TABLE ONE PROTEACEAE

STOCK SPECIES	SCION SPECIES	NUMBER GRAFTED	NUMBER SURVIVING	AGE OF OLDEST PLANT	COMPATIBILITY
	B.candolleana	1	1	24	?
	B.chamaephyton	1	0	4	?
	B.elderiana	1	0	4	X
	B.lehmanniana	1	1	24	?
	B.menziesii	7	4	30	?
	B.leptophylla	1	0	4	X
	B.incana	1	0	4	X
	B.pilostylis	2	1	18	?
	B.prionotes	1	1	36	+?
	B.speciosa	12	9	36	+?
	B.victoriae	6	2	28	+?
Banksia spinulosa var. spinulosa	*B. brownii*	2	0	12	X
	B. burdettii	3	0	6	X
	B. elderiana	3	2	30	+?
	B. laevigata sub-sp. fuscolutea	3	1	24	?
	B. lindleyana	2	0	8	X
	B. littoralis var littoralis	2	0	4	X
	B. nutans	2	0	15	X
	B. occidentalis	2	0	4	X
	B. pilostylis	2	0	15	X
	B. praemorsa	5	2	36	?
	B. prionotes	3	0	4	X
	B. sphaerocarpa	2	0	18	X
	B. verticillata	2	0	8	X
	B. victoriae	1	0	4	X
	B. violacea	2	0	6	X
	Dryandra praemorsa	8	5	60	+
	D. polycephala	2	0	5	X
	D. proteoides	3	0	8	X
	D. quercifolia	1	0	5	X
Banksia spinulosa var. collina	*B. ashbyi*	2	0	3	?
	B. brownii	3	2	56	+?
	B. laricina	1	1	60	+?
	B. laevigata sub-sp. fuscolutea	2	0	18	X
Banksia verticillata	*B. coccinea*	2	0	12	X
	B. scabrella	1	0	10	X
	B. micrantha	1	0	8	X
	B. oreophila	1	0	6	X
	B. elderiana	1	0	6	X
Grevillea robusta	*G.dryandri*	2	2	36	+
	G.candelabroides	2	2	36	+?
	G.petrophiloides	5	0	24	X
	G.wilsonii	2	2	36	+
Grevillea barklyana	*G.petrophiloides*	3	0	12	X
Grevillea 'Clearview David'	*G.asparagoides*	1	1	36	?
	G.eriostachya	2	0	15	X
	G.flexuosa	2	0	12	X
Grevillea banksii	*G.petrophiloides*	5	0	12	X
	G.'Misty Pink'	1	1	36	+
Grevillea rosmarinifolia	*G.petrophiloides*	3	2	30	?
	G.wilsonii	3	2	15	+
Hakea laurina	*H.francisiana*	5	0	18	X
	H.coriacea	2	0	20	X
	H.multilineata	7	0	24	X
Hakea nodosa	*H.coriacea*	3	1	18	?

TABLE ONE PROTEACEAE

STOCK SPECIES	SCION SPECIES	NUMBER GRAFTED	NUMBER SURVIV-ING	AGE OF OLDEST PLANT	COMPATI-BILITY
Hakea salicifolia	*H.francisiana*	29	15	18	+?
	H.multilineata	5	4	18	+?
	H.bucculenta	200	180	48	+
	H.coriacea	100	80	48	+
	H.francisiana	500	460	48	+
	H.grammatophylla	20	10	36	?
	H.lorea	6	3	30	?
	H.multilineata	300	275	48	+
	H.victoriae	6	0	14	X
Hakea sericea	*H.francisiana*	5	3	30	+?
	H.multilineata	2	1	30	+?

TABLE TWO MYRTACEAE

Astartea fascicularis	*Chamelaucium uncinatum*	6	0	18	X
	Darwinia leiostyla	3	0	12	X
	Verticordia chrysantha	2	0	12	X
Calytrix sullivanii	*Chamelaucium uncinatum*	3	1	18	X
	Darwinia leiostyla	2	0	8	X
Darwinia citriodora	*Chamelaucium uncinatum*	20	15	36	+?
	Actinodium cunninghamii	3	1	24	?
	Darwinia carnea	4	4	24	+
	D. collina	2	2	16	+
	D.hypericifolia	6	4	26	+
	D.leiostyla	20	18	36	+
	D.macrostegia	30	26	36	+
	D.oldfieldii	3	2	36	+?
	D.oxylepsis	10	9	36	+
	D.nieldiana	5	3	18	?
	D.purpurea	3	3	16	?
	D.squarrosa	4	3	18	+
	D.virescens	3	2	18	?
	Verticordia chrysantha	5.	4	36	+
	V.densiflora	2	2	16	?
	V.mitchelliana	5	3	36	+?
	V.monadelpha	4	3	30	+?
	V.nitens	10	0	13	X
Darwinia fascicularis	*D.macrostegia*	1	1	18	?
Darwinia grandiflora	*D.leiostyla*	2	1	24	?
	D.macrostegia	2	2	24	?
Eucalyptus gummifera	*Eucalyptus ficifolia*	10	5	36	?
Kunzea ambigua	*Beaufortia squarrosa*	3	0	8	X

TABLE TWO MYRTACEAE

STOCK SPECIES	SCION SPECIES	NUMBER GRAFTED	NUMBER SURVIV-ING	AGE OF OLDEST PLANT	COMPATI-BILITY
Kunzea ambigua	*Eremaea beaufortioides*	2	1	24	?
	Kunzea affinis	2	2	24	+
	K.baxteri	3	3	28	+
Leptospermum phylicoides	*Beaufortia squarrosa*	3	0	6	X
	B.sparsa	6	0	6	X
	Eremaea beaufortioides	4	0	5	X
	E.pauciflora	3	0	4	X
	E.fimbriata	3	0	4	X
	Kunzea affinis	5	5	30	+
	K.baxteri	15	13	30	+
	K.pulchella	3	3	24	+
	Chamelaucium uncinatum	10	0	12	X
	Melaleuca scabra	2	0	8	X
	Verticordia chrysantha	4	0	6	X
	V.mitchelliana	2	0	6	X
	Regelia velutina	5	0	6	X
Regelia ciliata	*Eremaea beaufortioides*	2	1	24	?
	Beaufortia schaueri	1	0	15	X
Regelia megacephala	*Beaufortia orbifolia*	2	0	6	X
	Regelia velutina	2	1	18	?
Thryptomene saxicola	*Actinodium cunninghamii*	*3*	*0*	*18*	*X*
	Chamelaucium uncinatum	5	0	12	X
	Darwinia leiostyla	*5*	*1*	*30*	+?
	D.macrostegia	5	0	10	X
	Verticordia mitchelliana	3	1	18	+?
	V.monadelpha	2	1	18	+?

TABLE THREE
GRAFTS OF OTHER PLANT FAMILIES

PAPILIONACEAE					
Clianthus puniceus	*Clianthus formosus*	3000	?	60	+
RUTACEAE					
Boronia clavata	*Boronia megastigma*	5	3	24	?
Correa alba	*Eriostemon verrucosus*	2	0	26	?
C 'Marions Marvel'	*E. australasius*	3	0	6	X
C. 'Dusky Pink'	*E. verrucosus*	1	0	15	?
	Correa 'Fat Fred'	1	1	18	+

Banksia grandis, *B. solandri*, *B. occidentalis*, and *B. verticillata* on *B. integrifolia* rootstock.

Hakea bucculenta, *H. francisiana*, *H. coriacea*, and *H. mullilineata* on *H. salicifolia* rootstock.

Kunzea spp. on *Kunzea ambigua*, and *Leptospermum phylicoides* rootstock.

Most *Darwinia* species and, perhaps, some *Verticordia* species on *Darwinia citriodora* rootstock.

Clianthus formosus on *Clianthus puniceus* rootstock.

It is, perhaps, surprising that so few of the trials produced satisfactory plants. A most important point, however, is that grafted plants should be grown for a number of years before a claim of success is justified.

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INFLUENCE OF DAYLENGTH ON THE PRODUCTION AND QUALITY OF CUTTINGS FROM FUCHSIA MOTHER PLANTS

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INTRODUCTION

Investigations into the reaction of fuchsias to daylength have been carried out by many workers including Roberts and Struckmeyer (6), Sachs and Bretz (7), Heide (4), Guttridge (3), Canham (2), Zimmer (9,10,11). In these investigations flowering was of primary interest. It was found that different fuchsia cultivars showed different reactions, and that different cultivar groups showed differences in flowering.

Most of the fuchsia cultivars offered for sale are long-day plants. In the literature these are named *Fuchsia* × *hybrida* or *Fuchsia*-hybrids, in spite of the fact that they mostly originate from *Fuchsia magellanica* and thus ought to be named *Magellanica* hybrids.

This large group should, however, be divided into two smaller groups, the larger being the obligate or qualitative long-day plants, and the smaller being the facultative or quan-

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This large group should, however, be divided into two smaller groups, the larger being the obligate or qualitative long-day plants, and the smaller being the facultative or quan-

titative long-day plants. 'Alice King', 'Beverly Hills', 'Dollarprinzessin', 'Hanna', 'Lord Byron', 'Marinka' and 'Swingtime' belong to the obligate group, and 'Beacon', 'Henriette Ernst', 'Jack Ackland', 'Pink Ballet Girl', and 'Winston Churchill' to the facultative group.

The critical daylength is usually around 12 hours. Very few of the currently commercially available fuchsia cultivars are neutral to daylength. Those that are, are mainly derived from *F. triphylla* and are classified as *F. triphylla* hybrids. The most well known cultivar of this group is 'Koralle', which also flowers during neutral and short-day periods. 'Elfriede Ott', 'Gartenmeister Bonstedt', 'Leverkusen', 'Trumpeter', 'Stella Ann' belong to this group as well as other species — *F. boliviana*, *F. cordifolia* and *F. fulgens*.

When cultivating fuchsias for flower beds, balconies, terraces, hanging baskets, and pot plants one does not only have to have a certain knowledge of the flowering response to plan flowering but a knowledge of vegetative growth requirements as well.

Investigations of flowering have shown that the cultivars in the obligate long-day group switch to fully vegetative growth when under critical daylength and, in the facultative long-day plants, flowering is least retarded. Based on the trials of Otto (5) and Bosse (1) it is recommended to cultivate the mother plants under 9 to 10 hours daylength to prevent flowering and to increase production of cuttings and the rooting of the cuttings. This is not possible in fuchsia cultivars which are daylight neutral. Even under severe short-day conditions they cannot be brought into a clear vegetative state as Zimmer (11) was able to achieve with 'Elfriede Ott'.

Fuchsias still play an important role in German horticulture as bedding and balcony plants. Hundreds of thousands of plants are cultivated annually for the beginning of the outdoor season in mid-May. Horticulturists are generally not using the knowledge of daylength responses to pretreat mother plants. As a consequence we still hear about difficulties with mother plants; tip cuttings forming buds which result in retarded rooting; and *Botrytis* in the propagation beds which has been caused or aggravated by falling flower buds and flowers.

These factors seemed to be of such importance that it was decided to investigate the problem of optimum daylength for fuchsia mother plants during the most important months for the production of cuttings — October to March.

The investigations were aimed at trying to:

1. Increase the number of cuttings per mother plant.

2. Improve the quality of cuttings, i.e. the fresh weight and, if possible, keeping a fully vegetative state (no flower buds).
3. Improve rooting of the cuttings.
4. Improve growth of the young plants.

MATERIALS AND METHODS

For the tests the cultivars, 'Beacon', 'La Perle', 'Lydia Götz' and 'Hanna' were chosen. All of these are long-day cultivars. Of these, 'Beacon' may be considered facultative and 'Hanna' obligate long-day plants. The *Triphylla*-hybrid, 'Koralle', which belongs to the day-neutral group was also used.

For both investigation years, 1981/82 and 1982/83, propagation of the mother plants was started at the beginning of July. These plants were grown from the end of July to the end of September, or the beginning of October, with a 9-hour day. After this period they were separated into different test groups. During the 1982/82 trial, 6, 8, 10, 12, and 16 hour daylength periods were used. During 1982/83 daylengths of 8, 9, 10, 11, 12 and 16 were used. For both trials daylengths of more than 8 hours were achieved by means of fluorescent tubes (Osram L65W/30R), with light intensity of 500 Lux (50 ft.c.).

The cuttings were harvested every fortnight. In 1982/82 there were 11 harvests and 9 in 1982/83. At three of each of these harvests (7th, 9th, and 11th in 1981/82 and 5th, 7th, and 9th in 1982/83) cuttings were taken and rooted, and plants were grown on and cultivated for four weeks more to a marketable stage. In doing so the rooting of the cuttings and the cultivation of the young plants were done under the normal daylight conditions of the location (50° northern latitude) in springtime.

This report uses as examples of the results, those of 'Beacon', 'Hanna', and Koralle'; one is facultative, one an obligate long-day plant, and one a daylength-neutral cultivar from the 9th and 11th harvest of the period 1981/82.

RESULTS

Increases in the number of cuttings harvested per mother plant were sometimes visible with the 10-hour treatment, but increased markedly after the 12-hour treatment of the mother plants. For all species in this trial the largest number of cuttings were harvested after 12 and 16 hours daylight. The fresh weight of the cuttings (which is an indicator of quality) increased with daylength. Mother plants cultivated under 6 and even 8-hour daylight yielded cuttings with low fresh weights.

The percentage of cuttings displaying reproductive growth is shown in Figure 1. It is clear that for 'Beacon' and for 'Hanna', the formation of flower buds starts slowly, according to their characteristics as long-day plants, only at daylengths of more than 10 hours, increasing slightly at 12 hours.

With the day-neutral cultivar, 'Koralle', there was sporadic bud formation during the whole winter. When the amount of light (intensity × time) increased considerably in March, bud formation increased.

Consequently the reproductive growth that started as a result of the increased daylength to the mother plant, continued right through the rooting phase of the cutting and during the whole growing period up to the marketable young plant. This is shown in Figure 2 for marketable young plants (altogether 7-week-old) from the 9th harvest and Figure 3 for the 11th harvest of cuttings. The increase of daylength and light intensity, especially from March onwards, intensified this effect considerably.

The young plants grown from cuttings from short-day treated mother plants (6-10 hours daylength) were vegetatively stronger (height of plant, number of leaves, fresh weight) before increased flower formation started, depending on daylength and light respectively. This can be seen in Figure 4 for 'Beacon' (top), 'Hanna' (center), and the day-neutral 'Koralle' (below), which showed no significant differences under various daylength treatments.

DISCUSSION

The results show that mother plants of fuchsia cultivars considered as long-day plants (in this case 'Beacon' and 'Hanna') show no flower formation under short-day conditions or, if there is any, it is very retarded and only sporadic. Short-day conditions encourage constant vegetative growth in these cultivars. Flower buds are only formed, with a simultaneous decrease in vegetative growth, when the plants are exposed to day-lengths of 11 and 12 hours or longer.

Day-neutral cultivars form buds independent of daylight, but are dependent on quantity of light (intensity × time). There are fewer buds formed under short day conditions with low light quantity and more with increasing quantity of light. The vegetative growth is influenced according to the given quantity of light.

This confirms the findings from Otto (5) and Bosse (1) who recommended short-day treatment of fuchsia mother plants during the summer half of the year, at least for long-day

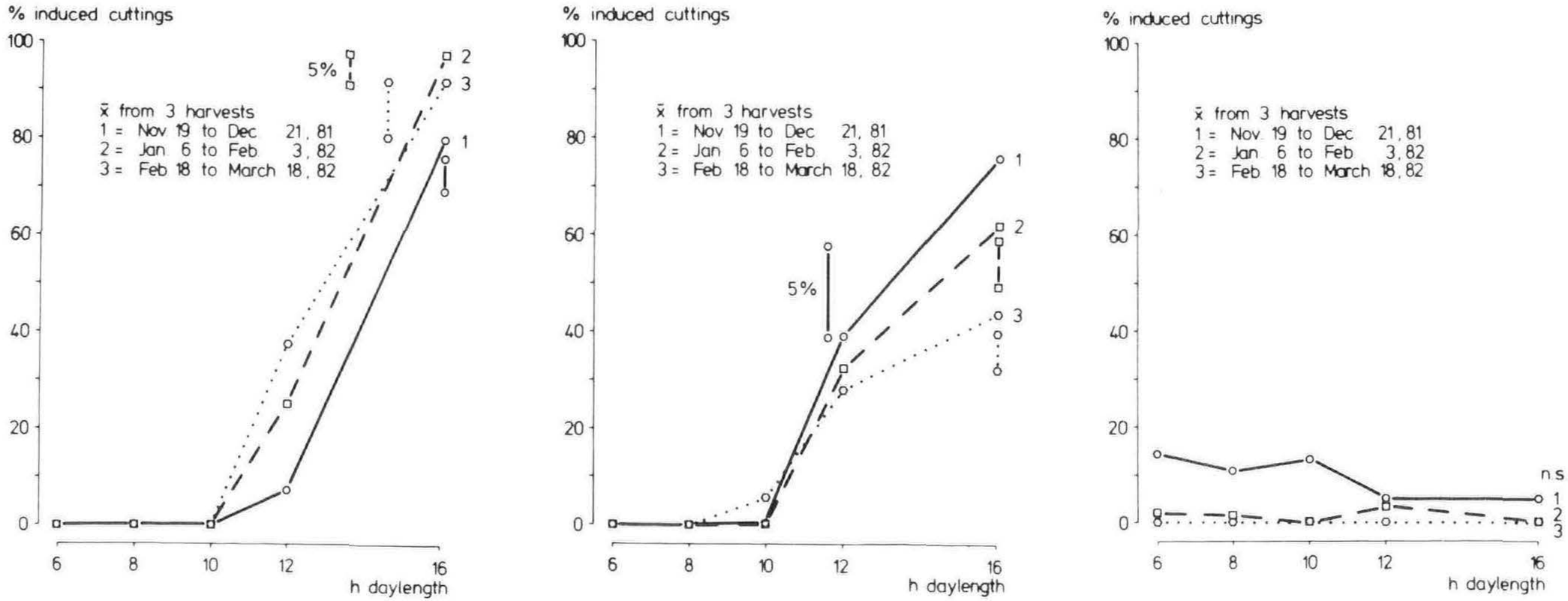

Figure 1. Percent induced cuttings from fuchsia-hybrids after treatment of mother plants with different daylengths. 'Beacon' (left), 'Hanna' (center), 'Koralle' (right).

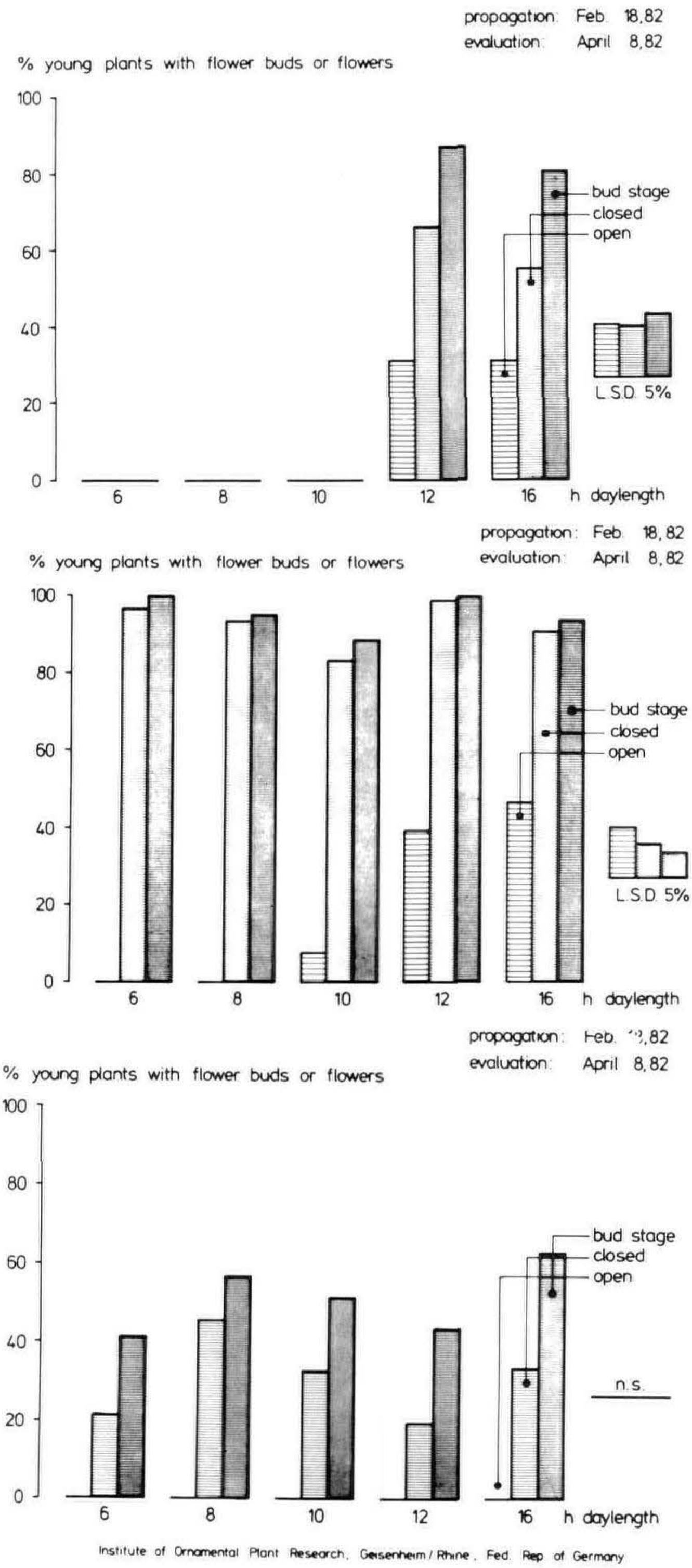

Figure 2. Percent young plants with flower buds or flowers from fuchsia-hybrids after treatment of mother plants with different day-lengths 'Beacon' (top), 'Hanna' (center), 'Koralle' (bottom). Propagated February 18, 1982. Evaluated April 8, 1982.

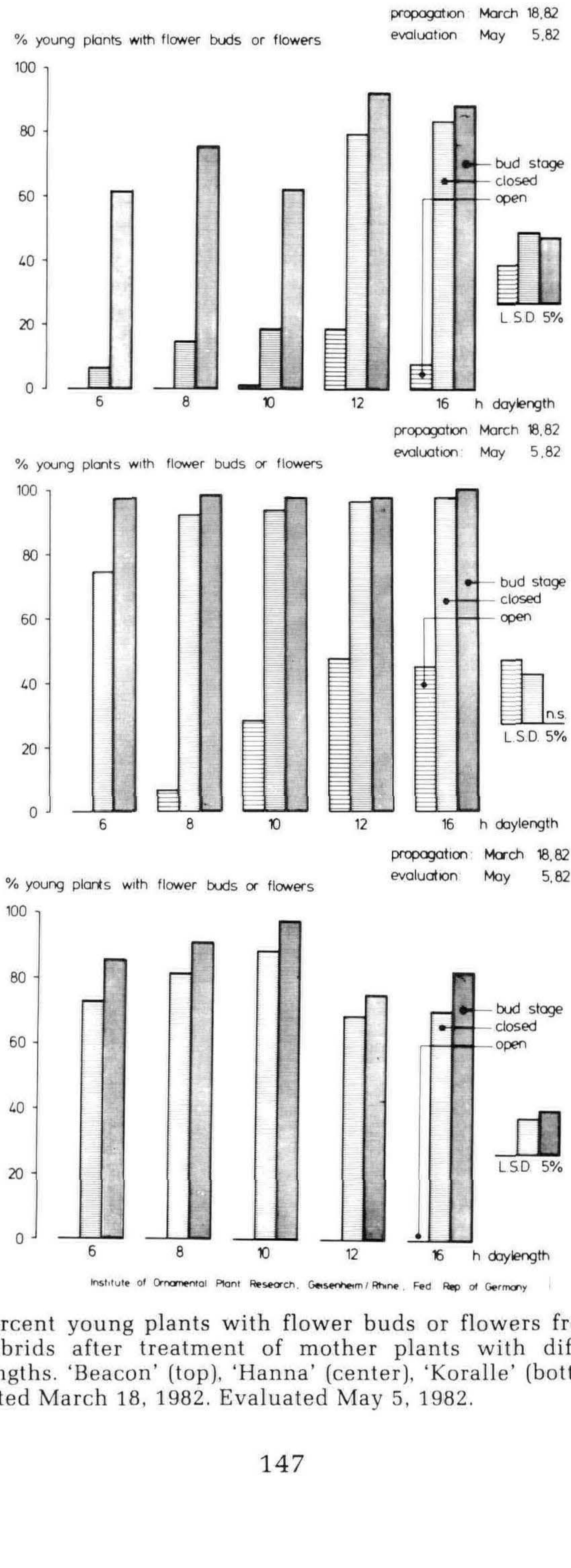

Figure 3. Percent young plants with flower buds or flowers from fuchsia-hybrids after treatment of mother plants with different day-lengths. 'Beacon' (top), 'Hanna' (center), 'Koralle' (bottom). Propagated March 18, 1982. Evaluated May 5, 1982.

cultivars, to obtain a constant supply of cuttings without flower buds.

The results of this investigation correspond with reports on reaction to daylength of long-day facultative and long day obligate cultivars (in this case: 'Beacon' and 'Hanna', respectively), as well as day-neutral fuchsia cultivars (here: 'Koralle'), especially Sachs and Bretz (7); Heide (4); Guttridge (3); Canham (2); Zimmer (11); and Töpperwein (8).

CONCLUSIONS

One can deduce the following which can be put into practice for the cultivation of mother plants for the production of cuttings and the subsequent production of young plants.

The cultivation of mother plants is optimal at 10 hours daylength. This is valid for long-day cultivars and for day-

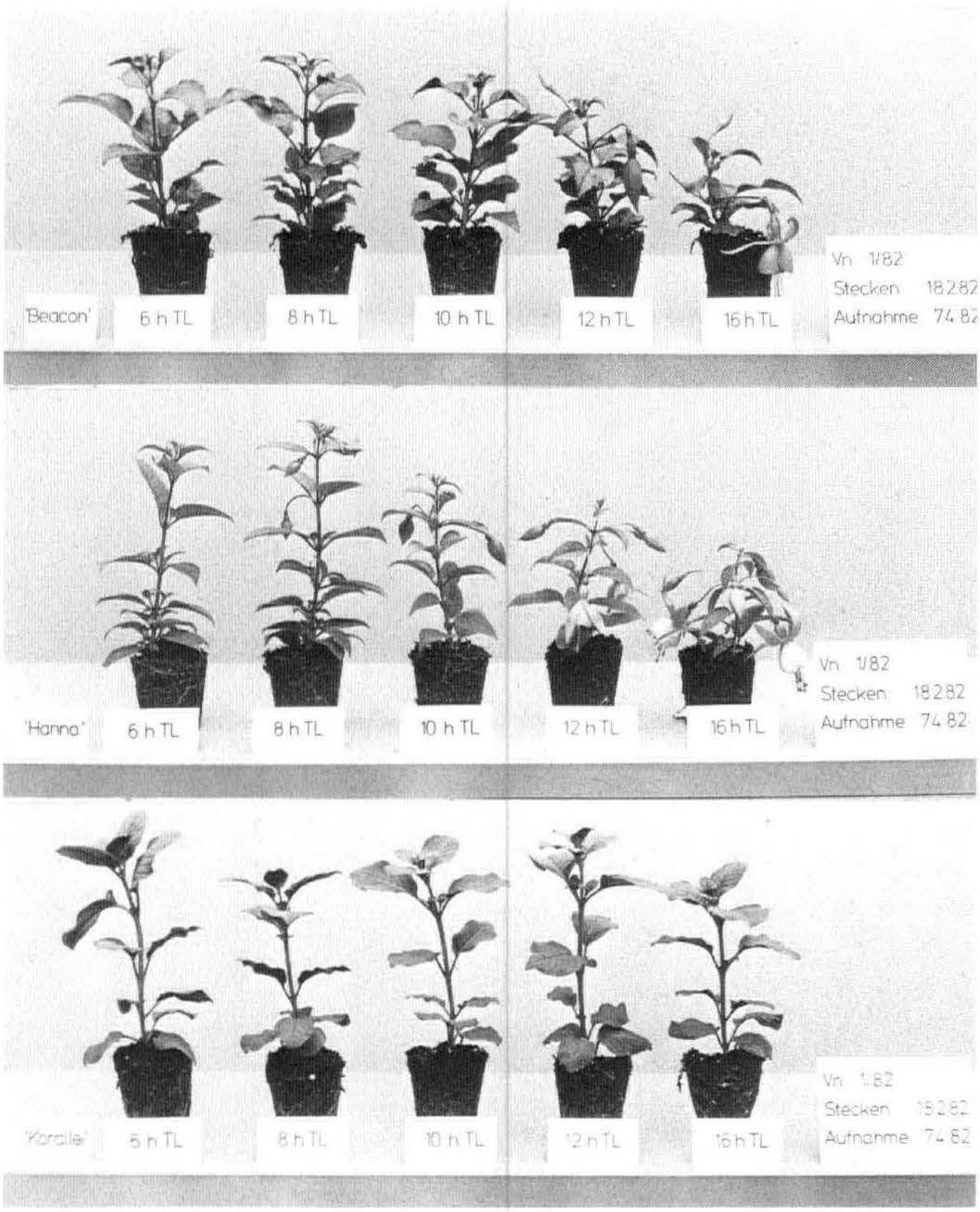

Figure 4. The effect of daylength on the growth of three different fuchsia cultivars, 'Beacon' (top) and 'Hanna' (center), both short-day plants, and 'Koralle' (bottom), a day-neutral cultivar.

neutral reacting cultivars. Extensive evaluation of the trial results has led to the judgement that this is a compromise between, on one hand, sufficient growth of the mother plants and sufficient production of cuttings, and on the other hand to produce a satisfactory quality of cuttings as measured by fresh weight and a lack of flower buds. Thus under central European conditions, i.e. locations on or around 50° northern latitude, fuchsia mother plants can be cultivated from the end of October to mid-February under natural daylength, plus 1 to 2 hours additional artificial light. Before and after this period the natural daylength should not exceed 10 hours. This also applies to the rooting of cuttings and the subsequent growth of young plants.

For marketing in our location at the beginning of the "balcony and outdoor" season (around the 10th to 15th May) the young fuchsia plants should be cultivated from at least the end of March onwards under natural daylength increasing this to 12 to 15 hours to allow flowering in time.

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DEVELOPMENT OF NURSERY TECHNIQUES

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Abstract. Major landmarks in the development of modern nursery techniques are outlined The John Innes Horticultural Institute in England demonstrated in 1934-39 that, with slight modifications, a single roughly standardized soil mix could be used for a wide variety of plants The first unified comprehensive approach to the special problems of plant growth in containers was evolved at the University of California in 1941-57 The U C. mixes were the first truly standardized, light weight, inert, well-aerated media that could be steamed without production of phytotoxicity Many modifications have since appeared, based on the principles presented in Manual 23, in which the mixes were described The U C System was uniquely evolved under stress of war conditions, with shortages of labor and materials; it was the result of the combined effort of many growers, research scientists, extension workers, and commercial laboratories, and was continually referred back to growers for modification. There was emphasis on using soil and plants free of pathogens, and practicing intensive sanitation Major advances in the System in the past 27 years are: aerated steam treatment of soil and propagules; addition of selected microorganisms (antagonists) to propagules or to treated soil for biological control of accidentally introduced pathogens and to increase plant growth through bacterization, use of minute meristems, cells, and protoplasts in propagation to improve pathogen control, prolonged mild heat therapy of plant propagules to decrease virus transmission; prevention of pathogen transmission in irrigation water, holding seed in polyethylene glycol following thermotherapy to permit metabolic damage to be repaired and the seed thus to recover from treatment

Although man was growing plants in containers in Egypt at least 4000 years ago (2), only in the last 50 has he examined the scientific bases for the practices developed. At first he probably used the soil from the area where the plant was obtained, but he later added various amendments to improve growth. The soil mix of an especially successful crop thus became the standard for that plant, even through the soil may not have been responsible for the success. Different mixes eventually came to be thought of as necessary for each crop, and the idea was reinforced by prevalent secrecy that prevented comparison with other mixes. Growing practices were long determined by rote, prescribed in the apprentice system then used. Some of these routines were compiled and published (13) as late as 1930 for growers to follow without considering the rationale involved.

This rule-of-thumb system continued until the twentieth century, and still persists among some untrained growers. "Root action," evidenced by new white roots when plants were knocked out of the container, was emphasized in growing, particularly in fertilizing and watering practices. This useful

concept, unfortunately, has declined with greater technical knowledge and methods.

SOIL MIXES

Although plants had been grown in sand culture by 1840, and in water culture in the 1860s, it was 90 years before these techniques affected grower practice. Hydroponics was widely and extravagantly publicized in the 1930s in the U.S., but commercial application was generally unsuccessful because of difficulties of adequate control of nutrient levels, aeration, glasshouse humidity, and root disease, and because of equipment cost. Laurie and Kiplinger tried sand and gravel culture in Ohio after 1931. Post and Seeley used constant-level subirrigation of soil in benches in New York about 1940, but slight change in water level led to inadequate moisture or to waterlogging. These methods are still used in special situations.

The John Innes Horticultural Institute in England developed a roughly standardized soil medium in 1934-39. Their demonstration that, with slight modifications, a single soil mix could be used for growing a wide range of plants is an important landmark in container culture. These mixes consisted of composted turf (especially grown on loam soil for this purpose), peat, coarse sand, hoof and horn meal, superphosphate, sulfate of potash, and chalk. These mixes were widely used despite the disadvantages of variability in and frequently unavailability of composted turf soil, the expense, labor, and space required for composting, excessive weight, toxicity when steamed together, and failure to eliminate pathogens when only the turf was steamed.

The first unified comprehensive approach to the special problems of container growing was made at the University of California in 1941-57. Leaf mold, horse manure, and fine sandy loam were used at first, but this mixture was abandoned because of salinity injury, post-steaming toxicity, variable results, and shrinkage. By 1947, Canadian peat, fine sand, and mineral fertilizers were used. Attempts to improve the mixes and to understand why some were better than others led to the U.C.-type mixes, the first truly standardized, light-weight, inert growing media. The concepts evolved have proved, as predicted, of greater permanent value than the five basic formulations presented. These principles apply to the many variations in the System that have since appeared [e.g., Peat-lite and Jiffy Mix (perlite or vermiculite with sphagnum peat); redwood sawdust, fine bark, perlite or pumice with fine sand; sphagnum peat with perlite, heat-processed montmorillonite clay, or sand; composted pine or hardwood bark with sand, perlite, pumice, expanded shale, or Styrofoam]. The trend ev-

erywhere is now toward inert, lightweight, standardized, artificial mixes, and away from the use of soil.

There are several misconceptions on ingredients for soil mixes that should be cleared up at this time. It has frequently been said, and is even widely believed, that peat moss is free of plant pathogens. It has even been suggested that it contains some material inhibitory to the growth of pathogenic fungi. However, many years of experience bear witness to the presence of water molds (*Pythium*, *Phytophthora*, and *Aphanomyces* spp.) in commercial peat moss from several geographical areas. For example, an azalea grower in Santa Barbara, California, sustained heavy losses from these pathogens in plants grown in nontreated German peat moss in ground beds. The pathogens were present in the peat moss as received. Canadian peat has also repeatedly been implicated in outbreaks of root rot.

The Einheitserde (Standardized Soil) was marketed in Germany after 1948 as a nontreated soil mix. It consisted of 50% peat and 50% well aggregated subsoil clay, plus mineral fertilizers. Because the peat was thought to be free of pathogens, and the clay was mined from deep subsoil, the mix was erroneously claimed to be free of pathogens. However, two German investigators showed in 1955 that the mix was infested with pathogens (2).

Similar misconceptions appeared in 1964 concerning the antagonistic effect on plant pathogens of several soils treated with aerated steam at 60 to 71°C. One of these soils was mined at considerable depth in wind-blown fine sand. Such materials, and sterile or inert media such as perlite, vermiculite, or sphagnum peat, lack antagonistic microorganisms and therefore should not be expected to inhibit pathogens following aerated steam treatment. When materials exhibit no antagonistic effect before such treatment, they should not be expected to show it after treatment; aerated steam treatments select antagonists, they do not create them (20).

THE U.C. SYSTEM

It is instructive to consider the circumstances that prompted development of the U.C. mixes. Following the Pearl Harbor attack in December, 1941, the California bedding plant industry was operated by inexperienced people under conditions of war shortages of materials and labor, but with available Army and Navy contracts for growing tomato, pepper, and pimiento transplants. Cooperation of the California Agricultural Experiment Station and Extension Service with several growers emphasized labor-saving methods, dependable production (to meet scheduled contracts), and large volume (5).

A disease complex caused large losses of seedlings and great mental confusion to growers (2). Salinity from water, leaf mold, and manures caused widespread losses, especially if soil was allowed to become at all dry. *Pythium ultimum* caused damping-off when soil was kept wet in an attempt to reduce salinity injury. *Rhizoctonia solani* caused damping-off when soil was kept at medium moisture levels trying to follow a median course. Since these factors occurred in any combination, it was impossible to consistently prevent losses by careful watering. The only available answer was to eliminate root pathogens by soil treatment. A further confusion resulted from erratic transmission of *Rhizoctonia* in pepper and tomato seed; a hot-water treatment was developed to control this (1).

Because steam treatment of soil that contained manures or leaf mold produced toxins that stunted seedlings, inert, simple, reproducible soil mixes without a clay fraction were developed that were not toxic following steaming.

War priorities made it very difficult for new nurserymen without a previous history of need to get equipment or trucks to steam or haul soil. We tried unsuccessfully to get a large fertilizer company to undertake supplying treated, fertilized nursery soil mixes. The opportunity for the first centralized soil supply service was thus lost, and did not become a reality until 30 years later in New Zealand. A mobile continuous batch soil steaming and flat-filling unit (Figure 1) was built by Wilton Abplamalp in Anaheim, California, and used by growers for several years; it was the prototype of many units used today.

By 1948 most of the components of the new system of growing had been fitted together in the operation of American Plant Growers in Lomita, California (5). A sand-peat mixture with commercial fertilizers was mixed and moistened in a concrete mixer, and placed in flats (Figure 2). The flats were treated in a cannery retort at 100°C for 30 minutes (Figure 3). When cooled, the flats were machine-sown with treated seed by a perforated vacuum plate, and then covered with thin tissue paper before being passed under an automatic sander to cover the seed. The flats were then sprayed with water and held in a germination room until seedling emergence. They were then promptly placed on glasshouse benches under humid warm conditions to promote rapid growth. Pepper seedlings required 50 days from seeding to hardening, a saving of 25-30 days over the old system. Flats were then moved on steel rollers to outdoor cold frames, and hardened-off by lower temperature and withholding water and fertilizer. The wiry plants were then hand-pulled and moved in boxes of peat

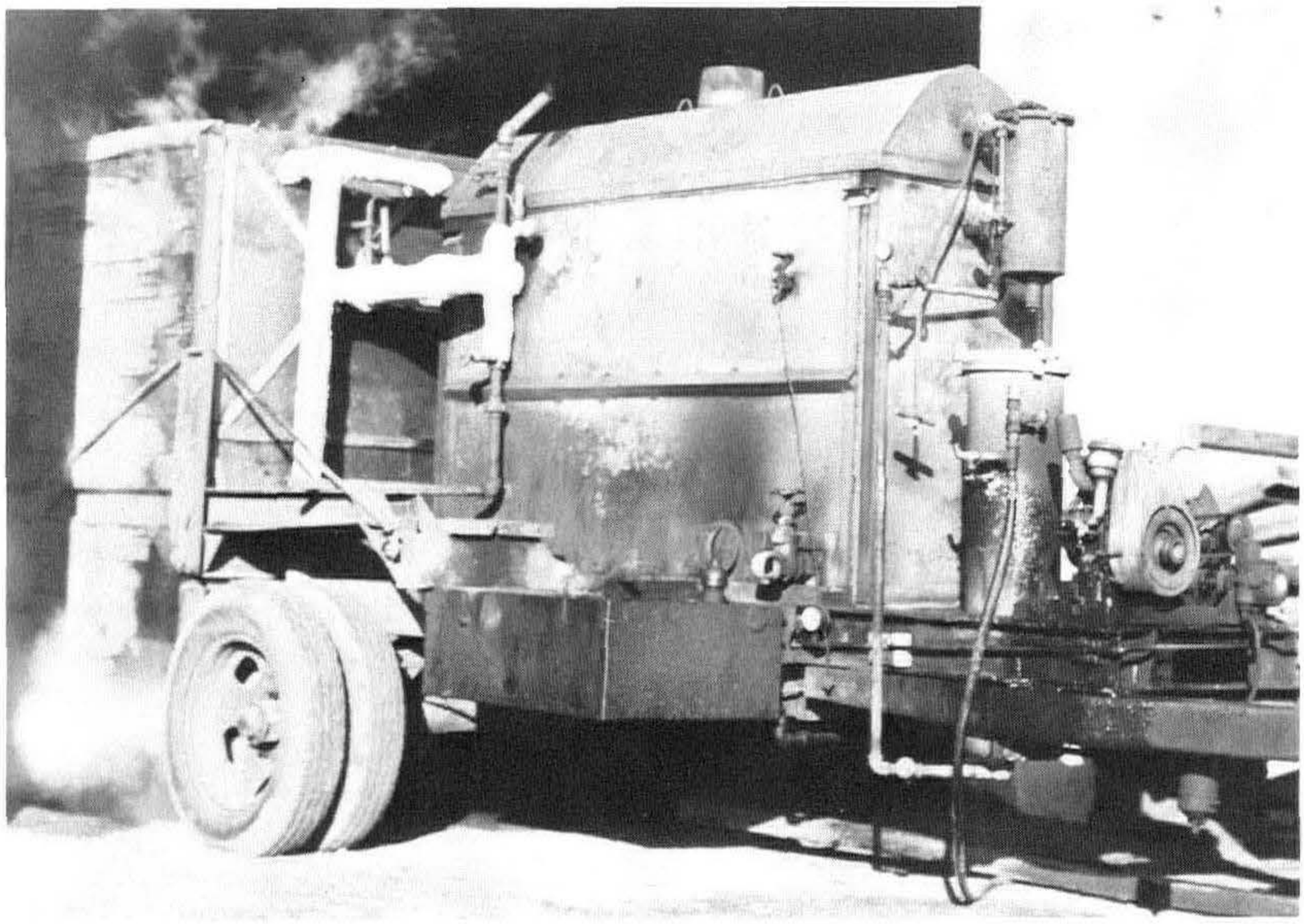

Figure 1. Mobile equipment built and used by Wilton Abplamalp, Anaheim, California, in the early 1940s for custom steaming of nursery soil. The steam generator is in front (*right*). The steam was injected into the soil in two continuous-batch type boxes at the rear (*left*). Each box held about two cubic yards of soil, and was dumped into a bin below, from which a flat-filler moved soil through an adjustable gate into flats passing below. One treatment box was heated to 100°C in 12 minutes, while the other was being filled by a conveyor belt. This unit was the prototype of many modern soil-steaming and flat-filling units. Photo courtesy of C. N. Roistacher.

moss to the field where they were machine planted. Sanitation and hygiene were emphasized throughout the procedure.

Details of the System were presented at the Refresher Courses for Nurserymen in San Luis Obispo in 1950, 1951, 1952, and 1958, provoking controversy. Some growers denounced it as ridiculous, unnecessary, and impractical hospital cleanliness; others who had used the scheme reported it as successful. Invaluable grower reaction and feedback was thus involved while the System was being developed. There was very close cooperation between more than a dozen investigators, growers, laboratories, and extension workers in a united way, with the sole purpose of getting the job done. There is a lesson here for our present time when such cooperation is rare and there is concern about who gets the credit.

Part of all of these methods have been widely used, and many modifications developed for adaptation to perennial or woody plants.

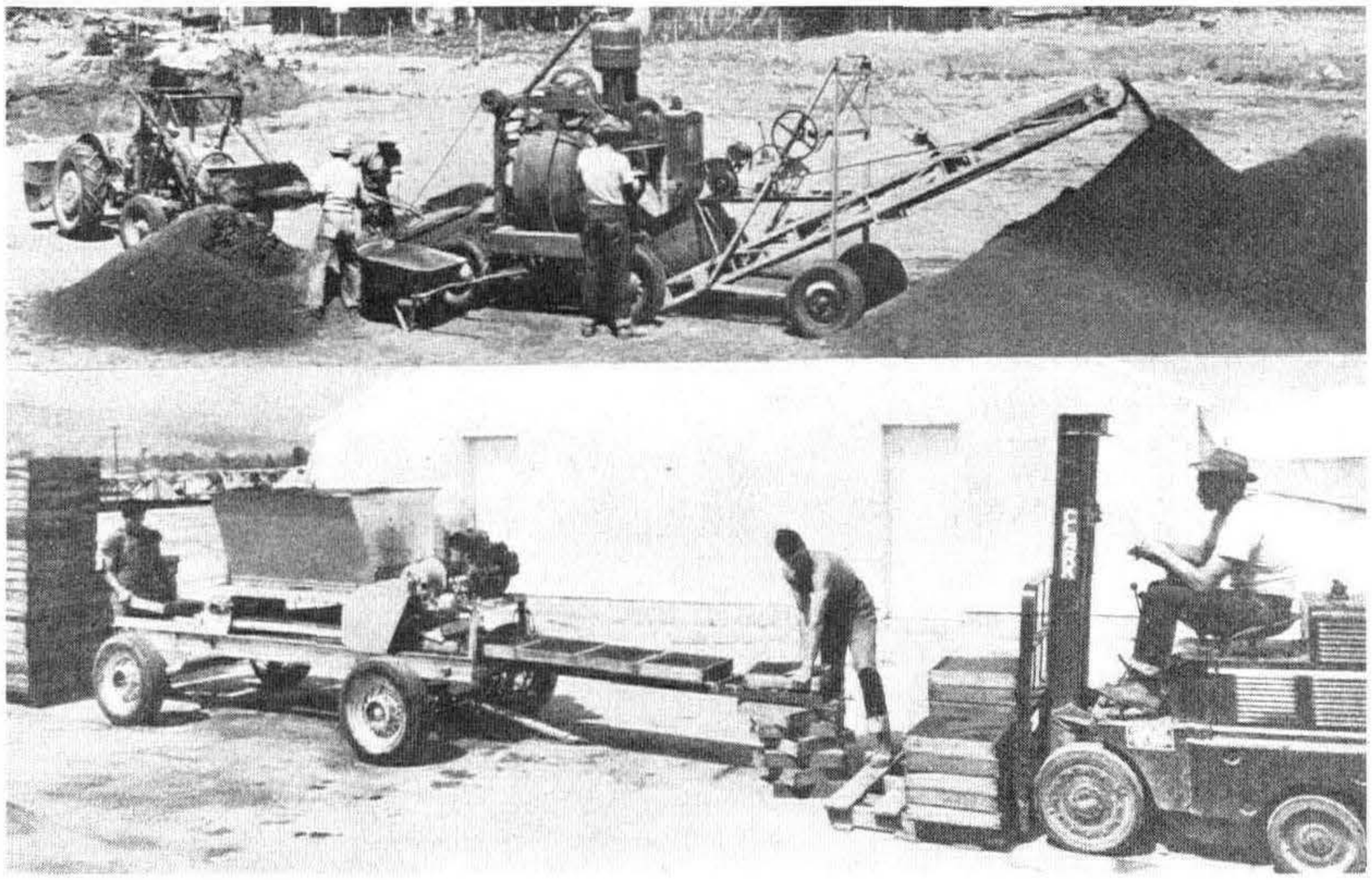

Figure 2. Soil-handling equipment in a bedding-plant nursery in the early 1940s. Upper photo shows method of blending ingredients of the soil mix and commercial fertilizer in a concrete mixer. Lower photo shows the mechanical flat filler built by Wilton Abplamalp and used by American Plant Growers, Lomita, California, for 30 years. The soil hopper was filled by a mechanical loader. This modified flat filler gave rise to many commercial units used today. Photos courtesy of American Plant Growers Inc., Carson, California.

Figure 3. Cannery retort used for soil steaming in the mid-1940s. Free-flowing steam was used, and the soil held at 100°C for 30 minutes. Photo courtesy of American Plant Growers Inc., Carson, California.

SOIL TREATMENT

Modern control of plant diseases is based on the principle that the ultimate sources of pathogens are previously infected plants and the soil, including its water and nonliving organic matter. Under the controlled environmental conditions of commercial glasshouses, application of this principle by planting pathogen-free stock in pathogen-free soil, and practicing sanitation to prevent recontamination, has practically eliminated many important diseases. Under relatively uncontrolled environment conditions of field plantings, however, the problem is more complex, and disease control therefore more complicated. A second principle, first enunciated by J. L. Jensen in Denmark in 1882, is that control of plant disease usually requires application of multiple integrated procedures, each operating in a different way or time to diminish disease, and collectively providing satisfactory control.

Soil treatment began in 1869 in France with the use of carbon disulfide, and this was soon followed by application of sulfur and formaldehyde. The first modern extensive soil fumigation in the field was in Hawaii in 1932-36 using chloropicrin, and was soon followed by application of DD, a mixture of 1,3-dichloropropene and 1,2-dichloropropane. The use of DD illustrates the operation of the Law of Lesser Concessions. Growers tried this relatively inexpensive soil treatment and found that it was economically profitable. Only then were they willing to try more expensive and effective treatments with chloropicrin or methyl bromide in the hope of even greater profit. They would not have tried these more costly materials without this intermediate successful experience.

Commercial soil steaming began in 1893, but application methods remained empirical for 60 years, with little scientific study or grower inventiveness. It had been known since about 1940 that moist heat of 60°C for 30 minutes would destroy plant pathogens except tobacco mosaic virus. However, the only way to achieve such treatment was to inject steam into a moving soil mass to attain and maintain that temperature. Critical investigations of soil steaming were made in England, Norway, and California in 1954-60. The studies on aerated steam in the first two places were made by engineers in an effort to reduce fuel consumption. Our California studies were aimed at avoiding the creation of a biological vacuum and the production of phytotoxins. Mixing air with 100°C steam dilutes it and lowers its temperature to a level determined by the ratio of air to steam. At 100°C this ratio is 0:1, at 82°C it is 1.5:1, and at 60°C it is 6.5:1 by weight. Aerated steam moves through the soil in the same manner and rate as does pure

steam. It is a frequent misconception that aerated steam is more complicated to use or more expensive than 100°C steam, although the reverse is actually true. Methods of commercially producing and utilizing aerated steam have been detailed in the 1976 IPPS Proceedings (6). The advantages of aerated steam over 100°C steam are: (a) microorganisms antagonistic to plant pathogens are not destroyed and provide a measure of biological control (4); (b) phytotoxicity does not result from steaming; (c) burns and discomfort for workmen are reduced; (d) soil cools more rapidly and can be used sooner; (e) plastic containers can be treated without heat deformation; (f) smothering molds are less likely to develop on treated soil; (g) lowered cost of generating the necessary steam.

Aerated steam treatment is more often used in Australia and New Zealand than in the U.S. and England. The Aussies and Kiwis came to soil treatment in the 1960s as aerated steam was being developed, and many started their first steaming with it. The use of 100°C steam was then the accepted method in the U.S., and the inertia of an established method has delayed change here.

Solarization, or the entrapment of solar radiation beneath clear polyethylene tarps, is a promising means of treating moistened field soil in areas of intense sunlight. The treatment works, in part, because of the prolonged exposure to elevated soil temperature, the time being much longer (several weeks compared with 30 minutes) and the temperature much lower (37° to 50°C compared with 60 to 100°C) than with usual soil steaming. Pathogens are killed, particularly near the surface (where most of them are), or they may be stressed and rendered more susceptible to killing by antagonists. Deeper pathogen propagules are also killed by undetermined conditions at depths below the zone of soil heating. The method has been successfully used on planted pistachio groves in southern California, controlling verticillium wilt without injuring the trees.

PATHOGEN-FREE PROPAGULES

That pathogen-free propagules are important in disease prevention was recognized by the middle, and emphasized by the end of the eighteenth century, when crude methods for their production were being devised. However, the widespread commercial production of such stock appeared only in the mid-twentieth century. Tip cuttings had often been used to decrease the amount of *Verticillium* infection, on the assumption that the fungus had not advanced into the shoot tip. However, in practice this was not sufficiently dependable for commercial use. A. W. Dimock in 1943 developed a culture-

indexing technique for producing chrysanthemum cuttings free of *Verticillium* for use in research. This cultured-cutting method was soon commercialized and quickly became the standard method for producing clean cuttings of rose, carnation, and sweet potato. Continuing the earlier work on tip cuttings, studies by several workers over the world on various perennial plants found that cultures of tiny apical meristems gave plants free of some viruses. F. Quak showed in 1957 that carnations free from fungi, bacteria, nematodes, and some viruses could be obtained by growing true apical meristems in culture, and she sometimes took them from plants exposed to long heat treatments. The method was soon applied to other ornamentals, to strawberry, sweet potato, and other crops. This was soon extended to monocotyledonous as well as dicotyledonous plants, and became the commercial method for obtaining pathogen-free clones.

The Law of Lesser Concessions also seems to govern the use of propagator-grown pathogen-free stock by growers. At first, a grower may buy a small number of clean cuttings, grow them on as a mother block, and use cuttings from this stock for a few years. When the second- or third-year crop develops disease losses, he may decide to propagate from them for only one year. It finally becomes evident that it is better to have the propagator produce the cuttings, and for him, the grower, to raise the crop. New growers still tend to progress through such steps in adopting any new practice. A procedure that cannot be adapted in steps wins acceptance more slowly than one that can (9).

ADVANCES IN THE LAST TWENTY-SEVEN YEARS

There have been six major additions to nursery procedures since U.C. Manual 23 appeared: a). the development and adoption of soil treatment by aerated steam (4,6,7,11); b). addition of selected antagonistic microorganisms to treated soil or plant propagules to decrease growth of an accidentally introduced pathogen (8,14) or to increase plant growth through bacterization (12,18); c). the use of minute meristems, cells, and protoplasts in propagation to reduce pathogen transmission (17,22); d). prolonged heat therapy of plant propagules to decrease virus transmission (3,19); e). prevention of pathogen transmission in irrigation water (10,15); and f). polyethylene glycol treatments to promote repair of metabolic damage of seeds from thermotherapy (16,21). These will now be considered in turn.

The destruction of microorganisms has been the dominant idea of chemical and thermal soil treatments since 1880-90,

and recommendations have tended toward overkill rather than minimal treatment. Broad-spectrum, high-potency chemicals at high dosages have been used in field treatment, and steam at 100 to 122°C for 30 minutes for soil in containers. There is now a marked trend toward minimal soil treatment with selective chemicals, and this unfortunately has given rise to the development of resistant strains of pathogens. We have progressively "cooled it" since about 1945 from 122°C for 6 to 8 hours (autoclaves), to 100°C for 30 minutes (flowing steam), to 82°C for 30 minutes (moving soil mass), and finally to 60°C for 30 minutes (aerated steam). The central fact here is that microorganisms differ in their resistance to heat, and that plant pathogens are more sensitive than many soil saprophytes to it. Aerated steam treatment at 60°C thus leaves a group of resident adapted saprophytes while eliminating pathogens in the soil; they luxuriate because of reduced competition, and are antagonistic to accidentally introduced pathogens. Other advantages of aerated steam treatment are reduction in resultant phytotoxicity, less discomfort and hazard for workers, and lower fuel cost.

The addition of selected antagonists to treated soil to compete with pathogens later accidentally introduced is a very promising supportive practice still too little used, apparently because a commercial product has not yet been made available, and because it is thought that soil treatment alone will provide adequate protection. However, a single antagonist may be effective against a single pathogen in a medium free from, or with a diminished population of, other microorganisms, as in glasshouse soils. Paradoxically, there are many successful applications to crops of much lower economic value (e.g., wheat, forest and fruit trees, vegetable crops) (8,14).

Microorganisms compete for nutrients, favorable sites, and oxygen, and are selected for tolerance of unfavorable conditions of carbon dioxide, pH, water, and other microorganisms. They secrete metabolic materials, some of which (antibiotics) inhibit other microorganisms, and others stimulate microorganisms to form essential stages of their life cycles. Biological control is the retention or restoration of a disease-suppressive biological balance, achieved through increasing antagonism of a pathogen by resident organisms through modification of cultural practices, or by introducing new antagonists.

A specific type of biocontrol by inoculation of propagules with selected bacteria prior to planting is attracting much notice from commercial laboratories and research scientists. Plant growth is significantly increased, even when disease is apparently absent, because growth-inhibiting nonparasitic pathogenic bacteria present on the roots are biologically con-

trolled. Bacteria that produce broad-spectrum antibiotics have been most effective for such increased growth (12). This bacterization offers a biological means of increasing crop yields without increasing energy demands or land area, and without environmental pollution (14).

Gene manipulation or genetic engineering of microorganisms for biological control is in its infancy, but has tremendous potential for improving the level of control achieved. Microorganisms may thus be tailored for specific purposes, such as transferring a gene for production of an antibiotic effective against a pathogen, from an organism unable to survive in the given habitat to another organism that survives well in that habitat but which produces no effective antibiotic. A promising and interesting new angle on genetic engineering is the genetic modification of crop plants to make them more favorable to biological control antagonists.

In general, the smaller the plant part used for vegetative propagation the better the chance of obtaining units free of pathogenic microorganisms and viruses, but the more complex and difficult the culture technique becomes. There has been a steady decrease in size of propagules from tip cuttings, to apical meristem cultures (1957), to single cell cultures (1958), to cultures of single naked protoplasts (1975). This is a highly specialized business of tremendous potential. Old cultivars, abandoned because of virus infection, may even be rescued. *The use of sterile explant cultures in plant introduction*, pioneered in 1976, greatly simplifies intercontinental movement of propagative material. Such cultures are now accepted for introduction of large numbers of propagules into Australia, where formerly only six cuttings of a cultivar were permitted. The use of such sterile cultures in place of the old mother-block system is already in practice in nurseries, greatly reducing costs and insuring better protection from infection by microorganisms and especially by viruses. The plants must, however, be checked periodically for genetic variability and for mutations. The practical problems of maintaining and multiplying the clean mother stock usually are more difficult than obtaining it in the first place. In a successful arrangement in England, a grower association finances the development and maintenance of such material at a government research station, for distribution to grower members.

Heat treatment of planting material briefly (30 to 60 minutes) at high temperatures (43 to 57°C) to eliminate pathogens has been used since 1887. Prolonged treatment (16 to 30 days) at moderate temperatures (36 to 37.8°C) came into use after 1940 to eliminate viruses and mycoplasmas in vegetative prop-

agules. It is widely and successfully used today to eliminate many viruses in propagules of woody and perennial plants.

In situations where nursery irrigation water comes from ponds or surface drainage, it may carry fungi, bacteria, or nematodes that cause plant disease, as well as troublesome algae. Since growers are now using planting material that is free of pathogens, and are treating their soil mixes, this source of contamination requires attention. Water contamination can be controlled by injecting chlorine gas or sodium hypochlorite into water to give 0.5 to 2.5 ppm of residual chlorine at the water-discharge point from the pipes.

Heat treatment of seeds decreases and retards their germination, apparently by affecting enzyme systems, particularly in seed more than a year old. The physiological injury sustained from treatment can be repaired by holding seed in polyethylene glycol 6000 for a time at an osmotic concentration that permits metabolic processes to repair the damage, without cell elongation or radicle emergence. This make possible treatment of seed at higher temperatures than could formerly be applied, improving the eradication of the pathogen.

It can fairly be said that nursery practices have been revolutionized in the last 27 years. However, it is also a fact that no grower is using all of the many available technical advances. There are certainly going to be many more advances in the future, but even if there are not, improvements can be made simply by fully utilizing presently available techniques. At which level of advancement will you settle?

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COST PARAMETERS FOR CHOOSING CROPS FOR MICROPROPAGATION

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We began growing foliage crops at Santa Rosa Tropicals in 1972. By 1973 we were using tissue culture propagation at a time when the techniques for commercial tissue culture were only 8 years old. Today we have a laboratory that occupies 4000 square feet, and 40,000 square feet of greenhouses. We are known predominantly for our ferns but we also do a great deal of speciality propagation of other crops such as *Syngonium*, *Spathiphyllum*, *Ficus*, *Anthurium*, *Nandina*, *Gypsophila*, and *Tupidanthus* species.

It is necessary to define certain terms that are common among tissue culture propagators. The industry has a naming convention that refers to the theoretical stages that plants go through in culture.

Stage I: The establishment of the culture in the laboratory.

Stage II: The expansion block in the laboratory. (This can sometimes be used as the final step in the lab. It can also be used several times before going on to another stage).

Stage III: Root initiation stage (or final adjustment prior to transplanting into potting mix).

Stage IV: Establishment into the world outside the culture vessel.

In the nursery industry there has always been a trend to do cost accounting by looking at the bank account . . . if there is money in the till, our pricing is right, etc. This practice has continued despite the excellent accounting formats available to the industry from many sources. Micropropagation in a laboratory responds to cost analysis just as any other production operation. Unlike the rest of the industry, there is less resistance to trying to analyze the costs of the production process, but this cost analysis is rarely detailed in the literature in a manner that gives some understanding of the variables involved. Proof of this misinformation comes from listening to telephone conversations that come in to any micropropagaton lab in a normal day. "Hi! I have just purchased this one of a kind sport of _____. I want your lab to grow some for me." When you tell the caller (for the thousandth time) that he has to agree to pay a minimum of thousands of dollars, that you are probably going to kill his

"one and only", since it doesn't break at the lateral buds, and that it will take 1½ to 3 years (if we're lucky), you are told ". . . that's crazy, I read that it only costs 7 cents and that it is fast, etc, etc, etc."

The usual, over-simplified published format for figuring laboratory plant costs takes *Materials*, adds some figure for *Direct Labor*, and uses this total for *Cost*. This *Direct Labor* amount is usually obtained from a theoretical geometric reduction of costs that occurs each time a technician handles the same culture through another pass of Stage II. Another figure is thrown in for *Overhead* and there you have your *Total Costs*. Add whatever markup you feel fair, and there . . . is the miracle of tissue culture propagation. Millions of plants for only pennies, just like nuclear power that was going to be so cheap that they wouldn't even have to bill us for it!!!

Actually, laboratory cost accounting is just like crop cost methods for the greenhouse. The elements are:

Materials

+Direct costs per sq. ft., × time on shelf

+Overhead costs per sq. ft., × time on the shelf

+Packaging + Delivery + Sales commissions

This is known as the rental method and has been used in nursery operations as the standard method for calculating costs because it avoids the need to have each employee record the exact time elapsed for work with a particular planting step. Trying to estimate how many plantlets a technician can handle in one hour has led to the misleadingly low figures would-be customers love to believe in.

The costs would look something like this if detailed out in cents per plant:

Materials	$0.015	
Direct	0.051	(0.0051 per plant per week for 10 weeks)
Overhead	0.025	(0.0025 per plant per week for 10 weeks)
Markup	0.045	
Packing, etc.	0.035	
Selling	$0.171	(10 week crop, zero empty benches!)

However, theoretical numbers don't matter. If your crop occupies only half the space available, and you don't put anything immediately in that empty space, then your area rent goes up by 1.5 times which jumps your selling price to $0.209. A crop time of 20 weeks would do the same, so that this could be $0.247, if both the vacancy rate and crop time came into effect.

This shows that for 17 to 25 cents you could get a *very* tender seedling equivalent from Stage III culture. This is only if the crops are production items that are regularly scheduled,

subcultured, and planted according to a master schedule. You must, therefore, compare what your costs for a standard plant "start" would be when you are considering micropropagation. Monrovia Nursery, Azusa, California, (*American Nurseryman*, 9/1/81) estimates their costs for liner production *after* collecting and sticking the cutting to be 24 cents. We feel that this parallels quite closely the cost of establishing a Stage III plant into a liner. Would your proposed crop take a 43 to 51 cent price including lab. and greenhouse costs?

This makes the assumption that the YIELD from each stage is reasonable. YIELD is the laboratory equivalent of pot size. When you take the "rent" format and apply it to container crops, or to pot crops, one of the key elements is the size of the container and the spacing. Parallel factors in the laboratory are the number of multiplications that you get at each "stage". As an example, our laboratory was approached by a plant biogenetics systems company. They had developed a tissue culture system for a plant that is very difficult to clone, had booked orders, and now wanted to sub-contract the production to a production facility such as ours.

We reviewed the entire prospectus that was submitted. We found a bit of information that might have been overlooked if we were not equating yield with pot size (so to speak). The Stage II multiplication rate was 1.5:1 (that is they got three plants from two cuttings). Our own area cost figures are for multiplication rates ranging from 10 to 20:1. This means that this proposed plant would be priced at $1.50 to $3.00 each and it would take our entire facility to produce the crop because it was the equivalent of switching from 4 in. pots to growing 15 gal. containers in the same area.

In conclusion, then, what are the correct crops to propagate in a lab? Plants with no standard, successful, competitive method of propagation and which are needed in large numbers. It is also a valuable tool when crops are needed for expansion to become a stock block where the high costs will be later amortized (as in strawberries, Malling apple rootstock, *Nandina domestica* 'Harbour Dwarf', etc.) Another valid application would be when clean stock is needed regardless of price. Currently drug and chemical production is also a major area of plant tissue culture research.

Micropropagation isn't a panacea for all crops that are difficult (or apparently impossible) to propagate. It can be a valuable tool if the parameters noted above are applied carefully.

PROPAGATION OF PROTEAS

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The family of plants named Proteaceae is very large and is indigenous to the southern hemisphere. Several of its genera have graced our California gardens for many years, such as the grevilleas, the hakeas, and macadamia. During the last 20 years there has been a growing interest in a number of proteas for flowers and foliage to be used in the cut flower industry. For the most part these are the banksias, the leucodendrons, the leucospermums, and the proteas.

It is the propagation of these plants that we will attempt to consider. As with most plants they are propagated by seed, by cuttings, and by grafting. With but one exception, seed can be obtained from plants already growing in the U.S. The exception is the large-flowered proteas which require hand pollination. In their native South Africa the sun bird *(Anthobaphes violacea)* does the pollinating. There are a number of seed merchants in both South Africa and Australia who will supply seed for very reasonable charge. The seed loses viability very rapidly so that fresh seed should be demanded.

The seed should be planted during October and the seed flats or seed beds should be located outdoors. It has been definitely noted that germination is increased by the changes in temperature from day to night. Seed from South Africa often carries pathogens which can later develop into serious diseases among the growing plants. Before planting, the seed should be immersed for 20 min. in water at 125°F.

The seed bed should be composed of 1 part perlite, 1 part sand, and 1 part ground redwood bark. The seed should be covered lightly with washed plaster sand.

Careful watch of the seed bed must be maintained for rodents. Mice seem to have a sixth sense in locating seed and can cause total destruction in a very short time. When the seed starts germination, a close watch must be kept for sow bugs. They, too, can cause great harm.

Watering will depend on location. Barring rainy weather, a light daily sprinkle is best. In colder areas some frost protection should be available for the unusual frosty night. The seedlings should be allowed to attain a height of 3 in. before being transferred to pots.

Cuttings should be taken during early summer, when the new growth has partially hardened. Length of the cutting is

usually 6 in. The lower leaves should be carefully stripped so as to cause no injury to the stem. An oblique cut with a sharp blade should be made just below a leaf node. It has been found that a dip of the cutting into 5000 ppm indolebutyric acid is helpful in inducing root growth. The cuttings should be stuck in a mixture of 1 part sand, 1 part perlite, and 1 part ground redwood bark.

The cutting flats should be placed under intermittent mist. The frequency of misting will vary with temperature and age of the cuttings. Good air circulation is essential. Bottom heat of 70° to 75°F is optional during summer but quite beneficial during winter. Periodic sprays of Captan and Benlate is helpful in controlling damping off.

The grafting of protea plants is a technique in a stage of development. Both cleft grafts and bud grafts have been made, but the rate of loss is extremely high. Perhaps with more experimentation success will be greater.

VOICE: Dr. Baker, what is the optimum concentration of chlorine to use in irrigation water?

KENNETH BAKER: It is 0.5 to 2.5 parts per million of residual chlorine at the point where the water comes out of the tap, and that level will not be harmful to plants.

VOICE: What is the contact time needed from the time chlorine is injected to the time you put it on the plants?

KENNETH BAKER: That is a very good point — the contact time. You can time it by putting in a dye at the point you are injecting chlorine to see how long it takes to come out, i.e., what the time interval is. At that concentration, a minute will be enough. Another method that some nurseries use is to pump the water into a tank overhead, then to add Clorox to bring the concentration to the desired level.

VOICE: Will wood shavings or other wood products break down to give toxicity when steaming?

KENNETH BAKER: In our experience this has not happened. However, I am sure all of these materials have not been tested. What ones would you plan to use?

VOICE: Redwood and birch.

KENNETH BAKER: As long as you have washed the redwood it should be all right. Ordinarily redwood is placed in piles with overhead sprinklers. A black material comes out in a gummy mass at the bottom. Materials such as horse manure or blood meal high in organic nitrogen give phytotoxicity troubles with steaming.

VOICE: For sanitizing pots or used containers, would you use ½ to 2½ ppm chlorine also?

KENNETH BAKER: No, I would go much higher than that, but you can also use methyl bromide to sanitize them. In using methyl bromide to sterilize containers have them wet before you treat them because when organisms and pathogens dry, they become very resistant to heat and chemicals. To make the treatments effective get the organisms in a moist condition. Do not treat soil or containers that are bone dry. Moisten them a day or so before you treat them.

VOICE: Polyethylene glycol — Would you tell us about using this to rejuvenate seeds?

KENNETH BAKER: This work was done in 1955 by Dr. Heydecker in England on seed treatment with polyethylene glycol 6000; and this has since been studied by a number of people. After treating seed with hot water or aerated steam, put the seed in a thin layer in a pan and cover with polyethylene glycol and then drain; this maintains an osmotic level specific for each kind of seed. The objective is to keep the seed as moist as possible without it germinating. This process was originally called "invigoration" of the seeds. If seeds are treated with polyethylene glycol, those seeds that are a little less mature than others will mature during that period, and when you plant the seeds there will be much more uniform germiantion. There seems to be some controversy in horticultural literature whether this is actually true. My experience is that it is true. It does tend to "invigorate" the weak seedlings so they will come up about as fast as the others, which is a very real help in the bedding plant industry.

VOICE: Dr. Baker, I don't understand your logic on "suppressants" on strawberry, because strawberry plant growers commonly use suppressants. It is like you have a disease and don't take penicillin, pretending it will go away. You have to do something to attack the problem.

KENNETH BAKER: I think you missed the essential point. The commercial propagator, who is selling plants to someone else is different from the fellow who takes those propagules and grows them on. The propagator's obligation is to produce plants that are free of pathogens, not just plants that are free of symptoms. The man who is growing them on for commercial production may use soil drenches. For the propagator to use drenches as a means of suppressing disease in his nursery, only to have it break out later when the grower plants the stock is unethical, irrational, and should be illegal. The grower cannot undo the problem passed on by the propagator.

The point is that the propagator should be producing a plant that is free of disease rather than merely free of symptoms. The growth potential of that plant when grown on is what is important.

A person who is growing the crop on can get along with what you may call household cleanliness, sanitation, and hygiene. The commercial propagator who is selling plants to people who get their livelihood from them has a responsibility for hospital, rather than mere household cleanliness.

VOICE: Are there any products that actually eradicate diseases?

KENNETH BAKER: There are fumigants such as chloropicrin and methyl bromide.

VOICE: No drenches such as Subdue, Ridomil?

KENNETH BAKER: Ridomil won't; it is just inhibitory. This is the problem. These materials simply inhibit growth of the pathogen for the time they are there. They do not reduce the potential of the pathogen to kill the plant after it has been planted in the home yard. Some of you are questioning whether this is true, but I can assure you that it is. A whole body of evidence bears it out. It becomes a question of whether the propagator should be allowed to produce material that is actually transmitting the pathogen to the soil, so that the man who buys the plants is going to inherit the trouble.

Many avocado orchards in southern California are planted with nursery trees that carried *Phytophthora cinnamomi* when planted. This sort of thing I would say is immoral. The assumption has been that, if a plant has root infection with *Pythium* or *Phytophthora*, it will show symptoms of the tops. That isn't true, because these root "nibblers" may be present and the only visible symptom will be that the plant will be a little smaller. It is a time bomb that will go off sooner or later. The cripplied plant is in your yard, or worse in a commercial orchard, and it will go along for maybe 3 or 10 years, and then, in an especially wet winter, the trees will collapse. The question is, is it not better to have avoided that in the first place rather than to have it die when the value of that tree is a great deal higher?

VOICE: Where do we go from here in terms of developing the concepts outlined in Manual 23? Will we be able to use some of these biological procedures to inoculate the good bacteria or reduce harmful bacteria and fungi? What can you say about extending this concept a little further? Once things are clean, how do we continue making use of some of these organisms?

KENNETH BAKER: Bacterization is at the forefront today, one of the really hot topics in plant culture. It has enormous potential; it is the only way I know of that we can increase yield of agricultural crops without increasing environmental pollution, without increasing land area, and without increasing energy demands. A number of laboratories and commercial companies obviously think the same. Gustafson Seed Co. has been running trials with peanuts this year on 12,500 acres. This is bacterization or innoculation of the seed with certain bacteria selected for the crop and the given area. These bacteria spread along the roots and even from row to row along them. They form a protective screen, a biological control through antibiosis. They control deleterious bacteria, of which there are many in the soil, that are inhibitory to plant growth. These harmful bacteria are not true parasites and do not cause root rot. You are not aware of their presence other than the plant does not grow well. They don't invade the plant — they are nonparasitic exopathogens on the surface of the roots. I do not know of any place you can yet obtain these microorganisms commercially; it is a frontier subject, but I would bet that in five years many of you will be using them. The reason for bringing it up is to make you aware of what is coming.

BRUCE BRIGGS: We grow many plants in a tissue-culture lab and they are basically clean, and they go into a clean mix. However, before they are shipped out, we do use Ridomil and Subdue to clear up mildew. With a good ventilation system we now do not have a mildew problem. Should we continue with these fungicides or should we drop them? When such plants leave us and go to an Eastern grower, I know his soil is not clean and his water system may be contaminated. If his plant has a little protection, he will come out better than if it did not have any. Can we look at it from that standpoint, or should we leave it out?

KENNETH BAKER: You should go ahead and use it for this reason: you are not using it to suppress disease to make the plant appear healthy while it is in your nursery. You are producing pathogen-free plants to the best of your ability. You are preventing various molds that may develop during shipments, if I understand correctly. There is nothing wrong with that because you are not attempting to suppress and defer diseases so that you will not suffer loss, but the secondary grower will.

QUALITY PLANTS START WITH PROPAGATION AND THE MEDIUM

PAUL T. GREEVER

Nurserymen's Exchange
2651 Cabrillo Highway
Half Moon Bay, California 94019

Production material for a wholesale nursery generally comes from two different propagation sources. One you have control over more directly than the other; in-house production plants provide you with cuttings. But when you are buying seed or cuttings from out-of-house sources, on a regular or as-needed basis, then your control is to continue to buy, or to stop buying from them. Our plant material at Nurserymen's Exchange comes from both of these sources. The production quantities that we work with demand that both sources be used. The cost in maintaining the extra square footage necessary for in-house stock plants, and their maintenance cost, may be a factor in it. The real advantage in the use of both sources is that often an increased demand for the plants in production or an error in stock plant production makes outside sources a good back-up program. An example is when our poinsettia stock program was set back some weeks in an error in the soil mix so that the plants had to be repotted, and thus production was cut back.

In-house Production. Our in-house production from the stock plants maintained in the nursery, and the use of our production plants, carry many programs. As plants need to be shaped, the cuttings are used by the particular department that propagated them. These cuttings are especially readily available on those species that are not sprayed with growth regulators to control their shape. Careful selection is made of cuttings to ensure not only quality plants but that they are true to the species and cultivars we wish to produce. Discarding of plant material has to be done when cuttings are either not true to cultivar or have other characteristics that we do not wish to perpetuate.

By careful planning, the process of shaping plants for sale and having available cuttings from production plants helps to cut the plant production costs.

Stock plants can be an asset if used with the idea that they will eventually be used for plant sales when their usefullness/shape and size meet the needs of the sales. We work for such a program so that we get the use of the cuttings — in many cases from the plant over a long period of time, and then when a full saleable plant has been grown with many lateral

breaks, as an example, the plant is sold on the market-place. The stock plants are routinely replaced with new plants to continue the program, or where a program will be phased out for a period of time, then they are sold with the plans to replace, or even buy in more cuttings prior to the need for the full use of the plants later in another year. Proper care of stock plants is a vital need in any stock plant program. Just as production plants are fertilized, sprayed for insects and diseases, the stock plants must be cared for in the same manner, and with more care, for this is how you keep your production program going.

Out-of House Sources. Out-of-house sources for cutting material requires a careful record keeping system and selective buying. The plants that may leave the source as excellent quality material may reach you as unuseable plants. Test loads of cuttings can be obtained from new sources to see how they hold up and then, by keeping records, you can see what happens to the plants in time. When the plants arrive at Nurserymen's Exchange they are inspected for defoliation, damaged tissue, pests, trueness to species and cultivar, and how it was packed for shipment. The information that is relevant is noted immediately so the shipper can be notified and also, so the purchasing department can be told if what was received did not meet what was ordered.

PLANT PRODUCTION SYSTEM

Plant production programs are set up on paper often a year in advance of the actual growing. This gives time for the program to be fitted into the space that is open for it, or the program (when it is a large one) may have to be planned so that others may plan their crop to finish to give the extra space. Planning on large programs gives the needed room for the quality plants we sell. Prior planning then also gives time for the set up of either system in the nursery for supplying the cutting stock needed; in-house, out-of-house sources, or a combination of both.

Careful planning by each department then allows the maximum use of space and the maximum use of propagation material in an orderly way. Since we use both rooted cuttings (RC) and unrooted cutting (URC) in all the departments in our production programs, the planning gives a weekly schedule for the arrival of the plant material that minimizes the cost of freight in bringing in the out-of-house material on a weekly basis.

Prior preparation by the department must include clean-up of the benches so that we will have clean pots filled with soil for sticking.

When cuttings arrive by motor or air freight they must be logged in by cultivar, quantity, and source.

For in-house sources, when the pots have been readied, then the cuttings are made. The benches are laid out by pot size and as the plant material arrives then it is moved to the benches so the employees can "stick", in the case of URC, or plant the rooted cuttings. The lead person is given a list of how many flats to plant and the size pot to plant; in addition, the number of cuttings per pot size.

As cuttings are either unpacked, received from another department, taken from stock plants, or in the process of planting them up, a quality control here is to teach the employee what you want the cutting to be like. It is at this time that the keen eye of an employee can save you work later on. Loss of turgidity, disease, improperly made cuttings, etc., can be found now and not used, or the problem solved before the plant is stuck in the medium with the problem being harder to solve later on.

A careful check at this early stage in production is made of the actual number of cuttings received, when from an out-of-house source, to check with production numbers and the invoice. Are we getting in more than our production schedule called for, and so perhaps we need to cut back in the weeks to come? Are we getting less than what we ordered? Records for plants from either cutting source will tell us if we are getting the proper rooting, as we have obtained in the past, or is disease occuring from one source or another. This is another quality control that we have to have in our system of producing plants.

We use auxins to stimulate root formation on some of the many kinds of plants we grow. We use both liquid and powder formulations.

ROOTING MEDIA

Propagation media varies with the plants we are growing. Seed is usually grown in a medium that is brought in for that purpose, as are the fern propagation media. For some kinds of cuttings, i.e. *Exacum*, we use rooting cubes. For the majority of the plants that we grow from cuttings the medium used is of our own formulation, and we do our own mixing.

Whether it be the 2¼ in. pots or larger, the cuttings we start are generally in the same medium that they will be "grown on" in (direct sticking). This method not only saves time, but by use of the same medium, cost of later transplanting is saved.

Since the medium is used both for rooting and growing on, aeration is important and a good supply of oxygen and CO_2 is essential. Under good aeration conditions, both gases are supplied at the levels needed to help in root stimulation. More roots will form in darkness than in light, a dark medium provides that. The medium structure is important even after the roots have been initiated, for if we then get a situation of low aeration caused by poor porosity, noncapillary porosity, or waterlogging, due to poor medium structure or poor irrigation management, a reduction in the growth of the new roots will result (1). The medium then must stand the test of time in holding its structure throughout the full cycle from propagation to sale of the plant.

Soil temperature affects rooting also and has a direct influence on the rapidity of root formation. This increased rooting temperature helps up to 90°F but over that can be detrimental.

Soil moisture affects rooting also; roots will not penetrate a dry medium so overhead mist by hand or automated equipment is used. Soil moisture must not be so high as to cut off oxygen penetration. Unrooted cuttings need the proper amounts of both gases and moisture.

Proper soil medium pH is essential to successful rooting — too low a pH and low levels of calcium can inhibit root growth.

The soil medium provides support for the cuttings, moisture, and other essential items. The medium can do its part but if the cutting does not have the proper supply of auxins and carbohydrates to supply the root forming cells and then the elongation of roots and growing tip, the medium is of little use. To maintain turgidity of the cuttings, intermittent mist is most often used, supplied by automation, hand misting or, in some areas, fog such as with the Mee System (2).

Media Preparation Overview. We use most of the standard media: peat, pumice, sand, and topsoil. For our mixes we use "Premix", that contains liming ingredients to give us a starting pH of 5.5 on most crops. Nitrogen, phosphorus, potassium, etc., are added in the "Premix" to get the plants off to a quality start. We have been working with one mix that includes incorporation of micronutrients at the time it is mixed and have seen some promising results with it. One mix that is different from the others included the use of lime plus an organic fertilizer that when "tracked properly" gives excellent results from propagation to the finished plant.

The mixes in greatest use at Nurserymen's Exchange include:

1. peat, bark, pumice, plus Premix
2. peat, bark, pumice, topsoil, plus Premix
3. peat-60%, pumice-40%, plus Premix, micronutrients, and wetting agent.
4. peat-80%, pumice-20% plus lime and organic Premix.

What we are working at now and have been able to do for many crops is to eliminate the topsoil entirely from our mixes. The step after the elimination of the topsoil is to use only a handful of soilless mixes that can be used on all the crops, from propagation through to saleable plant.

CONCLUSIONS

The key to quality in saleable plants in the wholesale nursery starts with the cutting material. You have a check on that quality by the records you keep of the plants, whether from your own stock plants or from sources that you buy-in. The employees are another key to your quality in that they know what quality you want "stuck" in the pots and they continue that process as they care for the plants. The final way that you can get your plants off to a good start is in the type of medium that you use for growing and making sure that it can meet the criteria that you establish that will give quality and quantity of plants.

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1. Furuta, Tok. 1984. Establishment of plants following transplanting. *Pacific Coast Nurseryman.* 43:51-55.
2. Hill, Martin J. 1981. Propagation using the fogging technique. *Proc. Inter. Plant Prop. Soc.* 31:376-380.

INTEGRATED TECHNIQUES FOR PROPAGATING AND CONVEYING COMPACT GRAFTED TREES UNDER THIRD WORLD CONDITIONS

JOHN MAURICE

Kibbutz Hazorea. 30-060, Israel

Abstract. Weight reduction to about 150 grams of grafted tropical and subtropical nursery trees has been achieved here by multi-directional air root-pruning, thereby moulding the root system into a flat compact mass that substitutes for containerization. This opens up the possibility of supplying genetically improved nursery trees to distant locations, particularly hill and arid regions in the Third World. At destination, the nearly bare roots can be inserted into a mud solution to fill in and protect the fibrous mass. This forms a flat solid rootplate that can be planted very fast by placing against an 18 cm. vertical wall of a small hole, made by a stroke or two of a hoe.

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In the first growing stage, rootstock seedlings are air root-pruned in baskets of 6 cm. depth. Subsequently about eight are transplanted horizontally into narrow plastic mesh trays by pressing the root systems flat on the substrate surface and covering. The trays are then placed in a semi-upright position on rods approaching eye level. The slanting position prevents the substrate from sliding out. The technical advantages of the method are: ease and perfection of flat root transplanting; preventing trees grown in a small volume of substrate from being blown over; allowing for a continuous thick mulch to prevent drying out of the surface and supplying constant nutrition; optimum aeration and drainage prevention of overheating of substrate at edges by use of a white polyethylene curtain; ease of extracting trees by shaking. Special micro-grafting processes are used; length is substituted for width in the cuts, to permit precise work on the slender upper part of the rootstocks. Reasons for the generally high positioning of the grafts are: ease of forcing the scions into growth; less wastage of rootstock growth when cutting down to scion; high grafting success; the perfection of graft unions when effectively moulded on relatively soft young rootstock growth. Thin scion material sometimes has to be grown on hedged mother trees.

Propagation as a catalyst for ecological regeneration. The increasing scale of both tropical forest destruction and desert encroachment is well publicized. Although reforestation is the generally accepted solution, it is too long a process to interest populations primarily needing quick growing crops for immediate consumption. One possible key to the reversal of the erosion problem could lie in the sphere of asexual propagation of crop bearing trees, initially by reason of their early bearing. If such trees could be made cheaply available in tropical hill and arid regions, and could prove more remunerative than the destructive arable cropping, then the promise of permanent yields could help tie shifting peasants to a productively restored piece of land. Planned mixed plantings of genetically standardized trees at village level would be a new economic factor in these areas: fruits, nuts, forage, and plantation trees eventually create multiple new trading products in local processing plants. Naturally this is an issue that has to be treated in a much wider social and economic context; but if mass clonal tree crop propagation can be accepted as a potential catalyst for ecological and economic regeneration, then the main technical problem is how such trees can be supplied to vast climatic regions where all modern facilities are lacking.

Poor communications make it impractical to transport unwieldy, heavy containerized nursery trees through hot climates; they are uneconomic for air-freighting and too cumbersome for primitive conveyence. They need to be lightweight, compact, well insulated and conveniently packed for watering in transit. Consequently they have to be extracted from the original substrate. Widely branched, inflexible, and sometimes spiralling roots, common to containerized and field-grown trees, cannot be handled bare-rooted for packing without de-

stroying the finer roots. In order to allow continuing functioning of these finer roots, they need to be concentrated within small dimensions, so that protection by some moist surrounding material can be arranged. As a result of this requirement, a flat, rectangular heavily-branched root configuration uses the least covering material when packed or re-rooted in, say, vermiculite or sawdust (Figure 1). At the ultimate field planting site, trees with root systems of this nature can be inserted in a mud solution prior to and until the moment of planting. The mud adheres to and fills in between the closely knitted roots, forming a flat rootplate. These rootplates are quickly planted by placing them up against vertical cuts in the soil made with a hoe.

The production methods for this kind of field plantable tree are described below.

Equipment. The nursery is preferably situated in the open, in full sun. The high density of the trees calls for maximum light; 8 mm metal rods at a height of about 1 metre run lengthways to form a table top. A single row of 60 cm trays are placed in a semi-upright position on the rods. The rows should

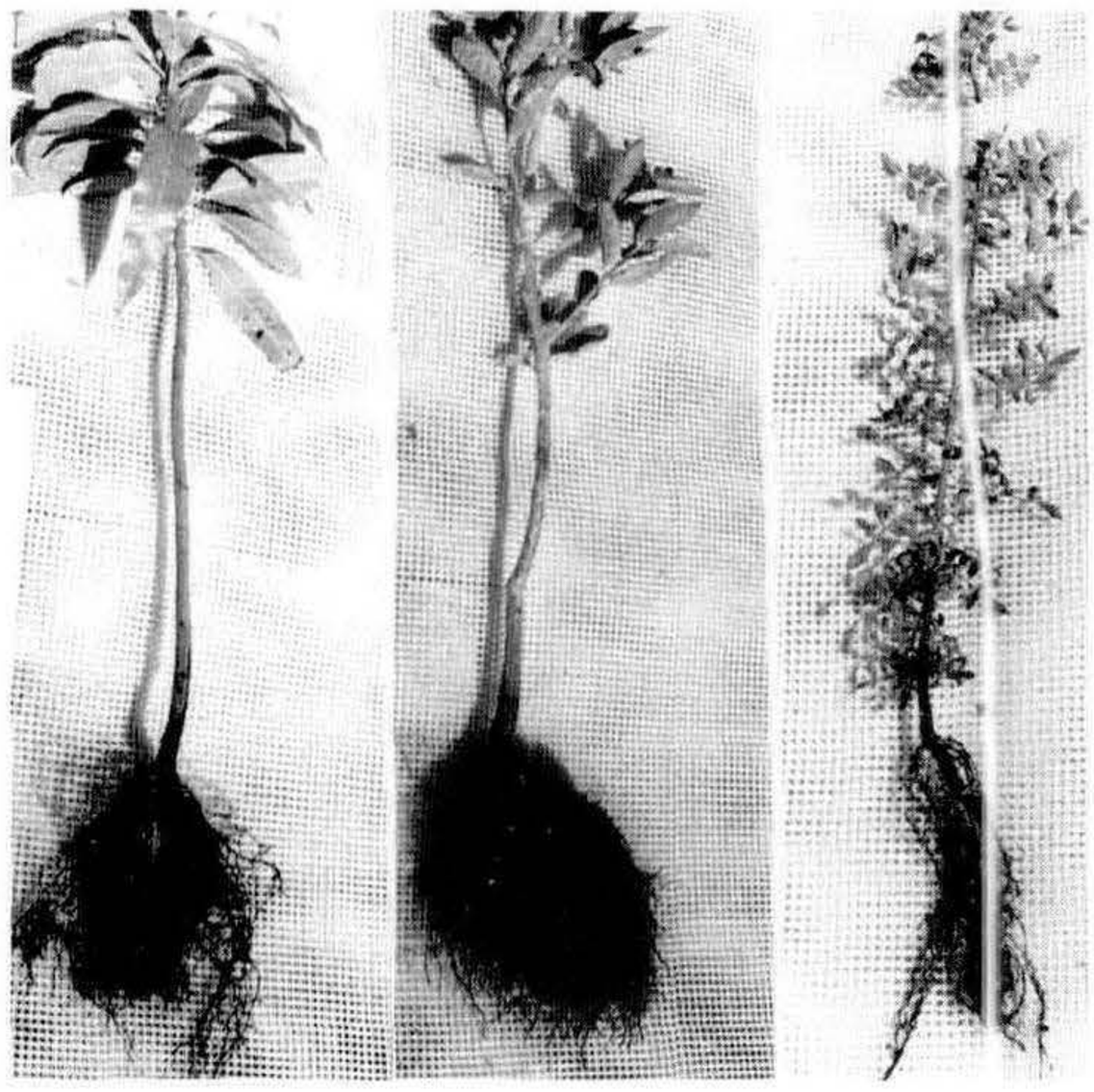

Figure 1. Root systems developed by plants propagated by the described methods.

preferably run north to south so as to allow shading underneath, if needed. Length of rows is as convenient. Firm black plastic mesh trays 60 cm × 18 cm × 6 cm are made by hand, but a manufactured product would be preferable; 60 cm lengths of plastic piping, or something similar, are attached to the upper back part of the trays, so that when they rest on each other, an air division remains, which prevents root interlacing (Figure 2). Wide sheets of white polyethylene are fixed

along the outside edges of the trays to prevent drying and overheating. Any suitable overhead watering system can be used.

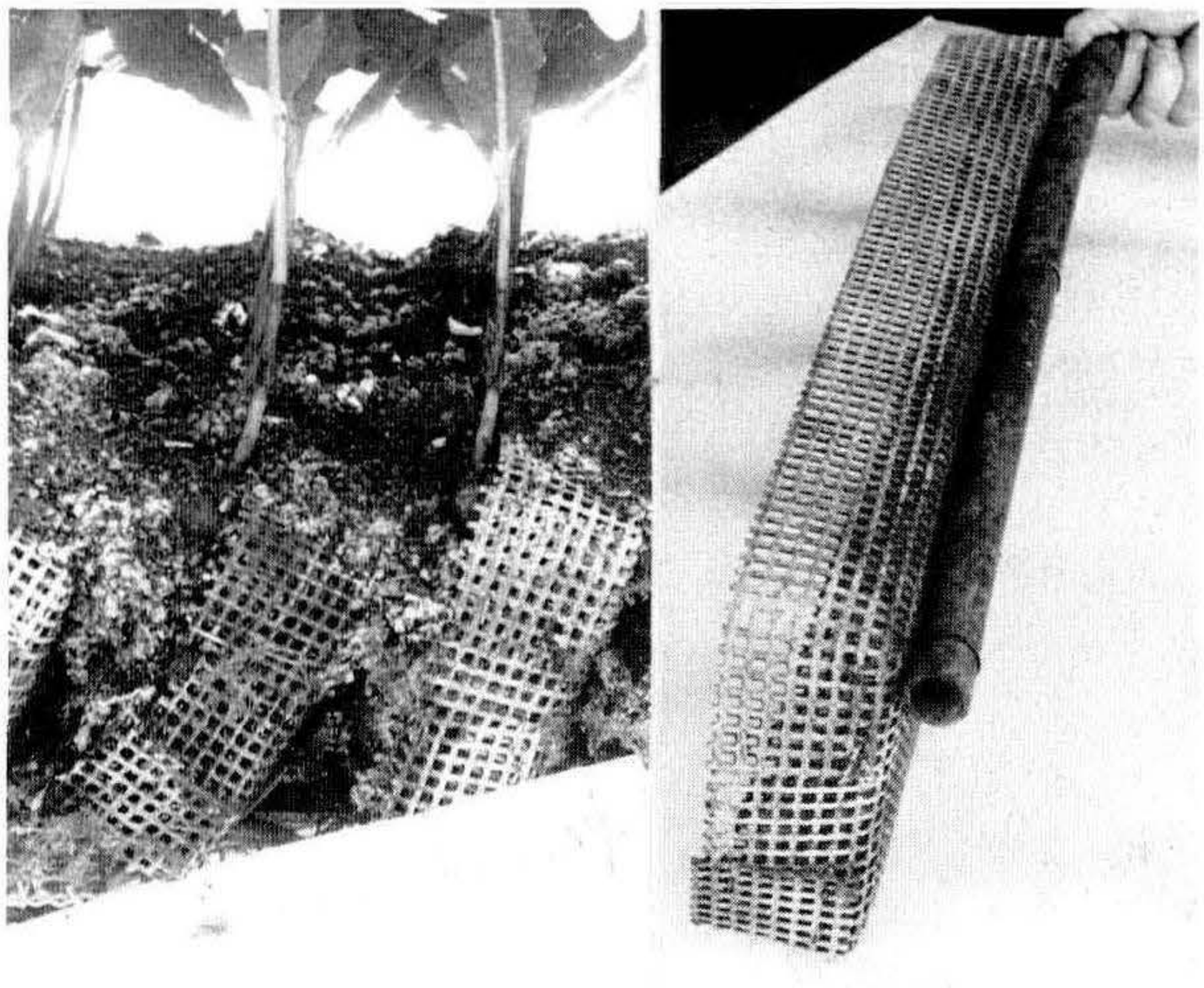

Figure 2. Plastic rooting trays showing their use when placed at an angle.

The factors determing the composition of the medium to fill the trays are much the same as with any other well drained form of containerization, except that it should be sufficiently adhesive not to slide out of the trays when they are in a slanting position. Numerous mixtures of quite different compositions have been under trial here, most having both good and bad points. The major consideration is probably what is most easily and cheaply available. Sawdust is lightweight and gives good fibrous rooting. It has two known shortcomings; nitrogen deficiency and sometimes toxicity. After exposure to winter rains it seems to be satisfactory, although somewhat variable. Nitrogen deficiency can be a problem and expensive to overcome; however, the nature of the semi-upright trays has made it possible to overcome this. The trays are filled with alternative vertical layers of sawdust and compost, four in all. The compost layers need to be thick enough to prevent the sawdust tying up available nitrogen, which occurs when sawdust and compost are mixed in the usual way. Another mixture that is, in fact, somewhat preferable to the above is tuff and composted sewage sludge, both cheaply available and the tuff being re-usable. It is heavier than the first mixture, but moisture control is better, and filling the trays is simpler. Peat, and various manufactured products are too expensive here, and unnecessary. A small percentage of loam in the mixtures helps to avoid nutritional problems.

A thick sheet of mulch is used above the trays as insulation and to prevent drying. Cotton seed husks are used for the purpose. They decompose slowly, but after a year they need replenishing. Sieved compost powder is broadcast on top of the mulch from time to time so as to supply additional nutrition by filtration.

First stage of air root-pruning in shallow baskets. Most rootstock seeds are germinated and grown in their early stages in the trays mentioned above but laid flat, giving a depth of 6 cm. These are also placed on the rodded tables so as to stop tap root growth almost immediately after germination and start lateral root development near the collar. The embryos of large seeds such as mango and pecan have to be planted uppermost in such a shallow substrate. Seedlings are retained in this growing condition usually until about May, when some lateral root development should have taken place but before the weather heats up too much to make transplanting a problem. There are five reasons for transplanting rather than direct sowing:

i). Convenience of concentration and care in early growth stage.

ii). Creating a root system that exploits the entire substrate, not only the lower part.

iii). Creating the initial flat configuration of the root system during the transplanting process, which is retained and required until the nursery trees are finally despatched.

iv). To obtain a full stand and to sort out the seedlings into uniform groups, consequently preventing domination of weaker plants by adjacent stronger ones, or alternatively, by eliminating the weaker ones.

v). To ensure that tap root cessation does not coincide with grafting operations. Top growth is naturally correlated with root growth, and is adversely affected for quite a long period when tap-root growth is artificially terminated. When this reduction in growth force coincides with grafting, it can cause failures. Terminating tap-root growth early appears to cause less shock than later on.

Flat transplanting process. Transplanting is fast and efficient. The previously filled trays are laid flat on a table. The roots of six or more seedlings are laid flat contiguously on the surface of the substrate, the collars at the upper edge of the tray. A final thin layer of any soft medium is poured over the roots and pressed down firmly. The operation should be quick, to avoid drying of hair roots, and watering immediate. When placing the seedlings in position during transplanting, ensure

that any natural incline of the stem is directed upwards from the substrate, so that when the trays are placed at a semi-upright angle on the rodded table, the seedlings stand more or less upright.

High positioning of micro-grafts on rootstock stems. Generally, the density of the trees on the tables is as high as is consistant with producing grafted trees large enough for field planting. There may, however, be a preference sometimes for very small trees, to be grown on to full size under nursery conditions at destination; in this event the growing period is shorter and tree density higher. The trees cannot conveniently be spread out to obtain more light as they grow larger, but there may be some thinning out by reason of weakness or grafting failures. Although some species can be completed as grafted trees in a single season, experience has indicated better field planting results by retaining most kinds in the nursery for a second season.

Visual and practical evidence shows that grafting on strong growing, juvenile, and relatively softwood rootstocks produces the healthiest and most successful graft union. Since the graft union is recognized as one of the most senstitive parts of a tree throughout its entire life, this kind of grafting is worth attaining, even though the procedures are more delicate and time consuming. Young seedlings are in the best physiological condition for this purpose, but often do not reach sufficient diameter to take even the smallest mature scions or buds; also they may lack the strength to force the scion buds into growth. This relatively softwood, fast-growing condition is to be found at a sufficient diameter at a later stage of growth, much higher up on rootstock stems. By using special micro-grafting techniques, this high positioning of grafts has now replaced the previous techniques used in this particular propagation system (Figure 3).

Length has to be substituted for width in all these micro-grafting operations. Slender scions or budwood is therefore required, but nutritionally high and with well-developed buds. They are best taken from mother plants that are constantly cut down to force out numerous thin shoots. If the scions are taken from normally growing trees, they should be selected from the outside perimeter; shoots that are thin as a result of shading in the inner parts of the tree are too weak for grafting purposes.

There are some additional reasons for high grafting:

i). It is easier to operate on compliant stems that are well above the dense lower crowded conditions.

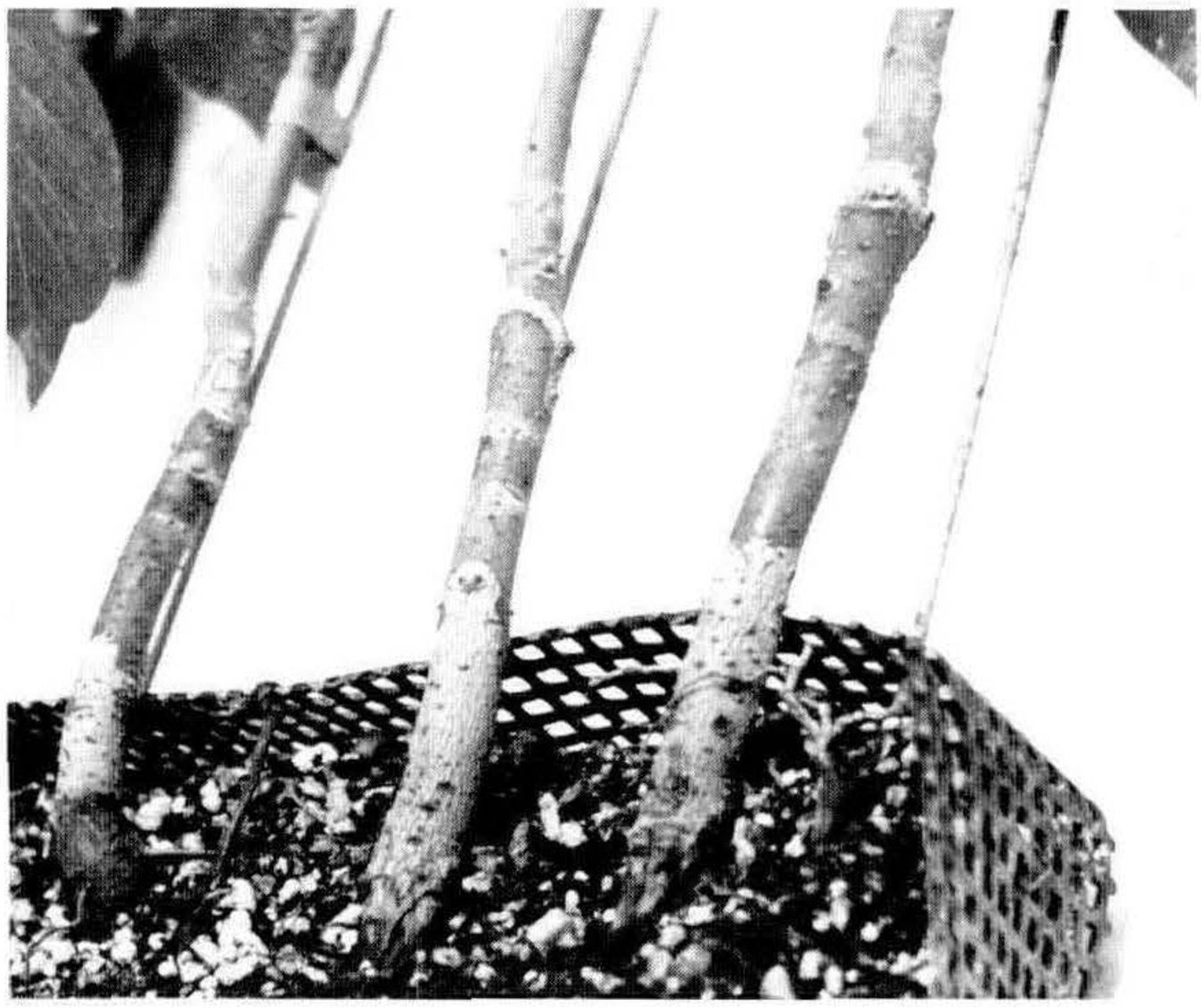

Figure 3. Finished plants showing graft union.

ii). To force out scion buds after grafting, it is advisable to cut down rather drastically to very near the graft; however, healthy leaves have to be retained, and these are not generally found lower down on the stem.

iii). There is less wastage of rootstock growth, consequently the trees are produced in shorter time.

Grafting techniques are under constant trial in relation to this growing method but, unfortunately, considerable more work needs to be carried out on tropical species under actual tropical conditions; only mango, cashew, and mangosteen have so far been tested. Under sub-tropical conditions here, good results have been obtained with pistachio, persimmon, pecan, walnut, avocado, citrus, cherimoya, macadamia, litchi, feijoa, loquat, guava, jujube, olive, carob, and oak.

Whenever possible, long chip budding is used because of it's simplicity; otherwise, side veneer and tip cleft with long cuts. For pecans and walnuts, a kind of long Forkert budding is easy and effective at normal budding height. Long strips are peeled downward on the rootstock and cut to form a pocket. The same is done on the budwood, but a slit is made on either side of the leafstalk to facilitate removal together with the bud-trace. The bark pocket prevents the bud-strip from swivelling. The buds are exposed. Fitting does not need to be precise.

All micro-grafting (not Forkert) is done with a mounted

injector razor blade, by wedging it together with a plastic slither into a flattened copper tube.

Tying is with white polyethylene strips. The tie is extended beyond the cut section of the side veneer and tip cleft grafts to cover the remainder of the scion, leaving a cavity at the end through which a shoot can subsequently grow. The plastic strip is secured with a pin.

Chip budding and side veneer grafting is on the north side, but due to the high positioning, sun may penetrate to a greater or lesser degree with some possibility of causing overheating during hot weather. Particularly difficult subjects may need additional protection; this can be arranged by encircling the graft with a rootstock leaf and securing it in position by the pin on the plastic tie. Tip cleft grafting needs a paper hat protection or an encircling leaf.

When the grafts have made sufficient growth, all buds on the rootstock should be firmly rubbed off.

Second stage growth of laboratory in vitro plantlets. With careful initial treatment, these plantlets can be grown on in trays to full-size nursery trees.

Preparing trees for despatch. The leaves of evergreen trees are severely reduced in number before removing from the trays. Several species of evergreen nursery trees with suberous roots have been packed completely defoliated under simulated hot conditions for 3 weeks, then planted out with shading. Etoilated shoots had just started to grow and needed careful handling. They all grew satisfactorily. Further tests will have to be carried out to find out the limits of this potential.

The trees are shaken out of the trays and the interlacing roots are quickly separated to prevent drying. The root systems can be placed flat in a container, with material such as vermiculite, sawdust, and woodshavings spread between them. Containers may be something like orange boxes, wooden framework supporting jute, or rectangular cane or bamboo baskets, all with an interior perforated polyethylene lining. Alternatively, they can be rolled in strips of polyethylene together with some added substrate, the minimum required to cover the roots. The stems of the trees are tied together and protected by moist paper, hessian, or the like.

The compact nature of the trees makes packing and insulation fairly simple, but the kind of packing material used must depend on the anticipated transit conditions. Allowance sometimes has to be made for additional watering and insulation en route, which needs planning, especially by primitive conveyence.

Planting out in the field. At destination, insertion of the close-knitted fibrous roots in a mud solution results in a flat rootplate, the mud filling in and adhering to the rootmass; these can be quickly planted in the field when placed up against 18 cm vertical cuts in the soil, made with a hoe. They establish themselves quickly, but sometimes need initial paper protection around the stems and, in arid climates, mulching.

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PROPAGATION OF PRAWNS AND PLANTS IN THE SAME ENVIRONMENT

GORDON R. LETTERMAN and ELLEN F. LETTERMAN

Neotoma Enterprises
Occidental, California 95465

Abstract. Neotoma Enterprises is investigating the potential of combining aquaculture, hydroponics, and solar technologies. Our experimental and prototype polyculture systems demonstrate a significant net income increase per square foot of growing area over conventional aquaculture and plant propagation facilities. The use of solar collectors and a large volume of water for heat storage minimize system heating costs.

INTRODUCTION

Recent years have seen large increases in production and marketing costs for many nurseries. Petroleum products used in fertilizers, heating, and transportation have risen dramatically in price during the last ten years. Land prices and taxes, especially in areas near large metropolitan centers, often make expansion of a business economically unfeasible.

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fluctuations, and reduce operating expenses to a level below that of a conventional greenhouse — all of which serve to increase profit potential.

In order for a single system to promote both plant and animal growth, the environmental parameters required for all species cultured must be met. These parameters include temperature, light, pH, oxygen, space, and nutrients. While it seems unlikely that optimal conditions can be achieved in all cases, it has proven feasible to create conditions where overall system production and profitability are increased over monoculture (independent plant propagation, or animal rearing) operations.

The high profit potential of a recirculating aquaculture-hydroponic system is due to the components being inherently complementary. The animals, which generate metabolic wastes (primarily ammonia), require water conditions where low levels of these products are maintained in order to thrive. The plants require these same elements and compounds at constant levels in order to remain healthy and grow at a profitable rate. Water circulation within a combined system carries the nutrient rich water from the prawns to the plants, where nutrients are removed, "purifying" the water before its return to the prawn culture tanks. A recirculating system has the added advantage of minimizing heat waste. The same solar-heated water is used to maintain acceptable temperature levels for both the plants and animals.

MATERIALS AND METHODS

A. **Solar Energy Inputs**

1. *Facility* — The greenhouse assoicated with our experimental systems makes available 1500 sq. ft. of floor space on three levels.

2. *Water Heater — Collection, Storage, and Distribution to Systems* — Solar panels supplemented when necessary by a wood-fired water heater maintain a water storage tank temperature in excess of 25°C. Heat is transferred from the storage tank to the culture system water by means of heat exchangers mounted in contact with the culture system. Differential thermostats which activate small circulating pumps maintain a constant preset temperature in the aquaculture and hydroponic componants.

B. **Species Selection**

The selection of the freshwater prawn, *Macrobrachium rosenbergii*, as the most likely animal candidate for the aquaculture component of a system is based on several factors.

These include known rearing technology, fast grow-out to market size, high market value, and a temperature range of 24° to 30°C (75° to 85°F.).

The temperature range for *Macrobrachium* allows a wide choice in selection of suitable plant species for culture in the hydroponic beds. Convection and radiation from the aquatic systems maintains greenhouse air temperature within an acceptable range for most tropical and semi-tropical species.

C. **Culture System**

Large *Macrobrachium* (6 to 10 per pound) require approximately 1 sq. ft. of substrate surface area per animal. This surface may be a tank bottom or a suspended substrate (such as plastic plant pots or flats). By using the suspension or stacking methods, several layers of prawns can be grown in the same floor space, thereby increasing total production.

Since the prawn is a nocturnal animal, no light is required in the tanks in which it is cultured. They can be located, for example, under a greenhouse floor or tables. The absence of light minimizes growth of algae in the system.

The aquaculture tanks may be constructed of any inert material such as aged concrete, fiberglass, or plastic-lined wood or metal. A maximum depth of 1 meter has proven acceptable. Oxygen levels required by the prawns are maintained in the tanks by means of aquarium airstones.

Seed starting flats with perforated bottoms are mounted on top of the prawn tanks 10 to 15 cm above the water level. Splash and mist created by the airstones keeps the medium in the seed flats warm, moist, and supplied with nutrients required as the plants begin to grow.

From the seed flats, the small plants are transferred to 2 in. pots, or to hydroponic growing beds. These beds may be mesh bags suspended in the aquaculture tanks, or separate tanks or troughs, again composed of inert material. The medium chosen for the hydroponic culture systems is mixed composition pea gravel, which serves well to support seedlings and cuttings. It is theorized that this medium may also provide some of the micronutrients and trace elements required by the plants.

The primary source of vitamins, micronutrients, and trace elements for the plants is found in the food provided to the prawns. While commercially available pelletized feeds have given acceptable prawn growth, the use of "live" foods such as vegetable material and fish processing wastes promotes better general health and growth, and are of significant value to the plants as well.

RESULTS AND CONCLUSIONS

It has proven technically feasable and economically profitable to culture prawns and plants in the same system. Prawn production at close to maximum levels can be attained. Plant production, while not at the levels demonstrated by chemically nutrified hydroponic systems, can still be expected at a level 30% above conventional propagation methods. The implementation of the stacking method (prawns below, plants above) requires no more floor space than a monoculture (aquatic or nursery) operation, while providing two marketable products instead of one.

Additional benefits of the solar-aquaculture-hydroponic system include:

1. Utilization of renewable resources as its driving force.

2. Labor intensive, but not requiring highly skilled labor for routine maintenance.

3. Construction from standard and readily available components.

4. Cost and energy effective.

5. Non-polluting (no discharge to the surrounding environment).

6. Water and energy conserving.

7. Adaptability to a wide range of plant and animal species, as well as geographical locations.

A multi-faceted system, such as the one described, is not without drawbacks. Of primary concern is the fact that many of the petroleum based pesticides currently used in nurseries are toxic to aquatic animals. Other factors which must be considered include the need for additional monitoring and control systems, meeting regulations concerning both animal and plant production, and the need of the culturist to have an understanding of both plant and animal biology.

Further development of biologically based pesticides should in the near future alleviate what appears to be the main problem. Rapid progress has been made in recent years in the development and application of alternative technologies. However, much experimental work has yet to be completed before large scale integrated alternative technology ventures can be considered anything other than high risk.

Current and predicted trends indicate continuity healthy markets for food and luxury or ornamental products. The business which can supply these markets, while reducing costs below those of competitors, should prove financially rewarding well into the future.

PLANT GENETIC ENGINEERING AND BIOTECHNOLOGIES· UPDATE

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INTRODUCTION

Although current technological focus in many of the biotechnology fields, such as genetic engineering, is on agricultural crops, there is every reason to believe that the development of these technologies will have a significant impact on horticultural practices.

Strategies used in the study of plant tissues and cells, the propagation of clonal plantlets, and the production of biosynthetics *in vitro*, are becoming increasingly sophisticated. *In vitro* techniques are being used in the production of novel germplasm for the development of new plant cultivars using a variety of technologies rapidly being developed by molecular and cell biologists. The core biotechnologies which can be applied to the improvement of a cultivar now include protoplast production, somatic cell genetics, and genetic engineering. In addition, plant propagation and cultivation techniques are being developed using the biotechnologies of monoclonal antibodies, plant growth promoting bacteria, and somatic seeds. In fact, the construction of a plant genetic vector using the Ti plasmid can be said to be nearing completion in a number of labs.

As an example, it now appears possible that the T-DNA can be used as a vector into monocots; it was previously thought that this was not the cause because no galls are formed. But, there is evidence now that characteristic amino acid derivatives, which are only produced by transformed plant cells, can be found in monocot cells after exposure to the Ti plasmid.

Another impressive breakthrough is the discovery that *transformed leaf disc cells can regenerate directly. One side* effect of the T-DNA vector in the past was that it interfered with regeneration of shoots; labs are now reporting that this segment has been successfully removed, resulting in a construct which allows DNA to enter the nucleus without interfering with regeneration. The method which has been shown to work is relatively simple. The leaf discs are treated with the bacterial vector causing transformation of the cut surface cells. These cells are then able to regenerate large numbers of plantlets which each carry the new trait. This technology will

enable the rapid production of transformed plants without first growing callus.

There are a few reports now of isolated plant genes, such as the salt tolerance, or proline overproduction gene, and the herbicide resistance gene, which have been isolated by Calgene researchers. A gene for the sweetening protein thaumadin, has been identified in England for potential use in changing the way plants taste. There are also viral genes which have been isolated. Viral genes may serve to protect the plants from invasion by the virus, much in the same way in which aviru-lent viruses function in plants.

Progress has also been made in verification of the heritability of the inserted DNA and in the proven expression of selectable genes such as antibiotic resistance genes in plant cells. It also appears that more than one insertion can be made into the genome when T-DNA is used, thereby possibly producing higher gene copy levels which may enhance expression of the trait.

The current state-of-the-art is now to the point where the T-DNA vector system has been taken apart and its critical components identified. Plant genes can be identified, isolated and moved (2). The next few years will see intensive focus on plant gene analysis in order to bring us to the point of actual productive utilization of genetic engineering technologies in the whole plant.

PROTOPLAST TECHNOLOGY

The use of protoplasts in plant improvement programs has become an alternative to genetic engineering for plants. This technology allows the expression of naturally occurring variant cells which are found in plant tissues and can be used to combine two different plants.

Protoplast technologies have been well developed for several crops, among which are potatoes. J.F. Shepard has pioneered much of the work on potatoes and has produced over 10,000 Russet Burbank clones derived from individual protoplasts (5). Unfortunately, alhtough many different types were found, none of these lines have been able to outcompete the original Russet Burbank in yield and other important horticultural characteristics (4). It may be that the best strategy for the use of protoplasts in plant improvement programs will be in either fusion of protoplasts or in using protoplasts in somatic cell genetics programs.

This past year, Pal Maliga has shown recombination in chloroplasts of fused protoplasts. This demonstrates the feasibility of using protoplast fusion as a method of combining

desirable traits from the cytoplasms of different culivars. The application of protoplast technologies to horticultural crops still involves a considerable effort in perfecting regeneration protocols for each individual species and cultivar of interest.

SOMATIC CELL GENETICS

The study and exploitation of *in vitro* genetic changes, which either occur spontaneously or are induced to occur via mutagenesis, has been termed somatic cell genetics. Somatic cell genetics can encompass both somaclonal variation, which may be derived from changes in vegetative cells prior to culture, or changes seen over time *in vitro*, and variation resulting from directed mutagenesis. Directed genetic change *in vitro* usually includes three phases: 1) the induction of variant cells via mutagenesis, 2) the isolation of elite cells via restrictive or selective conditions, and 3) the genetic analysis of the recovered variants.

There are several distinct advantages of the directed somatic cell genetics strategy over other approaches to plant improvement. The prime advantages are the enhancement of variability affected at the nuclear level, the ability to select only the few desirable variants from the large cell population. Somaclonal variation takes advantage only of naturally occuring and undefined phenotypic changes which may or may not be stable genetically. Directed somatic cell genetics allows the induction of genetic variability in millions of cells which can be screened using selection systems which permit the isolation of only those cells which exhibit a desired trait. Because of the broad impact of mutagens, many traits can be affected besides the prime target, thus giving a wide number of selections for evaluation *in vitro* as well as in the fields.

Chemical mutagens have a long history as a seed treatment and in the development of bacterial and microbial strains. The use of these chemicals in developing improved lines of plants is still being researched for optimum efficacy; however, evidence indicates that mutagen-induced genetic changes are both broader and more permanent than those seen as a result of somaclonal variation. Both mutagen-treated seeds and cells must demonstrate the stability of their genetic changes by successful passage through a sexual cycle. However, the ability to reduce the population through selection systems at the cellular level greatly reduces the labor and field space required for cellular versus seed systems. Additionally, directed somatic cell genetics systems allow screening of cells at a haploid level which permits the discovery of both recessive traits and dominant traits.

Cells which have been treated with mutagens can be selected for specific traits by the use of restrictive or selective growth conditions. For example, cells can be placed on a normally toxic salt concentration under which only salt tolerant cells can grow. Restrictive culture systems can eliminate all cells which do not possess the sought after trait, thereby reducing by 99% the number of plants which have to be evaluated. Disease toxins and actual pathogens, such as bacteria and nematodes, can be used in selection systems, although testing must be done to verify the correlation between the response of cells *in vitro* and the response of the whole plant in the field. Researchers have found that all three types of correlations can occur, i.e., both *in vitro* and *in vivo* responses to a screen are positive, or one, but not the other, responds to the screen (1). The combination of mutagenesis with subsequent selection of elite cells by restrictive culture is a powerful tool in the development of new genetic lines.

GROWTH PROMOTING BACTERIA

Plant growth promoting rhizobacteria (PGPR) are being researched at several labs including the University of California, Berkeley, lab where much of this research has been conducted. PGPR's are bacteria which inhabit the root zone of the plant and are responsible for an increased vigor response. There are literally millions of soil bacteria in a teaspoon of field soil. Researchers isolate the growth-promoting bacteria from soil samples on the basis of the response of individual colonies to *in vitro* challenges. The colonies are often selected because they are able to inhibit or kill pathogenic microorganisms such as soft rot bacteria (*Erwinia* spp.)

One of the methods whereby plant growth promoting rhizobacteria exert their beneficial influence appear to be in this antagonism to many of the mildly pathogenic orgnaisms which inhabit the soil in the plant's root zone. Through the use of careful screening, naturally occurring bacteria are being found which actively suppress root zone diseases of a broad number of species. Another way in which these bacteria appear to promote plant growth is through changing root structure and, possibly, nutrient uptake.

MONOCLONAL ANTIBODIES

Monoclonal antibodies are a fairly recent import into plant biology from medical research. Just as antibodies have become a conventional tool in the diagnosis of plant viruses, their purified counterpart, the monoclonal antibody, will rapidly take over and expand the use of antibodies in agriculture and horticulture.

Monoclonal antibodies are, as their name implies, single antibodies which are originally produced by sensitized, hybrid mouse cells and, after testing, are mass produced in mice, resulting in a large number of identical antibodies. The specificity of a monoclonal antibody is determined by the original sensitized lymphocyte. Since a wide variety of antibodies are formed when an animal is inoculated with an antigen, there are many monoclonal lines which can be chosen — either for extremely specific functions, such as to identify a precise isozyme protein, or for more general functions, such as to detect the presence of any of a number of strains of a pathogenic virus.

Monoclonal antibodies are being researched for agricultural applications and currently have many uses in plant biology. In genetic engineering, these antibodies can be used to capture specific gene products for their identification. Once identified, gene products which are specific to a tissue or a disease response, can then be traced to their gene of origin and to the genes which regulate this response. This is currently being used as an alternative to gene libraries.

Monoclonals are also being isolated for use in diagnostics. For example, they can be made to react specifically with a chemical pesticide and then used to identify trace levels of it in the soil or on the surface of a fruit or vegetable. They can also be used to identify pathogens such as bacteria or fungi which are living in the soil or on the surface of a leaf. As agricultural products are developed, monoclonal diagnostics will find their way onto the shelves of individual growers and pest control advisors for use in accurate and quick identification of exactly what is happening at the plant level.

In the future, we will be seeing a lot more applications of monoclonals as they become a routine tool in the examination of problems at the molecular level.

SOMATIC SEED TECHNIQUES FOR VEGETATIVE PROPAGATION

In the future, it will be possible to vegetatively propagate plants which do not breed true from seed by using somatic seeds. A somatic seed is an embryo grown from callus which is encased in a protective coat. Millions of somatic embryos can be formed from a single plant — in a sense they are all clones of each other. The advantages of using somatic embryos are that they are naturally singulated and possess both a shoot and a root axis in a very small unit. This makes them highly amenable to automation.

Currently, the state-of-the-art of embryo encapsulation

outstrips the art of producing somatic embryos. In other words, the delivery systems for somatic embryos are ready for the field but the biology of somatic seeds is still in the lab.

Somatic seeds are produced by the process of somatic embryogenesis whereby small, uncoated embryos are induced to form from callus cells. These embryos are currently being made for crop species such as celery, alfalfa, and oil palms and many additional species will rapidly be added to this list once the technique becomes a standard procedure. For example, we can already make somatic embryos for plants such as geraniums and strawberries. The forestry industry has a longstanding commitment to the development of somatic seed for Douglas fir because this is the only likely method of rapid vegetative propagation which could be both inexpensive and automatable in high numbers. Research is ongoing in the areas of somatic seed automation and controlled uniformity.

The requirements of a somatic seedcoat are, foremost, that it be nontoxic to the somatic embryo. This includes both during manufacture and afterwards during germination and conversion. It must also be pliable in order to protect and cushion the embryo but sufficiently rigid for handling during manufacture, transportation, and planting. The coating may need to serve as a substrate for the embryo by providing it with nutrients and growth or developmental control agents. The coating must be amenable to the process of singulation and adaptable to currently used equipment such as mechanical seeders. Preferably, it would allow for additional incorporation of biological agents, such as growth promoting bacteria and agricultural chemicals, such as fungicides. The current use of hydrogels as a somatic seedcoat meets all of these criteria.

In somatic embryos we frequently observe the precocious germination of a small plantlet directly from the embryo without the stages of maturation, desiccation, dormancy, and imbibition which normally precede radical emergence and the commencement of growth. In addition, we observe that a high percentage of somatic embryos in certain plants will not procede past radical emergence and growth into development of whole plants, as is signalled by the appearance of the first true leaves. In our labs we now refer to the final step in the development of a whole plant from a somatic embryo as "conversion".

One aspect of developing a field-ready somatic seed is that it must be fully hardened. This problem has been overcome in part by the use of airflow systems developed at PGI for the control of the *in vitro* gas environment. Using a continuous air flow, the embryos develop at a reduced relative humidity, which encourages the development of a normal cuticle.

NOVEL PROPAGATION TECHNIQUES

As researchers develop skills in gene identification and manipulation, they are likely to discover technique which will have broad impacts in totally unrelated fields. For example, transformation of cells at the base of a cutting, using a disarmed plasmid from a root-producing bacteria, or from an auxin-inducing fragment of the T-DNA may become a standard method for rooting certain cultivars. In this case the only plant cells which would be influenced would be those which had been treated with the special bacteria containing the root-promoting fragment from the rooty-tumor pathogen. The cut surface would receive the rooting genes which would have no effect except to induce the formation of roots.

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THE OBLIGATION OF THE PLANT PROPAGATOR

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Abstract. Because the ultimate sources of plant pathogens are previously diseased plants and the soil (including water and nonliving organic matter), propagators of pathogen-free plant materials are a primary or seminal source in modern plant production, and have special health responsibilities Pathogens must be eliminated in this culture, not inhibited or suppressed In addition to being a profitable business practice, there are very specific benefits from clean culture for both the propagator and the producer Nursery diseases have decreased in the last 27 years, but remain a lurking hazard, and growers must accordingly continue to practice clean culture In such a plant-health program, growers have an important role and they should be directly involved in the ongoing research program, as they

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were in the development of the U C. System of plant culture in 1941-57 Present efforts to standardize nursery stock solely by physical characteristics miss the essential point that growth potential and plant vigor are at least as significant as size. "Root nibblers," pathogens that attack root tips and insidiously reduce plant growth but only eventually kill the plant, are largely ignored in present schemes. A combination of such physical specifications and a certification of health status can make true standardization a reality, so needed in these times of mass marketing. For both propagators and producers, a triple program of planting truly healthy propagules in clean treated soil, and practicing careful sanitation and hygiene, will keep the plant pathogens at bay in the future.

The better nurserymen and propagators now realize that plant diseases are neither inevitable nor a trivial factor in the gamble involved in producing a crop. Their activities indicate an awareness, if not a full understanding that, in the last analysis, the sources of plant disease organisms are the soil (including its water and nonliving organic matter) and previously infected plants. Only rarely does one now hear the old alibis for a diseased crop, "It was due to the weather," "It was due to the new help," "The plants were overwatered."

It is a pleasure to report that many diseases of nursery and ornamental crops have been dramatically reduced in the last 40 years. Verticillium wilt and viroid stunt diseases of chrysanthemum may not be eliminated, but they are no longer regarded as inevitable, and they are a rarity. Fusarium and bacterial wilts of carnation are no longer a threat. These troubles have been minimized by the continuing patient efforts of growers to plant clean stock in clean soil, and to support them with rigorous sanitation.

Diseases have not been eliminated from the scene, however, and one hopes that periodic small outbreaks will be sufficient to stimulate growers to continue and even improve their present efforts. The hazard is that growers will become complacent, and that a new generation of them will arise who have never seen disease epidemics and who doubt their reality, or who think they are a thing of the past. An example of this is afforded by the fire-blight disease of pear and apple trees in New Zealand. It nearly annihilated the industry in 1919-29, and then subsided for unknown reasons, even though the virulent bacteria continue to be present. The disease has remained unimportant there, but in 1972-73 mild symptoms appeared. Growers brought in specimens, and when told that they had fire blight, not knowing what that was they failed to appreciate the potential seriousness of the situation. In 40 years a new generation of growers had no knowledge of the disease. If I did not think that disease epidemics could occur again, exhortation would not be necessary. Churches have been inveighing against sin for many generations, with little

result except to give the sinner a guilty conscience and thus lessen his pleasure. They have found it necessary to repeat the sermons at weekly intervals to be effective. It has been some years since I have carried this torch to you, and it now seems better strategy to try to explain why it is in growers' best interests to continue preventive measures of disease control, than to belabor your collective conscience in a revival meeting.

PROPAGATING FOR HEALTH

Growers were advised in Manual 23 (1), with reference to plant pathogens, "Don't fight 'em, eliminate 'em," advice still relevant today. One of the principal means of doing this is to use pathogen-free stock, and a number of specialist propagators now supply such stock. Increasingly, now one hears the comment from nurserymen, "I don't propagate, I buy 'em." This is a trend that can greatly help to vanquish plant disease — **if** propagators recognize that this gives them a great responsibility.

Propagators are a primary source or seminal business — the buck starts there. In general, the earlier in its life that a plant is infected by a pathogen, the worse the damage will be. This places a special burden of responsiblity on propagators who are in the clean-stock business; they must be especially careful to keep all disease out of their operation. Sanitation must be quite as good as in hospitals, and the help must be well trained and fully aware of their responsibilities.

Health, rather than disease, is the normal state for life. The pathogen-suppressive state is the normal condition of biologically buffered equilibrium. Although parasitism appears to be normal for some microorganisms, pathogenicity or the ability to produce disease, is uncommon. It is doubtful whether living things could have evolved, and quite certain that agriculture could not have developed, if this were not true. This healthful state is a result of the biological balance that has evolved in the interactions among living things. Interaction, harmful and beneficial, is the balance wheel of nature. To exist in such a complex association is to gain external protection and strength from the enhanced stability provided, as a stone gains stability and strength when built into a wall, as well as imparting these features to associated stones. The system is biologically buffered, and each organism maintains a fluctuating population density within certain definite limits. Only well-adapted and competitive living things have found an ecological niche, and to maintain possession they have had to integrate their population, timing, and activities with their associates and with the climatic cycle.

Diseases are an important factor in this plant-stabilization sequence. Because the rigorous disease control required of commercial propagators is an unnatural situation in the evolution process, requiring elimination of pathogens, it demands even greater attention to details than does routine nursery culture. As Ordish and Dufour (8) said, "farming is a most unnatural activity. Man has imposed on the environment a system of survival of what he wants to use over the Darwinian system of the fittest to survive. Consequently the farmer is engaged in a constant struggle with nature."

If one environmental factor is limiting to plant growth, the influence of other factors is altered. For example, low soil moisture affects plant growth more at high temperatures than under cool conditions because of the effect on plant transpiration. On the other hand, higher moisture has a more deleterious effect at low (but above about 4°C) than high temperatures because of waterlogged soil produced. The optimum for one factor is thus changed by variation in other factors, and if one practice is changed in grower procedures other practices may have to be adjusted. Thus, when poinsettia growers first adopted the U.C. System the plants grew too rapidly, became too tall, and the stems had to be "tromboned" before sale. Later planting solved the problem. In the same way, a disease-control procedure must fit into present grower practice or the practice must be modified before it will be acceptable.

Drenches with PCNB, Dexon, or similar chemicals may inhibit, but will not eliminate *Rhizoctonia*, *Pythium*, and *Phytophthora*, and frequent application may be required to be effective. This is disease suppression, not disease control, and should not be among the plant propagator's procedures. His responsibility is to produce pathogen-free stock, not merely to produce plants free of symptoms by suppressing disease until the plant is sold. If he fails to eliminate a pathogen, growers who buy the liners cannot rectify the defect. The use of pathogen-suppressive chemical drenches by a primary propagator to decrease disease loss in his nursery is unethical, irrational, and should be illegal. This is similar to removing crown galls or nematode galls from nursery stock, or bacterial fasciations from Esther Read daisies before sale — it is fraud, not disease control. However, the grower who is using the plants for crop production, such as a cut-flower chrysanthemum grower, may use these inhibitory materials with a clear conscience, but should use them as a secondary defense when all else has failed. This is comparable to the preferred medical practice of preventing infection, and using antibiotics as a last resort.

Alert intelligent growers play an important role in obser-

vations and in developing the working hypotheses with which all research begins. Because of their intimate daily contact with the crop, and intense personal interest in it, growers have often made early perceptive observations and have conducted far-sighted experiments that defined fruitful areas for investigation. Wise research workers pay close attention to grower observations and ideas, and encourage expression of them. Growers are an improtant part of the team, and should not be hesitant to actively participate in the investigation process.

BENEFITS FROM ELIMINATING DISEASES

1. **Greater profit:** Strawberries in California produced only about five tons per acre in the 1950's, but with present soil fumigation and use of clean stock replanted each year, yields of 30 to 40 tons per acre are not uncommon. Sweet potato production is now undergoing similar renovation. Chrysanthemum has become the leading florist crop through the development and commercialization of cultured disease-free cuttings, soil fumigation, daylength manipulation, scheduled year-round production, and developed public acceptance of mums every month of the year. Forty years ago some nurserymen thought disease was a good thing because it insured replacement sales. Unfortunately, it is still extremly difficult to obtain pathogen-free nursery stock to plant in the home yard. It should be self-evident that there is money to be made by growing the healthiest and best possible plants.

2. **Nursery culture is simplified, and plant-growth potential increased:** *Verticillium wilt of chrysantheumum* was sometimes minimized by skillful watering and by use of tolerant cultivars. Use of soil treatment and healthy cuttings made possible a wider selection of cultivars without the necessity of resistance, and has made "preventive watering" a lost art. Phytophthora root rot of heather can also be reduced by minimal watering, but this retards plant growth and is difficult to achieve.

3. **Improved timing and scheduling:** Plant diseases are unpredictable, even capricious, in occurrence and severity. Freedom from disease makes possible consistent timing, essential in today's marketplace.

4. **Increased environmental tolerance:** Bedding plants in southern California in the 1940s sustained losses from damping-off caused by *Pythium*, *Rhizoctonia*, and salinity. Soil moisture could not be adjusted to control this complex. By eliminating the pathogens through soil treatment, and salinity by improving the soil mixes, the useful range of soil moisture was greatly expanded.

5. **Improved evaluation of cultural practices:** A diseased plant cannot grow as well as its environment should permit, and hence gives no indication of the growth potential of a healthy plant. A deficient root system may restrict water and mineral absorption, and a plant so impaired will not respond to fertilizer application. Only the young white root tips need be injured by "root nibblers" to severely decrease plant growth. The only true indicator of the value of a cultural practice is provided by a healthy plant with a sound root system.

6. **The better the plant culture, the greater the benefit from elimination of disease:** The use of clean plants and soil treatment obviously give greater benefit to an excellent than to a careless grower.

7. **It is cheaper and more effective to prevent plant disease than to control it once started:** In this day of mechanization, standardization of product, packaging, and scheduled production, there is no place for plants of uncertain performance, variable size, capricious flowering, and slow growth. Beside lowering cost of production, healthy plants do not introduce a destructive persistent pathogen into the customer's yard, decreasing future successful plantings and sales.

Abundant grower experience indicates that the use of clean stock, clean soil, and sanitation will produce more uniform, healthier, and larger plants at lower cost, more reliably, and faster than before. This is profitable for the grower and makes friends of the customers.

PLANT STANDARDIZATION

The trend to mass marketing of nursery stock requires increasing standardization, and many agencies have rushed to get on the bandwagon of establishing standards. Published standards have in common prescription size specifications for plants, without considering how the stock was produced. The underlying fallacious assumption on which such specifications are based is that, if a root disease is present it will be evident and that the plant will soon die. By inversion, this is frequently taken to mean that if plants do not die they must be free of root pathogens, or at least those plants which survived must be healthy. Neither of these assumptions is true. Experience shows that nursery stock infected with *Phytophthora* often grows well enough in the nursery to be sold and planted. The pathogen may not kill the tree until years later during a wet winter, after the plant's value has increased many-fold. However, growth in the interim will be below par and the soil will be permanently infested. Growers are often surprised by the

growth potential of a really healthy plant. Most plants will grow tolerably well under a wide range of soil conditions, and unless there is a well-grown plant to compare it with, will appear satisfactory.

Growers generally recognize that two plants, apparently similar, may have vastly different growth potentials when planted. A well-grown plant produced without check under consistently favorable conditions and free of root-rot pathogens, is certainly a much better buy than a larger specimen slowly grown under intermittently unfavorable conditions, or one infected with root-rot fungi but not yet showing symptoms. Many of the state and nursery association standards ignore this rudimentary fact. One even frankly states that "Nursery stock when sold shall not be dead or in dying or seriously damaged condition." To accurately standardize plants it is necessary to assess their growth potential as well as to measure their size (2,4). It is not enough to specify, as one state does, that a certain grade requires "an exceptionally healthy and vigorous plant." A moment's reflection will show that plants must be grown for such standardization, not merely sized and standardized *after* they are randomly produced. Similarly, the quality of an automobile is determined more by quality control of materials on the assembly line than by measuring the overall length, quantity of chrome, or paint thickness of the finished product. In both cases, actual performance is the best criterion of quality. Growing procedure is the key to true standardization, not a series of photos of different plant shapes and sizes for each species. This does not necessarily mean that every grower must use the same method for producing a plant, but that those plants grown under the most favorable conditions will receive the best rating.

A means of describing the physical specifications of nursery stock is a necessary form of business shorthand, and as such should be continued and improved. To supplement these standards, a voluntary certification scheme for evaluating growth potential was suggested in 1959 (2). Official periodic inspections could provide information on the age of the plant in relation to its size, the time it has been in the container, the number of times it has been transplanted, and whether it has a root-bound condition. An estimate of root condition can be provided by examination of the root ball or by washing out a few representative samples. Information could also be collected on uniformity of plant growth rate, whether the soil was treated, whether the lining-out stock was pathogen-free, whether any plants had died and from what, whether specific sanitary precautions had been followed, whether any means of retarding or suppressing disease development had been prac-

ticed to conceal the presence of pathogens, and whether plants had been extensively forced to attain a certain size. There are precedents for such a program in the existing state certification schemes for seed potatoes, seeds, and for plants of strawberry, grape, avocado, peach, citrus, cherry, and sweet potato. It would be relatively easy to apply such a scheme to lining-out stock, and this would be a suitable place to begin. Grower participation should be voluntary, not legally required.

Under such a program a plant would always have a descriptive grade, and could have an additional certification. A buyer could then decide whether a certified No. 2 plant was a better economic risk for orchard planting than a cheaper No. 1 plant. Such a dual system appears to be the only feasible means of truly standardizing nursery stock.

SANITATION

> Sanitation is a way of life. It is the quality of living that is expressed in the clean home, the clean farm, the clean business and community. Being a way of life it must come from within the people; it is nourished by knowledge and grows as an obligation and an ideal in human relations.
>
> — National Sanitation Foundation

In the last analysis, the ultimate sources of plant pathogens are previously infected plants and the soil, including its water and nonliving organic matter. Thus, disease control in the nursery basically comes down to using treated or pathogen-free soil, pathogen-free planting stock, and routine sanitation to keep them both clean. Soil treatment methods are discussed in the IPPS Proceedings (5,7), methods of obtaining and maintaining pathogen-free propagules are discussed elsewhere (3,6,7). Sanitation (1,4) procedures prevent contamination of the soil, plant, or both, by pathogens during growth of the crop.

The primary propagator must practice hospital-level cleanliness because so many other growers are dependent on him and connot undo the results of any defects in his technique. This does not mean that other types of growers can be careless or sloppy, but that they should practice at least the level of sanitation that they expect in their homes. For example: dishes are carefully washed in hot water in the home, and plant containers should be disinfested unless they are new; one doesn't use another's toothbrush or towel, and nursery tools should be treated before re-use; wives don't condone tramping mud into the kitchen, and growers should not walk on flats or beds of treated soil; one sneezes or coughs into a handkerchief

to reduce spreading colds, and a grower should avoid scattering infested soil in watering or handling operations; one doesn't visit friends while suffering from mumps or chicken pox, and a grower shouldn't place plants of uncertain health in a block of healthy stock; polluted water is boiled before being drunk, and contaminated water should be chlorinated before use on plants; man has found it perilous to use human excrement for fertilizer, and it is dangerous to dump diseased or dead plants in a compost pile which is not treated before use; clean sheets are demanded on beds in hotels, and benches should be disinfested before re-use. Such social customs were unknown to primitive people, ignored in early civilizations, scorned as fussy in the Middle Ages, only grudgingly adopted in the nineteenth century. In many areas today, people look down on those who do not conform to such minimal standards. To which developmental stage does your concept of nursery cleanliness belong?

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CUTTING PROPAGATION OF *SEQUOIA SEMPERVIRENS* CULTIVARS

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Abstract. The introduction of several vegetatively propagated cultivars of *Sequoia sempervirens* (D. Don) Endl in recent years has resulted in vast improvements over the highly variable seed propagated specimens in ornamental use. Selected for superiority of growth habit, texture, and foliage color, these selected cultivars continue to gain in popularity in many areas for their use as landscape ornamentals The efficient, commercial cutting propagation of these selected cultivars requires the selection of the optimal type and concentration of rooting hormone for each cultivar.

Cuttings of three selected cultivars of *Sequoia sempervirens* were treated with a variety of rooting hormones and rooted in flats in a peat/perlite medium on oudoor rooting beds with full sun, bottom heat, and intermittent mist 'Majestic Beauty'™ rooted best with a combination of 3000 ppm IBA + 3000 ppm NAA. 'Santa Cruz' exhibited optimal rooting with 16,000 ppm IBA powder. 'Soquel' responded best with a combination of 6000 ppm IBA + 6000 ppm NAA.

INTRODUCTION

Sequoia sempervirens (D. Don) Endl., or "coast redwood", has long been admired for the beauty of its bark, foliage, and pyramidal form, as well as the sheer majesty of centuries old specimens in a native setting. Rapid growth, adaptibility to a wide range of soil and environmental conditions, relatively pest-free habit, woodsy appearance, and natural heritage have made the coast redwood a popular selection for use in the landscape. During the past few years, the introduction of several vegetatively propagated cultivars for landscape use has resulted in some major improvements over seedling stock.

Background. *Sequoia sempervirens* grows native only within the summer fog belt of northern California and the southwestern portion of Oregon, rarely more than 30 miles from the coast, although it widely planted as an ornamental in western Oregon and all but the hottest areas of California. Rated hardy through Zone 7, plants are not common north of Virginia in the eastern states. Coast redwood trees have also been grown successfully as ornamentals in areas of Australia, England, France, Italy, New Zealand, South America, and Spain (1,2,4,5,6,16,21).

Specimens of *Sequoia* were first carried to England in 1795 and remained undescribed until 1823 when Lambert classified them as *Taxodium sempervirens* in the family Taxodiaceae. In 1847, Endlicher classified them into their own genus, *Sequoia*, and retained the species name. The genus was named for

Sequoyah, a Cherokee half-breed of Georgia, who originated the Cherokee alphabet. The species name refers to its evergreen character. The early Spanish Californians referred to it as "palo colorado", meaning "red tree". It is commonly known as "redwood" or "coast redwood" because of its beautiful pink or reddish colored heartwood. Closely related to *Sequoia* are *Sequoiadendron giganteum*, the big tree, or Sierra redwood, and *Metasequoia glyptostroboides*, the dawn redwood, a deciduous species (1,2,5,8,21).

Use. In the home garden, *Sequoia* performs well as a shade tree, a specimen tree, or in groups. Trees grow well with an abundance of water, will grow in or next to a lawn, and are tolerant of most soil types if water is provided. Plants grow best in full sun in most areas, but will tolerate partial shade. Under optimal conditions, tree may grow up to five feet per year (6,15,20,22).

Sequoia rarely is affected by insect or disease problems, and is not attacked by *Botryosphaeria ribis*, causing branch die-back, as is *Sequoiadendron* when stressed by heat, drought, or air pollution. Growth and appearance of *Sequoia* may be less than optimal due to a lack of water, lack of available iron, or competition from other trees (15,22).

In the landscape, *Sequoia* has been used extensively along expressways and as specimens, or in groves in parks and on golf courses. Certain cultivars do well when planted close and topped at least once a year to form a feathery hedge or large divider (20,22).

Redwood constitutes a major portion of the California lumber industry, being slower than many other woods to burn, relatively resistant to termite attack for many years, and unusually resistant to other insects and fungi. The presence of a substance called tannin in the wood appears to be responsible for this resistance, and is also responsible for imparting the reddish pigment to the wood. Extensive commercial use of redwood has for many years been the basis of concern for their conservation from educational, social, and inspirational points of view. Much land has been set aside for their preservation in the California State and National Park Systems (8,21).

Selections. Seedlings of *Sequoia sempervirens* tend to vary greatly in growth habit and in the color and texture of the foliage, these characteristics being determined principally by heredity and are exhibited by the tree throughout its life. The habit of growth may range from quite open to very dense, stiff and bristly to graceful and pendulous, and suckering heavily or little at all. Branches may be stiff or arching, and may grow at a slightly upward angle or almost straight down. The foliage

color may vary from light to dark green, or silvery glaucous blue to deep blue green (15,20,22).

Prior to the 1970's, almost all *Sequoia* plants on the market were seedlings; only occasionally were a few novelty forms found in small quantities with some unusual foliage color or with pendulous, prostrate, or dwarf growth habits. In recent years, numerous cutting-grown selections have been made for ornamental use such as 'Aptos Blue' with dense blue green foliage on horizontal branches, and 'Los Altos' with deep green foliage on slightly arching branches. Three outstanding new selections being grown by Monrovia Nursery Company are 'Majestic Beauty'™, 'Santa Cruz', and 'Soqel' (2,6,16,20,22).

'Majestic Beauty'™ is a seedling selection originating at Monrovia Nursery in California. This cultivar is highly favored for its delicate, glaucous, blue-green foliage on horizontal, spreading branches and pendulous branchlets (16).

'Santa Cruz' features soft-textured, light green foliage on branches which point slightly downward, and is reported to take shearing quite well. This cultivar was selected by Beeline Nursery and introduced through the Saratoga Horticultural Foundation (16,22).

'Soquel', also introduced through Saratoga, is prized for its fine-textured, dark-green foliage, blue-green on the underside, on horizontal to slightly ascending branchlets which turn up at the tips. The growth habit of this cultivar is somewhat more compact than other cultivars, and also tends to sucker less (6,16,22).

Production. In recent years, demand for *Sequoia sempervirens* as an ornamental has increased due to the availability of selected, cutting-grown cultivars. Although *Sequoia* is propagated readily and economically from seed, in some cases cutting propagation has totally replaced seed propagation due to the superiority of specific clonal selections over the more variable seedlings. *Sequoia* is also readily propagated by means of tissue culture when large quantities of selected clones are required for container production or reforestation plantings (11,16,23).

With the improved selections, a minimum of staking and pruning is required to produce a full, quality plant for sale in the retail market. Vegetatively propagated plants tend to develop a central leader with little or no training. (16)

Propagation of *Sequoia* cultivars fits in well with a standard conifer cutting propagation scheme. Cuttings are normally made in the late fall and winter. Cuttings root in approximately four to five months, with rooting percentages varying from one cultivar to another. After potting, liners are ready for

sale after an additional six months. Plants canned into one gallons are ready for sale after eight months. Production of finished five and 15 gal. requires an additional year in each stage (16,19).

REVIEW OF LITERATURE

Relatively few formal studies have been conducted on the rooting of *Sequoia sempervirens*; more research has been conducted with the closely related species, *Sequoiadendron giganteum* and *Metasequoia glyptostroboides*. Jaroslavcev (12) reported that the most suitable time for taking cuttings of all three species was just prior to active growth. An inability to root *Sequoia* at any time of year was cited by Gil-Albert (10). Platt (18) reported that *Sequoiadendron* rooted best when cuttings were treated with 3000 ppm IBA (although the cuttings exhibited poor root development) while Wolford and Libby (24) indicated that 2000 ppm or 4000 ppm IBA and an organic propagation medium were optimum. Fins (9) found rooting of *Sequoiadendron* to be improved when cuttings were taken from juvenile growth and prepared with an angled basal cut, and when fertilizer was incorporated into the propagation medium under high mist conditions. An extended photoperiod was found by Baker (3) to improve rooting of *Metasequoia* under some conditions, while Lamb (14) indicated that sand alone was preferable over a sand/peat medium for propagation. Connor (7) reported that *Metasequoia* cuttings root well when dormant cuttings are prepared, placed in cold storage for 30 days, treated with 3000 ppm IBA, and rooted in a peat/perlite medium with bottom and intermittent mist.

MATERIALS AND METHODS

Experiments centered on the effects of selected types and concentrations of rooting hormones on the rooting of *Sequoia sempervirens*, cultivars 'Majestic Beauty'™, 'Santa Cruz', and 'Soquel'. The rooting hormones utilized were the auxins IBA (indole-3-butyric acid), NAA (α-naphthaleneacetic acid), combinations of IBA and NAA, and NOA (*B*-naphthoxyacetic acid). Auxins at concentrations of 3000 ppm, 6000 ppm, 8000 ppm, and the auxin combinations were prepared as solutions containing 55% methanol; IBA at concentrations of 16,000 ppm and 45,000 ppm were prepared as talc powders. (Refer to the data tables for the specific treatments utilized with each cultivar.)

Experiments were conducted over two consecutive seasons. Due to a limited amount of propagation material the first season, trials were limited to 'Santa Cruz' and 'Soquel', utilizing varying numbers of cuttings per treatment. The second season, formal trials were conducted with all three cultivars

based on information gained the first season utilizing three cutting flats per treatment stuck at the rate of 255 cuttings per flat.

Propagation material was collected from vigorous five-year-old stock plants in early February. Cuttings were prepared approximately 5 in. in length such that the outer tissue on the main stem on the cutting was brown at the base and green above. Side branchlets on the cuttings were trimmed back so that all cuttings were of an overall uniform size.

Prepared cuttings were washed and disinfected by immersing them for 5 sec. in a water bath containing 15 ppm chlorine followed by 5 sec. in 200 ppm Physan disinfectant. Cuttings then received a quick basal dip in their respective hormone treatments and were stuck into pasteurized flats containing 90% coarse perlite and 10% fine peat moss. Cutting flats were placed on outdoor heated concrete rooting beds in full sun with an average bottom heat temperature of 70°F and intermittent mist provided for 10 sec. every 12 to 30 minutes (depending on weather conditions).

After a rooting period of five months, bottom heat was discontinued and the mist frequency was gradually reduced during a two-week period to harden off the rooting cutting flats. The cuttings were then removed from the flats and the number of rooted cuttings and rooting percentages were determined.

RESULTS

The first three months of the rooting period were marked principally by basal callus formation, while the majority of the rooting occurred during the final two months. Cuttings produced two to four long, branched roots, with little variation in the average sizes of the root systems being noted between one treatment and another.

Table 1. Effects of selected hormone treatments on the rooting of *Sequoia sempervirens* 'Majestic Beauty'™

Treatment	Average No Rooted Per Flat +/− Std. Error[1]	Percent Rooted
3000 ppm IBA	20.0+/−11 0a[2]	7.8%
6000 ppm IBA	31.5+/−0.5a	12 4
16,000 ppm IBA powder	37.0+/−5.0a	14 5
3000 ppm NOA	44.5+/−36.5a	17 5
3000 ppm IBA + 3000 ppm NAA	165.0+/−6 0b	64.8
6000 ppm IBA + 6000 ppm NAA	159 0+/−6 0b	62 4

[1] 255 cuttings per flat. Three flats per treatment.
[2] Means followed by the same letter or letters are not significantly different at the 5% level (Duncan's Multiple Range Test)

Table 2. Effects of selected hormone treatments on the rooting of *Sequoia sempervirens* 'Santa Cruz' (Experiment 1)

Treatment	No. Stuck	No. Rooted	Percent Rooted
1000 ppm IBA	390	69	17 7%
3000 ppm IBA	400	227	56 8
6000 ppm IBA	510	261	51 2

Table 3. Effects of selected hormone treatments on the rooting of *Sequoia sempervirens* 'Santa Cruz' (Experiment 2)

Treatment	Average No Rooted Per Flat +/− Std Error[1]	Percent Rooted
3000 ppm IBA	118 3+/−37 1a[2]	46.4%
8000 ppm IBA	159.3+/−49 2a	62 5
16,000 ppm IBA powder	178 3+/−6 3a	69.9
3000 ppm IBA + 3000 ppm NAA	121 0+/−2 0a	47.5
6000 ppm IBA + 6000 ppm NAA	160 7+/−17 9a	63 0

[1] 255 cuttings per flat. Three flats per treatment

[2] Means followed by the same letter or letters are not significantly different at the 5% level (Duncan's Multiple Range Test).

Table 4. Effects of selected hormone treatments on the rooting of *Sequoia sempervirens* 'Soquel' (Experiment 1).

Treatment	No. Stuck	No. Rooted	Percent Rooted
1000 ppm IBA	400	6	1 5%
3000 ppm IBA	500	9	1.8
6000 ppm IBA	400	14	3 5
3000 ppm NAA	330	9	2 7
6000 ppm NAA	345	66	19 1
3000 ppm IBA + 3000 ppm NAA	215	80	37 2

Table 5. Effects of selected hormone treatments on the rooting of *Sequoia sempervirens* 'Soquel' (Experiment 2).

Treatment	Average No Rooted Per Flat +/− Std Error[1]	Percent Rooted
3000 ppm IBA + 3000 ppm NAA	78 7+/−10 9ab[2]	30.9%
6000 ppm IBA + 6000 ppm NAA	119 3+/−9.2a	46 8
8000 ppm IBA	65 3+/−4.6bc	25.6
16,000 ppm IBA powder	52.3+/−3.8bc	20 5
45,000 ppm IBA powder	56 3+/−6 2bc	22 1

[1] 255 cuttings per flat. Three flats per treatment.

[2] Means followed by the same letter or letters are not significantly different at the 5% level (Duncan's Multiple Range Test)

DISCUSSION

Results indicate that the optimum type and concentration of rooting hormone differs from one cultivar to another. In general, a combination of IBA and NAA, or IBA alone, in moderate to high concentrations will provide the best results. NAA alone, NOA, and low concentrations of IBA result in lower rooting percentages.

A combination of 3000 ppm IBA + 3000 ppm NAA was clearly the optimal treatment for 'Majestic Beauty'™; 16,000 ppm IBA powder was selected as the best treatment for 'Santa Cruz', while 8000 ppm IBA and 6000 ppm IBA + 6000 ppm NAA also gave good results with this cultivar. 'Soquel' responded best to a combination of 6000 ppm IBA + 6000 ppm NAA.

It appears that acceptable rooting of cuttings of selected cultivars of *Sequoia sempervirens* may be obtained if the optimal hormone treatment is determined. In addition, at the end of the rooting period, the callused, unrooted cuttings may be retreated with hormone and reset to stimulate additional rooting and increase the overall rooting percentage. The efficient volume production of superior cultivars for ornamental use should thus be possible in a conventional conifer cutting propagation program.

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TWIG GRAFTING OF MACADAMIA

JACK AHLSWEDE

Ahlswede Wholesale Nursery
717 Ora Avo Drive
Vista, California 92083

Most of you have probably eaten the nuts from macadamia trees but I am sure some of you have never seen the trees. In recent years this fruit has created a lot of interest in San Diego County, California, and around the world. Its climatic requirements are similar to avocados and it has been used as a replant for avocado groves which have become unproductive from root rot. It is also being used as a dooryard tree both for the nuts and for its good looks. At present there is a great deal of interest in establishing macadamia production as an agricultural industry in southern California, as has been done in Hawaii and other subtropical and tropical areas.

There are two species of macadamias grown commercially. *Macadamia integrifolia*, the most popular species in Hawaii,

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There are two species of macadamias grown commercially. *Macadamia integrifolia*, the most popular species in Hawaii,

and *M. tetraphylla*, the most widely grown in southern California.

My experience with macadamias dates back to the 1960's when I bought some seed from a tree on a ranch between Los Angeles and Santa Barbara because this tree was supposed to have the most uniform progeny and least likely to have chlorotic seedlings. In spite of this effort on our part, we still had a great deal of variation in our seedlings and quite a number of chlorotic offspring.

Ted Frolich at UCLA provided me with cuttings of 'Stevenson', a *M. tetraphylla* from Australia, and cuttings of 'Dr. Beaumont'. I grew these and then planted them in the field. The Stevenson tree, which is about 20 years old, has almost no chlorosis while the volunteer seedlings growing around it are quite chlorotic.

In the work we have done, it is obvious that macadamia is highly heterozygous and we must assume that if there is the amount of visible variability which we have observed, there must be a great deal of non-visible variability as to reactions to soil, nutrients, temperature, and other environmental factors. A researcher in Hawaii mentioned that they were finding a difference in maturity time of fruit of the same cultivar, growing in the same orchard, which he felt was due to rootstock variability.

In the citrus industry, the citrus nurseryman is very careful to rogue out all gametic seedlings using only nucellar seedlings as rootstock for citrus propagation to insure production of uniform trees.

Gametic seedlings are those developing in the usual manner of pollen being placed on the pistil and the seedling subsequently formed being a new plant bearing variable genetic traits. A nucellar seedling is similar to a bud from the parent tree as it arises in the nucellus of the seed. These seedlings are uniform as they arise from the single female parent.

Macadamias do not produce nucellar seedlings; so, in order to achieve the same uniformity as occurs in citrus, we elected to use selected clones grown from cuttings as our rootstock.

One of the most successful cultivars in our area has been Dr. Beaumont. This is widely planted as a landscape and home orchard tree. It sets fruit at a much younger age than most other cultivars, is tolerant to a wider range of soil conditions than most seedlings, is a handsome tree and grows well from cuttings.

When we became convinced that, for the sake of uniform-

ity in orchard trees, we must use a clonal rootstock, 'Beaumont', having a track record, was the logical choice. It appears to be an *M. integrifolia* × *M. tetraphylla* hybrid, and while it has been found in Hawaii that an overgrowth of the scion occurs when they graft *M. integrifolia* cultivars (which are most widely used there) on *M. tetraphylla* seedlings, we have no reason to believe that when we use a hybrid, such as 'Beaumont' as understock, and a *M. tetraphylla*, such as 'Cate' as a scion that we will have this problem. We first grafted established 'Beaumont' rooted cuttings, which we had grown in gallon cans for 6 to 8 months after rooting. We used a scion about 4 in. long and about 3/16 to ¼ in. caliper. We left the top whorl of leaves on the scion, cutting the leaves in half. We then cut off the understock at about 8 in., retaining leaves below the cut. We next inserted the scion with a cleft graft, tied it in with budding tape, and bagged the scion with a 4×2×8 in. plastic bag without any holes. We placed the grafts in a cool house under benches with very low light. This was done in November and by March we had about 80% take.

Our method of grafting established rooted cuttings in gallon cans was tedious so we looked for a better method of producing trees using a clonal rootstock. Don and Floyd Dillon, with Fred Real, in 1962, wrote a paper (1) describing their work using twig grafts, with an update in 1967 (2). This is a method of grafting cuttings during the rooting process. In our nursery we had used this method in producing citrus cultivars on *Poncirus trifoliata*. We are in the business of supplying 2½ in. pots to nurseries producing primarily for the landscape trade, and we were able to produce a very satisfactory liner using this method. In citrus we also graft very small seedlings in a 2½ in. pot.

In our work with citrus we use a scion about 4 in. long with two leaves which we cut in half. We root the "twig grafts", or heal in the grafts on seedlings, in a closed propagating frame in which we keep the humidity high by frequent mistings. We use this same method of "twig grafting" in our work with macadamias.

In field grafting macadamias, it has been found necessary to girdle the branches to be used as scions prior to cutting the budwood to get a high starch content. Stephenson notes this in the 1983 Yearbook of the California Macadamia Society (3).

We have found girdling is not necessary where we have leaves on our scion to produce starch during the healing in process. We use scions taken near the tips of the branches of the selected budwood tree, trim the leaves, then graft the scion to a cutting from the tree selected as the clonal root-

stock. In approximately 3 months the graft has healed and roots have formed on the rootstock. This then gives us trees which should react in a uniform manner when used in commercial plantings.

I want to compliment Don and Floyd Dillon and Fred Real on their papers covering twig grafting and given to this Society earlier. Anyone interested in this should certainly read their works. They give great descriptions on method, cleanliness, and facilities. Floyd, in his paper, gives full credit to Dr. Halma and Ted Frolich for their generous contribution to those of us who are working in propagation. It was my experience, too, that these two men were always ready to help us when we went to them with questions.

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USE OF MONOCHLORAMINE AS A DISINFECTANT FOR PRUNING SHEARS

CONRAD A. SKIMINA[1]

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Abstract. Chloramines were investigated for use in disinfection of pruning shears and their efficacy compared with Physan, isopropyl alcohol, propylene glycol, 8-hydroxyquinoline sulfate, and combinations of propylene glycol and terramycin and streptomycin. The objective was to find a suitable replacement for isopropyl alcohol which would have equal or better efficacy, good stability under high contamination, and lower cost Phytotoxicity and corrosiveness of several disinfectants were also investigated.

The best disinfectants were found to be Physan, isopropyl alcohol, and monochloramine Of these, monochloramine was found to be equal in efficacy to the alcohol, least corrosive, least costly, and had excellent stability under high contamination

INTRODUCTION

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cuts through roots, this can be a source of contamination and inoculation unless some provision is made to disinfect the pruning shears. In the search for a disinfectant we were looking for a stable product which will provide disinfection under high organic contamination. Many disinfectants such as sodium hypochlorite (Clorox) and the quaternary ammonium compounds react with organic matter and are quickly inactivated. For a number of years we used 70% isopropyl alcohol which retains its disinfection qualities under high organic contamination. However, with the costs of alcohol increasing, we found that during the peak potting period, we might use $230 worth of isopropyl alcohol per month. Consequently, we embarked on seeking and testing a number of disinfectants for their efficacy and stability. The culmination of these tests resulted in the use of monochloramine.

Although chloramines have been known since 1890 and were first used in water treatment in Canada in 1917 and used in a number of cities in the late 1920s in the United States, it is relatively unknown by the general public (1). A search of biological and horticultural journals reveals no information on the use of chloramines as disinfectants in horticulture. Jefferson Parish, Louisiana, has used monochloramine as the sole disinfectant for drinking water for over 30 years (Montgomery, James M., Consulting Engineers, Inc. 1981. Alternative Disinfectants for Trihalomethane Control: A Report to MWD, Dec: 2-36, unpublished). The city of Denver, Colorado, has used chloramines for water disinfection for over 70 years (1). The city of San Diego has converted from chlorination to chloramination as recently as 1982. The Metropolitan Water District of Southern California (MWD) converted to chloramination November 1, 1984 (personal communication with the MWD, May 31, 1984). The purpose of this change was to reduce the production of trihalomethanes, which are suspected carcinogens. Trihalomethanes are produced when chlorine reacts with trace organics in water supplies. Monrovia Nursery has been chloraminating its recycled water since the treatment plant's inception in 1979. MWD will be using monochloramine, because it does not have the typical chlorine taste or odor, and is more acceptable than chlorination of water.

Chloramine is the general term for any of the three forms: monochloramine, dichloramine, and trichloramine. Monochloramine (NH_2Cl) forms when chlorine reacts with ammonia in a Cl:N ratio of 5:1 or less. When the ratio of Cl:N is greater than 5:1, dichloramines and trichloramines begin to form.

MATERIALS AND METHODS

Two methods of evaluating the bacteriacidal qualities of

monochloramine were used: a) artificial inoculation of monochloramine solutions with a portion of old propagation medium, and b) actual field use of the disinfectant for dipping pruning shears. Samples of the solutions were withdrawn at different intervals of time and inoculated on nutrient agar in petri dishes by dipping an L-shaped glass rod into the sample and smearing the unfiltered, undiluted solution over the surface of the agar. The petri dishes were then placed in an incubator at 27°C (81°C) or 30°C (86°F) for periods of 24 to 96 hours. Individual colonies of bacteria were counted at the end of each incubation period.

For artificial inoculation, 20 cc of spent propagation medium (8 perlite:1 peat) was macerated in a blender with 250 cc of tap water. The suspension was added to a 1 liter volumetric flask, ammonium sulfate added, dissolved; followed by the addition of sodium hypochlorite solution and water to bring to volume. This resulted in a heavily contaminated sample having a turbidity of 85 ntu. Samples were withdrawn at intervals of time and transferred to nutrient agar in petri dishes. The inoculated dishes were then incubated.

For evaluation under actual field conditions, several concentrations of the disinfectants were made up, and poured into containers for dipping pruning shears. The solutions were not changed during the entire day. This resulted in "zero" contamination initially with the solutions gradually increasing in contamination as the day progressed. This is in contrast to the artificial inoculation where the solution was highly contaminated initially. The artificial inoculation delineates the efficacy of the product as a bacteriacide based on the longevity of exposure of the organisms to the disinfectant. The field evaluation, in contrast, has continuous re-inoculation every time the shears are dipped.

The corrosiveness of some of the solutions was tested by partially immersing a 7.6 cm (3 in.) × 2.5 cm (1 in.) piece of sanded degreased, cold-rolled steel bar. After 192 hours, the bars were removed and observed for pitting and corrosion.

The phytotoxicity of the solutions were tested by spraying the disinfectant on the bare roots and the tops of tomato plants grown in pots. Another test evaluated 340 and 680 mgl^{-1}(ppm) monochloramine sprayed on bare roots of five different ornamentals. The solutions were sprayed to wet the surfaces of all roots surrounding a 2832 cc (1 gal.) container root ball. Observations for phytotoxicity were made 8 days after spraying the solutions.

RESULTS

The efficacy trials indicated that propylene glycol, propylene glycol + antibiotics, and 8-hydroxyquinoline sulfate were poor disinfectants, whereas Physan, isopropyl alcohol and monochloramine were excellent (Tables 1, 2, 3, 4). These tests verified our previous tests indicating that isopropyl alcohol is effective. With the field condition test, where there was continual contamination of the solutions, the 340 mgl^{-1} monochloramine solution became progressively more contaminated with time and failed to control the increasing numbers of organisms (Table 3). In contrast, the 680 mgl^{-1} monochloramine provided excellent control of the microorganisms, even under progressively greater contamination with time. The artificial inoculation test demonstrated that efficacy of monochloramine increases with increasing concentration and time. After 30 minutes, the 680 mgl^{-1} solution samples failed to produce any colonies of bacteria (Table 4). These tests indicated the slower, but more persistent nature of monochloramine in providing disinfection under conditions of high contamination.

Table 1. Efficacy of disinfectants for shear dipping under field conditions

		Bacterial colonies/dish (48 hrs. @ 27°C)			
Disinfectant	Minutes.[z]	105	225	340	580
Physan, 400 mgl^{-1}[x]		3	>6[y]	>9	9
Physan, 600 mgl^{-1}		1	2	2	2
Isopropyl alcohol, 70%		2	4	1	2
Propylene glycol, 2000 mgl^{-1}		>100	>7	>50	>50
Isopropyl alcohol, 70% + propylene glycol, 2000 mgl^{-1}		6	0	2	1
Streptomycin, 200 mgl^{-1} + Terramycin, 100 mgl^{-1} + Propylene glycol, 2000 mgl^{-1}		>50	17	22	>35

[z] Minutes after dipping began Solutions were used entire day without changing.

[y] Numbers preceded by ">" refer to coalescing colonies, making it difficult to count individual colonies

[x] mgl^{-1} = ppm

Phytotoxicity tests conducted with monochloramine on tomato plants indicated no phytotoxicity to the tops or roots to 250 mgl^{-1} monochloramine, whereas there was some phytotoxicity to isopropyl alcohol (Table 5). At 680 mgl^{-1}, monochloramine did not affect *Agapanthus* or *Asparagus*, but did affect *Brunfelsia*, *Cortaderia*, and *Lonicera* to a slight extent (Table 6). However, these tests applied considerably more solution to more roots than the very slight amount that would wipe-off a cutting blade of a shear.

Table 2. Efficacy of disinfectants for shear dipping under field conditions

Disinfectant	Hours [z]	Bacterial colonies/dish (96 hrs @ 27°C) 2.0	3 75	5 75	7.75
Physan, 600 mgl^{-1} [x]		>30[y]	5	10	14
Physan, 900 mgl^{-1}		1	6	3	7
Physan, 1200 mgl^{-1}		2	9	1	10
Isopropyl alcohol, 70%		1	2	2	4
Physan, 600 mgl^{-1} + isopropyl alcohol, 50%		1	>30	>30	1
Physan, 600 mgl^{-1} + isopropyl alcohol, 70%		2	1	3	3
8-hydroxyquinoline sulfate, 1000 mgl^{-1}		>60	>60	>30	>60
8-hydroxyquinoline sulfate, 2000 mgl^{-1}		>60	>60	>50	>60
8-hydroxyquinoline sulfate, 1000 mgl^{-1} + isopropyl alcohol, 50%		2	1	0	1
Monochloramine, 250 mgl^{-1}		1	1	2	4

[z] Hours after dipping begun
[y] Numbers preceded by ">" refer to coalescing colonies, making it difficult to count individual colonies.
[x] mgl^{-1} = ppm

Table 3. Efficacy of monochloramine under field conditions

Monochloramine	Time [z]	Bacterial colonies/dish (24 hrs at 30°C) 1100	1200	1300	1400	1500
340 mgl^{-1} [x]		2.3[y]	18 7	15.0	31 3	>49
680 mgl^{-1}		1 3	0.0	0 0	0.3	1.3

[z] Time of sampling. Start time: 800 hours.
[y] Means of 3 replicates
[x] mgl^{-1} = ppm

Table 4. Efficacy of monochloramine in artifically inoculated solutions.

Monochloramine	Minutes [z]	Bacterial colonies/dish (24 hrs. at 30°C) 5	30	60	120	180	240
0.0		167[y]	185	217	202	200	200
85 mgl^{-1} [x]		22	7	3	2	1	0 5
170 mgl^{-1}		19	2	35	0.3	0	0.5
340 mgl^{-1}		19	2	1	0	1	0
680 mgl^{-1}		22	0 3	0	0	0	

[z] Minutes after inoculation, sampling period
[y] Means of 3 replicates
[x] mgl^{-1} = ppm

The corrosion test indicated, unexpectedly, that 70% isopropyl alcohol was the most corrosive of the disinfectants and sodium hypochlorite, the least. Physan was more corrosive than the monochloramine, although neither produced any rust pitting as was evident with the alcohol (Table 7).

Table 5. Phytotoxicity of disinfectants on tomato plants [z]

Disinfectant	Phytotoxicity	
	Roots	Tops
Monochloramine, 250mgl^{-1} [y]	None	None
Isopropyl alcohol, 70%	*Fair*	*None*
8-hydroxyquinoline sulfate, 1000 mgl^{-1}	Slight	None
Check	None	None

[z] Pearson's Improved tomato
[y] mgl^{-1} = ppm

Table 6. Phytotoxicity of monochloramine on five ornamentals

Mono-chloramine	Root phytotoxicity rating[z]				
	Brunfelsia paucıflora 'Floribunda'	*Cortaderia selloana*	*Agapanthus africanus*	*Asparagus densiflorus* 'Sprengeri'	*Lonicera japonica* 'Halliana'
0 0	0 0	0 0	0.0	0.0	0.0
340 mgl^{-1} [y]	1 5	1 0	0 0	0.0	1 5
680 mgl^{-1}	1 5	1 0	0 0	0 0	1 5

[z] Rating method 0 = no roots affected, 10 = 100% of roots affected
[y] mgl^{-1} = ppm

Table 7. Corrosiveness of disinfectants to steel, 192 hours exposure

Disinfectant	Rating[z]	
Monochloramine, 250 mgl^{-1} [y]	3	
Isopropyl alcohol, 70%	6	(rust pitting)
8-hydroxyquinoline sulfate, 1000 mgl^{-1} + isopropyl alcohol, 50%	2	(surface fixation)
Sodium hypochlorite, 250 mgl^{-1}	1	
Physan, 600 mgl^{-1}	5	
Check, tap water	4	

[z] Rating by rank, 1 = least affected, 6 = most affected Ratings 2, 3, 4, 5 showed no pitting or rusting
[y] mgl^{-1} = ppm

Table 8. Cost of disinfectants, 1984

Disinfectant	U S $ per 3 785 liters (1 gal)
Physan, 600 mgl^{-1} [z] + Isopropyl alcohol, 70%	1 85
Isopropyl alcohol, 70%	1 81
8-hydroxyquinoline sulfate, 1000 mgl^{-1} + Isopropyl alcohol, 50%	1.56
Isopropyl alcohol, 50%	1 29
Streptomycin, 200 mgl^{-1} + Terramycin, 100 mgl^{-1} + Propylene glycol, 2000 mgl^{-1}	0 15
Physan, 600 mgl^{-1}	0 04
Monochloramine, 680 mgl^{-1}	0.01

[z] mgl^{-1} = ppm

CONCLUSIONS

Monochloramine at 680 mgl^{-1} appears to be a suitable replacement for 70% isopropyl alcohol. It provides equal or better disinfection, and is considerably less expensive (Table 8). A 680 mgl^{-1} monochloramine solution costs about $0.01/gal.(3.785 liters) compared with $1.81/gal.(3.785 liters) for 70% alcohol. Because the cost of monochloramine is so low, a nurseryman can frequently discard and replenish solutions without economic concern. These solutions can easily be made from locally available materials such as liquid pool chlorine (sodium hypochlorite) or Clorox and ammonium sulphate. Pool chlorine solutions deteriorate rapidly, and a supposedly 10% labelled chlorine solution may be close to 7%, as we found with 3-month old material. Consequently, it is wise to test the available chlorine with a test kit, or assume deterioration with time and adjust the make-up of the solutions accordingly. Monochloramine solutions should be made using a ratio of 2:1 Cl:N or less to assure sufficient ammonia to form monochloramine. Concentration of chlorine using liquid sodium hypochlorite should be based on percent available chlorine rather than percent sodium hypochlorite.

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COMPUTERIZED IRRIGATION AND ENVIRONMENTAL CONTROL SYSTEMS FOR GREENHOUSE PROPAGATION AND NURSERY PRODUCTION

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As our understanding has grown of the relationship between plant growth and environmental conditions, it has become a standard practice in nursery production and greenhouse propagation to exercise control over these *environmental conditions.*

The advent of computerized control systems has made possible the means whereby environmental conditions are monitored, and automatically modified per the operator's preprogrammed instructions. The complexity of this function is best and most effectively performed by the computer — leav-

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ing time for the operator (nursery/greenhouse manager) to perform his/her appropriate management functions. Not only can the computer perform the monitor and control functions, it can also generate a data base for the manager to manage from.

Why a computer? The key concept in nursery and greenhouse control is that every function is inter-related, in cause and/or effect, to other functions. For example, bench misting of cuttings should be at a frequency such that the cutting remains "turgid" or fresh, but we want to avoid excessive foliage wetting to prevent fungus diseases. Simply setting a time clock for 10 seconds "on", 5 minutes between cycles, is failing to take into account sudden cloud cover, sudden change in relative humidity, etc. Also, during daylight, the solar radiation varies, at its peak around noon, and influences the rate of evapotranspiration.

The goal of the person in charge of the propagation operation is for the highest quality and greatest quantity of production at the lowest possible cost of production. This requires constant and accurate monitoring of the environmental conditions and operation of the various control systems — a level of skill that is typically found only with the nursery/greenhouse manager. Add to this the requirement for around-the-clock monitoring and operation, and it soon becomes evident where the computer can assist the manager.

A computer, to date, does not have any form of intelligence. It simply is a storage bank of the operator's pre-programmed responses (open a vent, turn on valve #20, turn on lights, etc.) to external signals or programmed intervals (temperature, time of day, light intensity, etc.) The computer performs the function of scanning sensors as well as reading the operator's program, processing the information (it searches for the correct pre-programmed response), and executing a given command — all at a speed that is beyond human capability.

As an example, referring back to the bench misting of cuttings, assume the nursery/greenhouse manager has a computerized control system. The controlled or automated functions include:

— Mist system valves and pump
— Greenhouse roof vents
— Overhead heat
— Cooling pads (fan and circulating pump)
— Bottom heat on bench
— pH control — acid and base dosing for mist water source
— E.C. control/de-ionizer monitoring for mist water

source

To complete the system, the computer will monitor:
— Solar radiation
— Greenhouse ambient temperature
— Outside wind speed and direction
— Rooting medium temperature
— Supply water pH and E.C.
— Greenhouse relative humidity

The manager's task is now to load the computer with the relevant information regarding:

— Programmed combinations/sequences of valves/devices
— Duration of valve/device operations
— Frequency of valve/device operations
— Temperature set points for vent positions/cooling pad system activation, or heating systems activation.
— pH set points and which material to dose into water supply
— E.C. set point to trigger alarm and stop misting if deionizer loads up.
— Conditions under which the computer is to start, wait (later to resume when the condition reverses), or to stop a given operation or function.

In the example of bench misting, the program might include:

(GROUP 1) Activate mist valves sequentially, 10 seconds duration, every 10 minutes, start 07:00, stop 10:00; condition of operation (condition #1) —

START: line pressure greater than 90 p.s.i.

WAIT: line p. less than 90 p.s.i., OR relative humidity greater than 80%.

RESUME: line pressure greater or equal to 90 p.s.i. AND relative humidity less than or equal to 80%.

STOP: E.C. greater than 0.5 mmhos/ALARM.

(GROUP 2) Activate mist valves sequentially, 15 seconds duration, every 6 minutes, start 10:00, stop 14:00; condition #1.

(GROUP 3) Activate mist valves sequentially, 8 seconds duration, every 15 minutes, start 14:00, stop 18:00; condition #1.

Similarly, groups can be written for automatic operation of the water treatment equipment, greenhouse vents, heating and cooling systems, and so on. The application has been demonstrated here in a simplified and abbreviated manner. Remember that the computer integrates all the variables into one

control system, performing the monitor and control function with great speed and without taking time out for lunch, coffee breaks, holidays, etc. The nursery/greenhouse manager is now free to go about his/her duties.

Benefits.

— The computer performs *continuously* the monitor and control functions with speed and accuracy.

— Alarm signalling by the computer can advise the manager when his/her attention is required.

— The computer generates records of its operation for the manager.

— A print-out records events as they occur.

— Greater control of costs of production through precise and timely control; savings are commonly seen in energy (electricity, gas, fuel oil), manpower, water, fertilizers, pesticides, water treatment chemicals, etc.

— Higher quality plant materials and decreased loss of plants due to close control of the greenhouse or nursery environmental conditions.

Typical applications. Computerized control systems for nurseries and greenhouse are commercially available for:

— Mist propagation
— Hydroculture (hydroponics)
— Aeroponics
— Tissue culture/micropropagation
— Drip irrigation for pots and containerized stock
— Drip and conventional irrigation for field-grown stock
— Greenhouse environmental control

APPLICATION OF A MICROCOMPUTER IN A WHOLESALE NURSERY

KATHLEEN FAIRBANK and SERGE ZIMBEROFF

Santa Rosa Tropicals
P.O. Box 6183
Santa Rosa, California 95406

At our nursery we need to manage the complex scheduling that comes in hand with our production volume. In order to schedule the propagation of over three million plants, manage labor data of 30 employees, and handle over 100 orders a week, we gradually turned to the computer for assistance. Our first microcomputer was purchased in October, 1982. Shortly thereafter we needed another microcomputer to handle all the work that had been transferred onto the computer.

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There are four basic types of programs available to use on a microcomputer: *word processing*, *spreadsheets*, *database management*, and *graphics*. We use the first three types quite extensively.

Word processing programs allow the computer to act as a very sophisticated typewriter. A document written with a word processing program is extremely flexible. The user can type a document on the keyboard, get a permanent copy, easily revise it, and print it out again.

Spreadsheet programs allow the computer to act as an electronic calculator. The user can create and print reports with formulas in different locations on the form so calculations can be performed as other values are entered. S/he can then change the formulas or manipulate different data items and see how they affect the final results. For example, the user may want to make a sheet to calculate the labor costs of planting three different plant cultivars and the amount of time it takes to plant a flat. S/he would set up the general structure of the form and enter formulas for the calculations that need to be performed (see Table 1). Once the form has been set up s/he can enter the data and print it out (see Table 2). Workers' wages may be raised from $4.25 per hour to $5.00 per hour, or a way may be found to plant pyracanthas faster. With this form the user can test to see how each change will affect the labor costs per plant (Table 3 illustrates the affect of the wage change on the cost).

Table 1. Blank form initially set up to calculate weekly labor costs per plant

Labor Rate $

Plants	plants/ flat	hours	number planted	cost/pl cents	hours/ flat
Acer				@	*
Rhododendron				@	*
Pyracantha				@	*
Total		#	#	$	

Note: The formulas represented by each symbol is listed below:

@ $\frac{\text{labor rate} \times \text{hours}}{\text{number planted}}$

* $\frac{\text{hours}}{(\text{number planted})/\text{plants/flat}}$

add the column

$ $\frac{\text{total hours} \times \text{labor rate}}{\text{total number planted}}$

Table 2. Weekly labor costs per plant

Labor rate $4 25

Plants	plants/ flat	hours	number planted	cost/pl (cents)	hours/ flat
Acer	36	30	1800	7 08	0 60
Rhododendron	72	40	5040	3.37	0.57
Pyracantha	36	10	3600	1.18	0.10
Total		80	10,440	3 26	

Table 3. Weekly labor costs per plant

Labor rate $5 00

Plants	plants/ flat	hours	number planted	cost/pl (cents)	hours/ flat
Acer	36	30	1800	8 33	0 60
Rhododendron	72	40	5040	3 97	0 57
Pyracantha	36	10	3600	1.39	0 10
Total		80	10,440	3 83	

Data base programs allow the user to store and manipulate many bits of information. They are similar to filing cabinets full of employee records. Once the records have been filed, information such as addresses, salaries, and annual tax records can be taken and used for reports or calculations. They could also handle payables or receivables. For example, suppose the user entered information about each customer, what they have on order, and what they have ordered in the past. From this information invoices and reports can be printed. The reports can include what and how much each customer has ordered in the past, what a customer has on order, who has a certain plant on order, and a list of the plants to be shipped on Friday.

Graphics programs allow the user to see a pictorial display of data s/he has entered. Often pictorial displays are easier to interpret and it is easier to see trends than with raw data.

At our nursery we have found many uses for each type of program. Below I outline some of the uses we have found for each.

We use a word processing program for any documents which change often but where the basic format and information remain the same. (We cannot do any calculations with our word processor.)

I. Word processing
   A. Letters of recommendation
   B. Business letters
   C. Price list — plant availability
   D. List of the plants we offer

Spreadsheets are also good for documents which have a basic format that doesn't change. Data can be entered on the document and calculations performed with that data.

II. Spreadsheet
    A. Sales summaries
        1. By month
        2. Comparison with previous years
    B. Cost accounting
    C. Inventory valuation
    D. Production records
        1. Yield
        2. Weekly plant counts
        3. Efficiency calculations
        4. Individual plant percentages
    E. Fertilizer calculations

There is a special advantage using the spreadsheet for production records. Our department supervisors enter the data, not the main office. Therefore we have current data and we skip the time delay required for middle management to enter this data.

We use our database management extensively, for any application where we have many records of related information.

III. Database management
    A. Reference index
        1. Search
            a. Genus
            b. Family
            c. Author
            d. Topic
        2. Print cards
    B. Plant scheduling
        1. Print out cards to show when and how many of each plant to propagate
        2. List the amounts of each plant we want to finish throughout the year
        3. Print schedules showing quantities and timing for each plant so that the right stages are ready in the right numbers and at the right time of year
    C. Order and inventory control
        1. Enter and print single or multiple orders
        2. Update inventory

3. Get reports
    a. What did customer 'X' order in March last year
    b. Who has plant 'V' on order for next month
    c. What do we need to ship on Friday
    d. What is the current inventory
    e. What does customer 'X' have on order

D. Printing special forms
    1. Phytosanitary forms
    2. Waybills
    3. Shipping labels

Although we don't have a graphics program we have managed to mimic one with the database management program to print out our shipping labels with block letters.

IV. Graphics
    A. Graphs
        1. Pie
        2. Bar
        3. Line
    B. Shipping labels
    C. Data trends

Everything we have accomplished with our microcomputer can be done by anyone with a background in high school algebra (and a little background in computer theory). However, be aware that it is an incredibly time-consuming process to get these programs running. We have been working on the database programs for over a year and a half!

New software allows different programs to be integrated with one another. Once the data have been entered they can be used by the different programs, and the user doesn't have to reenter for each type of program.

If you decide to buy a microcomputer for your business, you should buy it from a local dealer because you might have problems with the hardware (the actual computer system) or the software (the programs) and need someone nearby to answer your questions. You should first decide, however, what you want to do with a computer, then find the programs that seem most likely to do those tasks, and lastly purchase the "toys," the computer and all of its related parts which can use those programs.

Our nursery had its eleventh birthday this past July. We have grown slowly and steadily and there is one thing we

agree upon; we don't always love our computers, but we could not accomplish what we are doing without them.

PHIL BARKER: I would like to ask Gene Blythe of Monrovia Nursery about the possibility of micropropagation of sequoias. In your production program have you chosen to use cuttings rather than micropropagation?

GENE BLYTHE: Up to this point we have been using exclusively cutting propagation for the sequoia cultivars. We have been experimenting with tissue culture and feel that it will be feasible. We can produce large quantities of plants throughout the year this way, whereas with cutting propagation plants can only be produced at one time per year. Our lab is under construction now and we will be opening it in another month and at that time we will most likely begin *in vitro* propagation of sequoias, at first to supplement the cutting propagation, and later on probably to take over the propagation entirely. We find it a great advantage to stagger the production through the year.

BRUCE BRIGGS: My question has to do with a tree developing a central leader in a hurry and when it does not do this. We notice a trend with Colorado blue spruce or Douglas fir when grown from cuttings that there is a relationship between the quantity of roots and how quickly it develops a central leader. If you can get a mass of roots growing immediately you get a nice central leader. But if you get only one or two roots coming out you have to wait a few years for a mass of roots to develop before you get a central leader. Have you noticed this with sequoia?

GENE BLYTHE: No, we find that even though we may begin with material from lateral branches that we do get production of a strong leader without any problem. With 'Majestic Beauty' it does take a little bit more training than with other cultivars, but we have not run into any problems at all in developing a good central leader.

BRUCE BRIGGS: We inject chlorine into our water system for sanitation and have for many years and we also have, on the other hand, injected fertilizers, such as ammonia sulfate into the water. We can raise chlorine up to 25 parts per million, inject it through the water system, put it in a container that has soil, and take a leachate coming out of the bottom and it will remain pretty near 25 parts per million. Normally it should be zero because of the soil. My question is then does it pick up some of the other parts which are stable?

CONRAD SKIMINA: Yes. In fact, you are making monochloramine, because if you have ammonium nitrate or ammo-

nium sulfate in the liquid fertilizer in your water system, the chlorine will immediately react with the ammonium compounds. It is an almost instantaneous reaction. However, you should have the ammonia in the water first before you inject the chlorine, although that is not particularly important in your situation. It is for the cities with drinking water because they do not want to form tri-halomethanes. They have to have the ammonia in the water first before they inject the chlorine, otherwise the chlorine immediately reacts with the organic compounds and forms tri-halomethanes and then it is too late to eliminate the tri-halomethanes. So they inject the ammonium compound first, or simultaneously with the chlorine, and it is an instantaneous reaction with the ammonia, forming chloramine. You have chloramine in your water system and that is why you have the stability of the disinfection. We have used monochloramine in our water treatment plant since its inception in 1979.

VOICE: Are viruses and fungi controlled by chloramines?

CONRAD SKIMINA: Since cities are very particular about drinking water, they are going to be sure that chloramines have disinfection capabilities for bacteria and fungi. I am sure the fungi are controlled. And I know for a fact, that if you have some nematodes and put monochloramine on them, they stiffen up in 60 seconds. Nematodes are hard to kill with straight chlorine. So we know that we can kill nematodes and bacteria, as well as the fungi. Concerning the viruses, I have no information. Viruses are difficult to control. With quaternary ammonium compounds you control some viruses, but with monochloramine I really don't know.

VOICE: What effect does chloramine have on your skin compared to bleach?

CONRAD SKIMINA: Well, straight bleach would be hard on the skin because it also contains sodium hydroxide. In a diluted state, when making monochloramine, I don't think there will be a problem. I don't think it would be as bad as alcohol for drying out the skin. Of course, you might be using 1000 ppm monochloramine. When you get up to really high concentrations I do not know what the problems might be. However, I sprayed 680 ppm on plant foliage and had no phytotoxicity problems, but did find phytotoxicity with 10 ppm monochloramine dripping on one spot on one leaf continuously for a ten hour period. I did get blanching in that one spot from 10 ppm, but with just occasional exposure I don't think there will be a problem.

BRUCE LANE: I was wondering if you have considered using this chlorine to replace your 10 ppm surface chlorine solution?

CONRAD SKIMINA: Well, we can, but chlorine gas is very cheap. As a prewash water for our cuttings — we inject chlorine gas into a continuously flowing stream of water into a washtub; overflowing so we have a purging of any debris, organic matter or organisms, and a continuous replenishment of a fresh 20 ppm chlorinated solution. A tank of chlorine (150 pounds) is going to last you ages at 20 ppm. It is very cheap. It is a lot less than a penny a gallon. A tank of chlorine provides considerably more chlorine than we can use in a year. I was amazed at how little is used at that concentration.

VOICE: For a large operation you can afford to have gaseous chlorine injected, but for a small operation would you use it?

CONRAD SKIMINA: Well, it's going to cost you more for the demurrage on the tank than it is for the chlorine. The usual charge is $6 a month for demurrage. The chlorine cost is insignificant. If smaller tanks are unavailable, you are going to have to go to a sodium hypochlorite solution. That is more difficult to handle; you need injection equipment and the material is very alkaline. Or, you could go to monochloramine, as a last resort.

VOICE: What is the reliability of sensors in the computer controls?

DAVID MEGEATH: It depends. With soil moisture sensors, you will get arguments from one end of the spectrum to the other as to the reliability of them. A system like this takes maintenance. You cannot just stick a sensor out there and expect it to perform routinely for ten years. You have to monitor them on a maintenance basis. We have worked, for example, with flow meters in our computer systems, we have worked with weather stations and so on and we find that in the operation of system, maybe as often as every three to six months, you want to make sure the sensors are really operating. Now some computer systems have the ability to check on their own for malfunctioning devices. An example might be a water meter. The computer has been given a command to start irrigation somewhere and it knows that the flow meter is supposed to be spinning and giving a contact or some sort of signal, and all of a sudden there's nothing happening. The computer will lock out and say "I am not watering", and there are systems that will feed back and say "unopen valve." There's no clear answer to your question — the reliability of computers varies also.

VOICE: Are there computer programs available, prepackaged so to speak, or is this one of those deals where you have to pay unbelievable amounts of money to have someone come in and program it for you?

DAVID MEGEATH: We have both. I deal with preprogrammed packages. There are systems that you buy off the shelf that are intended for greenhouse environmental control, for hydroculture, or for irrigation. I deal primarily with the irrigation-type systems — automation. Let us consider a standard package from a service point of view of the manufacturer — you get yourself into a lot of trouble the minute you start customizing the system. With what I deal with, it is a standard package, software and hardware, so that our service technicians are able to go from Florida to Arizona to California to Hawaii to Italy and so on, and it's exactly the same package wherever they go. The only thing that is varied is the operator's programming within the limits of that software.

VOICE: Do you find a lot of problems with heat, humidity, and dust you find in the nursery with your computer systems and hardware?

DAVID MEGEATH: That is another reason for going to a device that is built for commercial control. What I deal with is all hermetically sealed units. The keypad of a small controller which is computerized is a membrane keyboard as opposed to having push-buttons, like a little calculator would be. There's a lot of thought that goes on as to what environment it has to work in. We work with mil-spec components so our components are rated at temperatures that are far in excess of the typical greenhouse range. We have systems in Arizona working, for example, on 10,000 acres of drip irrigation on cotton — and it gets hot in Gila Bend. We build in lightning protection, surge protection, etc. When you have fertilizers and acids and all sorts of wild chemicals you are spraying around the nursery, you've got to think about that. So, there are systems that address environmental problems and take care of them.

PHIL BARKER: I suppose it's fair to ask, given the fact that computers are with us and will be, what type of a track record have you built up so far showing improved productivity of crops through the use of some of these computer systems?

DAVID MEGEATH: The question is, "Do we have any track record, any documentation. We say the computer can give you all these benefits — show me, show me." My experience has been primarily with irrigation applications which basically works from containerized nursery growing on out, as I mentioned, to 10,000 acres in agriculture. The computer cannot do it by itself. This is a qualification to the answer. If

you don't have excellent hardware that the computer is operating, whether it be mist propagation or drip irrigation or whatever we are working with, we are looking at the uniformity of the complete system. To get an increase in production is possible only when the computer is hooked to a system that is of a level of technology that allows it to do its job. I have seen an application in nursery containerized growing with uniformity of plant materials that is unequaled, but that is because there is a drip irrigation system, in combination with the computer, automating the application of the water, and the application of fertilizer. The savings are there, the real increase in yield comes from the correct and proper program. You have probably all heard the phrase, "garbage in — garbage out", on computers. Eventually, sooner or later, it comes back to the operator running the computer.

SOIL MIXING FOR SMALL GROWERS

JOHN E. RODEBAUGH

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When the current soil mixing systems were reviewed for the preparation of this report, it became readily apparent that very few changes in soil mixing systems have occurred during the past 25 years. The purpose of a soil mixing system should be to achieve a uniform blend of selected dry chemicals, or chemicals which have been placed in aqueous solution with bulk ingredients. Any system which can do this in a reasonable period of time is acceptable and probably has been used at some time in the industry.

The modified concrete mixer is the most common soil mixing machine in use in the medium sized nurseries and greenhouses. With this piece of equipment a batch type system is developed and when the ingredients are added to each batch accurately, the results are quite uniform. Some growers even steam pasteurize or fumigate their soil in these mixers. One of the major disadvantages is the relatively long mixing and unloading time which results in substantial grinding and pulverizing of the bulk ingredients. This is aggravated when either sand, pumice, or lava rock is one of the bulk ingredients.

The second most common mixing system is the use of a tractor with a bucket to blend the ingredients on a hard sur-

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The second most common mixing system is the use of a tractor with a bucket to blend the ingredients on a hard sur-

faced slab, or even the ground, until the mix is uniform. Usually turning the pile of ingredients three times provides a uniform blend. This system has also proven to be quite efficient and reliable. The major disadvantage is the space involved and, if the mix is to be sterilized, it must be loaded into a trailer and steamed, or covered with a tarp, and treated with gas.

A few growers are using custom built soil mixers which greatly reduce the mixing and unloading time. Their cost is usually quite high compared to the concrete mixer.

The smaller growers are using minature modifications of these mixing systems or are buying premixed soil from services which custom blend the materials to the growers' specifications.

When the small grower increases to the size where he needs more than several yards of soil per day, he has to decide if he can afford to continue to mix his own soil. At this point, a substantial investment in equipment and machinery is involved. A tractor with a bucket loader is usually purchased and sometimes a forklift is also used to help service the mixing equipment. A mixer of some type must also be purchased, or a hard surfaced slab prepared, so that the soil can be mixed in either a pile or a windrow. In addition to the equipment storage, space for the bulk ingredients must be provided and, in many cases, this area has to be subtracted from the land available for production. In urban areas, where land costs are high, this represents a significant loss.

When all of the costs are given a realistic value, many growers will find that they do not save money by mixing their own soil. At this point, the custom soil mixer can provide a real service to the grower. In some areas we understand the service has been expanded to one of providing custom blended pasteurized soil in nursery flats, or greenhouse pots, which are stacked on a pallet and delivered to the nursery ready for planting. It is anticipated that services of this type will become more common in the future.

In summary, there seems to be no one soil mixing system for the smaller grower that is far superior to all others. Any system that produces a uniform sanitary soil mix is acceptable.

WESTERN REGION 1984 CURTIS J. ALLEY MERIT AWARD

Presented by Bruce Briggs at the
Western Region Annual Banquet

The Western Region's 1984 Award of Merit receipient received a BS degree in Horticulture from Oregon State University in 1936, where he was an outstanding horticulture student. He continued to work on advanced degrees at Oregon State University into the late 40's.

After serving in the military in European combat during W.W. II he worked in the ornamental horticulture field at the California Nursery Co., Fremont, California. Following further work experiences he continued his educational activities at California Polytechnic State University, San Luis Obispo, where he became Department Chairman in Ornamental Horticulture.

Some of the awards he received in recognition for his outstanding teaching abilities are: The California Association of Nurserymens' Leadership Award, Honorary Future Farmer (FFA), Outstanding Teacher Award by American Society of Horticultural Science, and the American Florists' Education Award. These are only some of his accomplishments in the field of education.

In this area of dedication to education, I have had the occasion to work with him. An incident I remember was at a dinner meeting at the Eastern Region of the IPPS. He made it known he would seek out a table of students he had not spoken to before to possibly exchange ideas and to better understand students and their needs throughout the United States.

He actively worked in promoting the IPPS. He placed our logo, "To Seek and to Share", on each Region's podium plaque and on our lapel buttons. We recognize him for his work in making the gavel, which is made up of representative woods from countries of the world having IPPS Regions. This is a symbol which has been passed on into the International Board on which he has been a member.

I am sure some of the countries like Australia and New Zealand recognize him for the many students of theirs he has taught in the U.S. and sent back to their countries richer for having worked with him. Also, he will be remembered for his description of the "Tail Pipe Cooker", used while he traveled by car in New Zealand and elsewhere.

Each year at New Year's Day we are reminded of his many hours of work spent on the Rose Parade working with

Cal Poly students to develop their floats.

It is a great honor for me to present to O.A. "Jolly" Batcheller, an outstanding person, with so many awards and past dedications to the principles of IPPS, with the 1984 Western Region Award of Merit.

TISSUE CULTURE PROPAGATION OF KIWIFRUIT

A. STANDARDI and F. CATALANO

Fruit Science Institute
University of Perugia,
Perugia, Italy

Abstract. Since kiwifruit cultivation is increasing rapidly in Italy, better propagation methods are needed. A method is described for tissue culture propagation of kiwifruit by meristem-tips dissected from resting buds and actively growing shoot tips using a modified Lepoivre medium A multiplication rate of 5 3 was achieved for each 30-day subculture period Single shoots, 30 to 35 mm long, with 2 to 4 leaves, could be rooted in paperpots containing a soil-like mixture, wetted by half-strength macro-micro nutrient solution After 3 weeks, about 90% of shoots rooted and within 60 days all developed into plants 150 to 200 mm long with 6 to 10 leaves.

Kiwifruit (*Actinidia chinensis* Planch.) is a relatively new and increasingly important commercial crop in Italy. In 1978 the cultivated area was only 800 hectares, but this had increased to 1,860 hectares by 1983. Of this area, 816 hectares were in production with the remainder in young, non-bearing plantings. The distribution of the plantings is 62% in the north (Po Valley and near the French and Austrian borders), 30% in central Italy (near Rome) and 8% in the south and on Sicily and Sardinia. Most plantings (72%) are less than 1 hectare; the average area per planting is larger in central Italy and in the southern part than in the northern part (16).

'Hayward' is the leading pistillate cultivar (72%) with 'Abbott' and 'Monty' the other major ones. The staminate cultivar generally used is 'Tomuri', but in more than 50% of the orchards the pollenizer is unknown. Drip or spray irrigation is used on 81% of the farms. For new orchards, plantlets from self-rooted cuttings and/or from grafting on seedlings are usually employed.

These vegetative propagation techniques require 2 to 3 years in order to obtain commercial plants. Furthermore the traditional propagation methods are not very productive. Consequently the possibility of propagating kiwifruit by *in vitro* techniques was tested. Several preliminary trials on kiwi propagation *in vitro* have been carried out (2, 5, 6, 7), but these methods were not fully effective for commercial applications.

In the Fruit Science Institute of the University of Perugia, several investigations have been carried out since 1979 regarding the micropropagation of 'Hayward' and 'Tomuri' kiwifruit (11, 12, 13, 14). In this report we describe the stages of kiwi micropropagation indicating that this technique can be employed as an alternative method of vegetative multiplication.

METHODS AND RESULTS

Stage 1. Choice of initial explant and establishment of the aseptic culture.

As initial explant we have used both meristem-tips (0.2 to 0.5 mm long), and apical shoots (10 to 15 mm long), because presumably they have the highest genetic stability (1, 4, 15). The woody shoots with buds were collected during the winter, sprayed with benomyl (0.3 g/liter), and then stored at 1°C.

From these buds the meristem-tips were excised during March and April, using the following sterilization method, the best among several tested. Initially the woody shoots were dipped for 5 minutes in ethanol (80% v/v), soaked for 20 minutes in a solution of 4% calcium hypochlorite and rinsed twice in sterile distilled water. The meristem-tips were dissected aseptically under a stereo microscope.

Single meristem-tips were placed in vials (15 × 100 mm) containing 4 ml of the medium listed in Table 1. These cultures were placed in the dark overnight and then transferred to a growth room at 24 ± 1°C and 2.1 klux of light provided by Philips TL 40W/33 and Sylvania Grolux fluorescent lights. Light was provided for 1 hour out of every 3 the first day increasing to 16 hr light and 8 hr dark after 15 days.

We preferred using meristem-tips rather than apical shoots as initial explants because the dormant buds (a) can be stored at low temperatures extending the time at which cultures can be initiated, (b) can be sterilized more easily than herbaceous shoots, and (c) can produce virus-free plants if very small (0.2 to 0.3 mm) meristem-tips are taken. However, the dissection of meristem-tips requires more time and care than apical shoots and the meristem-tips take longer before producing the first shoot.

Within one week of the beginning of the culture, 30 to 40% of meristem-tips are usually contaminated, but this value rises to 60 to 70% when apical shoots ar employed as initial explants. After 20 to 40 days, meristem-tips developed into rosettes 5 to 10 mm high with 2 to 4 leaves. Increasing naphthaleneacetic acid (NAA) levels in the establishment medium resulted in callus formation at the base of the rosette. Indole-3-acetic acid (IAA) at 0.005 and 0.05 mg/liter was no better than NAA, but produced callus at 0.5 mg/liter.

Table 1. Composition of organization, proliferation and rooting-acclimatization media

COMPOUNDS	STAGE 1 mg/l	STAGE 2 mg/l	STAGE 3 mg/l
MACROELEMENTS			
KNO_3	1,800	1,800	900
$Ca(NO_3)_2$ $4H_2O$	1,200	1,200	600
NH_4NO_3	400	400	200
$MgSO_4$ $7H_2O$	360	360	180
KH_2PO_4	270	270	135
MICROELEMENTS			
$FeSO_4$	27.85	27.85	27.85
NaEDTA	37 25	37 25	37 25
$ZnSO_4$ $7H_2O$	10	8.6	8 6
H_3BO_3	10	6 2	6 2
$MnSO_4$ H_2O	18	1 0	0.025
$CuSO_4$ $5H_2O$	0 025	0 025	0.025
Na_2MoO_4 $2H_2O$	0.25	0.25	0 25
KI	0	0.08	0 08
$CoCl_2$	0	0.025	0 025
ORGANIC COMPOUNDS			
Myo-Inositol	100	100	100
Nicotinic acid	5	0	0
Glycine	2	0	0
Pyridoxine HCl	0.5	0	0
Thiamin HCl	0.5	4	4
Folic acid	0.5	0	0
Biotin	0 65	0	0
PHYTOHORMONES			
Gibberellic acid* (GA_3)	0 1	1 0	0
Benzyladenine (BA)	0 5	1.0	0
Naphthaleneacetic acid (NAA)	0 02	0	0
Sugar	20,000	20,000	0
Agar	7,000	7,000	0
pH**	5 8	5.5	5 5

All the media were autoclaved at 110°C for 25 and 30 minutes (stages 1, 2 and 3, respectively)
* Added after autoclaving by millipore filter (micron 0 22).
** Adjusted by 0.1 N NaOH in agar-media and by $CaCO_3$ in soils

Stage 2. Proliferation.

For the first subculture 25 × 160 mm vials containing 20 ml of proliferation medium (Table 1) were used. Culture conditions were 24 ± 1°C with a photoperiod of 16 hr and light intensity of 2.1 klux from fluorescent lights.

After 20 to 30 days each rosette developed into one or two shoots, 10 to 20 mm long, with 2 to 4 leaves (Figure 1). Five of these shoots were placed into 500 ml jars containing 200 ml of medium (Table 1). After 30 days in this proliferation medium, in the same environmental conditions mentioned above, each shoot produced an average of 5.3 new shoots. Attempts to

increase the multiplication rate were carried out by testing 15 macro- and micronutrient combinations, selected among media formulations suggested by other authors (3, 8, 9, 10) for several woody plants. However, the medium formulation listed in Table 1 showed the best proliferative activity. Some nutrient conditions caused a higher multiplication rate, but the resulting shoots did not root and/or showed a large callus at the base.

Four different concentrations (0, 0.1, 1, 10 mg/liter) of both gibberellic acid (GA_3) and benzyladenine (BA) combinations were tested without mineral nutrient modifications. The best results were obtained when both growth regulators were present at 1 mg/liter (Table 2).

Figure 1. Kiwifruit shoot developed from rosette after 3 weeks on proliferation medium.

Table 2. Multiplication rates observed in the various hormonal combinations.

BA concentration (mg/liter)	GA_3 concentration (mg/liter)				
	0.00	0.01	0.10	1.00	Mean
0.00	1.3	1.6	1.4	1.6	1.5
0.10	3.5	2.3	2.9	2.8	2.9
1.00	3.6	4.0	3.9	5.0	4.1
10.0	1.8	2.0	1.5	1.5	1.7
Mean	2.6	2.5	2.4	2.7	—

GA_3: Gibberellic acid.
BA: Benzyladenine.

Stage 3. Rooting and acclimatization.

For rooting purposes shoots 30 to 35 mm long with 2 to 4 leaves were used. Culture conditions were the same as for Stage 2. Initially 5 shoots were placed in each jar containing 200 ml of rooting medium (Table 1) with indole-3-butyric acid (IBA) at 1 mg/liter. With this treatment, only 37.5% of the cuttings rooted and the new plantlets had a large basal callus. The rooting percentage improved to 75% when the shoots were dipped in sterile solution of 10 mg/liter IBA for 5 seconds and then placed in agar medium (Table 1) without auxin. When the shoots were placed for 10 days in a medium with 1 mg/liter IBA and then transferred to auxin-free medium, 80% rooting was obtained. After 4 weeks, these plantlets were transplanted into pots containing a peat-sand mixture (1:1) and left in the growth room under a plastic tunnel with decreasing humidity for 10 days.

Then the pots containing the plantlets were transferred to a greenhouse under intermittent mist. Although rooting had been satisfactory, many of the plantlets died during this step.

In an attempt to overcome this problem, the following method was tested. After proliferation, single shoots were placed in paperpots (38 × 35 mm) containing a soil-like substrate (Torboflor) wetted by Stage 3 macro and micro elements (Table 1) and with a pH level of 5.5 adjusted by powdered marble ($CaCO_3$). Then, 20 paperpots were placed in closed glass jars, (Figure 2) sealed by Parafilm and transferred to growth room conditions. After about 3 weeks, the emergence of physiologically functional roots occurred. This was detected by the growth restart of plantlets (Figure 3). At this time the jar caps were removed and containers were left in the same growth room and the plantlets were sprayed periodically with water. After 2 weeks, the plantlets were transplanted to pots containing Torboflor, without disturbing the root systems, and then transferred into a greenhouse. This method avoided root system acclimatization stress. As a consequence, about 90% of the shoots rooted and developed into plantlets that reached heights between 15 and 20 cm with 6 to 10 leaves in 2 months.

OTHER OBSERVATIONS

Shoots of 'Hayward' kiwifruit subcultured monthly for a period of over two years and those subcultured only 3 to 4 times were compared. Increase in the number of subcultures was accompanied by an increase in multiplication rate and a progressive decrease in shoot length and callus weight at the base of the explant. The rooting ability of shoots and the number of chromosomes found in the root apex remained

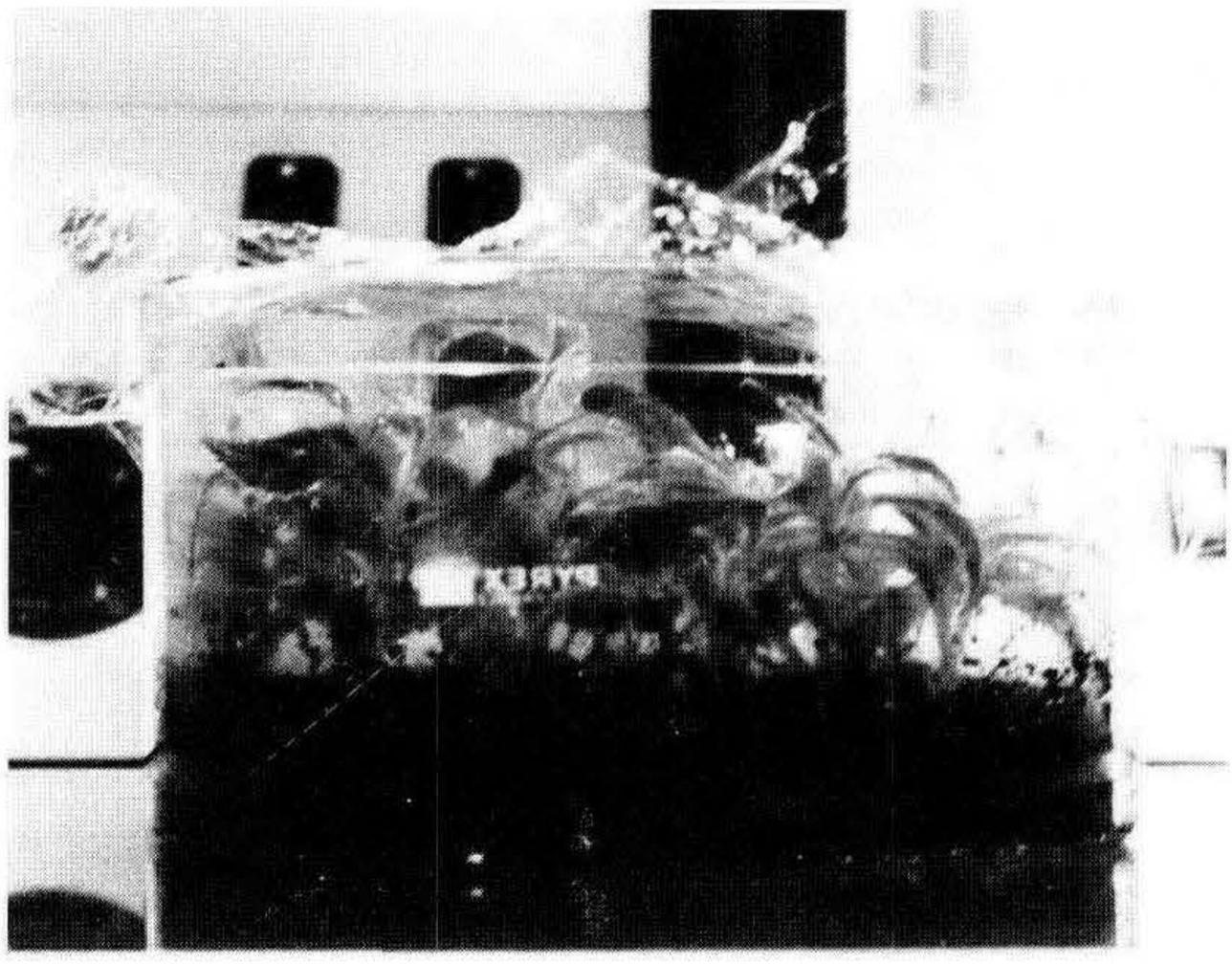

Figure 2. Shoots being rooted in "Torboflor" contained in 38 × 35 mm paper pots placed in large, closed glass container.

Figure 3. Rooted plants in paper pots ready to be transplanted to larger containers 5 weeks after beginning of rooting.

constant. The following mean values were measured after the third subculture: a) multiplication rate, 3.4; b) shoot length, 4.4 cm; and c) callus weight, 0.50 g; while after 28 subcultures these were 5.8, 3.5 cm and 0.23 g, respectively. Similar results were found with explants from the 4th and 29th subcultures and they also showed no correlation between multiplication rate and shoot length. There was no significant difference in rooting ability in shoots obtained at different culture ages, except for the average number of roots per rooted plantlet, which was higher in plantlets obtained after the 28th subculture (Table 3).

Table 3. Rooting ability of shoots after 3 and 28 subcultures

Number of subcultures	Means of 50 shoots*		
	Rooting (percent)	roots/plant (number)	root/length (mm)
3	88.0 a	3 8 a	35 a
28	96 0 a	5 6 b	31 a

* Mean separation within columns by Duncan's multiple range test, 5% level

It seems, therefore, that kiwifruit shoots have good genetic stability and do not lose their morphogenetic capacity, even when kept for a long period of time in proliferation phase in the conditions described here. The increase in multiplication rate and decrease in callus weight that accompanied an increased number of subcultures show that 'Hayward' is well adapted to *in vitro* culture conditions. Finally these satisfactory results permit us to believe that kiwifruit can be vegetatively propagated by the *in vitro* culture technique. Nevertheless, behavior in the field of micropropagated plants must be checked and compared with that of plants originating from traditional methods of multiplication. For this purpose, in 1983, micropropagated plants, and those from self-rooted cuttings, were planted in the field and are being observed to evaluate their field performance and phenotypic stability.

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MICROGRAFTING: A TOOL FOR THE PLANT PROPAGATOR

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Micrografting is a relatively new technique for the production of grafted plants *in vitro*. It was developed by Murashige *et al.* (4) in the early 1970's to rid *Citrus* cultivars of viruses. This technique can be more effective than thermotherapy, apical meristem culture, or embryogenesis (*in vivo* or *in vitro*) in the elimination of viruses from desired cultivars. Micrografted plants bypass the juvenile phase which does not occur if viruses are eliminated through nucellar embryony in *Citrus*.

Micrografting requires very few materials, but it does require precise manipulation of small tissues and plant organs. Seeds must be available that can be sown aseptically *in vitro* and thus serve as seedling rootstocks. Shoot-tips (0.1 to 0.2 mm in length) are taken from surface disinfested scions and placed on the decapitated seedling under aseptic conditions (Figure 1, a-d). If successful, the grafted plant develops and is then tested for the presence of viruses.

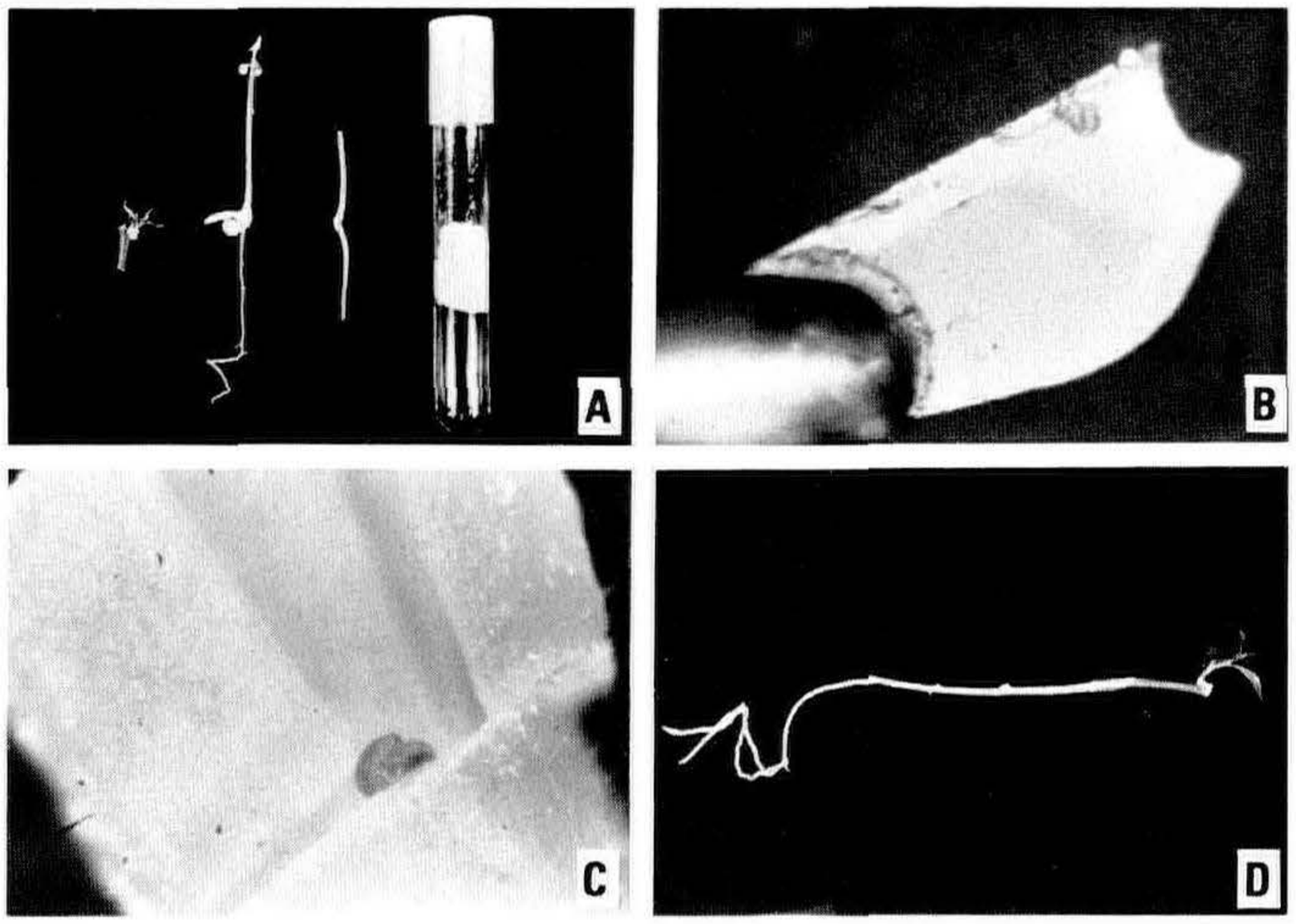

Figure 1. A — Materials needed to perform a micrograft, from left to right: a shoot-tip source, an aseptically-sown seedling, the seedling prepared for the graft by decapitation and root reduction, culture tube containing a suitable liquid medium and a filter paper support; B — A shoot-tip (0.2 mm) on a razor blade fragment; C — Shoot-tip on the cortical surface in an inverted-T incision; D — successful, intact *Citrus* micrograft after ca. 3 weeks in culture; notice root regrowth and shoot emergence from inverted-T incision.

The majority of micrografting work to date has focused on the elimination of viruses from citrus and stone fruits (3,4). However, there are other possible areas of interest to plant propagators and horticulturists that might be investigated using this technique. Cultivar improvement is the subject of extensive effort by horticulturists/geneticists. Whether by genetic or cultural means, improved growth rates, improved nutritional and water use efficiencies, and improved flowering characteristics are goals of many breeding programs. The results of repeated culturing of shoot apices of geranium, *in vitro*, suggests that latent viruses may be present in these plants and, when eliminated or diminished, result in increased plant vigor, water and nutrient use efficiency, and uniformity of flowering (W. Oglevee, personal communication). If latent viruses (non-pathogenic) are present and disrupt normal metabolism, their elimination by micrografting might be feasible and the hypothesis that latent viruses affect cellular metabolism could be tested. Improvement might be defined as the elimination of non-pathogenic viruses responsible for variegation *(Euonymus, Nandina)* or improvement might be measured in physiological terms such as increased photosynthetic rates.

Rejuvenation is an area of extreme interest to plant propagators working with woody perennials that show a concomitant loss of rootability as the plant develops ontogenetically. French workers have found that by repeatedly grafting mature, difficult-to-root, Douglas fir trees, the plants are gradually rejuvenated and by the fifth serial graft the plants root easily (2). Might it be possible to supplant the five serial grafts utilizing fully-developed buds by a single micrograft utilizing a shoot-tip measuring 0.1 to 0.2 mm? The micrografting technique is available to test this hypothesis using difficult-to-root *Eucalyptus spp.* as shoot-tip donors and aseptically sown seeds as rootstocks.

Micrografting is a difficult technique with success rates usually below 50%. This generally is not a limitation in virus elimination since once a single plant has been identified as virus-free it can be propagated by conventional means. However, to be able to perform some of the experimentation outlined above, it clearly would be an advantage to have success rates that approach 100%.

In *Citrus*, several parameters have been studied to increase the success rate. The placement of the apical meristem on the seedling rootstock has been found to be critical (1,5). Placement of the shoot-tip in contact with the vascular ring or on the cortical surface in an inverted-T incision have been shown to be the most successful treatments (Figure 2). It has been recommended to place *Citrus* shoot-tips on the seedling root-

stock in an inverted-T to maximize the possibility of success (1,5).

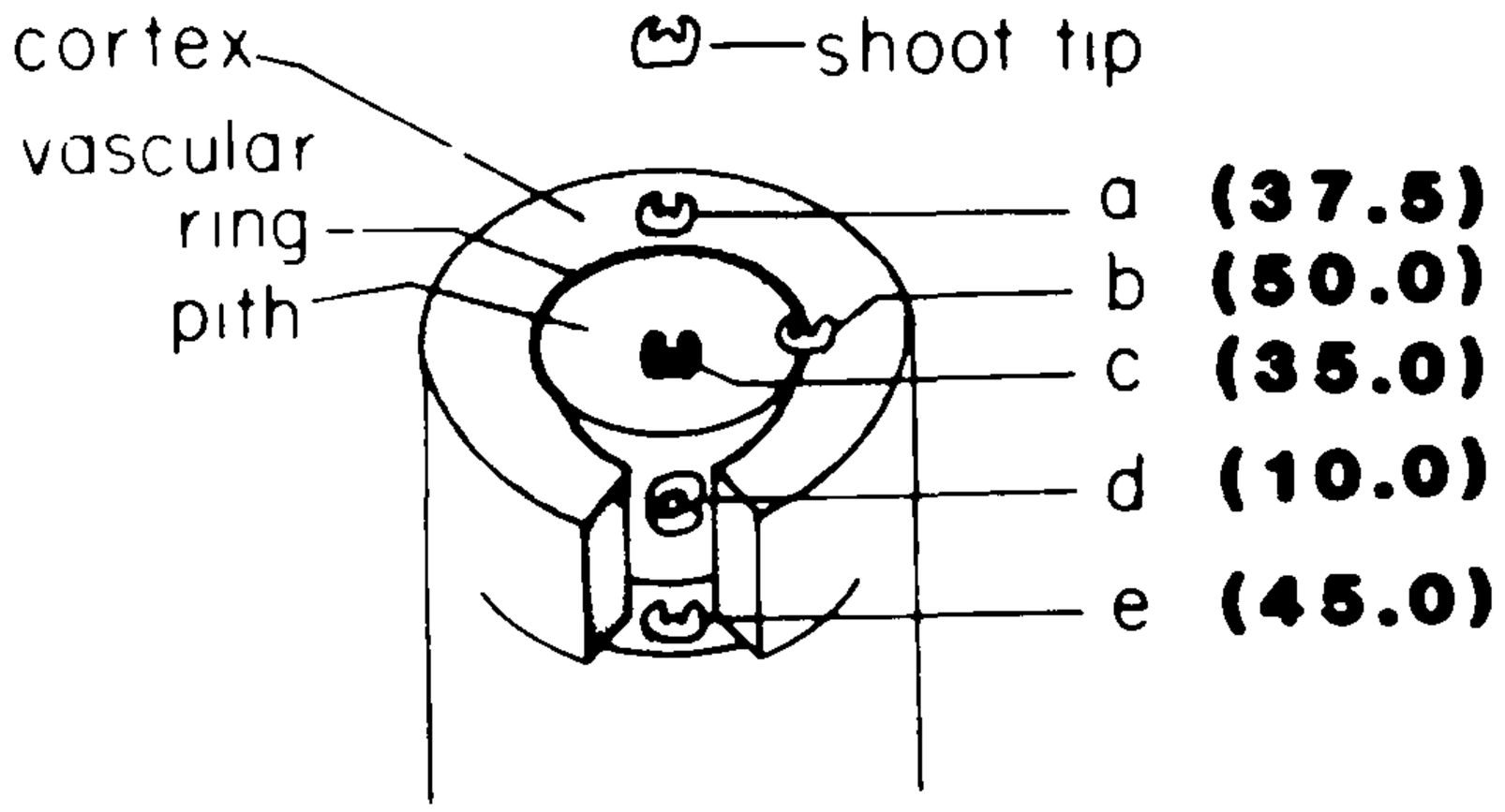

Figure 2. Various locations on the seedling rootstock where the shoot-tip may be placed. Bold numbers in parentheses are the percent successful micrografts when the shoot-tip is placed in that location Drawing and data from Navarro *et al* (5)

The age of the developing seedling rootstock also affects the success rate in *Citrus* (Figure 3). The greatest success was achieved using seedlings two weeks after sowing (5). When younger seedlings were used as rootstocks the micrografted shoot-tips were overwhelmed by callus growth and after 2 weeks the shoot-tips tended to die after being micrografted.

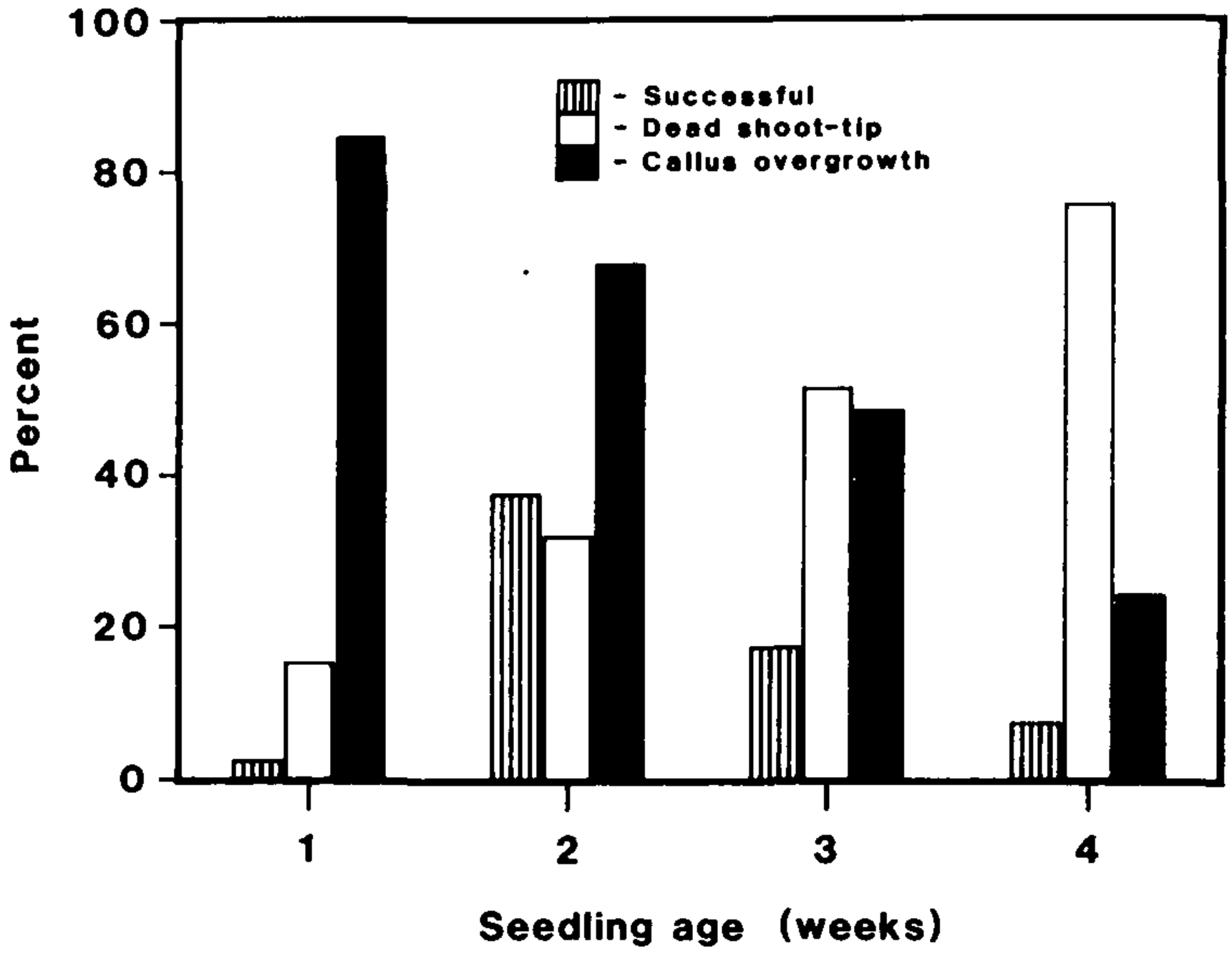

Figure 3. The effect of seedling age on the rate of success from *Citrus* micrografts Data from Navarro *et al.* (5).

There is an inverse relationship between the size of the shoot-tip and the micrografting success rate. Navarro *et al.* (5) found that increasing the shoot-tip size of 'Robertson' navel orange from 0.05 mm to 0.5 mm also increased the success rate from 1.8% to 47.3%. One must keep in mind, however, that larger shoot-tips also are more likely to contain viruses.

There are well-established occurrences of graft incompatabilities in fruit trees and this seems also to occur in micrografting. Edriss and Burger (1) have shown varying micrografting success rates in combinations of 'Troyer' citrange, 'Carrizo' citrange, and 'Sacaton' citrumelo rootstocks and 'Mexican' lime, 'Valencia' orange, and 'Star Ruby' grapefruit (Table 1). Jonard *et al.* have been able to detect early incompatabilities which only appear in the orchard after several years (3).

Table 1. Percent successful grafts among 3 *Citrus* scions and 3 trifoliolate rootstocks. Values are means ± 1 standard deviation.

	Percent successful grafts		
Rootstock	'Mexican' lime	'Valencia' orange	'Star Ruby' grapefruit
'Troyer' citrange	24 4 ± 6.2	17.7 ± 5 5	23 3 ± 5.2
'Carrizo' citrange	63 8 ± 8.1	50 0 ± 6 9	38 3 ± 4 8
'Sacaton' citrumelo	64 4 ± 7 0	44 4 ± 6 2	28.2 ± 4.8

from Edriss and Burger (1)

Pretreatments of the shoot-tip and/or seedling rootstock have been shown to increase the micrografting success rate. Jonard *et al.* (3) treated peach shoot-tips in 0.1 mg zeatin/l and increased the success rate by 300% (Table 2). Edriss and Burger (1) found that a pre-grafting treatment of the seedling trifoliolate rootstocks in 10 mg 2,4-D/l or 1 mg kinetin/l increased success rates by 200% (Table 3).

Table 2. Effects of pre-treatments on the success of in vitro micrografting of peach trees

Treatment of apex with zeatin		Number of grafts,	Number of living	Number of developed plants,	Percent success
mg/l	Hours	N_1	apices,	N_2	N_2/N_1
0		23	11	5	21.7
0 01	48	20	10	10	50
0 01	240	19	16	11	57 9
0 1	48	25	16	16	64
1 0	48	10	3	2	20

from Jonard *et al.* (3)

Each species that is used in micrografting will certainly have its own special requirements for success. The work cited

here is presented only as a reference of parameters that have been studied and have been found to affect the micrografting procedure.

Table 3. The effect of growth regulator pre-treatments on the grafting success of 'Star Ruby' grapefruit onto 3 rootstock cultivars.

Pre-treatment	Conc. (mg/l)	Percent successful grafts			
		'Troyer'	'Carrizo'	'Sacaton'	Mean ± S.D.
2,4-D	1	50	26.6	66 6	47.8 ± 16 4
2,4-D	10	75 4	73 3	78.5	75 7 ± 2.1
Kinetin	1	66 6	85.0	71 4	74 4 ± 7 8
Kinetin	10	33 3	56.6	33 3	41 1 ± 11 0
2,4-D + Kinetin	1 + 10	44 4	44.4	41 6	43.5 ± 1 3
2,4-D + Kinetin	10 + 1	61.6	55.5	50 0	55.7 ± 4 7
Water (control)	—	23 3	38.5	28 6	30 1 ± 6 3

from Edriss and Burger (1)

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PROSPECTS FOR GENETIC ENGINEERING IN PLANT PROPAGATION

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The rapidly evolving technology of genetic engineering is opening up exciting new possibilities for plant science and for plant propagation. Although, until now, practical applications of gene splicing techniques have lagged behind fundamental advances, several applications are now ripe for exploitation and it is these that I wish to address.

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Kinetin	10	33 3	56.6	33 3	41 1 ± 11 0
2,4-D + Kinetin	1 + 10	44 4	44.4	41 6	43.5 ± 1 3
2,4-D + Kinetin	10 + 1	61.6	55.5	50 0	55.7 ± 4 7
Water (control)	—	23 3	38.5	28 6	30 1 ± 6 3

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The rapidly evolving technology of genetic engineering is opening up exciting new possibilities for plant science and for plant propagation. Although, until now, practical applications of gene splicing techniques have lagged behind fundamental advances, several applications are now ripe for exploitation and it is these that I wish to address.

What is genetic engineering? Genetic engineering is less a discipline than a group of techniques applicable within many disciplines. These techniques are based upon an increasingly detailed understanding of the way DNA (deoxyribonucleic acid) is made, structured, read, regulated, processed, and translated into the metabolic machinery of life. Many of the tools of genetic engineering are, in fact, the very tools that cells use to manipulate their hereditary material and reproduce themselves. These tools include such things as plasmids, viruses, transposable elements, and restriction enzymes, all naturally occuring molecules that have been isolated, modified, and utilized by molecular biologists during the last two decades.

What are plasmids, viruses, transposable elements, and restriction enzymes? Very briefly, *plasmids* are extrachromosomal, usually circular, pieces of DNA, originally discovered in bacteria and since found in yeasts and mitochondria as well. Some plasmids have the ability to integrate into a chromosome of their host and later excise and move into other cells. In the process, the plasmids can move genes from one cell to another and alter their heritable characteristics. A bacterium, *Agrobacterium tumefasciens*, contains a plasmid that can spontaneously integrate into dicotyledonous host plants and insert bacterial genes that will be expressed by the plant.

Plant viruses are naturally occuring infective entities that consist of nucleic acid (RNA or DNA) often enclosed in a protein coat. The nucleic acid is the infective part and, as such, can move viral genes from one plant to another.

Transposable elements were originally described in maize but have since been found in bacteria, yeast, and *Drosophila* and, perhaps, in snapdragon as well. Transposable elements consist of short pieces of DNA that have the peculiar property of being able to insert into many parts of the host genome and affect the regulation of adjacent genes. Many transposable elements contain marker genes for antibiotic resistance and hence can be traced in and recovered from the host genome along with the adjacent genes whose regulation has been affected. In this way, selected genes can be located in a host plant or bacterium and in some cases those genes can be cloned (copied).

Restriction enzymes were discovered in bacteria and several hundred have now been found and purified for use. These enzymes recognize and cut given DNA sequences (usually 4 to 6 base pairs long) in such a way as to produce pieces of DNA with homologous or 'sticky' ends (Figure 1). Thus, any piece of DNA cut with a given restriction enzyme will have an end

that will match with and bind to the homologous end of any other piece of DNA cut with the same enzyme. The utility of this is obvious and far reaching. Selected pieces of DNA can be cut and then ligated (joined) to the ends of other pieces of DNA to make novel combinations of genes and gene parts. In addition, DNA molecules can be recognized by their number and location of restriction enzyme sites and changes in base sequence can result in changes in fragment size after cutting with restriction enzymes. Such enzymes are fundamental to genetic engineering and are a powerful tool for cutting and splicing DNA, the blueprint for life.

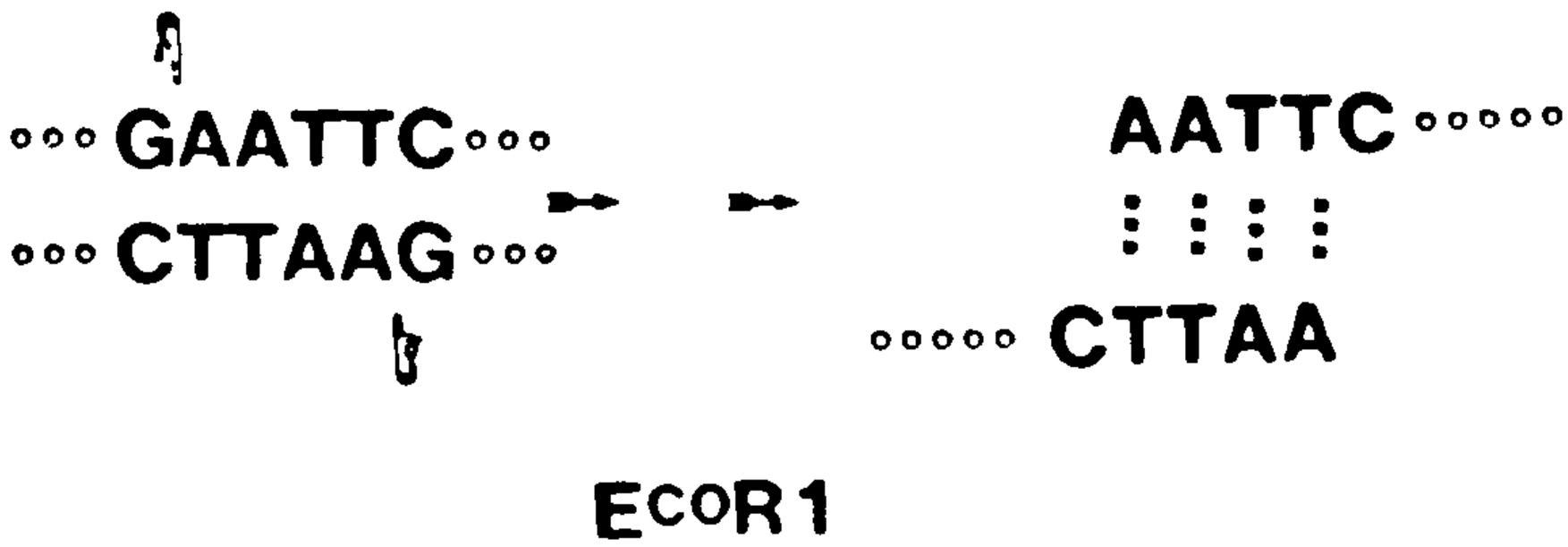

Figure 1. The restriction enzyme EcoRl cuts the double stranded DNA molecule at the two sites indicated by the pointing fingers It only does so after recognizing the six-base sequence at left After cutting, two DNA strands with the complementary sequences shown on right can be joined together as shown by solid dotted lines Hollow dotted lines indicate unspecified DNA base sequences

How can plant propagators benefit from these new tools? Specific genes can be turned on and off by transposable elements. Such elements insert in the genome and often prevent the reading of an adjacent gene. One must then select a plant with a transposable element in the gene of choice. For example, in maize, transposable elements were first recognized by their ability to alter pigment formation in corn kernels. These elements move in and out of the pigment gene, turning it off and on resulting in a color mosaic that we call Indian corn. Such an element, if stabilized and transferred to other plants could be used to rapidly select for rich color variation that could otherwise only be secured through years of breeding. If the elements recently identified in snapdragon turn out to be true transposable elements, we may already have a system for selecting color variants in an ornamental plant.

The Ti (tumor inducing) plasmid of the bacterium *Agrobacterium tumefasciens* (cause of crown gall disease) has some

unique features that make it particularly useful. Upon plant infection by the bacterium, the plasmid integrates into a plant chromosome and causes the plant to read and express bacterial genes. Among others, this plasmid carries genes for the production of the plant hormones, auxin and cytokinin, and these genes are expressed in the plant. It is the additional production of these bacterially coded plant hormones that is largely responsible for the plant tumors that are characteristic of infection by this plant pathogen. But the genetic engineers have gone to work and selected strains of *Agrobacterium* that code for high auxin production and low cytokinin production or low auxin and high cytokinin. The result is bacteria that will induce either root formation or shoot formation rather than the disorganized cell proliferation that results in a tumor. In fact, a naturally occurring species of related bacterium, *Agrobacterium rhizogenes*, causes a root proliferation known as hairy-root disease. Preliminary work has already begun at the University of California at Davis to use the "rooty" bacterial strains to induce rooting in woody perennial plants. The utility of such a method of rooting would be great.

Male sterility is a trait that may be amendable to transfer into commercial crops to facilitate production of hybrid seed. Male sterility in maize has been found to be located on the mitochondrial genome and may be amendable to cloning on a mitochondrial plasmid and transfer into the mitochondria of other plants. Other types of male germicide genes may exist in other plants and could be of great use.

Plant disease resistance has been little studied on a molecular level but some progress has recently been made in understanding the molecular genetics of plant-pathogen interactions. The ability of plants to express hypersensitive resistance to disease-causing microorganisms results from the interaction of genes in the plant with genes in the pathogen. This interaction was first clearly expressed by Flor (1) and was based on the pattern of inheritance of resistance genes in a host and avirulence genes in the pathogen. Thus, disease resistance is expressed when resistance genes in the plant interact with avirulence genes in the pathogen. Workers at the University of California at Berkeley have recently cloned an avirulence gene from a bacterial plant pathogen and are currently well positioned to study the analagous resistance gene in the plant (3). Such resistance genes, if cloned, would be invaluable in producing disease resistant plant lines without the necessity of generations of backcrosses to incorporate the genes into a new genetic background.

Looking even further into the future, recent work opens

the possibility of constructing artificial chromosomes for insertion into higher organisms. Small artificial chromosomes have already been constructed and put into yeast where they have behaved stably through mitosis and meiosis (2,4). Artificial chromosomes in plants would make possible the insertion and stable replication of large pieces of foreign DNA and the creation of wholly new organisms. Though there are certainly many problems to work out and years of research ahead, the prospects for advances in the genetic modification of plants are quite exciting. With the proper attention and research, plants could be modified to make propagation easier, faster, cheaper, and more reliable through genetically programmed disease resistance, rootability, shoot production, and interesting new genetically programmed variants of successful cultivars.

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VOICE: Are all viruses removed from the very young tissues of the apical meristem in meristem culture?

DAVID BURGER: My understanding is, and it is not a complete understanding, that much of the way viruses get into tissues is through vascular systems, and in the apical meristems in the very young cells of the shoot apex there is not a well-defined vascular system. So that if viruses were to get into the apex they would have to do it by diffusion and that is quite slow, as opposed to being transported with the vascular stream. So my understanding is that most shoot apical meristems do not contain viruses for this reason. If it is the case, quite often heat treatment can be used ahead of time before micrografting techniques are used. This way their differential growth is being used so that the plant outgrows the virus.

HARRY LAGERSTEDT: I have three quick questions on micrografting of citrus. *One*, why do you remove the cotyledons? *Two*, why do you remove the root system? and *Three*, what is the time interval between grafting and putting the grafts into containers?

DAVID BURGER: In answer to the first question, in citrus if the cotyledons are attached then the axillary bud in that cotyledon actually tends to grow faster than if it's removed. Also, once the micrograft has been performed you are almost always back into the culture tube on a weekly basis, if not on a daily basis, removing adventitious buds that are forming, and so it is just a matter whether that axillary bud does elongate — you are going to remove the cotyledons anyhow. It's just a matter of ease.

The answer to the second question is very similar in that after the micrograft is performed it is a very difficult technique to get that completed micrograft into the culture tube. You want to have the root as short as possible so that it goes easily into the culture vessel. We shorten it to 2 cm. below the cotyledons basically because that is a very straight portion of the root system and it slides easily into the culture tube.

Lastly, the length of time between micrografting and placing the graft into the containers is quite variable. It can be anywhere from a few weeks to a couple of months. It depends on the success or the ability of the person doing the micrografting, the cultivars that are used, and the conditions that occur.

DON DILLON: Why go through all the trouble of grafting? Why don't you just put a set of roots on your meristem?

DAVID BURGER: You mean take the apical meristem and have it develop adventitious roots. That's a very good alternative and it would be very viable. Unfortunately, many woody plants and many plants in general are difficult to meristem. Orchids have been quite successful and many other plants have been as well. There are others that have been quite resistant to being amenable to this technique. I feel that by doing a graft we avoid the problem of the plant not being able to form entire plants on its own — then we will provide the roots for the shoot tip. But it is a very good alternative and you are absolutely right — that for plants that will form roots from an apical meristem, that is definitely the way to go.

DON DILLON: Now, have you tried it on citrus and found it did not work?

DAVID BURGER: No, I have not tried it and I am unaware of people that have meristemmed citrus. I think that if it had been successful it would probably be used more.

PROPAGATION TRIALS IN KENYA

CHRISTOPHER FAIRWEATHER

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In 1979 I started our first trials to establish a small propagation unit in the Highlands of Kenya, with the intention of rooting a range of hardy shrubs for the European market. We managed to obtain a small area of land situated at an altitude of 7000 ft. in one of the main tea *(Camellia sinensis)* [syn. *C. thea*] growing districts. Rainfall at this altitude is generally around 60-70 in. per annum, the long rains arriving during March, April and May. Later in the year are the less reliable short rains which occur in October/November.

The first task was to establish a stock bed to supply the necessary cuttings. As very little local material was available in the plants we required, this operation had to begin with very small rooted cuttings.

For the next three years we had to wait for the plants to develop. This was slower than expected and various hazards such as extreme hail storms occurred, which almost finished the whole project.

By 1982 the plants had developed from small 6 in. rooted cuttings up to 2 to 3 ft. bushy specimens. The main plants we had started for our trials included three camellias, 'Donation', Adolphe Audusson', and 'Aerjeshii', *Magnolia* × *soulangiana* and *M. stellata*, *Elaeagnus* 'Limelight', *Ceanothus dentatus* and *C.* 'cascade', *Pittosporum* 'Irene Patterson' and *P. garnettii*, and × *Cupressocyparis leylandii* 'Castlewellan'.

In January, 1982, we inserted around 3000 cuttings from a selection of all these shrubs. As plastic trays are difficult to obtain in Kenya we made up stout wooden boxes from local timber. As a rooting medium, which had to be sterile for export to England, we used a mix of 50% washed river sand and 50% local vermiculite with a small amount of polystyrene granules added for improved drainage.

All camellias and magnolias were taken as leaf-bud cuttings, the remainder as tip cuttings, wounded, dipped in Seradix No. 2 and watered in with Benlate. The filled trays were placed in a polyhouse where they were hand-misted twice a day.

Temperatures during the day rose to around 90°F which resulted in high temperatures in the polythene tunnel. To cool the houses we covered the whole structure with dense hessian

and sprayed the paths regularly.

To combat *Botrytis* we introduced a routine fungicide spray using Captan and Benlate every 10 to 14 days. With the high temperatures and humidity this was a constant danger. Within 8 to 10 weeks we had achieved around 70% rooting, the trays were removed from the polythene tunnel, and all cuttings allowed to harden off outside.

We air-freighted our first shipments to England of 2000 rooted cuttings in June, 1982. These cuttings were ready earlier, but we decided to wait until temperatures and light conditions were at their best in England, with equally cool conditions in Kenya. After passing the necessary Ministry of Agriculture health checks we had the cuttings back on our nursery 18 hours after their shipment from Nairobi. They were all potted into 7 cm pots within 24 hours, placed in a closed polyhouse and covered with a sheet of white papronet.

The cuttings had made no new growth from the moment we had taken them in January/February until their arrival in England in June. Within 2 to 3 weeks of potting we noticed new root movement and this was quickly followed by 2 to 3 in. of fresh shoot growth.

We experienced a minimum of loss in nearly all cultivars, the exceptions being ceanothus and × *Cupressocyparis leylandii* 'Castlewellan'. By late spring the following year we had well established liners ready for resale or potting on.

THE GENUS *PIERIS*: ITS PROPAGATION AND PRODUCTION

CHRISTOPHER LANE

Hadlow College, Hadlow
Tonbridge, Kent

Pieris belongs to the family Ericaceae and, like other members of the family such as *Kalmia* and *Rhododendron*, they thrive in light shade and do best with a cool, moist root run. Whilst perhaps not the choicest of evergreen shrubs they do offer a distinct ornamental quality for acid soils.

The most distinctive feature is, of course, the colour of the young growth. This can vary from brilliant red to pink, as well as creamy yellow, bronze, or copper. The flowers which are usually white, but sometimes pink or red, are lily-of-the-valley shaped and born profusely on racemes or panicles. Various species and hybrids flower in the garden from February to June. The flower buds, which are formed in late summer are

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also attractive during the winter months, particularly those of a bronzy colour.

Most plants are very compact in growth habit, making dense, shapely bushes up to 2 × 2 metres. *Pieris formosa* var. *forrestii*, however, will grow up to 4 metres. Dead heading of old flowers is beneficial. This removes the unsightly dead flowers. Improved growth will result, giving better flowering the following season. This task is best performed with secateurs as the dead flowers are not easily pinched out.

The genus is fairly small containing only a few species, and perhaps only two of these are of real commercial importance.

These are: (1) *Pieris formosa* var. *forrestii*, native to the Himalayas, and (2) *Pieris japonica*, native to Japan. Of much less importance are *Pieris floribunda* from North America and *Pieris taiwanensis* from Formosa. There are, however, some hybrid groups, one of which is very important commercially. This is *P. formosa* var. *forrestii* × *P. japonica*. Hybrids of less commercial importance are: *P. floribunda* × *P. japonica*, and *P. taiwanensis* × *P. japonica*.

Production Sequence. July-Dec. 1984. (cuttings rooted); March 1985. (potted off in 9 cm container); Jan.-Feb. 1986. (potted on into 2 litre container); Sept. 1986 to March 1987. (marketed).

Source of cutting material. a) From stock plants planted outside in a sheltered and/or protected site, as young growth is subject to late spring frost damage. b) From young stock or liners in the nursery. Many of the liners need to be cut back to encourage bushy growth and this material can be used for cuttings.

Time of year. Cuttings can be rooted any time between June and December. In most seasons *Pieris* will produce two flushes of growth. Even if the early spring growth is frosted, new shoots will appear after 2 to 3 weeks. Cuttings can be taken after the first flush has hardened in late June or early July. Alternatively, cuttings can be taken from September until December after the second flush has hardened. In my experience more cuttings are available from the second flush. These root more consistently and fewer flowers are formed on the stock plant to inhibit next year's growth.

Type of cutting. A 6 to 10 cm nodal tip cutting is taken. The lower leaves are removed and the terminal cluster reduced to 4 to 6 leaves depending on their size. With *P. formosa* var. *forrestii* cultivars the leaf size can be reduced to facilitate insertion of cuttings. Wounding of the cuttings is beneficial to

rooting if the wood is reasonably hard — a 1 cm long basal slice wound is given.

Treatment. Hormone treatment is beneficial to rooting and, in the past, 0.8% IBA in talc has been used. However, last year excellent results were achieved using 2500 ppm IBA and NAA as a 5-sec. quick-dip.

After care. Forty to fifty prepared cuttings are inserted per standard seed tray, the number depending on the size of the cuttings. The cutting compost used is a very open one, as most standard seed trays are poorly drained. The compost is 2 parts perlite to 1 part moss peat. The larger trays with mesh bases now available are much better for economical heat transfer. The larger trays with mesh bases now available are much better for economical heat transfer. The trays are placed on a mist bed. The mist is operated automatically up to mid-or late October and manually thereafter. The basal temperature is 21°C. One must ensure that the compost in the base of the tray does not dry out when the mist is operated manually. This is critical at the point where cuttings are starting to root. If the trays tend to be dry then give them a thorough soaking. Cuttings usually take 5 to 8 weeks to root and should then be overwintered in the trays.

Growing on. Flowers or shoots which form on the cuttings whilst in the cutting trays should be cut out in the dormant season. Ideally the rooted cuttings should be potted off just before they break into growth; 9 cm. containers are used and they are potted into an ericaceous compost containing a slow-release fertiliser. They are then placed pot thick into a cold dutch light structure to be grown on.

In the autumn the liners are pruned back fairly hard to encourage bushy growth and the best material from these prunings can be used for cuttings. *Pieris formosa* var. *forrestii* cultivars and *Pieris* 'Forrest Flame' will not produce bushy plants unless cut back. In the main, *Pieris japonica* cultivars are naturally more bushy and therefore it is easier to produce a shapely container plant. Any flower panicles present should also be removed at this time.

In the following late winter the liners are graded and only first grade ones are potted on into 2 litre containers. Second grade *P. formosa* var. *forrestii* 'Wakehurst' and *P.* 'Forest Flame' are usually left in the 9 cm containers and potted on later in the year, or with the following year's crop, as demand for these is usually good. Second grades in the other *Pieris* are usually thrown away. After potting they are placed pot thick in a cold dutch light structure. After the first flush of growth has hardened, usually in early June, they are moved out onto

sand beds in a twin-span netting-covered structure, where they are placed with suitable spacing.

Weed control. Directly after potting in January or February Napropamide and Simazine are applied to the containers through the irrigation system by means of an internal bag type dilutor. Half rate of the herbicides are applied. This is 5 liters c. p. per hectare. The liners are also treated this way directly after potting off in March. It is best to water the herbicide in after application. Then when the plants are moved out to the twin-span netted structure and placed on the sand beds Oxadiazon granules are applied at 200 kg/hectare.

Growth regulators. Sometimes some *Pieris* plants make a late flush of growth in October which is usually killed by the first frost. This year Alar is being tried to prevent such late growth. Application is made after the 2nd flush has hardened up; at the rate of 2500 ppm.

Marketing. This is from late summer onwards, the majority of plants being sold the following spring, just before they come into flower.

Selection of species and cultivars.

Pieris 'Brouwers Beauty', (*P. japonica* × *P. floribunda*). This is worth trying as it is extremely hardy and has more attractive flowers than *P. floribunda*.

Pieris 'Forest Flame' (*P. formosa* var. *forrestii* × *P. japonica*). This is well known and deservedly one of the most popular *Pieris*. However, another *Pieris* of the same parentage, 'Tilford' should be grown more. It has bright-red, young growth which breaks out late after the frosts and is a more compact bushy plant.

Pieris formosa var. *forrestii* 'Wakehurst'. This is the most widely grown clone, but two relatively new ones worth growing are: 'Balls of Fire' (like a compact 'Wakehurst') and 'Rowallane' (for its yellow new growth).

There is now a glut of *Pieris japonica* cultivars available when one looks in Continental, Japanese, North American, New Zealand and English catalogues. At least 35 are known to me and whilst it is impossible to assess all of these properly, the following are some of my favorites:

P. j. 'Blush' — pale pink, nice foliage.
P. j. 'Pink Delight' — good strong pink.
P. j. 'Valley Valentine' — good red flowers.
P. j. 'Mountain Fire' — brilliant red young growth.
P. j. 'Little Heath' — small compact variegated clone with lovely pink colourations in young growth.
P. j. 'White Rim' — lovely cream variegation.
P. j. 'Dorothy Wyckoff' — good white flowers, bronze winter buds, and

superb dark foliage.
P. j. 'White Cascade' — long racemes of white flowers; good grower.

Pieris 'Grayswood', (*P. japonica* × *P. taiwanensis*), often sold in the past as *P. taiwanensis*, a superb plant with long racemes of white flowers, dark winter buds, and coppery young growth. I believe that this should be much more widely grown.

Pieris 'Purity' is another of my favourites, placed at the end because in my mind there is doubt that it is a true *P. japonica*. It looks like a compact *P. taiwanensis*. However, it is far superior, with a profusion of erect white racemes in March or April.

Pests and diseases

a) *Vine weevil*. Easily controlled by incorporating Aldrin dust into the compost at the rate of 2 Kg c.p. per 1.3 cu. metre.

b) *Red spider*. This is only troublesome where plants are grown under glass or polythene protection. Spray with Plictrant 600F as soon as mites are observed.

Apart from the above, *Pieris* plants are remarkably free from pests and diseases.

CONCLUSIONS

I feel that this crop is well worth growing as it presents a challenge to the nurseryman. Good cultural practices are required in order to produce a dense, shapely plant with plenty of flower buds for spring sales. Alas, not enough plants of this quality are seen. The production of larger plants in containers up to 10 litres also presents a challenge. The production of quality plants and marketing at the optimum time should increase sales of this beautiful genus.

PROPAGATION AND PRODUCTION OF *GARRYA ELLIPTICA*

DAVID RIDGWAY

Hadlow College of Agriculture and Education
Hadlow, Nr. Tonbridge, Kent

Garrya elliptica is listed as one of the most difficult plants to propagate, and many growers are reluctant to attempt production because of the numerous problems which can make it an uneconomic proposition. However, it is possible to overcome these problems with the equipment and facilities now available, and to achieve successful propagation.

The most important cultivar grown in Great Britain is the

superb dark foliage.
P. j. 'White Cascade' — long racemes of white flowers; good grower.

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The most important cultivar grown in Great Britain is the

male cultivar *Garrya elliptica* 'James Roof', which produces catkins 300 mm long.

IMPORTANT CONSIDERATIONS WITH *GARRYA ELLIPTICA* PRODUCTION

1. It is often difficult to achieve an economic rooting percentage. Therefore stock plant maintenance, selection of cutting material, porocity and hygiene of rooting compost, and correct management of the propagation facility is of paramount importance in achieving acceptable results.

2. *Garrya* reacts unfavourably to root distrubances, therefore special attention must be given when handling the rooted cuttings.

3. High fertility in the potting compost must be avoided. *Garrya* naturally grows in arid conditions with low soil fertility.

PROPAGATION

Stock plants. The stock plant is an essential consideration in the successful propagation of *Garrya elliptica*.

The hedge system for growing stock plants, with the hard pruning tactics to promote vigorous young growth, should not be used. This encourages the wrong type of growth for rooting *Garrya elliptica* cuttings. The growth produced is overly vigorous, forming many strong "water shoots".

Older, well established stock plants of known rooting performance of good form should be used. These are planted in a situation where they can be allowed to develop naturally and given light pruning to contain them in their allotted space. A biennial pruning method could be adopted for the stock hedge system.

The selection and preparation of cutting material is also an important consideration. Tip nodal cuttings, collected from late summer to December, approximately 10 cm long, or side shoots taken with a heel should be used, ensuring with both types that the terminal bud is well developed. Thick, vigorous "water shoots", displaying a flush of autumn re-growth should be avoided.

Wounding is optional; if carried out, then a light wound should be made, approximately 2 cm long. Deep wounding will often result in loss of cuttings by fungal infections.

A rooting hormone has shown to be effective but use powder formulations only, i.e. Seradix No. 3 (0.8% IBA). The damage which is often caused to exposed cells at the base of cuttings with liquid formulations (alcohol, acetone), will en-

courage decay to spread rapidly, to which *Garrya elliptica* is particularly prone. Cuttings should begin rooting within 6 to 8 weeks and be well rooted after 12 weeks.

Rooting Compost. As stated above, excessive root disturbance must be avoided; therefore, the compost medium should hold on to the very brittle root systems, thus forming a "plug". However, its moisture retentiveness should be at a minimum.

A suggested compost is 60% medium moss peat, 40% 5 mm crushed grit or perlite. Ideally, this medium should be sterilized; *Garrya elliptica* cuttings are very prone to pathogenic infection.

Propagation facilities. Either intermittent mist or film plastic (19 μm, 75 gauge), both systems with basal heat (15° to 18°C).

Mist — Reduce the incidence of mist to a minimum. This can be achieved by turning off the mist at night and manually operating during overcast days. Keep cuttings from direct rays of the sun, as the combination of water globules and sun will cause excessive scorch to foliage.

Film plastic — No special treatment; use the system as with other crops.

Pest and disease control.

Pests — take precautions against sclerid fly larvae; suggest 2 to 3 drenches during rooting of demeton-S-methyle (Metasystox 55), diazinon, (Basudin 40 wp), or diflubenzuron (Dimilin).

Disease — Routine application in strict weekly rotation of captan, Benlate, and Rovral.

GROWING ON

Systems preventing root disturbance. The greatest problem with growing on rooted cuttings of *Garrya elliptica* is that they react unfavourably to any root disturbance and it is to this point that special care and attention must be given.

Unit Containers. Rooting should be carried out in some form of unit container system, thus avoiding root disturbance when potting off.

Preformed propagation block systems should be avoided, i.e. Jiffy 7s or 9s, root blocks, etc. The medium, from which they are formed holds too much moisture resulting in poor rooting; they are also expensive and take up large areas of propagation space. For such systems to be effective, virtually 100% rooting must be assured.

A "trough" system, with dividing walls between each compartment is advised, enabling one to adjust the rooting medi-

um accordingly. *Example*: The "Quick-Pot Propagation Trays" from P and G Horticulture Ltd. Tray type with 77 compartments, 40 × 40 mm overall tray size.

Over-wintering. Once rooted, remove trays from propagation area and place in a cool growing house; keep as dry as possible. *Garrya* can adapt to drought conditions very well but if kept wet and cold the rooted cuttings will damp-off quickly.

Potting off. Wait until the rooted cuttings complete their first spring flush of growth. This first extension growth should be kept to a minimum; do not encourage it with excessive watering or liquid feeding. Do not handle the rooted cuttings until this growth hardens up and produces a terminal bud.

To pot off during "full-flush" can result in high establishment losses. The whole plant is under stress; it is physically in a very vulnerable condition, the roots are fully active, supplying water to the extension growth to maintain turgidity. To disturb the young plants at this stage is to damage the extremely brittle roots resulting in the young growth collapsing, turning black and dying. Very rarely does the plant recover from this shock. This condition is less of a problem if a unit container system is used.

Only handle the rooted cutting when the demands on the root system by the foliage is at a minimum.

Subsequent Growing on. *Garrya elliptica* rooted cuttings can be grown as a one or two year crop, the latter being preferable.

One year production. Pot rooted cutting direct into its final container (2 or 3 litre), and place in a polythene structure. The day temperatures and humidity can be allowed to get "quite high" before ventilating. Harden off during July. Plants should be pinched back to encourage at least 3 stems to break low down on the plant. Plants may require support with a 60 cm split canes. Fertility in the compost should be kept to a minimum, i.e. half-rate Osmocote is ideal, without supplementary liquid feeding. This method should be used only if the cuttings are rooted directly into a unit container system, combined with other precautions as mentioned.

Two year production. Pot rooted cuttings into 9 cm pot then grow on under protection — pruning back to encourage branching. Pot on the following May into 2 to 3 litre containers. Grow on under protection — harden off by end of July. A well branched plant should be produced which may require a 60 cm split cane for support. Sell that autumn at about 60 cm overall height.

To successfully produce *Garrya elliptica* its requirements

must be fully understood. It is a plant that will not tolerate standard production techniques, i.e. standard propagation and potting composts, propagation procedures, and generally hard handling. *Garrya elliptica* will not tolerate root disturbance when actively growing, or high fertility.

Once the plant is established, it will grow away vigorously and, as long as the procedures described are adhered to, a profitable plant can be produced with minimum losses.

CLIMBERS — SOME ASPECTS OF OUR PRODUCTION

DENIS J. BRADSHAW

J. Bradshaw & Son — Busheyfields Nursery
Herne, Herne Bay, Kent

We are a small family firm growing a range of plants, but specialising in clematis and climbing plants. We grow 135 species and cultivars of *Clematis* and between 70 and 80 cultivars of other climbing plants, as well as many climbing roses and wall shrubs. Clematis are sold as bare-root liners, 7 cm pot liners, and 4 ft. caned plants.

Propagation Facilities. We have one 65 × 14 ft single skinned polytunnel, covered with white polythene. This has two 6 ft beds at ground level with a centre pathway. The beds are insulated with 2 in thick polystyrene wrapped in polythene, with 3 to 4 in of pea grit underneath for drainage. This is covered with a 3 in layer of durite sand beneath which there are five electric heating cables, each controlled by Camplex probe thermostats, giving a bottom heat of 68-70°F. We used to have a hand operated mist line, but now find it more convenient to use a fine sprayer on the end of a hosepipe. As the light intensity increases we cover the tunnel with a 50% shade material.

Propagation Methods.

1) *Seed* — We raise only a few plants by seed: *Billardeira longiflora*, *Eccremocarpus scaber*, and the wall shrub, *Piptanthus laburnifolius*. Seed is collected from stock plants and sown in February-March in standard 2 in deep seed trays. They are pricked out into 7 cm pots and then potted on, after cutting back, into final pots.

2) *Grafting* — We do some grafting, mainly *Wisteria sinensis* and *W. floribunda* cultivars. We have established neither good stock plants nor surplus young plants and therefore find it difficult to get enough good scion wood. We still buy-in one year grafts and use their tops for scion material. Grafting is

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done in February, using a side graft and binding with ½" polythene tape. These grafts are then plunged into peat in deep trays and placed in the propagation tunnel. When callusing commences, but before too much movement into growth, they are potted into 3 or 4 litre pots and caned. These are placed in an unheated closed tunnel. As growth progresses they are tied into a cane and the polythene tape is undone. They are stopped when they reach the top of the 4 ft cane, and generally produce enough good strong shoots to overwinter well. Thin-stemmed plants are cut back in the spring and grown on for sales later.

3) Cuttings. Most of our propagation is from leaf-bud cuttings, single or double, depending on the subject. Clematis is our largest crop; we take 100,000 cuttings between the end of April and the end of June. The following procedures, which apply particularly to clematis will also apply to the majority of our other climbing plants.

Sources of cutting material are:

1) Liners — 7 cm. These are overwintered in unheated poly-tunnels and are in Empot carrying trays. It is easy to collect material when the trays are routinely moved.

2) Stock plants. These are in 5 litre pots, housed in an unheated poly-tunnel. Each pot is labelled and also charted on a plan to avoid possible errors. The stock plants are pinched and/or cut back earlier in the year to encourage multiple stems and also to delay the production of cutting material until after the main batch of liner material is taken. By increasing the number of stems it helps to reduce internode length and also leaf size, which can otherwise be a problem.

Compost — We use a 10:7 peat/durite sand mix adding, as a precautionary measure, Aaterra and Aldrin.

Trays — We used standard 2 in deep seed trays, but if we are keeping cuttings for selling as bare root liners in February, we use 3 in deep trays. In both cases 100 cuttings per tray are inserted.

Knives — All our leaf-bud cuttings, including clematis, are made with a Vitrex Cuttey-A knife, with snap-off blades. These can thus be replaced as required.

Procedures. Collection of cutting material is made by the main propagator only. He is responsible for labelling, charting, and recording numbers, after care, and also recording any rogues in a 'rogue' book, hopefully reducing chances of mistakes. Material is brought into the shed and kept damped down. This is done throughout the day as required. None should be left until the next day. At peak cutting time several

women are employed. These are casual employees who generally work 3 to 3½ hours per day.

In view of the recent interest by both A.D.A.S. and the ATB in methods of handling, I thought our techniques might be of interest.

Each person has 8 filled seed trays, in addition to Seradix No. 2 rooting powder, a bucket of dilute Benlate, a strainer, a spare bucket, a knife and rubber gloves. The stem is picked up at its base. The first cut is made approximately 1¼ in below a pair of buds and the second removes the centre leaflet. If there are more than two buds, or the removal of a down hanging leaflet is required, then a third cut is made across the main stem above the buds. This cuts one leaf petiole simultaneously, leaving the stem against the knife. The completed cutting, in the other hand, is then dropped into the Benlate dip. This is continued up the stem until the soft tip is discarded. The finished cutting has approximately ¼ in of leaf petiole left on one side, ¼ in of stem above a pair of buds and one or two leaflets on the other side. No wounding is generally done unless the stock is in short supply and harder stems have to be used. When there are a good number of cuttings in the bucket, the bucket is emptied through a strainer, made of screening material, into the empty bucket. This is always done as a matter of course whether it is a change of cultivar or not. The strained cuttings are put into a clean seed tray to drain further and are then ready for insertion. We use both hands, but one hand is used for dis-entangling and feeding the cuttings into the other hand. The cuttings are dipped into hormone powder and inserted by this hand. We find this quicker than trying to stick with both hands. The trays are watered, stood onto a barrow and labelled. They are then taken to the propagation tunnel by the propagator. Usually 3,000 to 3,200 cuttings are stuck in a morning by four persons who work on a casual basis.

It is necessary to be almost fanatical about keeping cultivars true to name and, therefore, the head propagator checks *all* material before it goes into the shed. The workers make cuttings of the main cultivars, whilst the head propagator makes cuttings of all the smaller batches, the ones most easily mixed up, because of the small numbers.

When new stock plants are purchased we record where they came from and leave one shoot per plant to flower, to verify trueness to name. A weekly check is made by the head propagator and myself on cultivars coming into flower. We also mark separately the boxes of cuttings taken from liner material, as opposed to stock plant material. Rogue plants are

removed. Regretfully mistakes do still occur even after all of these checks.

Because we use hand misting we can treat batches individually and when cuttings have stood 3 to 4 days we can reduce the water. Some fibrous rooted species like *Clematis macropetala* are very sensitive to overwatering. In April and early May cuttings may take 3 to 4 weeks to root; as light intensity and heat increase, they root in 2 to 3 weeks. Weekly sprays of fungicides are used as a precautionary measure, and Rovral, Cuprokylt, Benlate and Thiram are used in rotation.

When cuttings are rooted we move them into another tunnel, with only one end closed. This has a centre sprayline which is turned on as required. Seven to ten days later the cuttings are top dressed with Vitax Q4 or Glasgro which is well washed in.

Pot Liners. When time permits, normally towards the end of July, the cuttings are potted into 7 cm pots with the exception of bare-root cuttings which are required for sale in February. The roots and tops of the cuttings are lightly trimmed, dipped in Benlate and stood into Empot carriers in a closed unheated polytunnel. We maintain humid conditions for the first few days and then gradually increase the ventilation. Shading with windbreak material is generally required to prevent scorching.

We find most clematis benefit from being potted before the end of August, when light intensity starts dropping. This allows good establishment before the winter.

The majority of the other climbing plants are handled in a similar way. *Actinida kolomitka, Aristolochia durior*, some *Jasminum* spp., *Solanum* spp., and *Vitis coignetiae* all benefit from being taken as early cuttings and being potted early before winter. Coarser growing plants, like some of the *Lonicera* spp. are taken later, overwintered in trays, and are potted directly into their final pots in the spring.

Final Potting. Most clematis and vigorous climbing plants are potted on in May or June. They are then placed outside within a windbreak protected area in rows of four. We used to string the tops of the canes, which is quick and cheap, but not so convenient if small quantities need to be taken out. This year we are trying cane clips. Less vigorous climbers, for example *Clematis* 'Mrs. Thompson' and C. 'Miss Bateman' or *Trachelospermum asiaticum*, are stood pot-thick in polytunnels. Other more tender subjects, like *Solanum* and *Campsis*, are also grown entirely in tunnels for winter protection.

If clematis are not sold in the autumn, then all cultivars,

except spring flowering ones, are cut back hard in January or February to produce good basal growth for the spring sales.

Due to the increase in spring and early summer sales, we also pot liners up in January and grow them pot-thick in polytunnels. This can work well but heaven help you if, due to sale pressure at that time, tying isn't kept up to date!

Roses. We are experimenting with various methods for producing climbing roses in order to service an expanding market. Some are simply field-grown and potted up; some are dormant-bud potted and some are from cuttings.

As the first two methods are well known I shall describe our cutting method of production. Nodal stem cuttings, consisting of three nodes, are taken in July and August. Most of the stock comes from field grown plants. Cuttings are made with secateurs; then dipped into a Benlate solution and Seradix No. 2 and inserted in 7 cm pots in Empot carriers. The removal of some leaves and basal thorns produce a wound which aids rooting. In the propagation tunnel routine spraying is carried out as with clematis; rooting occurs in 3 to 4 weeks. Ramblers, like *Rosa* 'Albertine' and *R.* 'Alberic Barbier', root well. Repeat flowering climbers such as *R.* 'Handel' and *R.* 'Golden Showers' are also good rooters. These are weaned in another tunnel and if time permits, top dressed in autumn, or alternatively, in spring.

If these are potted on in March-April and stood in polytunnels, growth is rapid and they should make good saleable plants by June or July. But how do you handle them if space is at a premium and they stand pot-thick? Last year we moved them outside in June and July and caned, tied, and cut them back. For vigorous cultivars, like 'Albertine', you need armour plating!

This year we are late in potting on and have decided, because of the handling problem, to stand them outside on a two-row system. Tying will be easier but will enough saleable plants be produced for the autumn?

In conclusion, may I say that I believe climbers to be a worthwhile and interesting crop but we have still to solve all the handling problems associated with them.

RHODODENDRON PRODUCTION

DAVID HILL

Boningale Nurseries, Holyhead Road, Wolverhampton

The use of tissue culture methods in propagation or rhododendrons has greatly improved their rooting, but has given rise to two significant problems related to the production of quality plants for sale. These are:

1) The production of a bushy plant.

2) Ensuring plentiful flower buds.

These criteria are of utmost importance from the sales point of view. Rhododendrons which are of a "leggy" form or do not possess many flower buds and are not desirable in the market place. In the retail market, a well-budded or flowering plant sells itself. At Boningale Nurseries Limited, we are not a large scale producer of rhododendrons, nor can we claim to be specialists, but through our experience to date we are upgrading the quality of our production. The main objectives of this paper are: (1) to communicate some of our knowledge; and (2) stimulate interest amongst others to initiate research into production techniques for the benefit of the industry as a whole.

The key to the production of high quality material is not an exact seasonal schedule, but an assessment of the optimum time according to the condition of each individual crop. It is very easy to miss this optimum time when one is fully occupied with significant tasks, such as the potting of shrubs, and lose a few weeks of growth.

In order to illustrate more specifically the significant aspects of production, I will summarise production techniques which are followed by our nurseries. At Boningale, we produce approximately 6,000 large-leave rhododendrons, plus 2,000 dwarf rhododendrons per annum; 2,000 large-leaved rhododendrons are imported from Holland as rooted cuttings, plus 1,000 from North America as plantlets raised by tissue culture, to supplement the quantity and range of cultivars of our own rooted cuttings.

When rooted cuttings have made sufficient growth, which is usually by early April, they are potted into 11 cm rigid pots by hand. This ensures minimum damage to the root system. Rhododendron cuttings generally produce only one or two major roots with many fibrous ancillary roots. Therefore, it is vital to use careful handling. At this stage initial pruning is implemented by pinching out the central terminal bud. This results in production of four or five breaks and creates the "framework" for future growth. Our potting medium is com-

posed of the following ingredients:

Irish moss peat	9 grower bales
Grodan or Rock Wool	3 grower bales
Osmocote 18:11:10 (12/14 months release)	8½ lbs.
Magnesium lime	5 lbs.
Fritted trace elements	1 lb. 12 ozs.
Potassium sulphate	2 lb.

After potting, plants are returned to the glasshouse, where they are set on waist level benches, which are covered with a layer of peat. The glasshouse is shaded; all watering is by hand. We spray the rhododendrons with Benlate to prevent *Phytophthora cinnamomi* and *Botrytis*. We feed the plants with Soluble Sangral on a fortnightly basis to enhance plant vigour and colour.

At the time of transfer to the greenhouse it may be found necessary to carry out further pinching to ensure a good framework. It has been noted that some cultivars, such as *Rhododendron* 'Professor H.J. Zayyer' produce growth beneath the soil level which supplements the plant structure.

During the course of a favourable growing season, two flushes of growth are produced. The first flush is checked as previously mentioned and, at the second flush, the dominant bud is again pinched out to promote further branching. A quality plant requires a minimum of two or three laterals but we aim to achieve five or six.

Before the first of the autumn frosts in early September the liners are placed pot-thick in a frameyard protected from easterly winds by a Rokolene windbreak. All the cultivars grown by our own nursery are hardy but are provided with a protective layer of straw or Rokolene in the coldest winter months to prevent scorching of foliage. Until late March or early April, dependent upon weather, all that is necessary is to undertake periodic checks to monitor the condition of the material and, if straw is used for protection, to check for rodents. In early spring, ideally before any significant growth is made, the rhododendrons are potted up. Large leaved cultivars go into 6-litre pots and dwarf cultivars go into 2-litre containers. It is at this stage that care and time are crucial. Individual handling of the plants is influential in producing a quality crop — no shears are used here!

We work in twos, the first person pruning or 'pinching out', the second preparing the plants for potting. If the plant is either one-sided, single stemmed, or has made "leggy" growth on the second flush, we prune them to the first set of leaves.

Hopefully, the majority of our plants do not possess any of these deficiencies. They have the central terminal growth

pinched out to stimulate production of further laterals lower down. Grading of the material is important and weak or very poorly formed plants are removed in order to obtain maximum use of valuable space.

The second person takes the pot off the pruned and pinched plant and "tickles" the root ball! Teasing the roots assists their expansion and establishment in the new compost medium. Plants are placed in trays, labelled, and transferred for machine potting.

When potted the rhododendrons are placed on raised sanded beds pot-thick. This is to assist their protection in the event of severe weather conditions. Rhododendrons, azaleas, and magnolias are placed so that careful control of watering can be achieved.

Proper watering is particularly important. Excess standing water in badly drained situations creates ideal conditions for waterborne diseases, primarily *Phytophthora cinnamomi*, for which there exists no guaranteed method of elimination. The best course of action is to attempt to prohibit its occurrence. Watering at night is preferable. Water either drains away or is removed by evaporation during the course of the next day. In the U.S.A., where *Phytophthora* is more prevalent, a Benlate drench is applied at each potting stage. Overwatering also causes production of long "leggy" shoots, when our aim is to produce short strong growth, therefore watering should be kept to a minimal level.

We have noted that plants located on the perimeter of a block in our container unit tend to be shorter and produce a greater number of flower buds. I attribute this to the fact that even under the most efficient irrigation system these receive less water and evaporation is more rapid. Plants which are subjects to a degree of stress generally react by producing more flower buds.

We have the advantage of an automatic timing device situated adjacent to the rhododendron bed, which makes for ease of checking and adjustment. If we consider it necessary the clock is altered daily and we follow the principle that when in doubt, do not water! In warm weather such as in the late spring and early summer, the irrigation is timed for an average of 15 to 20 minutes each evening. Generally one major flush of growth is produced during the course of the growing season, but occasionally a secondary flush occurs.

We make periodic checks for any evidence of pests, disease, and weeds and spray in accordance with the following programme:

Herbicide: February to October, at nine week intervals. Simazine is used at 2.67 lbs per three beds (20,000 plants per bed, 1800 m^2 per bed).

Pest and Disease Control: March or April to October at monthly intervals. Quantities applied per bed (1800 m^2):

Captan, 10-oz; Poliverdol, 1 pint; Dinocap, 4 fl oz; Spredite, 4 fl oz; Pirimore, 15 fl oz.

Approximately 30% of our 6-litre large-leaved rhododendron cultivars attain a saleable standard in 12 months. With dwarf rhododendrons a much higher percentage is obtained. Plants requiring a second season of growth have the dominant bud pinched out early the following spring. Re-spacing of plants may be necessary to prevent "leggy" growth being formed.

Slow-release fertilizer is applied in the form of one 6 gm Agriform tablet per plant. Liquid fertilizers can be utilised as a further method of promoting flower bud production. At Wells Nurseries, rhododendron specialists in the U.S.A., liquid fertilizer treatment (20:20:20) is applied until July. The fertilizer constituents are then changed to 15:45:5 (high phosphate content) to promote bud production. Existing research supports this use of phosphates to increase budding, and has indicated that utilisation of growth retardents gives similar results.

In addition to good growing techniques, the selection of rhododendron cultivars, which bud well in their first and second years of growth, is important. Rhododendrons noted for this characteristic include *Rhododendron* 'Fastuosum Flore Pleno', *Rhododendron* 'Cunningham's White' and *Rhododendron* 'Gomer Waterer'. Yakushimanum types of rhododendron possess both the marketable qualities of compact habit and abundance of flower buds. In some parts of the U.S.A. it is considered advantageous for bud production to grow rhododendrons in the field for one year and then pot up the material.

To conclude, I consider that production and marketing of quality rhododendrons is dependent on four main factors:

1. *Market demand:* Contact with, and response to, customer demand, for specific types and cultivars.

2. *Production methods:* Particular care and attention be given to the correct timing of pruning, grading of plants, pinching of terminal buds in the second year, and careful monitoring of watering and feeding, as well as adequate pest and disease prevention. With further reference to feeding of plants, I am of the opinion that growers need to communicate their requirements more clearly to fertilizer manufacturers to obtain

fertilizers which correspond more specifically to rhododendron needs.

3. Further research into the use of chemical agents which induce bud production.

4. New cultivars which possess desirable characteristics of form and of plentiful flowers should be selected.

STORAGE OF UNROOTED CONIFEROUS CUTTINGS

VOLKER BEHRENS

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INTRODUCTION

Seasonal peaks of work-load are the main reason why German nursery managers have shifted the period for propagating conifers by cuttings into the winter months, November, and December (4). But as a result, more heating and more intensive phytosanitary treatments are necessary. Rising energy costs led to the idea of collecting the cuttings in November, preparing them for insertion and then storing them up until March. The main spring selling season in German nurseries starts in March. For this reason collecting and preparing the cuttings has to be done earlier, if possible in early winter.

Suitable storage conditions must be used to avoid a significant reduction of the rooting capacity. That is why:

- water losses of the cuttings have to be kept to a minimum (13).
- the spread of pathogenic fungi has to be avoided (10), and
- respiration has to be kept low, especially if a definite amount of food reserves is necessary for quick and sufficient rooting (13,19).

All this is possible with storage at low temperature and high humidity and perhaps controlled atmosphere (CA) is advantageous (2,5).

Cuttings of conifers cultivated in Germany have the advantage of being resistant to low temperatures if collected at the proper time of the year, but these cuttings have the disadvantage of not being storage organs which can accumulate food reserves in larger amounts. Thus, the storage temperature for coniferous cuttings might be below freezing, and this seems to

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be of some significance because diminishing the consumption of reserve material is very important.

Storing bare-rooted woody plants is a technique well known by nurserymen (3,15,20). The publications on cold storage of unrooted cuttings primarily concern herbaceous or deciduous plants (6,16); only a few refer to coniferous cuttings (7,11,12,14). However, conditions necessary for successful winter storage of cuttings of ornamental conifers have not yet been investigated.

MATERIALS AND METHODS

Based on the experience of storing bare-rooted woody plants and fruits as well as on the results of a pilot test, experiments were carried out to investigate the influence of the storage at +2°C, 0°C, −2°C, and −4°C. Furthermore, for each temperature normal atmosphere was compared with controlled atmosphere (CA) of 3% CO_2 and 3% O_2.

Cuttings were packed in perforated polyethylene bags and stored in jacketed cold stores. In a separate experiment the effect of a jacketed cold store was compared with the effect of a conventional directly cooled store, whereby in the latter case the cuttings were covered with plastic film.

The influence of cutting preparation and bundling (25 cuttings/bundle) was investigated. The cuttings were prepared by stripping-off the needles from the lower stem portion and applying a rooting-powder and fungicide mixture (0.4% IBA, and captan) to the base of the cuttings.

After storing for four months (November 15 to March 15), the cuttings were inserted in a medium of peat and sand (1:1, v/v) and placed in a plastic tunnel in an unheated greenhouse.

The experiments were carried out on ten different species and cultivars of ornamental conifers (see Figures 3 and 4).

The final criterion in judging a suitable storage method is the quantity of saleable liners — not just the rooting percentage. Prolonging the production period cannot be accepted. Cuttings could only grow to a saleable liner in the usual time if they had formed a good root system by the middle of the growing season. That is why the counting of well-rooted cuttings was done in early July.

Percentages were transformed with the angular transformation and data subjected to standard analysis of variance procedures, LSD $\alpha = 0.05$ Tukey-Test.

RESULTS

Cuttings stored best if they were not bundled (Figure 1). Species that are sensitive to fungal attack showed grey mold infection if bundled, even at temperatures of −2°C; they also rooted less well. The temperature within the tightly bundled plant material was at least 3°C higher than in the surrounding storage atmosphere. A more uniform distribution of the temperature was possible if cuttings were not stored in large compacted batches but in loose lots.

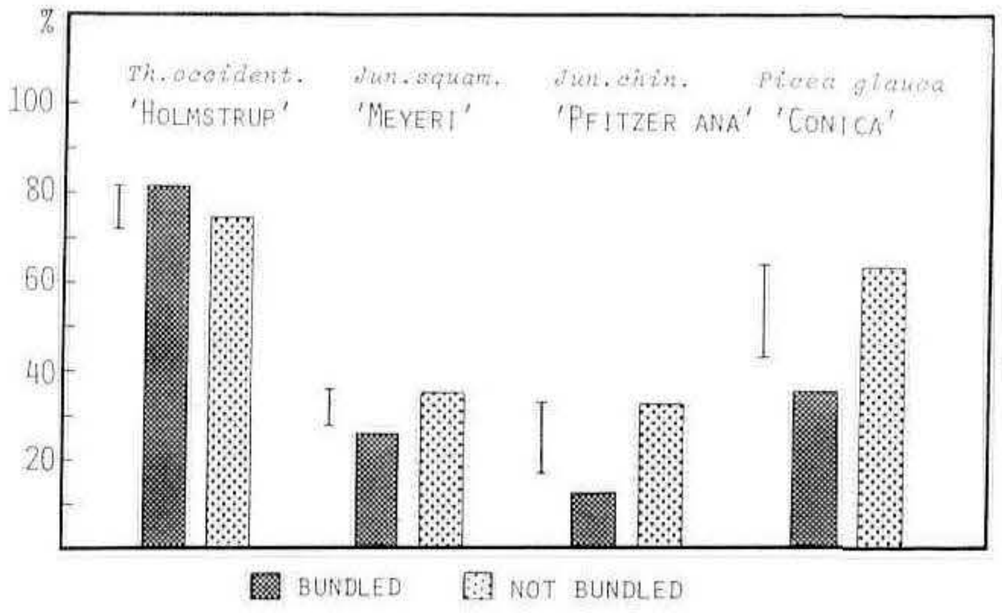


Figure 1. Influence of bundling on the rooting percentage of stored cuttings.

Depending on the cooling system employed, different ways of protecting against desiccation were necessary. In a jacketed cold store cuttings needed no additional covering with plastic film, but good results were achieved after packing them in perforated polyethylene bags. On the other hand, perforated poly-bags and additional wrapping with plastic were necessary in a storage room with direct cooling. In both cases rooting results were similar.

Preparing the cuttings ready for insertion was possible before storage as there was no significant influence upon results. Only for species susceptible to fungal attack was the fungicide treatment advantageous.

Controlled atmosphere storage had a significant influence on the rooting capacity of only four of the tested species (Figure 2). Presented are the summarized results of the differ-

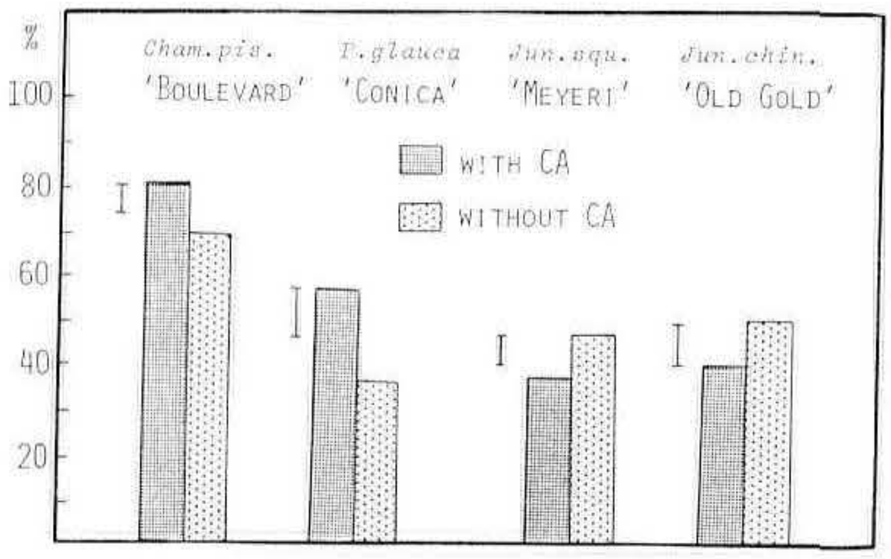


Figure 2. Influence of storage atmosphere on the rooting percentage of cuttings.

ent storage temperatures. *Chamaecyparis pisifera* 'Boulevard' and *Picea glauca* 'Conica' were in a better condition if stored in CA rather than in a normal atmosphere. This was particularly so at temperatures above freezing. On the other hand, *Juniperus* rooted better after storage in normal atmosphere, especially at temperatures below freezing. Of more significance was the influence of the storage temperatures (Figures 3 and 4).

Figure 3 shows those species that gave the same results in different years. Storage at +2°C proved to be least satisfactory, the rooting percentages were significantly lower than at the other temperatures. But the optimal storage temperature was different from one species to another: 2°C below freezing for *Chamaecyparis lawsoniana* cultivars; −4°C to 0°C for *C. pisifera*, and freezing point for *Thuja*.

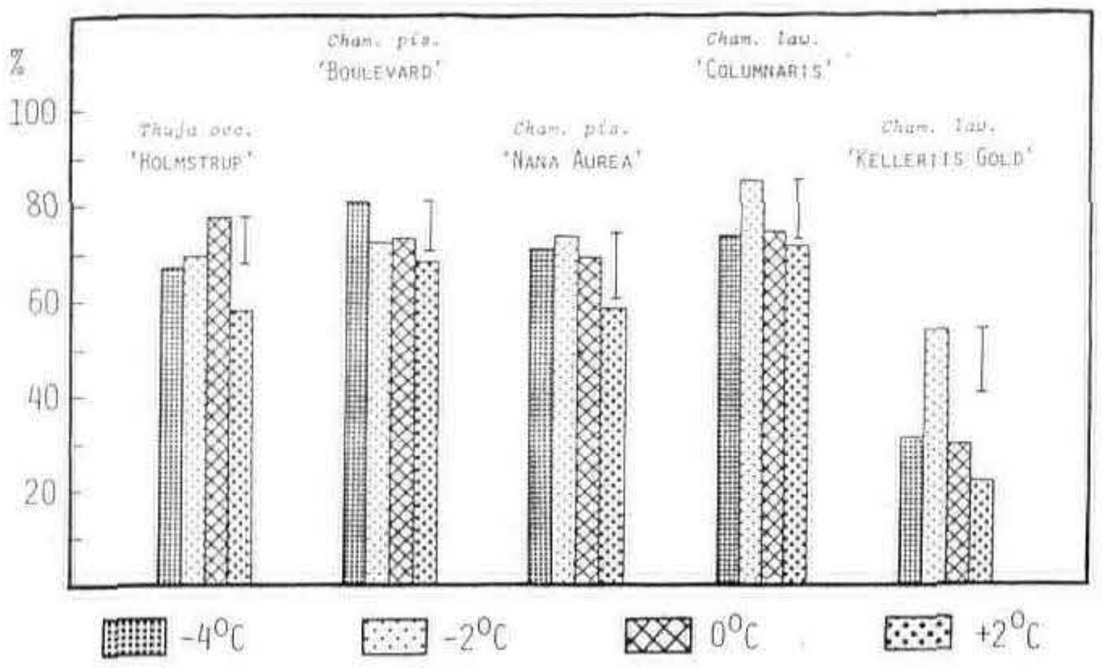


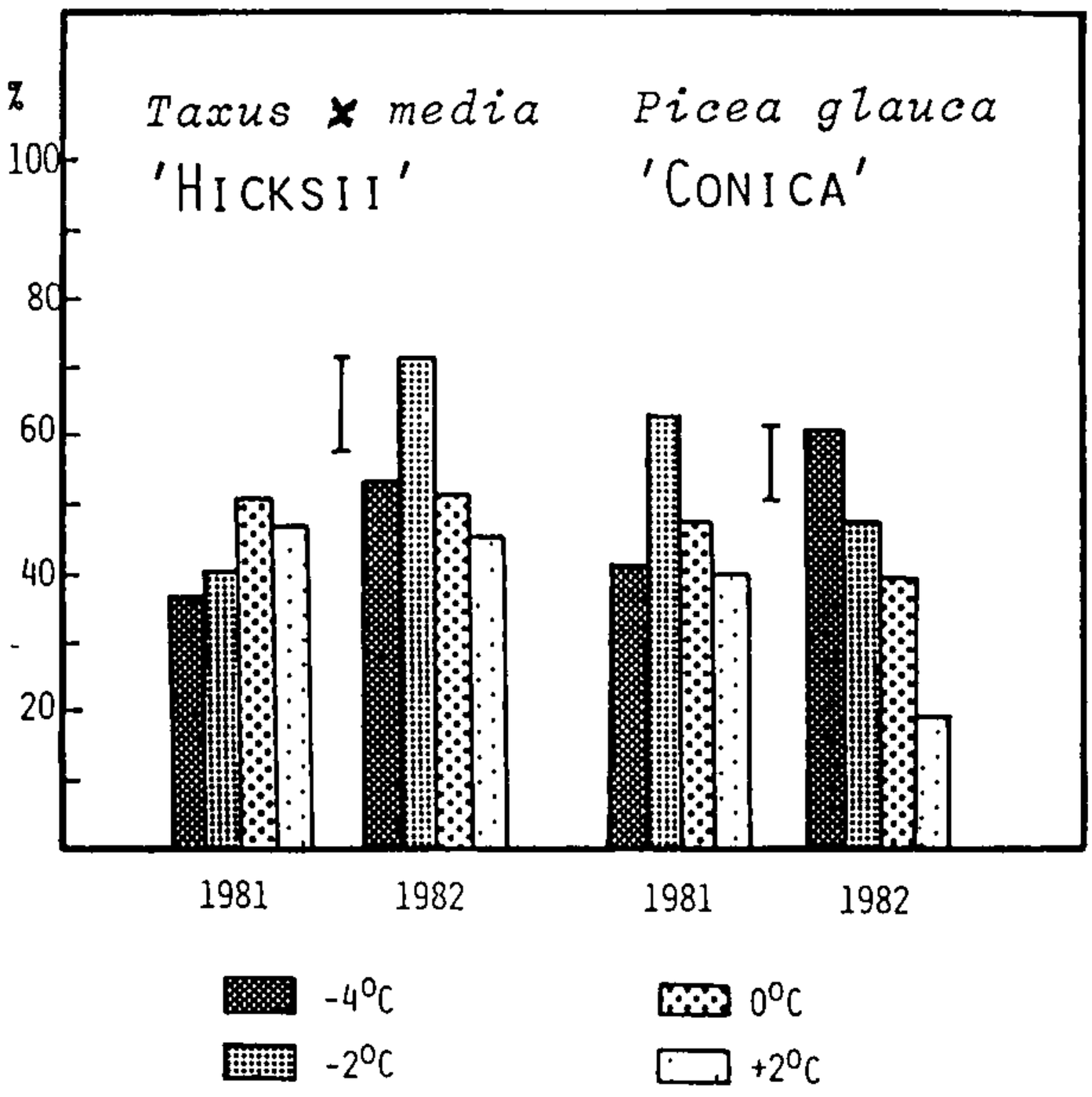
Figure 3. Influence of different storage temperatures on the rooting percentage of cuttings. *Left to right. Thuja occidentalis* 'Holmstrup', *Chamaecyparis pisifera* 'Boulevard', *C. pisifera* 'Nana Aurea', *C. lawsoniana* 'Columnaris', *C. lawsoniana* 'Kelleriis Gold'.

For the other species (Figure 4) a temperature of +2°C did not lead to the highest rooting percentages either, it often led to the lowest ones. Which temperature was best depended not only on the species but also on the year. From 1981 to 1982 the optimal temperature shifted to the next lower temperature for *Taxus* and *Picea* and to higher temperatures for *Juniperus*.

DISCUSSION AND CONCLUSION

Conditions for successful storage could be found for nearly all species. The optimal storage condition resulted in the same propagation success as the conventional propagation method.

Water losses were about the same regardless of storage conditions, and the cuttings could be kept healthy during storage. On the other hand, consumption of reserve materials was different. Fats and proteins were not used as food reserves. As expected, the temperature of +2°C led to the highest reduction



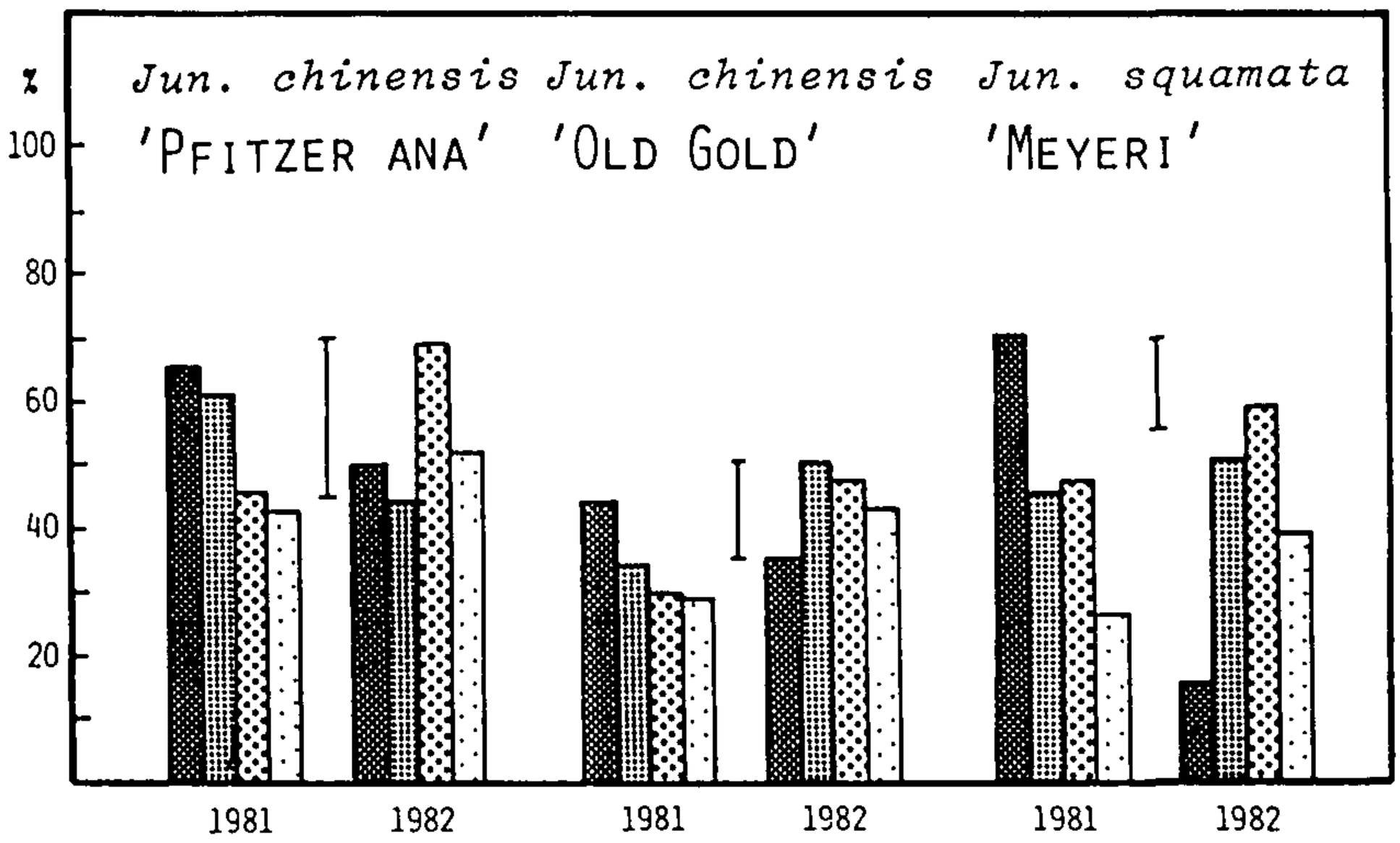


Figure 4. Influence of different storage temperatures on the rooting percentage of cuttings in 1981 and 1982.

of sugars and other carbohydrates; the lower the storage temperature the smaller the carbohydrate losses through respiration (1).

There are two advantages in diminishing losses of reserve materials:

— keeping the right amount of carbohydrates for successful rooting (13,18,19).
— maintaining the frost hardiness of the cuttings (8,9).

Depending on which reason is more important and depending on the initial content of food reserves and frost protecting materials, the optimal storage temperature varies for the different species and years.

Plant parts which are not storage organs can hardly be enriched with high amounts of photosynthetic products. Thus, stored cuttings may run out of their food reserves and probably start to exhaust their frost protecting materials (17). Then rooting may be reduced as a result of frost damage, especially if cuttings are stored at −4°C. This could mean that cuttings which have developed a greater frost hardiness on the stock plant are most suitable for successful storage. The plant cells contain a much higher percentage of various organic compounds which can be used for frost protection and for metabolic processes during storage and rooting. The weather conditions which are favourable for building up frost hardiness are not present at the same time every year. Cuttings collected at a fixed date may not have the same degree of hardiness.

A temperature of 0°C to −2°C was the most satisfactory for all species on an average over the different years.

Taking into account the results of this investigation a propagation programme can be proposed for the production of winter-propagated conifers:

— Collection of cuttings only after the build-up of sufficient frost hardiness (after a period of low temperature).
— Preparation of cuttings ready for insertion.
— Packing loose in perforated poly-bags.
— Storage in a jacketed cold store or polyethylene wrapped in a conventional cold store.
— Storage temperature of −1°C to −3°C.
— Storage period up to 4 months.
— Keeping the tops of the cuttings cold and the buds quiescent during rooting.
— A good phytosanitary programme.
— Potting from June to July.

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BLACK POLYTHENE MULCHES AS AN AID IN FIELD PROPAGATION OF HARDWOOD CUTTINGS

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Abstract. The response of *Salix* and *Populus* hardwood cuttings to mulching with black polythene during field propagation was studied. The effect of the mulch was to suppress weed growth, increase soil temperature, and conserve soil moisture, as compared with a non-mulched control. Results of trials in 1982 and 1983 demonstrated an increase in growth with both species due to mulching.

Work at Long Ashton Research Station from 1973 to 1975 (1,2,3) has demonstrated the benefits of polythene mulches for strawberry cultivation. Mulching produced larger plants, with more runners, which flowered and fruited earlier than the non-mulched controls. The number and weight of fruit were higher from mulched plots. Comparisons between clear and black polythene showed that clear polythene produced a greater growth response than black polythene. Clear polythene, however, did not surpress weed growth, and subsequent weed seed germination lifted the mulch.

Recent work at East Malling Research Station (4,5) has investigated the effect of polythene film on soil temperatures beneath maiden fruit trees. Materials studied included black polythene, perforated black polythene, and reflective polythene. A black polythene mulch increased soil temperatures by about 2°C in the early part of the season, the reflective polythene reduced soil temperatures by 6°C at 5cm depth and 3°C at 20 cm depth.

The objective of the experiments reported in this paper are to ascertain the advantages and disadvantages of using a black polythene mulch in the field propagation of hardwood cuttings and to determine whether the use of a mulch would aid rooting establishment and growth.

MATERIALS AND METHODS

In the first trial (1981-82) hardwood cuttings of *Salix viminalis*, *Salix fragilis* 'Basfordiana', *Salix alba* 'Lancashire Dicks', *Populus trichocarpa* × *P. balsamifera* 'Clone 32', *Populus* × robusta, and Populus nigra 'Vereekens' were collected in late November, 1981. All cuttings were graded by weight into three categories, 0-15 g, 16-30 g, and 31-45 g. The base of each cutting was dipped for 5 seconds in an indolebutyric acid solution of 2500 ppm and allowed to dry before insertion. Cuttings were struck in beds 1 m wide, with 0.5 m between

the rows and 0.05 m between cuttings within the row, giving a density of 60 cuttings/m^2. Half of the beds were covered with 200 gauge black polythene which was laid by hand and the cuttings were pushed through the polythene. For each weight grade there were 3 replicates, each of 20 cuttings, with and without black polythene, arranged in a randomised block design.

In the 1982-83 experiment the materials and methods were identical to the first, except that the cuttings were not graded by weight and the collection of cuttings was delayed until mid-February. Soil temperature and moisture deficit were monitored.

RESULTS

The height of the main shoot at the end of each growing season is shown in Table 1 (1981-82 experiment) and Table 2 (1982-83 experiment). In both trials the use of a black polythene mulch encouraged the growth of all species and all weight grades. Failure to grade cuttings for the second trial increased variation in the analysis of that experiment.

Table 1. Height of shoots from mulched and non-mulched treatments (1981-82).

	Height of main shoot (cm)						
	Mulched			Non-mulched			
Cutting weight (g)	0-15	16-30	31-45	0-15	16-30	31-45	Mean
Species							
Salix viminalis	105	106	102	84	88	98	97
S. *fragilis* 'Basfordiana'	72	85	87	59	57	55	69
S. alba 'Lancashire Dicks'	76	70	75	56	50	51	63
Populus nigra 'Vereekens'	31	37	35	27	27	28	31
P. × *robusta*	40	38	34	30	30	30	34
Populus 'Clone 32'	49	52	48	46	44	47	48
Mean	62	65	64	50	49	52	—
S E. species, 2.46							
S.E. treatment, 1.42							
S.E. weight, 1.94							

Establishment figures for both trials are shown in Table 3. Despite increased extension growth resulting from the use of black polythene mulch the establishment figures were lower where mulching had been used, but differences between treatments are slight.

Cuttings were monitored for bud development in March-April. There was little difference in the date of 50% bud break between mulched and non-mulched treatments although there was a distinct trend for mulched plots to break bud earlier.

Table 2. Height of shoots from mulched and non-mulched treatments (1982-83).

Species	Height of main-shoot (cm)		
	Mulched	Non-mulched	Mean
Salix viminalis	106.9	101.7	104.3
S. fragilis 'Basfordiana'	77.2	57.4	67.3
S. alba 'Lancashire Dicks'	87.2	69.8	78.5
Populus nigra 'Vereekens'	62.3	51.3	56.8
P. × robusta	54.5	48.6	51.6
Populus 'Clone 32'	80.9	66.2	73.6
Mean	78.2	65.8	—
S.E. species, 38.6			
S E treatment, 22.3			

Table 3. Percentage establishment of cuttings from mulched and non-mulched plots for both 1981 and 1982 experiments.

Species	Percentage establishment			
	Mulched		Non-mulched	
	81-82	82-83	81-82	82-83
Salix viminalis	97.8%	97.7%	98.9%	100.0%
S. fragilis 'Basfordiana'	95.0	93.7	100.0	99.3
S. alba 'Lancashire Dicks'	63.3	85.0	81.0	90.0
Populus nigra 'Vereekens'	82.2	98.0	79.4	100.0
P. × robusta	83.8	96.3	83.8	100.0
Populus 'Clone 32'	95.0	95.7	98.9	99.3
Mean	96.0	94.4	90.3	98.1

Results for the 1982-83 experiment are shown in Table 4.

Table 4. Date of 50% bud break on cutting material for 1982-83 experiment.

Species	Date of 50% bud break	
	Mulched 82-83	Non-mulched 82-83
Salix viminalis	Mar. 19	Mar. 19
S. fragilis 'Basfordiana'	Apr. 2	Apr. 8
S. alba 'Lancashire Dicks'	Mar. 24	Mar. 25
Populus nigra 'Vereekens'	Apr. 11	Apr. 12
P. × robusta	Apr. 11	Apr. 12
Populus 'Clone 32'	Mar. 23	Mar. 24

Records of soil temperature were taken during experiments. In the 1981-82 trial temperature was measured between May and August whereas in the 1982-83 trial the soil temperature was measured from March to October. Figure 1 shows the mean monthly soil temperature for both experiments. The soil temperature in 1983 was consistently higher under the mulch especially during the early part of the season.

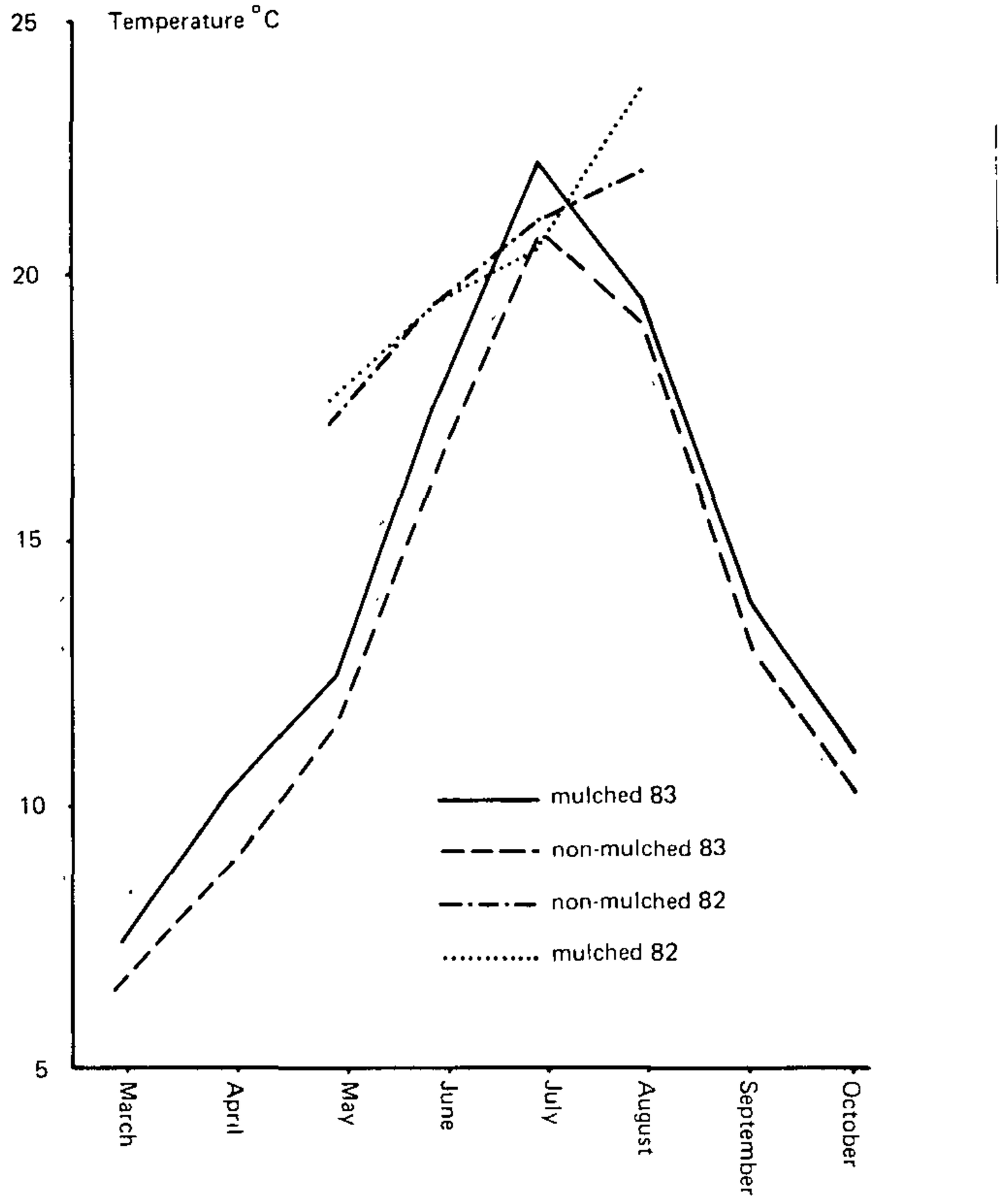

Figure 1. Mean soil temperatures for each month for mulched and non-mulched treatments for both 1982 and 1983 trials.

In the 1982-83 trial the soil moisture was measured in mulched and non-mulched plots using a soil moisture tensiometer. Results of the determinations are shown in Table 5.

Table 5. Soil moisture deficit for 1982-83 experiment expressed as centibars of soil suction.

	Average soil moisture deficit (centibars of soil suction)	
Month	Mulched	Non-mulched
March	6.3	5.9
April	4.5	3.7
May	2.5	1.9
June	3.2	4.3
July	16.8	18.7
August	60.7	50.7
September	51.3	44.5
October	9.2	5.0

During March to May, 1983, the season was particularly wet and non-mulched plots were considerably wetter than mulched plots. This was reversed in June and July when mulched plots were more moist than non-mulched plots; from August to October mulched plots were again drier.

DISCUSSION

Both experiments showed that insertion of hardwood cuttings of *Salix* and *Populus* through a black polythene mulch gave improved shoot extension growth. This is in agreement with work at East Malling Research Station (4,5) which showed that shoot length of maiden fruit trees was increased by 28% when grown with a polythene mulch.

Suppression of weed growth should assist in the establishment and growth of cuttings; however, the non-mulched plots were maintained in a weed free condition by hand-weeding and consequently improved growth cannot be due entirely to lack of weed competition. It is more likely that the improved growth is as a result of higher soil temperature and conservation of moisture, as indicated in the results of the monitoring programme. The tendency for the black polythene to reduce infiltration of water during periods of high rainfall could lead to problems during prolonged dry spells, particularly if lateral movement of water in the soil is limited either by the nature of the soil structure or the polythene skirt which is buried to provide anchorage.

Whilst the use of clear polythene may give an improved response, compared to black polythene, as was the case for strawberries at Long Ashton (1,2,3), the problem of weed competition requires a residual herbicide programme. Although the black polythene did suppress weed growth, occasional weeds appeared where the polythene had become torn around the base of cuttings.

Initial attempts to lay the polythene mulch underlined the importance of keeping the mulch taut across the bed. Loose polythene which flapped in the wind had a damaging effect on the emergent buds. Direct insertion of the cuttings by pushing them through the polythene can loosen the mulch. This can be overcome by use of polythene with planting holes already in it or by puncturing the polythene *in situ* with a sharp instrument rather than a blunt-ended cutting.

Although the polythene in both experiments was laid by hand, it is feasible to lay the polythene using a tractor-mounted machine which has a capital cost of between £500-600. The comparative cost of some of the plastic mulches is shown in Table 6. It should be noted that the list of products is not

exhaustive and serves only as a guide of the relative costs involved.

Table 6. Comparative cost of different mulching materials.

Product	Roll width*	Roll length	Useable area	No of rolls	Cost	Cost	Cost	Gauge
	m	m	m^2	/ha	£/roll	£/ha	£/m^2	
BCL polythene	1.225	150	150	67	12.90	864	0.09	200
BCL polythene	1.325	150	150	67	14.00	938	0.09	200
ICI mulch	1 300	200	200	50	14.95	748	0.07	150
Polycrop blanket	1.330	600	600	17	66 00	1122	0.11	—

* It is assumed that additional breadth will be used for anchorage. BCL = British Cellophane Ltd; ICI = Imperial Chemical Industries.

The approximate cost of Simazine applied at 1.1 kg/ha would be in the region of £12/ha which is less than the cost of the polythene. The cost of a polythene mulch per plant becomes progressively more expensive as the density of cuttings is decreased.

In conclusion, the use of black polythene mulch improves the growing environment of cuttings and does promote additional growth. When production is carried out on a large scale the mechanisation of the technique may prove too costly at present but the technique has considerable advantages for propagation and the production of difficult species.

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CONTAINER TREE PRODUCTION

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Production of Maiden Trees. Five acres of tree stocks are planted annually. This is in a seven year rotation with strawberries. During the final year of the rotation the area is put down to a grass ley. This enables perennial weed to be selectively treated with herbicides during the year. The Westerwolth ryegrass is ploughed in as green manure after the addition of 100 tons per acre of farmyard manure in the early autumn. One acre of land is being sterilized with methyl bromide this year applied by contractors. We are attempting to reduce the problem of verticillium wilt, particularly on *Acer* trees. This occurs as a result of following strawberries in a cropping rotation.

The soil is ploughed and then worked down to a fine tilth in late autumn in readiness for planting. After this, we do not have to use a heavy tractor on the land again during the wet winter weather. Planting commences as early in the autumn as possible. This is done by using a combination of a mini-tractor and single share slitter which is very light and permits planting throughout the winter in favourable conditions.

Planting is carried out by hand in 45 ft. wide beds. This allows for efficient spraying by a Victair blast sprayer later on. Irrigation in the summer by a trolley mounted 'Rain-Gun' is also possible in this bed width. Due to the fact that trees are lifted after one year, the stocks are planted at 9 in. intervals in the row and 3 ft. between rows.

The rootstocks are all of British origin, mainly bought in. However, we supplement these with some of our own being mainly fruit and *Prunus* 'Colt' cherry rootstocks. In order to propagate the latter we use our own modified "Garner Bin" system.

Cuttings are stuck in deep plastic crates instead of the traditional bin. The crates are then stood down onto a bottom heated area in a cold, double-skinned polytunnel for the appropriate period of time. Temperature at the base of the cuttings is controlled by Nobel sensors placed in the crates. The treatment otherwise for the hardwood cuttings is standard. The advantage of this system is its flexibility, since one batch of cuttings can be removed after the necessary propagation time. They can be held until planting conditions are favourable in a cool but dry situation. The propagation area can be immediately filled by a second batch of cuttings. During the

maiden crop weed control is carried out usiiig is a mixture of Simazine and Venzar, with additional spot treatment with Paraquat or Roundup. We only use the chip budding technique, budsticks being taken from an area of mother trees which are irrigated by a low level system. We use a combination of degradable rubber strips for easily propagated subjects such as apples, pears, and *Sorbus* and 1-in. polythene tape for the more difficult *Acer*, birch, and small, budded *Prunus*.

A soil analysis is carried out prior to the commencement *of the second year. Any nutritional deficiencies can be correct*ed at this time by the implementation of a fertilizer programme. After the heading-back of the rootstocks in February bud clips are applied on most cultivars in order to produce a straight stem and also to reduce the amount of caning necessary. We still have to cane certain genera because of the problems of blow-out of the young growth on subjects such as *Crataegus*, *Laburnum*, plums, and all weeping trees. As an aid to caning, a Kango hammer drill is used to make the hole in the ground.

During the second year routine maintenance consists of tying, trimming side shoots, weed control and irrigation. Additionally a 14 day pest and disease spray programme is carried out.

Lifting. Lifting commences about mid-November. All pruning operations necessary are carried out in the field. Bush fruit trees are tipped at 2 ft. 9 in. and the side shoots are trimmed or removed as necessary. Ornamentals are tipped at 5 ft. and the stems cleaned up to 3 ft. Undercutting is done by using the combination of a Barton winch and an Egedal plough with lifting forks. The lifted maiden trees are transported to a potting shed by means of low loading trailers drawn by Kubota mini-tractors.

Blocking-up begins at about the same time as pruning commences. This is the removal of the unsold container trees from the growing area. They are moved to a holding area with a post and wire support system and irrigation and roadways for despatch. This enables the growing areas to be cleaned and capillary lines relaid in preparation for the newly potted crop.

Potting. During potting a severe root pruning is necessary in order that the maidens can be potted into 12 litre polypots for fruit trees, and 18 litre polypots for the ornamentals. All potting is done by hand around a semi-circular bench which is fed with compost by a pivoted conveyor. This enables delivery of the compost to the front of the operator. The compost is a 75% Finnish; 25% grit mix, and 12 to 14 month Fictoe. The peat has a good structure and is generally weed-free.

After potting, the trees are moved by means of low loading trailers to the growing areas. They are stood down at a final spacing of 2 ft. between the trees in the row and 3 ft. between the rows and the capillary lines are used as markers. In the majority of cases no permanent tree support system is used. A 7 ft cane is used for ornamentals and a 4 ft cane for bush fruit trees. These are inserted to the depth of over 2 ft. through the pot and into the underlying soil, using a Kango drill in order to make the hole. Max Tapener tying machines are used to tie the maiden trees to the canes. The strongest tape is used and this is later supplemented by a plastic "sack-tie" at the top of the tree. This prevents the head breaking away from the cane when it becomes heavy. Trees are therefore despatched complete with their canes simply by lifting the tree and cutting off the section of cane below the pot.

A small area of post and wire training system is being looked at this year, in readiness for using rigid containers. The obvious drawback is a very much higher level of investment, especially in view of the amount of space given to the trees.

We now use capillary irrigation almost entirely. It is more effective and there is a saving of water. Since there is no run off we have reduced erosion and problems of diseases spread by water splash, such as bacterial canker, are kept to a minimum. The irrigation is automatically controlled on a time clock system which gives accurate control.

Bench grafting of several genera of trees takes place during February. *Salix caprea* 'Pendula' and *Salix purpurea* 'Pendula' are whip-grafted onto 5 ft. stems of *Salix* × *smithiana*. These stocks are raised from hardwood cuttings which are inserted into 4 litre pots during the previous year. The grafts are dipped in wax and stood down under glass or in a cold polythene tunnel until about May. They are then potted on and stood down outside to be grown on until the sales period, which is from September onwards. Another tree which is grown by the same production method is *Robinia pseudoacacia* 'Frisia,' grafted onto *Robinia pseudoacacia*, as this makes a more manageable tree than a two-year tree potted as a maiden.

Weed Control. Weeds are controlled between the containers by using a mixture of Simazine and Venzar at 2 lbs. c.p. of each per acre. This mixture is applied twice during the growing season. The first time is in February or March and again in late June, while one can still walk between the rows. Spot treatment is carried out as necessary with either Paraquat or Roundup. Tenoran has been used in the past for weed control on top of the containers, however Banweed 'S' is now being used with good effect and gives considerably longer control.

Maintenance of the container trees during the summer is restricted to cleaning up the stems by about mid-May to leave approximately a 2 ft. head. If it is done at this time the shoots can be rubbed out by hand, rather than having to use secateurs later in the season. Fan training of apples, plums, and cherries takes place during the summer.

Throughout the season a regular 10/14 spray programme is maintained against scab, mildew, caterpillars, aphids, and diseases such as willow canker.

Descriptive labels are attached to the trees before dispatch during the sales period, which extends from late August until the following May.

John Gaggini to John Hedger: Would you please elaborate on the propagation of *Salix caprea* 'Pendula'. What sort of wax do you use?

Hedger: *Salix caprea* 'Pendula', we graft onto *Salix smithiantha*, and for *S. purpurea* 'Pendula' we use *S. daphnoides*. We use low melting point paraffin wax for grafting which we obtain in one kilogram packets. Great care must be taken so as not to overheat the wax and burn the plant.

John Gaggini to John Hedger. What sort of take are you obtaining?

Hedger: About 95% with good rootstocks and scion materials.

Queston to John Hedger: Do you establish the stocks in pots before grafting?

Hedger: Yes, they are established by inserting cuttings into 4 litre polypots during the previous year. They are, therefore, one year old and 6 to 7 feet high at grafting.

ANEMONE TUBER PRODUCTION IN SOUTHWEST ENGLAND

MRS. L.M. GILL
Ministry of Agriculture, Fisheries and Food
Rosewarne Experimental Horticulture Station
Camborne, Cornwall

Techniques for producing anemone tubers were developed at Rosewarne over the last 26 years in parallel with a breeding programme to produce a winter hardy strain of anemone. Since the de Caen anemone was not easy to propagate vegeta-

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tively it was also necessary to study seed production and, in particular, methods of sowing.

The Saint Piran strain which became available in 1978 contains 9 individual groups which are grown in isolation until the final mass seeding prior to the sale of the tubers.

Although there have been certain modifications, this basic system continues to be used by the commercial producers, Wyvern Growers in Somerset.

Seed production. Cultural requirements such as rotation, manuring, soil preparation, depth and density of planting, weed and pest control are the same as for commercial flower production, as detailed in the revised edition of the Anemone Advisory Leaflet 353 of the Ministry of Agriculture, Fisheries & Food. However a rigorous programme of sprays and roguing is essential in order to produce good quality tubers for multiplication of stock or for sale.

In order to maintain the winter hardy strain, seed is saved from selected plants known to have produced good quality flowers from autumn to spring. Tubers of 2 to 3 cm size are planted in early June and flower from September onwards; the final selection and roguing takes place in late March. This ensures that plants are selected from the commercial situation, and the spring harvest provides for sowing in August. However, 3 to 4 cm tubers are used in the multiplication of the 9 basic groups and are usually planted in July.

Tubers are planted by hand or machine in drills 2.5 to 5.0 cm deep at a density of 148,000/ha (60,000/acre). Generous spacing minimises disturbance at roguing time and provides a free circulation of air and better disease control.

In the Rosewarne breeding programme pollination takes place under insect proof cages. The flowers are hand pollinated just before the buds open. There is no need to remove the stamen since the stigma ripens before pollen is shed.

Basic group seed is produced in the open but in isolation. Plots are at least 270 metres apart to avoid cross pollination. Tubers of the 9 basic groups are mixed before planting to produce Saint Piran seed. Cross pollination takes place and this natural hybridization results in an attractive range of colours of blue, magenta, red, bicolours, and white. The period from initial selection to the commercial tuber is at least 12 years.

It is unusual for a good seed head to develop if a flower is fertilized only by its own pollen; however satisfactory pollination can take place from older flowers on the same plant. The seed head takes 3 to 4 weeks to develop and ripen, at which

stage the head softens and bursts to release fluffy lint covered achenes. A good head may contain approximately 1,500 seeds of which up to 50% are viable. When seed ripens it can easily blow away and daily collection is, therefore, essential to avoid waste.

Although attempts have been made to harvest the seed mechanically, hand collection is preferable. Only the best heads are picked as they are about to burst. These are dried in trays under glass or in polythene tunnels, with heat being given in periods of wet weather. The seed is turned daily to speed the drying process and is finally cleaned, bagged, and stored in a dry, vermin-proof place.

Seed must be cleaned in order to avoid nozzle blockage at sowing time. Hand cleaning is expensive but equipment developed at Rosewarne and further modified by Wyvern Growers has reduced labour input and ensures that seed is ready to sow in July or August.

Seed yields vary according to season and for a commercial area of Saint Piran the range is 78 to 120 kg/ha and in an exceptional year 156 kg/ha. Yields also vary in the basic groups. Reds are usually less productive than magenta, blue, and bicolours. Allowing for roguing, yields may be as low as 58 kg/ha.

Tuber production. Studies of tuber-raising techniques commenced in 1961 with frameyard production. This technique is still being used to maintain basic groups and replacement material.

Seed is sown in frames at 5 grammes per square metre in August and the seedlings grow through the winter with the protection of lights from January to March when they are uncovered. By June or July the foliage dies down and lights are replaced to speed the drying process. Dried foliage is burned by flame gun. Tubers are harvested over a riddle, washed, placed in trays, dried, graded, bagged, and stored in a dry place until required for planting the following year.

Since 1965 tuber production was extended to off-Station areas where soils were thought to be relatively free from stones. The first trial occupied a few square metres of sandy land at Hayle and within the next 10 years the area increased to 1.2 ha. During this period many aspects of production were studied. Machinery was developed to remove stones and sowing in sand was replaced by the technique of sowing in alginate solution. Soil stabilising materials were tested to overcome erosion of sandy soils, and various types of shelter were compared. Wooden lath fencing proved to be the most effective and durable. Good weed control has been the key to success.

Work on pre-harvest treatments, tuber harvesting, cleaning and drying, made commercial production on a limited scale the next priority.

Assistance was sought from advisers and growers on suitable soil types in the South of England and tuber production trials were carried out in Sussex, Hampshire, and Somerset. The Yeovil sands in Somerset proved to be the most suitable of the sites tested and it is here that commercial quantities of tubers and seed are being produced.

Tuber production commenced in 1976 with 0.1 ha and by 1981 it has risen to 6.5 ha with an output of 2.9 million tubers/ha. Production is based upon the bed system and fluid seed spraying methods developed at Rosewarne, but considerable progress has been made in harvesting, cleaning, and drying. Seed is sown from July to August on prepared beds 1.8 m wide, using 24 to 42 kg of seed in 4,000 litres of a 10.5% solution of alginate/ha. The lower seed rate is used where irrigation is available. Shelter and soil stabilisers are not required since it is less windy and the soil finer textured than in the original trials in Cornwall.

Weeds are controlled with pre-emergence sprays of Paraquat, followed by Terbacil at 0.3 kg of the proprietary product per ha plus a repeat Terbacil treatment applied post-emergence in November. Although at present there is no label recommendation, this herbicide has given good weed control except where winter germination of mayweed has occurred. Trials are in progress to try and solve this problem.

A regular spray programme ensures that healthy stock is maintained in seed and tuber production areas. This is backed by regular inspections to ensure freedom from fungus diseases, such as *Colletotrichum* and plum rust and to reduce the spread of virus.

Flailing and sweeping of beds has superseded burning over, which was too slow for the commercial operation. The purchase and modification of a Dutch harvester has speeded the harvesting process.

Tubers are cleaned in fast flowing water and dried quickly in wire bottomed trays stacked over an air duct or in bulk bins. When dry they are graded into five sizes ranging from 1 to 2 cm, and over 5 cm, and bagged in batches of 5,000 before despatch. Tubers are now available for commercial and retail outlets through Lingarden Limited, Weston, Spalding, and Lincolnshire.

Maintenance of basic and replacement material — As commercial production has increased over the past 9 years the

areas at Rosewarne devoted to seeds and tubers have been reduced to those necessary for the provision of basic material and reserves in case of emergency. The whole of the work of maintaining the basic groups, and the breeding of replacements have now been taken over by the Somerset producers. Plant health, hardiness, flower yield and quality are still to receive the highest priority.

Development of the Saint Piran strain has improved the prospects of anemone flower production and provided opportunities to develop home and export markets for tubers. The success of this venture has combined the best elements of ADAS and specialist resources with grower co-operation.

Question to Mrs. Gill: Are anemones being grown in gardens apart fom the southwest of England?

Mrs. Gill. Yes, they are grown in areas as far north as Perth in Scotland with protection, such as in cold greenhouses.

NEW NARCISSUS AND THEIR PROPAGATION

W. JAMES HOUGHTON
Tomlin Brothers Ltd.
Polgoon, Penzance, Cornwall

We owe the beauty of new cultivars of daffodils to the dedication of past and present hybridizers and daffodil lovers. During the last 100 years daffodils have been collected from the wild and crossbred, with the selections becoming better and more colourful with each generation.

In this world of daffodils the names of breeders that have given us the beauties that we enjoy today, to mention a few, are Reverend William Herbert, Edward Leeds, Peter Barr, Reverend George Engleneart, William Backhouse, The Brodie of Brodie, Guy Wilson, Lionel Richardson, P.D. Williams, and so many more very dedicated folk, including those hybridising today. At daffodil shows the results of their work can be seen in all its splendour. There are eleven distinct divisions of narcissi. Each year at shows a new cultivar more elegant than its predecessors will surprisingly come to light. It may be one of the large trumpets, a double, a small cup, tazetta, or a cheeky little rock daffodil.

Most of the new cultivars have been bred specifically for the show bench. Rosewarne Experimental Station, however, at

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Most of the new cultivars have been bred specifically for the show bench. Rosewarne Experimental Station, however, at

the request of Southwest growers, started a breeding programme in 1963 to create a group of daffodils suitable for the cut flower and bulb trade. The requirements were for hardier, taller, prolific, earlier and disease resistant cultivars with customer appeal. This is some task! The task was given to Miss Barbara Fry whose achievements and dedication in the work are quite remarkable. Her resultant cultivars, produced with the help of the Rosewarne staff, are also remarkable.

The first two of these were released and sold in 1981, named 'Tamara' and 'Tamsin.' Both are yellow; 'Tamara' is a 2YY and 'Tamsin' a 1YY. Two tazettas were also sold and bought by the Isles of Scilly growers. Tazettas grow very well on the Scillies. 'Tamara' was bought by the Cornwall Area Bulb Growers Association, and 'Tamsin' by a company in Lincolnshire. Since C.A.B.G.A. bought 'Tamara' it has been propagated and is now divided between the growers who shared the cost of the stocks and propagation. More cultivars will shortly be released from Rosewarne after rigorous testing and then sold by N.S.D.O.

Commercial daffodil production in our country is very important as more are grown here than anywhere else in the world. Exports of both flowers and bulbs are increasing. Bulbs and flowers are exported to the U.S.A., Canada and to the countries of the European Economic Community, (E.E.C.) chiefly to Holland and Scandinavia. Daffodil flowers and bulbs are produced anywhere from Cornwall to Scotland but Lincolnshire is the largest producer.

When a new cultivar has been tested and is becoming known, then it is bulked up until it becomes commercially viable.

Propagation. When an outstanding new cultivar is introduced it is, of course, in great demand and bulbs are eagerly bought by amateurs, commercial growers, and hybridizers.

The natural increase of daffodil bulbs is painfully slow and new techniques have been recently introduced. These are (a) twin scaling, (b) chipping, and (c) tissue culture.

(a) *Twin scaling*. This method entails the cutting of the bulb in a special way. It is cut through the root plate into eight or more pieces, each piece retaining a portion of the plate. These portions are then cut with two scales on each piece, hence the term twin-scaling, giving 32 to 40 or more twin scales from each parent bulb. A bulbil should develop on each section. The smaller the pieces the smaller the bulbil and some do not emerge the first year. Quite a few fail completely.

(b) *Chipping*. This is almost the same method as twin scaling. The bulb is cut across the root plate into 16 pieces

only. With these larger pieces there are no fatalities and indeed some sections develop two bulbils on them.

In both the above methods knives are disinfected after cutting each bulb and the chips are given a "bath" of a fungicide solution for 30 minutes. They are then drained and stored in damp vermiculite for 90 days at 20 to 21°C. Then they are planted in a sheltered site near the nursery and left down for two years. The crop is dug when the bulbils are large enough and they are then field-planted.

If further bulking up is desired then the larger of the bulbs can be cut again. The smaller bulbs will wait until they are lifted the next year; 6½ times the weight of the mother bulbs has been achieved in two years. Over 17 bulbs to one parent can be produced.

(c) *Tissue culture.* Small portions of the bulb are placed in flasks onto a nutrient agar solution and small bulbils are rapidly produced. At present, however, it is costly and not a reliable method.

Great difficulty has been experienced in weaning the propagules into soil or compost. However, given time this method could become the best of the three.

Most cultivars of commercial daffodils have some virus in them. Some show virus symptoms more than others. G.C.R.I. has been busy during the last few years virus indexing daffodils. This should lead to better cultivars in terms of texture, colour, and size in the future.

EDUCATION AND TRAINING FOR THE NURSERY INDUSTRY

BILL SIMPSON[1]

Pershore College of Horticulture
Pershore

Introduction — Education and Training. Over recent years technological advances in the production and marketing of hardy nursery stock have emphasised the need for high standards of education and training for the industry. With a greatly reduced labour force and an increased reliance on mechanical and scientific aids, staff must be highly skilled as craftsmen, technicians, supervisors, technologists, managers, and scientists. The training and education services have met this challenge. The Agricultural Training Board (ATB) through its advi-

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sory field staff, identify where and what training is needed and see that it is provided. Local Education Authorities (LEA), through their colleges, or the universities, offer comprehensive technical horticultural courses.

Training Groups. The nursery sector is well served by colleges, while the Board has encouraged the formation of Training Groups in major areas of production. Examples of such groups are the Hampshire Nursery Training Group, the East Anglian Training Group, and the Mercia Training Group. In each case an employed officer undertakes training needs assessments for members, organises courses, liaises with the Board and the colleges. Thus, small businesses are able to enjoy a service comparable with that offered by the Training Department of a large firm.

Youth Training Schemes. New workers in any industry, need organized training if they are to reach the standards of skill and proficiency which will be expected of them. The Youth Training Scheme (YTS) is designed to provide young school leaves with a structured programme of training and education together with planned on-job experience and supervised practice. The Programme based on published guidelines must include 13 weeks of off-job training and education consisting of an induction period, occupationally based training preferably leading to certification — Phase I qualification; transferable and enterprise skills; personal development skills taught in an integrated manner together with counselling, assessing and advising. For the remainder of the year, approximately 34 weeks, the trainees are engaged in occupationally based work experience, supervised practice and training on the holdings.

The Craftsman. Formal craft education and training for a three-year period comprises attendance, part-time, on day-release or block-release courses, plus acquisition of craft skills. This is certificated by taking nationally recognized, practical proficiency tests developed by the National Proficiency Tests Council (NPTC). Analysis of employment categories by specialist panels has resulted in the design of test activities to assess a skilled craftsman. The detailed notes and schedules ensure that uniform standards are applied by the examiners — selected from the nursery industry, who are trained in the principles of assessment using objective methods.

Craftsmen receive a 15% wage premium under the Agricultural Wages Board (AWB) regulations. Day or block release educational provision prepares candidates for Phases I and II qualifications of City & Guilds of London Institute (CGLI) or the equivalent regional examining body.

The National Farmers' Union/Horticultural Trades Association Nurserymen's Committee was instrumental in seeking specialist educational courses — part-time over two years (2 × 180 hrs) for Phase II Hardy Nursery Stock Production. Additionally, they approved educational centres with appropriate facilities and resources as follows:

Askham Bryan College of Agriculture and Horticulture
Brooksby College of Agriculture and Horticulture
Hadlow College of Agriculture and Horticulture
Merrist Wood Agricultural College
Pershore College of Horticulture.

Hadlow and Pershore Colleges have block release courses in Garden Centre Practices while other educational establishments offer Phase II courses to meet local needs.

Fourteen colleges in the U.K. provide a one-year full-time course for those aiming to work in practical horticulture, which leads to the National Certificate in Horticulture (NCH). Students must have completed at least twelve months pre-college horticultural work experience. Horticultural principles and practices, mechanisation, and supervisory management are covered, but considerable emphasis is placed on practical craft skills. Nursery practices are included in all courses, though Merrist Wood and Pershore Colleges have developed this specialism to a greater extent. Other specialist provisions at an advanced level includes a supplementary one-year, full-time course in Garden Centre Management leading to the Advanced National Certificate in Horticulture (ANCH) offered at Pershore College. The course also prepares students for a National Examination Board in Supervisory Studies (NEBSS) qualification in Supervisory Management. This is a bridge between craft and technician levels of education designed for the potential supervisor/enterprise manager.

Technicians. At middle management, the nursery sector seeks technicians having practical knowledge and ability combined with the qualities of a supervisor. The three-year sandwich course prepares personnel for technician posts. Introduced in 1969, the National Diploma (formerly OND) is now an established, recognized qualification for those responsible for the day to day running of a small business or the supervision of other workers. Applicants must have completed one year of practical work experience before entering college and have passed at least four subjects at GCE 'O' level (grades A, B or C) or equivalent. The subjects must include two sciences (or mathematics and a science), together with a subject testing the command of English.

The structure of the National Diploma (ND) course is two years of full-time education at a college, integrated with one year of supervised, practical training. In most cases, the first college year is of a general nature designed to develop an understanding of the principles and practices of horticulture and includes a substantial science component. During the industrial placement "sandwich" year, students develop practical skills on a nursery approved by the College. Reports and projects are compiled based on employment which form a significant element of the final award. Five colleges in England currently offer such courses in commercial horticulture, some of which are of a general nature, while others enable a student to study a specialist branch of horticulture in the final year. In the latter category, Hadlow College has a well developed nursery option. Two centres offer highly specialised Diploma course — Merrist Wood Agricultural College, with a National Diploma in Nursery Practices, and Pershore College of Horticulture, with a National Diploma in Horticulture (Hardy Nursery Stock Production). Pershore also has a Garden Centre Management option within its Diploma course, i.e., National Diploma in Horticulture (Garden Centre Sales & Organisation).

The West of Scotland Agricultural College at Auchincruive has a good reputation for nursery work and has just introduced the "sandwich" Diploma, validated by the Scottish Technical Education Council (SCOTEC). Curriculum planning is at an advanced stage to launch a new eleven-month Higher Diploma Course at Auchincruive for those who have the ability and wish to progress and gain a technologist qualification.

Technologists. In England, the *ab initio* Higher National Diploma in Commercial Horticulture equips students for managerial posts. A technologist is responsible for planning, developing and organising production and marketing on a nursery. The structure of the course is similar to ND but there is a greater emphasis on science and management. Academic entry requirements are the same as for National Diploma though GCE 'O' level mathematics is compulsory and, additionally, applicants must have passed one science GCE 'A' level and studied a second to advanced standard. Specialist aspects of the nursery industry are developed in the latter stages of the Writtle Agricultural College Higher National Diploma in commercial horticulture course.

Award Making Organisations. All Diplomas in England and Wales are now validated by the Business and Technician Education Council (B/TEC), as from October, 1983. The equivalent body in Scotland is SCOTEC, soon to be renamed the Scottish Vocational Education Council, (SOVEC).

Managers and Scientists. Graduates with appropriate experience are qualified for managerial positions, technical and scientific posts in the nursery industry. To meet university entry requirements, applicants must have passed at least five subjects at GCE 'O' level together with two at 'A' level, preferably biology and chemistry Horticultural degrees are conferred at the following universities — Bath, London (Wye College) Nottingham, Reading, and Strathclyde. Each course is distinct, but due emphasis is placed on basic sciences and their application to horticulture. The economic significance of horticulture and management aspects are also studied. Specialisms such as nursery stock production can be developed through project work or individual investigations.

Finally, a formal professional qualification held in very high esteem is the Master of Horticulture Award of the Royal Horticultural Society (MHort (RHS)). No specific courses cover the entire syllabus but Pershore and Writtle Colleges have one-year programmes of study which prepare candidates for the appropriate examinations. Besides possessing five specified GCE 'O' level passes or equivalent, all candidates must have been employed full-time in horticulture for six years. Of this period, at least three years must have been spent in bona-fide practical work, other than as a student in training. Graduates seek employment as Advisory Officers, Lecturers, Research Assistants, Scientific Officers, Consultants, and in nursery businesses in senior management posts.

Career Development. The needs for mid-career training in the nursery sector are met by the range of ATB short courses on new techniques, such as propagation methods, grading, containerising nursery stock, supervisory management, etc. The Professional, Industrial and Commercial Updating (PICKUP) courses are also available through colleges and other agencies on technical developments, e.g micropropagation; computers for stock control and labelling, etc. The HTA regularly holds training seminars while three colleges, Hadlow, Merrist Wood, and Pershore have annual conferences to deal with the latest research and commercial nursery practices.

Summary. Thus, the Board and its training groups, colleges, universities, and the research establishments all ensure that there is an adequate supply of well educated and trained personnel at craft, technician, and technologist level for nurseries and garden centres.

NATIONAL PROFICIENCY TEST COUNCIL (N.P.T.C.) SETTING — HOW PROFICIENT?

NORMAN S. STANDBROOK

Hinton Nurseries
Christchurch, Dorset, BH25 7DY

N.P.T.C. training during the present time must be seriously considered by all aspiring nurserymen, large or small. In my opinion, there must be a continuing awareness of the need for efficiency and expertise in our industry. The whole concept of training must be put into perspective. We must identify the areas we need to cover, and I suggest there are many.

To this end the N.P.T.C. has evolved a whole series of tests as listed in their schedule of activities booklet, which enable people of all ages to become proficient in the crafts of their choosing. To become a craftsman in the nursery stock section a candidate must pass in at least five activities, including plant identification and the propagation of plants in either the glasshouse or the frame/case or field. On passing the five tests the candidate will be entitled to a Certificate of Craftsmanship in addition to an increase in wages. The aim of the N.P.T.C. is to ensure that the same standards of craftsmanship are maintained throughout the country. This is achieved by setting up a panel of standard setters, which meet regularly with the examiners.

I can well remember the attitude of some nurserymen before the days of the N.P.T.C. It was very inward looking in that they would only pass on their considerable knowledge to a favoured few. The best instance I can recall was when, as an enquiring adolescent, I plucked up courage to ask a question at an A.D.A.S. meeting on the introduction of mist propagation in hardy nursery stock I was firmly, but politely, told by a very eminent propagation expert to whom the question was addressed, that he was unable to give any details as his employer regarded his work as a trade secret! Fortunately a few years later this attitude was changed and a much more progressive outlook on training at all levels became the norm in most establishments. The system seems to be working quite well, at least in Hampshire where we have the largest input of candidates for tests. However, I do feel that there is room for some improvement. A more wholehearted approach to the subject is very necessary as I think that some people tend only to pay lip service to the matter of organized training. Where it is sometimes necessary to allow a student a reasonable length of time in order to achieve a task, owing to other more pressing pursuits on the nursery, the person involved sometimes has only

the minimum of training opportunity before coming forward to take a test. The examiner is the sole adjudicator and decides whether a person passes or fails a test based only upon the candidate's performance.

There is a need for more examiners and standard setters, and general support from within the industry.

The N.P.T.C. test is usually conducted either individually with the candidate on the employer's nursery, or in one central nursery or garden when several candidates can be tested. Here all the facilities to give a fair and unbiased test are available. Examiners do everything possible to put the candidate at ease.

To become a craftsman a candidate has to show the examiner that he can work with the minimum of supervision and be able to do the job skillfully at a commercially accepted speed What exactly is an acceptable commercial speed? To give a standard speed for tasks is to say the least very difficult, as there are so many outside influences to contend with. For instance, how can the examiner evaluate bench grafting if the person involved has first to collect the stocks, gather the scions and transfer the grafts to the propagating house after grafting? Then arrange, water, and shade the grafts all in about 45 minutes. As only a few grafts are completed in the given time by the candidate the examiner must be given a certain amount of leeway in determining whether or not, in his opinion, the candidate under test conditions is performing to the best of his or her ability. Quite often when the candidate is left alone to graft a batch of plants a first rate job is achieved in a short space of time, but when being watched, the same candidate will be all at sea. However, a good examiner will soon be able to spot the people who have had the experience and who are able to produce good work.

I believe that experience is all important. It is no good giving a candidate a few hours work with a knife and expecting him to become as truly proficient as one who has been doing the job for years. This leaves us with the questions of how fast and how good should the candidate be to pass?

Speed does not necessarily mean efficiency. What does the industry want? Some people feel that a candidate is being asked too much when required to identify 25 out of 30 plants put before him. Not only must he know the genetic names but also the cultivar where applicable. The plants to be identified should be those grown on the candidate's holding and not obscure or rare types.

I understand that in the new proposals which may apply in 1985, it has been suggested that a 70% pass mark will apply,

thus reducing the number to 21 out of 30. I have my own thoughts on this! A candidate should, in my opinion, be able to make and insert about 50 cuttings for either a bed or box in 30 minutes. He or she should also be able to demonstrate a basic knowledge of hormones if used and the after care required. The actual number here must be a variable depending on the type of material used.

Another problem in assessment is rose budding, and fruit or ornamentals tree budding. Again, what is an acceptable speed? I put it to you that the first requirement is that the operation must be successful. What is the use of putting on 1,000 buds a day if half fail? Secondly, that the tying or covering is just as important as the carpentry of the budding itself. So the number that a craftsman should be able to achieve under reasonable conditions in about 30 minutes, I would suggest 25 to 30 buds. Obviously more experienced hands can work faster. The emphasis being placed on the word "experienced".

Finally I would like to give one other example. Field lifting by hand sounds a simple task, but to some candidates it becomes an onerous one! Again, the time allowed is usually about 30 minutes, with the person concerned being asked to lift 5 conifers of a given size and quality, and to root ball them. In addition the candidate must lift 10 bare-root trees to a select grade and height and stem circumference. They are then bundled and left covered with straw or another suitable material for protection in readiness for collection. The trees must also be labelled. This all seems quite simple but the operations are sometimes carried out very badly. The labelling and counting sometimes have to be seen to be believed!

How about the examiners? These are practical people with a certain amount of technical ability, who have been recommended as testers by the industry. The recommendations come from nurserymen, A.D.A.S. Advisers, skilled craftsmen, and N.F U. workers unions. To do the job properly an examiner must be a fair-minded and thick-skinned character. It is impossible to keep everyone happy.

More examiners are needed. Examiner training is given in the following ways: There are three training days and these are not necessarily consecutive. Firstly, the trainee attends a test where he or she just "looks and learns". Secondly, the examiner attends a standard setting day where the standard of craft level to be attained is rigorously discussed and an acceptable level of proficiency is arrived at with a National Standard Setter. Thirdly, there are updating days held at least every two or three years. Standard Setters are normally recruited from

senior examiners or people recommended by the County Proficiency Test Committee. Their main duty is to set and maintain standards nationwide They do this by involvement at examiner training days and monitoring tests in progress. They meet regularly in order to update and streamline the tests. They are sometimes elected to specialist panels in order to keep a weather eye on any new technology, such as the use of computers and micropropagation.

How can the industry help itself with regard to training? I hear a lot of comments about this or that being too soft an option, or something else being too hard to achieve, so I suggest the best way to get things done, or altered, is to become actively involved. As an examiner be heard by your County Committee Finally, prepare the candidate properly before sending him or her for testing so that both you and the candidate will benefit.

What is a craftsman? The English Dictionary's definition is "A man with ability, skill and guile, and possessing a manual art". Is this the type of person we are hoping to pass or is this setting our sights too high? For most nurseries this definition, while being desirable, is not really obtainable for a number of reasons. The student is not left for long enough time in any one department to learn the skill thoroughly, because he is required elsewhere on the establishment for other seasonal work. I suggest, therefore, that perhaps the term "craftsman — Grade II", and later when more experience and skill have been acquired "Craftsman Grade I". Perhaps another title altogether may be appropriate.

I believe that to a large extent, with modern ideas and technology, fewer true craftsmen as we know them will be required. But more well-trained nursery staff who can competently deal with a given situation will always be wanted.

SHARE YOUR KNOWLEDGE AND EXPERIENCE — THE NURSERYMAN'S ROLE IN PASSING ON CRAFTS

DOUGLAS WEGUELIN
Frome, Somerset

Are we, as nurserymen, passing on all the skills we have personally, or are we leaving this to the colleges, day-release schemes, or Training Boards? The modern nurseryman or woman is so involved with computers, cash flow, profits, plants, pots and pans, and all that sells well, that he or she is

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often far too involved with these things to spend a few hours teaching (and getting to know) staff, particularly the junior.

I can look back 55 years when George Tucker showed me how to graft *Gypsophila paniculata* 'Bristol Fairy' and how he taught me to tie a reef knot instead of a granny. It is good to see he is here in our Society today. I was apprenticed to his father to learn the nursery trade. I believe that time spent with staff is a good investment. They appreciate the fact that the boss or manager can spend time teaching and that you can do the job that you are asking them to do!

When I intended to retire at 65, I sold my nursery to Rochfords, the houseplant growers, my nursery being Barters Farm Nursery at Chapmanslade near Westbury in Wiltshire. I was asked to stay on as Managing Director of my own company and also to become Director on the main board of Thomas Rochford and Sons Limited. During this time I spent some time at Rochfords teaching three or four of their senior apprentices how to bench graft. We tried such things as wisteria, hibiscus and *Robinia*. We were hoping to start a tree and shrub propagating department within the glasshouse company. I was surprised how much interest these lads showed. A director spending time with them and teaching a skill was something new for them as they had spent all their working life on house plant production.

How many skills and old crafts are we losing? Take our beautiful buildings of Salisbury and Wells Cathedrals and many hundreds more. Where have all the skills in woodworking and stone carving gone today? The late Mr. Russell of Windlesham Nursery once told me how, as a young man, he used to bud *Acer japonicum* 'Aureum' in the field and obtain good whips in a year. This plant is now good only for bonsai! Why not get it grown again if there is any plant left when the virus has been taken out! Budding and grafting purple beech and birch was often done successfully in the open ground.

I suggest you spend a day with three or four of your younger staff and really talk to them. You will get to know them and they will know who you are and that you have craft skills which they could learn.

1.) Start by locking the door, cutting off the telephone and sit down at a table. You could start by asking their names. Do you even know them?

2.) Ask them if they have ever used a sharp knife

3.) Show them how to sharpen a grafting knife. Also show them where the first-aid box is!

4.) Show them how to hold a knife and draw it through the wood, starting with a whip and tongue graft.

5.) Show them how to make a straight cut and keep them practising. Don't forget that boys and girls are not allowed to take knives to school these days like we were. Desks would have lasted longer if this had been the rule for my day!

6.) Show them how to tie a graft with plastic or rubber. Shows them the simple way of finishing a tie by passing the last turn under the thumb instead of tying a knot. One craft you can tell them about, but don't demonstrate it, is the material that was used to protect the graft: Cow manure and chopped straw mixed up and applied by hand.

You may learn something yourself. You will know your staff better, and you may have discovered a potentially very skilled young person for the future.

SUN FRAME PROPAGATION

JOANNA S. WOOD

Agricultural Development and Advisory Service
Colchester, Essex

This paper reviews work the author was involved with while working at Efford Experimental Horticulture Station, Lymington, Hampshire. Work on field-grown nursery stock was started at Efford in 1981. Investigating aspects of propagation was a logical starting point. Following developments made with the rooting of cuttings under glass, it seemed likely that improvements could be made with the relatively cheap low tunnel or sun frame technique.

The sun frame technique for propagating softwood cuttings is not new — cold frames covered by Dutch lights were in use from the 19th century. Modern materials such as polythene sheeting for tunnels and automatic misting have brought it up to date. As the plant material from sun frames has been mostly destined for field planting and the landscape market, the range of species grown has been limited. If plant quality could be improved there would be an opportunity to extend the species range as a cheaper alternative propagation technique to heated glass. This would, in turn, create opportunities for supplying a range of markets such as containers and prepacks.

The two major problems encountered on nurseries who were using sun frames were:

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The two major problems encountered on nurseries who were using sun frames were:

1) maintaining the quality of rooted cuttings, and
2) the length of time spent in the frame (up to two years)

The two aspects became the main themes for investigation with trials examining the effects of spacing and nutrition on plant quality and development. However, before a description of these trials, the question, "What is a sun frame?" needs answering.

METHODS AND MATERIALS

Construction of sun frames. A sun frame consists of a raised bed 1.25 m wide with wood plank sides and can be of any length (12 m long at Efford). Approximately equal volumes of peat, lime-free sandy grit, and soil are mixed with a rotary cultivator to give a depth of compost of about 200 mm above normal soil level. The compost is covered with a thin layer of sandy grit (approx 10 mm — sufficient to help reduce weed germination). At Efford a 6 mm water pipe is used to make the main support hoops as they take the weight of the mist line. If the mist line were supported from the ground then galvanised wire hoops could be used. The hoops are placed at the ends of the frame and at 3 m intervals with plastic hoops in between to give additional support for the polythene cover.

A mist line giving good coverage of the bed and providing 100% relative humidity is essential for good rooting, so it is worth installing the best system that can be afforded. Automation is very useful although a manual system can be operated. At Efford the misting equipment consists of a 12 mm PVC water pipe with Macpenny No 2 brass mist jets spaced at 1 m intervals. A control panel allows each frame to be operated independently, while a time clock controls frequency of misting.

Cutting preparation and insertion. Cuttings are taken typically in mid- to late June, stripped of lower leaves and trimmed. The tips are pinched out to encourage branching, and any visible floral buds removed. A hormone rooting powder is used as a standard treatment. A nailboard of the required cutting spacing to mark out the bed is also useful, particularly for insertion of weaker stemmed species into the compost. Immediately after "sticking", the cuttings are drenched with an anti-*Botrytis* fungicide and, if necessary, an aphid killing insecticide. The frame is then covered with 150 gauge white polythene sheet which is attached by wooden lathes to the wood plank sides. Additional shading can be provided by a lightweight windbreak/shade netting, although experience suggests this may be unnecessary when mist is used. Bursts of mist are required about every 30 to 60 min.

during the day, depending on the weather. Alternatively an "artificial leaf" control system can be used.

Hardening off. Slits are cut in the polythene tunnel usually in early August. The polythene is removed and mist turned off about one week later. Netting may be necessary at this stage in very hot, dry conditions. This is removed in September. All further irrigation needed during growing on is provided by two lines of seep-hose per frame.

EXPERIMENTS AND RESULTS

Cutting densities. A series of trials were carried out during 1981-83 using *Hypericum* 'Hidcote', *Philadelphus virginalis* 'Burfordensis', and *Viburnum* × *bodnantense* 'Dawn'. These trials demonstrated the dramatic increase in both shoot and root growth achievable by increasing cutting spacings from a typical 50mm × 50mm to 75mm × 75mm and 100mm × 100mm. *Viburnum*, in particular, responded to the wider spacings, winter losses in the frame being greatly reduced. These benefits were also carried over into the field after planting out; larger plants from wider cutting spacings established better and produced high grade marketable plants more quickly.

Nutrition. In the early trials of sun frames a liquid feed applied through the seephose was found to be necessary. This was particularly so if the plants remained in the frame for another growing season. Following work with propagation under glass at Efford, the use of slow-release fertilizers was suggested as an alternative method of maintaining quality in the frame. The first trial in 1982 using 10 different deciduous shrub species gave dramatic results. The slow-release fertilizers, which were incorporated in the rooting medium before the cuttings were inserted, greatly improved both the growth and visual appearance of all species when compared with the unfertilized "standard treatment". The differences were very noticeable from mid-August onwards, both for Osmocote 16:9:9 (16 to 18 month formulation) and Ficote 16:10:10 (140-day formulation). Both materials were used at 2 kg/m^3, with a cutting spacing of 75mm × 75mm.

Growth was so much improved it became obvious that the terminal bud should be removed from cuttings before insertion to encourage a more bushy habit. This then became a standard practice. It was also found that a thick 75mm layer of sand over the rooting medium, as practised previously, was unnecessary. Cuttings grew better when able to root directly into the fertilized medium with only a 10 mm layer of sand.

Combining cutting density, nutrition, and time of planting out. The dramatic results following the use of slow-release

fertilizers, with their effects on the speed of propagation and quality of plant produced, opened up a new set of prospects worth investigation. A combined trial to look at the various factors involved was the next step. In 1983 a multifactorial trial was set up with the following treatments:

1	Slow-release fertilizers	Osmocote 16 9 9 + Mg (16-18 month) Ficote 16 10.10 (140 day)
2	Rate of fertilizer	nil 1 kg/m^3 2 kg/m^3
3	Cutting spacings	75 mm × 75 mm 100 mm × 100 mm 125 mm × 125 mm 150 mm × 150 mm
4	Transplanting times	autumn 1983 spring 1984 autumn 1984
5	Species	*Cornus alba* 'Elegantissima' *Forsythia* × *intermedia* 'Lynwood' *Potentilla fruticosa* 'Katherine Dykes'

Propagation results. All three species responded to both wider spacing and the slow-release fertilizers with increased root and shoot growth However, *Potentilla* and *Cornus*, in particular, showed little response to wider spacings on unfertilized plots. Generally, the 1 kg/m^3 of fertilizer gave as good a result as 2 kg/m^3. *Potentilla* appeared sensitive to the higher rate of Osmocote, root growth being poorer in this treatment (Table 1).

Table 1. Main effects of slow-release fertilizers and cutting spacing on shoot and root growth by October 1983

	Mean dry weight, g/plant					
	Shoots			Roots		
	Potentilla	*Cornus*	*Forsythia*	*Potentilla*	*Cornus*	*Forsythia*
1 Fertilizer kg/m^3 (figures averaged across spacings)						
Untreated, nil	3 5	1 0	3 2	1 1	1 0	1 5
Osmocote) 1	5 5	2 2	4 0	1 2	1 6	1 9
16 9 9) 2	4 7	2 4	6 2	0 7	2 0	1 9
Fricote) 1	3 8	2 7	6 4	1 2	2 5	2 2
16 10 10) 2	6 4	2 3	6 1	1 6	4 1	1 9
2 Cutting spacings (figures averaged across fertilizers)						
75 mm × 75 mm	3 7	1 5	3 8	0 7	1 5	1 4
100 mm × 100 mm	3 9	1 9	4 6	0 9	1 9	1 9
125 mm × 125 mm	5 0	2 5	5 7	1 4	2 7	2 0
150 mm × 150 mm	6 5	2 5	7 2	1 6	2 9	2 2

A similar pattern of shoot weights was observed for the dormant cuttings lifted in March, 1984. For *Cornus* and *Forsythia*, root weights had greatly increased during the mild winter, especially at the wider cutting spacings. Also the depression in growth of *Potentilla* at the high rate of Osmocote observed in October, was less evident.

Establishment and growth from the frame. For field planting from the frame, growth of all species was improved from the spring planting. It was best where slow-release fertilizers had been used during propagation. *Potentilla*, in particular, suffered from autumn plantings with very poor establishment, especially the untreated and Osmocote-fertilized plots.

Containerised plants responded to transplanting times in a similar way. Virtually none of the early batch of *Potentilla* survived. This may have been due to the relatively soft growth of autumn-transplanted plants. The differences due to spacing and nutrition during propagation seem to disappear much earlier in containerised plants than those in the field.

Plants left in the frame for another season generally appear overcrowded, but at some spacings the quality may be good enough for marketing direct from the frame.

FUTURE PROSPECTS

Work on testing a wider range of deciduous shrubs for propagation by this method is now in progress. Great success has been achieved, for instance, with *Rosa rugosa* species and cultivars, e.g. *Rosa rugosa* 'Frau Dagmar Hastrup'. Often considered a difficult subject, excellent quality plants have been produced by the sun frame method.

With some modifications (no mist line is required) hardwood cuttings of some evergreen and conifer subjects can be propagated in sun frames. More work will be done to establish production schedules for this aspect.

The range of markets for material from sun frames has been extended beyond field grown shrubs to include containers and possibly the pre-pack market. 'Direct sticking' of cuttings into pots inside a sun frame remains an area for further investigation.

SUMMARY

1. Sun frame propagation is a relatively low cost technique which, with the use of some modern materials, can give good quality plants suitable for a number of outlets.

2. Lower cutting densities and the incorporation of slow-release fertilizer into the rooting medium have given dramatic improvements in growth and quality, together with a significant reduction in propagation time.

3. Because the technique is relatively cheap compared with using heated glass, it may be possible now to propagate a wider range of species economically by this method.

4. Eventually some production schedules suitable for particular market requirements for individual, or groups of species may be developed.

Question to Joanna Wood: Is supplementary shading necessary?

Joanna Wood. We thought that supplementary shading would be necessary and I used it in my trials on the East coast. Margaret Scott has carried out trials at Efford without shading and there have been no problems. As the light intensity levels are higher on the South coast, we would conclude that supplementary shading is not necessary.

Question to Joanna Wood: How is weed control achieved in the sun frames?

Joanna Wood: We were putting on a fairly deep layer of sand onto the beds but found this sand layer to be unnecessary as the weeds are so lush and lank that they are easily removed by hand after the covers are removed. With no sand layer the roots of the cuttings can exploit the slow-release fertiliser more quickly.

STARTING A NURSERY AFTER COLLEGE

KENNETH G. ELLARD
Welland Vale Nurseries Ltd.
Glaston Road
Uppingham, Leicestershire

I shall give a brief account of why we started a nursery and include a short history of Welland Vale Nurseries. I will then outline the various problems and limiting factors we encountered and describe how we attempted to solve them.

The idea of starting a nursery was first discussed among various friends while still in the first year of our Ordinary National Diploma (OND) course at Pershore. At that time several people were interested in the project. However, by the end of the third year interest had waned and, on leaving college in the summer of 1972, only 3 people remained committed to the idea — these being Trevor Burns, who now deals with sales, Nick Cox, from whom we parted company after one year, and myself.

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The initial impetus for the project which may well have been alcohol-induced, probably came from a romantic view of life and a naivety of business. We had very little experience in nursery work and none of business. None of the partners' families had any connection with the nursery trade and all of us came from cities. So it was going to be very much a question of learning as we went. At that time we did not consider the task too daunting and the comparatively low wages being offered to OND students reinforced our feeling that nothing would be lost by trying to set up for a few years.

At the time of leaving college in summer 1972, our capital was approximately £650, which we used to buy an old pick-up truck and a few tools, whereupon we started landscaping. However, by Christmas of that year the money had run out and in January, 1973, we started working full-time on a local building site. This continued until the spring when we resumed landscaping work. Shortly after this Nick Cox left and Trevor Burns and I continued, using Uppingham as our base which is the location of our current nursery business.

By the summer of 1974 we had accumulated approximately £3500 worth of capital by paying ourselves subsistence wages. At this point we began looking for land in the area and consequently met Alan Carr who is our third partner. He owned 4 acres of wind-swept land on top of a hill which we were only too pleased to obtain. We concluded leasing arrangements in November, 1974, and formed a limited company at the same time.

This 4-acre green-field site had neither mains water nor electricity, although it did have a well from which we could extract about 200 gallons per day. In 1975 we started growing on a part time basis some plants which included wallflowers, spring cabbage, and a few lettuce. At the same time we propagated nursery stock for container growing which was our intended purpose for the land. Turnover on sales in 1975 was £964 By the middle of 1976 mains water and a 3-phase electricity supply had been installed and a turnover of £3374 was achieved from similar crops to the previous year. We were still combining part-time work in the nursery with landscaping because we lacked sufficient capital.

In 1977, both Trevor and I began working full-time on the nursery using propagated material from the autumn of 1976. At this time facilities consisted of 3 propagating tunnels, a water tank, pump house with a 3-phase pump and a small amount of irrigation equipment. The turnover in 1977 increased to £9625, mainly from container-grown liners and ground cover.

Each succeeding year we increased production, laid down more standing beds and improved facilities as money became available. In 1980 we purchased 4 acres of adjoining land. At this point we reappraised our progress and made new plans for coping with the effects of doubling the nursery area. Since 1980 we have increased production while slowly developing the new land for standing beds as required.

At this stage I should say that the solutions to our problems and the time-table of development were strongly influenced by a shortage of capital and our reluctance to finance development by borrowing.

Our ambition was to create a container nursery and for this we drew a site plan on which we detailed the position of all facilities, incorporating our ideas for creating an efficient layout for the future. The first practical task was to set up the basic facilities necessary for container growing. These were polythene tunnels, standing beds, an irrigation system and windbreaks.

Our first tunnel was destroyed in a storm and was replaced by a larger stronger type. We have used this type since. The standing beds were improved. At first they were made of levelled soil with an adjacent soil path. Hardcore was then used to create good access, and gravel was spread for standing pots on. Irrigation was standardised to Cameron spraylines in the tunnels and Rotoframe sprinklers for outside stock and these are operated manually from standpipes. Windbreaks proved necessary at an early stage due to the exposed position of the land, and consist of a combination of Paraweb and × *Cupressocyparis leylandii* plantings.

During these early years all the potting was done inside the polytunnels which we also used for the storage of materials and equipment. A considerable amount of improvisation was required in order to achieve production with facilities which were really very primitive for container growing. Our office at this time consisted of a telephone on a shelf in the pump house. It remained like this until the end of 1981.

We very soon realised the limitations of working in a polythene tunnel and were therefore prompted to construct a small building from concrete blocks. This gave us better access, a concrete floor, more efficient electric lighting, and room for four people to pot. Compost was mixed 3 bales at a time on the floor using a Howard Gem rotovator and turned by hand into a heap against the wall. From here it was shovelled manually onto the bench by each worker as required. We had bought several old Bonser trucks in various states of disrepair to move plants. These were cajoled into running spasmodically

and were used to tow shelved trailers made from angle iron. We were able to continue like this for about 18 months until the Bonsers were superseded by a 14 HP Kubota tractor.

By 1980 we had achieved the basic growing facilities, limited potting facilities, and an embryonic transport system. At the same time we began negotiations for the purchase of an additional 4 acres. This forced us to analyse what we had learned on the manufacturing aspect of container nursery stock production. It can be summarised as follows:

1) As production of saleable plants increased, the existing system of mixing and handling compost became progressively more inefficient. Eventually the point arrived where the potting operation became the major factor limiting an increase in production.

2) A high proportion of the potting day was spent physically moving the compost within the potting environment.

3) Efficient and reliable transport away from the potting area was essential.

4) Hand potting speeds were improved by using rigid pots.

5) A system of bonus payments seemed to stimulate morale and improve potting rates.

We reviewed our facilities in respect of these lessons and having in mind the required increase in production, we arrived at the following conclusions:

1) That the irrigation system as originally designed was adequate but should be automated at the earliest date. We were spending a lot of time running up and down turning valves on and off.

2) That the road and path system suited our working methods as it allowed access by mini tractor to any point along the length of each standing bed.

3) That the Kubota mini-tractor gave us sufficient power for a small overall tractor size and was ideal for towing on hard surfaces.

4) That our policy of hand potting gave us great flexibility in the use of labour and was worth continuing.

5) That a mechanical system of mixing compost and placing it onto the bench must be devised to reduce the amount of non-productive time.

6) That transport from the potting shed should be improved by refining the original system of tractor-towed trailers.

7) That a system of individual performance bonuses should be introduced in order to motivate those involved in

potting and to maximise the benefits from the proposed capital investment.

8) That the original potting shed whilst adequate as a basic facility, was not big enough nor sufficiently adaptable for projected production.

These eight points instigated the following projects:

1. Construction of a main production building
2. Installation of a compost handling system
3. Making of an internal transport system
4. Improvement of practical management techniques

I would now like to take each of these projects in turn and explain our approach to the problems they represented.

1. **Construction of a main production building.** As this new building was to be built from scratch we tried to incorporate features which would improve working methods. We drew a diagrammatic plan to scale of the working area including the position of benches and trailers and suggested methods of access. We also required an office and a mess room. These facilities were incorporated into a scheme which would fit inside a standard steel portal frame building, 30 ft wide by 75 ft long, with concrete block walls and an insulated asbestos roof. It was erected in the winter of 1981/2 by a local builder. When the contractor finished we began fitting out the building with potting benches along one wall and fluorescent lights above each potting station.

2. **Installation of a compost handling system.** To achieve a more efficient compost handling system a 70 ft long conveyor belt was constructed from second-hand parts along the wall to the rear of the potting benches. This enables compost to be deposited directly onto the bench without using up valuable floorspace. We built an elevator, again from second-hand parts, to carry compost to the conveyor belt. Both the elevator and the conveyor belt can be operated by the potters by means of 24 volt low tension switches.

Initially, compost was mixed as before with the rotovator and shovelled onto the elevator. A Gregoire drum mixer was bought in 1982 which empties compost directly onto the elevator, thus improving the situation of bulk materials handling.

3. **Making of an internal transport system.** Looking at the various options available, we returned to our original concept of four-wheeled trailers towed by a mini-tractor because they had proved very flexible in the past. They suited our sloping site and the design of the potting shed. The layout of pathways between standing beds meant that pots could be placed on the trailers at the point of potting and off-loaded directly adjacent

to the relevant bed. The bed could also be changed immediately for any given load of plants.

Having decided to continue with trailers, we reassessed the prototypes towed by the Bonsers and improved their design. As we were unable to find a suitable trailer on the market at what we considered to be a reasonable price, we decided to fabricate it ourselves.

We worked out overall dimensions suitable for all sizes of pot and Empot trays that we thought we would be using. A prototype was built and tested and this was used as a model for the others. They have since proved sufficiently versatile to be used for transport and as mobile benches for the staff when packing or knocking out.

4. **Improvement of practical management techniques.** The basic idea behind all of these projects was to create a cohesive base from which we could expand production. The successful operation of most systems in horticulture rely upon the people who are involved in their day to day use. Staff motivation is therefore important. Making the potting operation easier and faster with the use of rigid pots for all saleable plants has helped to motivate staff. This was reinforced with the introduction of a bonus scheme which rewards the staff individually for their personal performance whilst potting.

In conclusion, our main aim has been to make the physical side of container nursery stock production less arduous by combining good nursery layout and mechanisation where possible. In order to achieve this we have invested the maximum amount possible each year. Although I have described the creation of our nursery in terms of individual problems and solutions, I am sure you will appreciate that, in reality, it is never that simple.

IMPROVING THE ROOTING OF *SYRINGA VULGARIS* CUTTINGS BY ETIOLATION

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Abstract. An increase in the rooting percentage of cuttings of *Syringa vulgaris* 'Madame Lemoine' was observed in response to an etiolation treatment in the field in 1983. This result was not supported by data in 1984, possibly due to the disturbances of cuttings in an attempt to assess the time of root development. Variation in the rooting of shoots within treatments was associated with their stock plant origin.

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Shoots grown in light and dark in controlled temperature environments developed at the same rate Consequently differences in the striking date and also in the rooting environment between treatments were avoided Cuttings which developed at 25°C rooted earlier than cuttings developed at 15°C High temperatures alone may account for rapid shoot extension whereas improved rooting was, in general, associated with the combination of high temperatures and low light levels The value of studying etiolation in systems facilitating more precise control of the shoot environment during treatment is discussed.

REVIEW OF LITERATURE

Etiolation as a process involves the development of shoots in a dark environment and, for a range of woody ornamental plants, a period of approximately four weeks is required for the development of suitable cutting material. Recent reviews of the literature covering early research in etiolation are presented by Delargy and Wright (2) and Harrison-Murray (4).

Extensive work on apple rootstocks, e.g. Malling 9, and some ornamentals has been carried out at East Malling Research Station (6). A number of physiological and environmental stimuli may be involved in the root initiation process (11) which means that the design of covers used for etiolating shoots is of primary concern. High temperatures and high humidities associated with completely enclosed etiolation covers can result in major disease problems. Work with the apple rootstock, Malling 9, using covers with minimal ventilation has shown that a low irradiance of up to 2.5% of available daylight was as effective as complete darkness for stimulating rooting (5). Subsequently, to avoid disease problems, covers were ventilated either by splitting and partly patching the polythene or by cutting away a section at the base of the cover. The observation that a high level of ventilation, during the etiolation of Malling 9 shoots, reduced rooting indicated that high temperatures were more important than high humidity in promoting rooting of cuttings (6).

Etiolation studies have been carried out on a range of hardy ornamental nursery stock (HONS) including *Syringa* species (12). Based on field studies using non-ventilated black covers it was concluded that the response to etiolation is species specific and can be variable between successive years.

The propagation of a range of cultivars of *S. vulgaris* using nodal and tip cuttings has been studied in Poland (1). High rooting percentages and root numbers were associated with young shoots being taken as cuttings early in the growing season when the flowers were at the beginning of anthesis or at full anthesis

This paper reports the results obtained from etiolation experiments in the field and in controlled environment cabi-

nets for *Syringa vulgaris* 'Madame Lemoine'. This study forms part of a wider programme to improve the rooting of shoots of HONS by treatments applied to the stock plants.

MATERIALS AND METHODS

Field Etiolation 1983. Thirty 2-year-old field-grown plants of *Syringa vulgaris* 'Madame Lemoine' (clone 1) grafted on *S. vulgaris* were obtained from Coles Nurseries, Leicester and replanted 0.6 m apart in the field in April, 1982. In early March, 1983, these stock plants were pruned to leave approximately six buds per main stem.

Four wood-framed covers were constructed with gaps at the base and the top overhung by flaps of polythene to permit ventilation. Two of the frames were covered with clear and two with black polythene (500 gauge). Light levels under the covers and in the open were monitored using a scanning spectroradiometer (Licor LI 1800). Temperatures were monitored with a Grant recorder and humidity measured with an Assman Hygrometer. In addition, weather station data was available.

The stock plants were sprayed with Rovral (iprodione) at bud break and the covers placed over them to provide the 3 treatments, viz. black cover (etiolation), clear cover, and no cover (control). Seven plants received each treatment, with groups of 3 and 4 under the treatment covers. At the end of the period of each treatment (Table 1) the basal section of one side of the polythene covers was removed 3 days prior to striking the cuttings to permit "regreening" of the shoots.

Table 1. Environmental data and the dates of treatments for field etiolation and controlled environment etiolation of *Syringa vulgaris* 'Madame Lemoine'

	1983 Field			1984 Field		1984 Controlled Environment			
	Control	Clear cover	Black cover	Control	Black cover	Light 15°C	Light 25°C	Dark 15°C	Dark 25°C
Date covers on 'bud break'	—	3 May	3 May	—	21 April	6 April	6 April	6 April	6 April
Date cuttings struck	7 June	27 May	31 May	28 May	24 May	21 April	15 April	21 April	15 April
Duration of treatment (days)	—	21	25	—	30	14	8	14	8
Regreening (days)	—	3	3	—	3	1	1	1	1
Mean minimum temp °C	7 2	6 6	6 7	4 2	4 0	14	24	14	24
Mean maximum temp °C	14 8	25 0	18 0	14 8	18 5	16	26	16	26
% Daylight	100	70	0 2	100	0 2	—	—	—	—
Humidity % RH	*	*	*	35-85	34-87	73-88	65-76	72-83	67-76

* Recordings not taken

When the shoots in the different treatments were between 6 and 11 cm in length they were prepared as basal cuttings without removing any leaves to reduce wounding. Cuttings remained in groups (according to stock plant) and half of them were given a 5 sec. dip in a 0.2% solution of indolebutyric acid (IBA) in 50% acetone. The cuttings were inserted in a moss peat: perlite (1:1, v/v) rooting medium in lines radiating from mist nozzles. The mist bench was enclosed with a polythene tent and the irradiance at cutting level was 159.3 Wm^{-2} (677 $\mu Em^{-2}s^{-1}$). Compost temperature was set at 20°C, although temperatures up to 28°C were occasionally recorded. Fungicides, Rovral and Ronilan (vinclozolin) used alternatively, were applied at intervals of 14 days. The rooting of cuttings was recorded as percent cuttings rooted, number of roots per cutting, and root length per cutting 42 days after sticking.

Field Etiolation 1984. The clonal stock plants used in 1983 were divided into 8 groups with half of the plants receiving an etiolation treatment under 4 black polythene ventilated covers. As in 1983, the etiolated shoots were regreened for 3 days (Table 1). Cuttings received the same handling except that no IBA treatment was used and a shade screen was installed over the mist benches to reduce temperature extremes. The irradiance at the height of the cuttings was reduced to 80.6 Wm^{-2} (342.6 $\mu Em^{-2}s^{-1}$). The rooting of cuttings was recorded on days 14, 24, 32 and 42 post striking.

Controlled Environment Etiolation 1984. Twenty-four 2-year-old field-grown plants (clone 2) grafted on *S. vulgaris* were obtained from Notcutts, Suffolk and planted in March, 1983, in a peat-based compost with Osmocote in 30-litre containers. On 8th March, 1984, they were lightly pruned. At the time of bud break the plants were transferred to 6 controlled environment cabinets to be grown at either 15°C or 25°C with and without light (70.6 Wm^{-2} [300 $\mu Em^{-2}s^{-1}$]) provided from warm white fluorescent lamps. Black polythene with small slits was used to black out half of each cabinet. Three cabinets were run at 15 ± 1°C and three at 25 ± 1°C, with two plants in each environment in each cabinet. All of the plants were sprayed with Rovral prior to placing in treatment. Regreening of etiolated shoots was limited to one day (Table 1). The preparation and handling of cuttings and the recording of rooting was carried out as noted above.

RESULTS

Over any 24-hour period considerable variation in temperature was noted for the different treatments, as shown in Figure 1 for a moderately sunny day. The temperature under

ventilated black covers was 1 to 4°C higher than the control. By contrast, non-ventilated covers were 4 to 10°C higher than the control (Figure 1A). The temperature under ventilated clear covers used in the 1983 field experiment was 1 to 5°C higher than the ventilated black covers (Figure 1B).

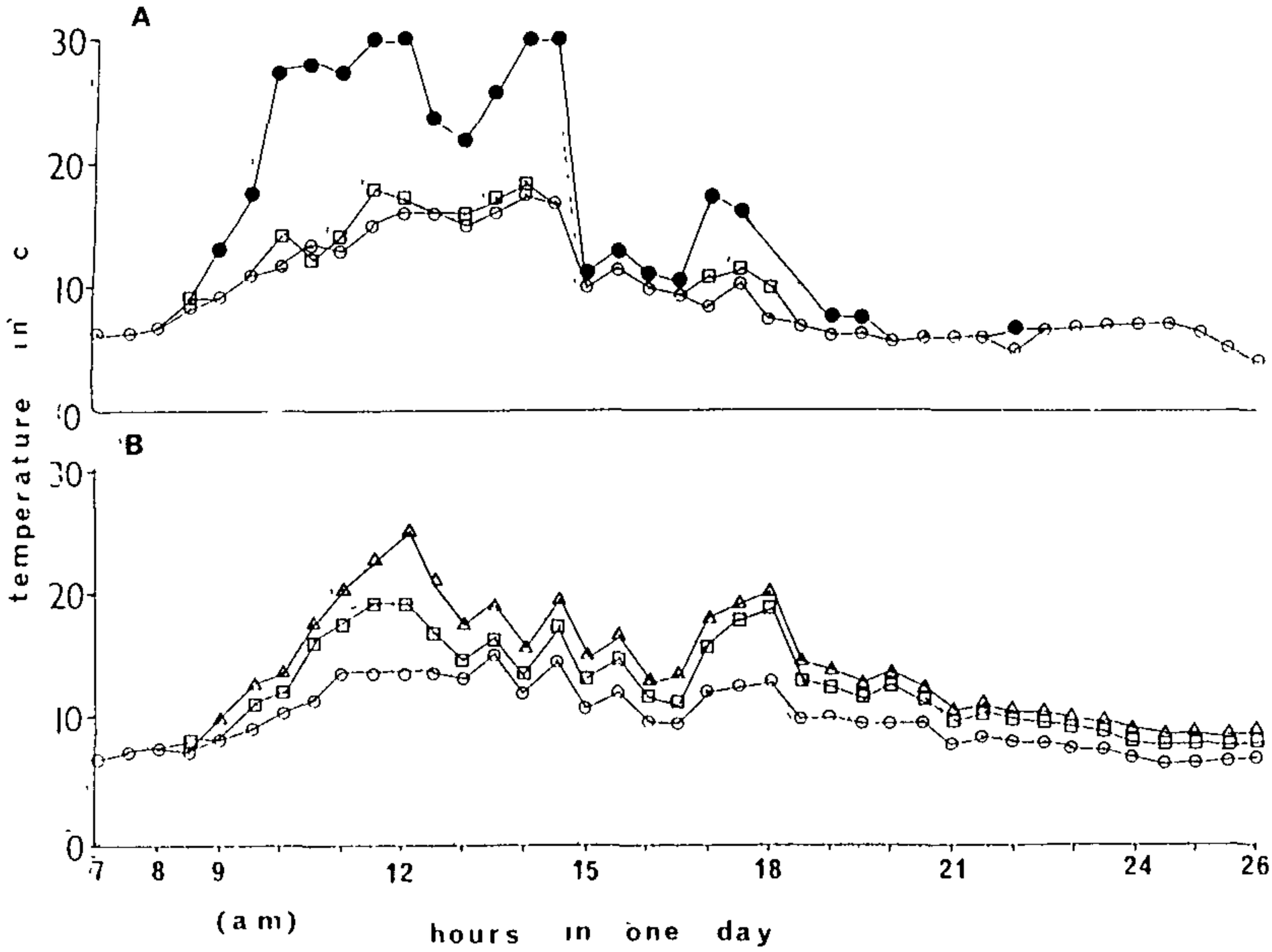

Figure 1. Temperature variations over a period of 24 hours during the field etiolation in 1984
A Ventilated (⊡) and non-ventilated (●) black polythene covers compared to the control (○)
B Ventilated black (□) and clear (▷) polythene covers compared to the control (○)

In the 1983 field experiment the etiolation treatment significantly increased ($P < 0.001$) the number of cuttings which rooted and the rooting percentage (Figure 2A). However, the mean root number per rooted cuttings was not significantly different (Figure 2B).

Etiolation of shoots in the 1984 field experiment did not increase the number of cuttings which rooted. Eight cuttings rooted from the etiolation treatment, and 9 from the control, representing 6.5 and 7.5% rooting, respectively.

The number of cuttings which rooted and the rooting percentages for the controlled environment experiment are shown in Figure 3. Data are presented for days 32 and 60 from the time of striking the cuttings.

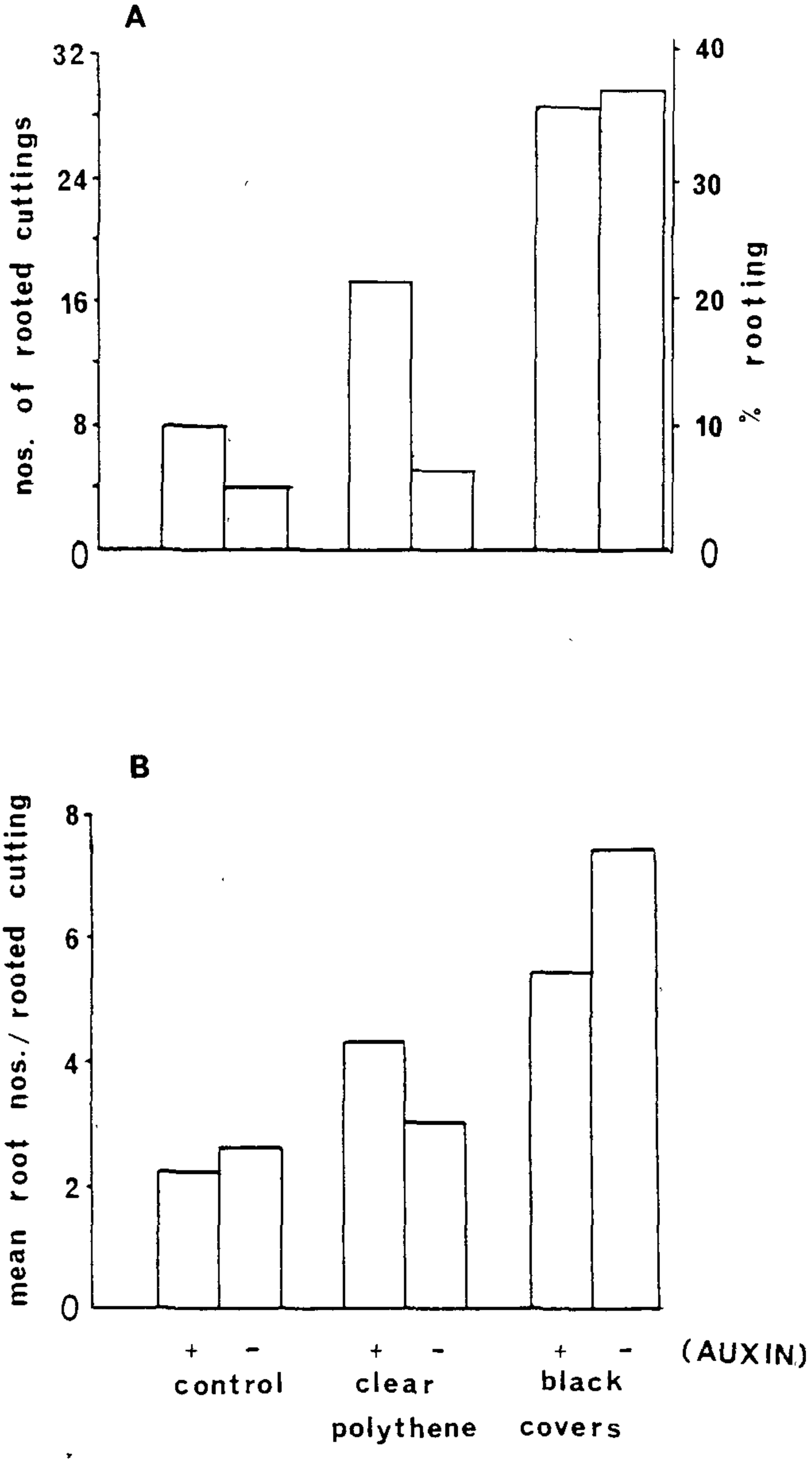

Figure 2. The rooting of cuttings of *Syringa vulgaris* 'Madame Lemoine', 42 days post striking, from the 1983 field etiolation experiment, 75 cuttings per treatment.
A The number and percentage of cuttings rooted
B The number of roots per rooted cutting
Note auxin treatment = ±0 2% IBA in 50% acetone, 5 sec dip

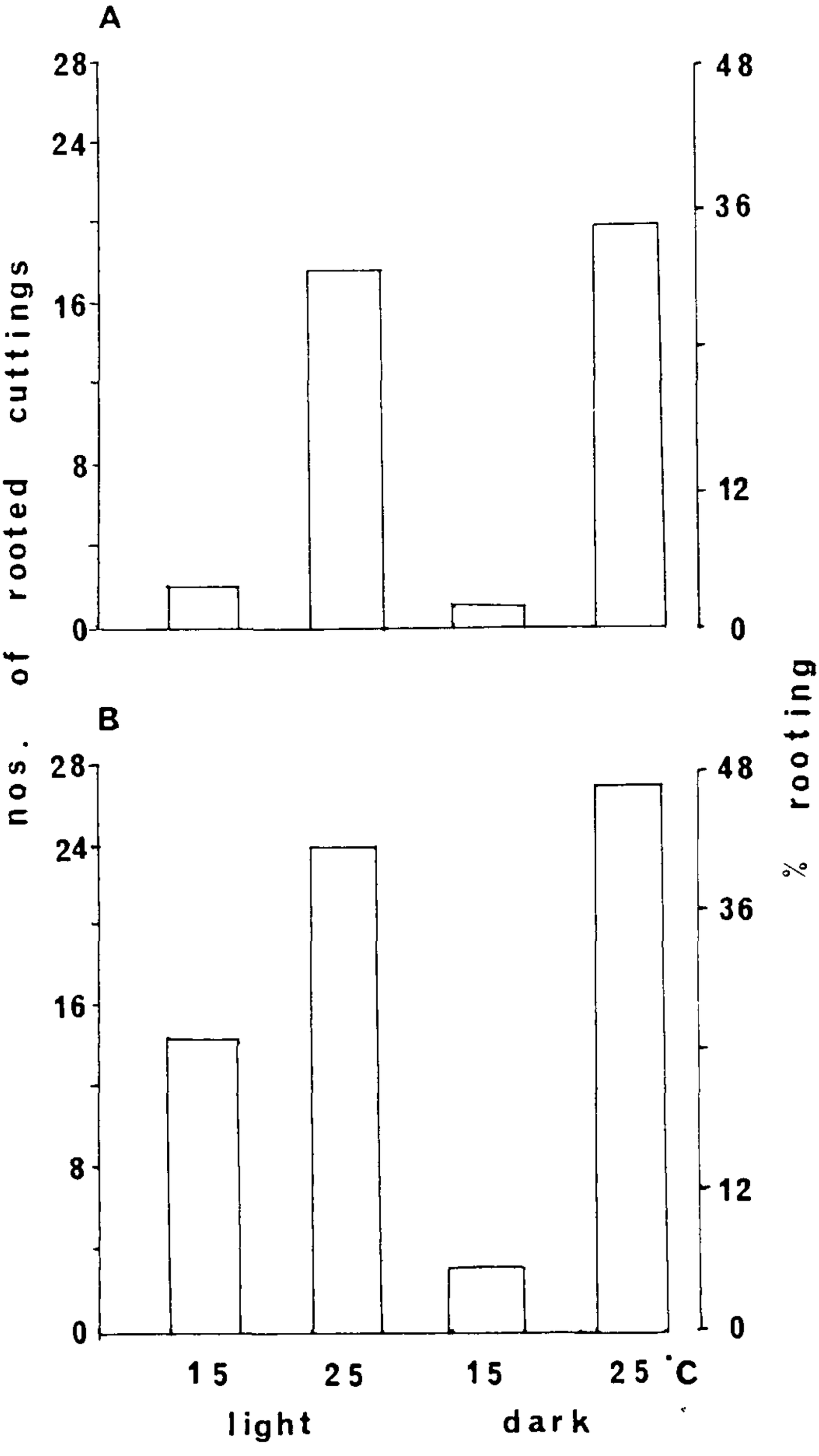

Figure 3. *The effect of light and temperature on the rooting of cuttings of* Syringa *vulgaris* 'Madame Lemoine', in the 1984 controlled environment etiolation experiment, 54 cuttings per treatment No auxin treatment.
A 32 days post striking
B 60 days post striking

Table 2 shows the rooting performance of cuttings (42 days from striking) taken from individual stock plants. The plants selected represent the limits of the range of rooting performance within the treatments in the 1983 field experiment and the 1984 controlled environment experiment.

Table 2. Rooting performance of cuttings from individual stock plants of *Syringa vulgaris* 'Madame Lemoine' 1983 field experiment (clone 1) and 1984 controlled environment experiment (clone 2) Mean rooting percentage based on cuttings taken from 7 stock plants

	1983 Field						1984 Controlled Environment							
			Polythene covers				Light				Dark			
	Control		Clear		Black		15°C		25°C		15°C		25°C	
Stock plant number	24	23	12	2	19	21	15	6	23	20	4	8	29	16
No of cuttings taken	29	27	25	21	21	11	9	18	10	22	16	10	11	10
No of cuttings rooted	1	7	2	4	1	7	0	5	1	8	0	2	1	8
Rooting %	3	26	8	19	5	64	0	28	10	36	0	20	9	80
Mean rooting %	9		14		40		*		*		*		43	

* insufficient rooting percentages were obtained to enable the mean rooting percentage to be calculated

DISCUSSION

In the 1983 field experiment the increased percentage rooting of cuttings achieved with the ventilated black covers (38% versus 5% for the control) was comparable to the enhanced rooting reported by Rowell (12), when non-ventilated covers were used (28% versus 6% for the control). Percentage rooting increased from 11% (control) to 37% (etiolated) when cuttings were treated with IBA; however IBA did not increase the rooting percentage of etiolated shoots.

Shoots from plants covered with clear polythene, although developing the earliest, were slower to root than etiolated shoots. The rooting percentages follow a similar pattern to those reported for the apple rootstock Malling 9 when non-ventilated black covers, clear covers, and controls gave 50, 28, and 4% respectively. Similarly, for Malling 9, root numbers per rooted cutting were 33.5, 4, and 1.5, respectively (6).

Variation within treatments (Table 2) prevents the observations on root numbers (Figure 2B) being significantly different between treatments. Rooting percentages of cuttings from individual plants in clone 1 varied within treatments by 5% to as much as 64%. Similarly in clone 2, used in the controlled environment experiment, where sufficient rooting percentages were available for comparison, a range of 2% to 80% was noted.

The absence of any response to the etiolation treatment in the 1984 field experiment will be discussed in terms of (i) treatment, (ii) plant material, and (iii) the rooting environment.

Treatment. Differences in field results between successive years are usually attributed to variation in climatic factors. For a study of etiolation in the field the design of the covers will have direct effects on the shoot environment and therefore on the treatment. The covers used in 1983 and 1984 were identical in design, therefore differences in climatic factors between the two years can be discussed in relation to the treatment results. The major differences between the two years were the lower relative humidity (41% versus 52%) and lower mean minimum temperatures (4.2°C versus 7.2°C) in 1984 as compared to 1983. In both years the mean maximum temperature was 14.8°C. Humidity is not regarded to be as significant as temperature in causing enhanced rooting following an etiolation treatment (5,6), and differences in the maximum temperatures under different treatments are likely to be more important. However, in this study it is not possible to explain the differences in rooting performance between the two years in terms of temperature since the maximum temperatures were comparable (Table 1). Likewise, the ventilation of the covers probably did not vary greatly between the two years as the run of wind for 1983 and 1984 was comparable (8.8 and 9.1 km h^{-1} respectively).

Plant Material. The same stock plants were used in both the 1983 and 1984 field experiments. Difficulties were encountered in re-arranging plants between treatments in 1984 to achieve an equal distribution of plants which had been etiolated or which exhibited a known level of rooting ability in 1983 (Table 2). Rowell (pers. comm.) also noted variation among stock plants in etiolation studies with S. *vulgaris*. An attempt was made to apply the etiolation treatment to one half of individual stock plants using black polythene bags, leaving the other half of each plant as a control. However, difficulties in disease management and mechanical damage to the shoots prevented the study being completed.

Rooting Environment. In the 1984 field experiment an attempt was made to identify the period in which roots were initiated. Inadequate replication prevented sequential harvesting of cuttings and the low percentage rooting made selection of random sub-samples hazardous in terms of missing the result. Cuttings were therefore examined on 3 occasions with both control and etiolated cuttings subjected to the same degree of disturbance. As a result of this attempt to monitor rooting the water status of cuttings in 1984 may have been significantly altered. Drops of moisture were removed from

leaf surfaces during the inspection of cuttings and water stress may have occurred (3), although the capacity of *Syringa* cuttings to take up water from the leaf surface is not known. The etiolated cuttings may have been more susceptible to water loss during handling due to a potential reduction in the thickness of cell walls and the cuticle following the etiolation treatment, as reported for cuttings of the apple rootstock, Malling 9 (7). It is well known that the successful rooting of cuttings is dependent on the maintenance of a high leaf water potential and a positive water balance in cuttings (8,9).

Shading of the mist benches in 1984 reduced the irradiance level at the height of the cuttings to 80 Wm^{-2}. However, quantum irradiance figures of 100 Wm^{-2} (3) and radiant energies of 1.5 MJ (10) have been shown to provide sufficient light for photosynthesis in the mist bench. Although these figures are not directly comparable to the 80 Wm^{-2} recorded, low irradiance is unlikely to have been a major factor in the low rooting percentage observed in 1984.

From the results of the controlled environment experiment it is evident that early rooting is linked to high temperatures. The 15°C and 25°C temperature regimes were selected as they represent the range of temperatures recorded under the different covers in the field.

The difference in rooting percentage between cuttings from clear covers (6.5%, Figure 2) and the light 25°C controlled environment (31.5%, Figure 3) is unlikely to be related to temperature. Irradiances of 244.7 Wm^{-2} (1040 $\mu Em^{-2}s^{-1}$) and 70.6 Wm^{-2} (300 $\mu Em^{-2}s^{-1}$) were recorded, respectively. A further difference, however, was in light quality with recorded spectra of 400-1100 nm under the clear covers and 405-700 nm in the controlled environment. The latter environment was artificially high in red light and this may have influenced rooting.

Shoots in both light and dark treatments within the controlled environment temperature regimes developed together. This has major advantages for the study of etiolation since it ensures that the early environment for the control and etiolated cuttings is identical. In view of this the rooting of cuttings associated with the 15°C dark-treated plants can be directly regarded as a treatment effect. Furthermore, the death of the apex and upper leaves of *Syringa* cuttings, which has led to the tradition on some nurseries of removing the shoot tip at the time of striking cuttings, is associated with exposure of the cuttings to high temperatures and water stress. Over the two years of the present study it was noted that a period of cool, cloudy days following striking of the cuttings may permit the apices to remain intact or "functioning" for a longer time.

Whether high temperatures hasten or cause the death of shoot apices has yet to be ascertained.

The equal rates of shoot development in the light and dark at 15°C and similarly at 25°C further establish temperature as an important factor in the etiolation process. A comparable observation has been made from controlled environment etiolation studies with *Cotinus coggygria* 'Royal Purple'.

The value of studying etiolation in both the field and in controlled environments is apparent and to take this control of variable factors a step further an *in vitro* culture system for etiolating shoots is being developed. Treatments will be applied to clonal shoots to avoid the variation among stock plants reported in this paper. The production of shoots in culture will also give access to a large population of shoots in a similar physiological state throughout the year. By studying etiolation at these three levels in parallel it is hoped that a greater understanding of the rooting process in woody plants will be obtained.

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EXPERIENCES WITH HERBICIDES ON CONTAINERS

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INTRODUCTION

It has been established for some time that labour is the highest cost when producing nursery stock. Therefore there is a need to ensure the highest proportion of those labour costs should go into production. Despatching and aftercare are the other high labour areas. Aftercare sometimes implies afterthought, or the time we have left between potting and despatching.

There is a neglected argument of forethought with herbicides, as this should be the first rule of growing. Good weed control, like early propagation, comes down to timing. The criteria is to apply a herbicide seal to the compost as soon after potting as possible and follow it up at regular intervals, not allowing an infestation to take place. With labour costs high you cannot afford to delay a routine spray, as problem weeds germinate all too quickly and hand weeding is labour intensive and costly.

To my surprise I have found few species of problem weeds, but these few are not to be underestimated. They include, especially in the propagation stage *Cardamine hirsuta*, which if controlled at this stage, would not lead to problems once the plants are on the container beds, and *Epilobium spp.* which has an extreme ability to produce vast numbers of seed and then remain as a perennial weed over the winter period. Also *Poa annua* which builds up mainly due to the overuse of one herbicide (Tenoran).

We shall, firstly, look at the chemicals which have given the most success in preventing germination of weed seeds:

10 Loach, K. and D N Whalley 1978 Water and carbohydrate relationships during the rooting of cuttings. *Acta Hortic* 79 161-168

11 Loreti, F and P L Pisani 1982 Physiological and technical factors affecting rooting in woody species *Proc. 21st Inter Hort Congress.* 1 294-309

12 Rowell, D J 1981 Etiolation of stock plants for improved rooting of cuttings II Initial experience with hardy ornamental nursery stock *Proc Inter Plant Prop Soc* 31 392-395

EXPERIENCES WITH HERBICIDES ON CONTAINERS

PAUL M. UNDERHILL

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INTRODUCTION

It has been established for some time that labour is the highest cost when producing nursery stock. Therefore there is a need to ensure the highest proportion of those labour costs should go into production. Despatching and aftercare are the other high labour areas. Aftercare sometimes implies afterthought, or the time we have left between potting and despatching.

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We shall, firstly, look at the chemicals which have given the most success in preventing germination of weed seeds:

A personal comparison of pre-emergence herbicides:

SIMAZINE (50% w/w Simazine)

For use with containerised nursery stock I have found half-rate Simazine at 1 lb/acre in 100 gallons of water gives fair control of wide ranges of weeds, and is useable on many species of nursery stock including green conifers, i.e. × *Cupressocyparis leylandii*. The chemical is cheap and long lasting but is not the complete answer as it does damage certain species. I have had problems with *Forsythia*, *Deutzia*, *Philadelphus* and *Weigela*. Affected plants may not grow out of damage for the following season. Washing off, as in the case of Tenoran (chloroxuran) has helped to minimise damage. Simazine when applied 4-6 weeks after potting, will be the only application in the season. Best control is given, however, when used in conjunction with other chemicals, i.e. Ronstar (oxidiazon) after potting, Simazine, and then Tenoran, on every other application (8 weeks between sprays). The Tenoran is of particular benefit for the control of liverwort and mosses and other types of weeds that Simazine does not control.

TENORAN (Chloroxuron)

I find some nurserymen shying away from this chemical, especially after damage has occurred, but this can be eliminated by washing off quickly and thoroughly after application. When I came out of college the recommendations for interval between applications were: 6-12 weeks (Weed Control Handbook, Vol II), 6-8 weeks (manufacturer's recommendation), but this gave poor control and much embarrassment. With shortening the spray interval to four weeks I achieved excellent control.

In conjunction with this, uneven application is the biggest problem and so I developed a boom to work in conjunction with a Centurian sprayer, to give the maximum coverage and wash off. Any such boom should be designed ideally with an extra angled nozzle to cover the edges of the bed. This is usually the worst place for germinating weeds. The rate of 2 lbs c.p in 100 gallons is effective.

RONSTAR granules (Oxidiazon)

I have been using the granular formulation of Ronstar for about four years now and have found it especially useful for applying after potting, before other routine sprays. Application has proved difficult as uneven placement of the granule occurs, tending to bounce off the pots, or with dense foliage not penetrating to the compost surface. There is also the need to apply the chemical when the foliage is dry and tap off with a cane, as contact with foliage may result in scorching. The application rate is 2kg over 100M. This interval between appli-

cation is 10 weeks, which makes it longer lasting than Tenoran, but like Simazine it is best used in conjunction with Tenoran to control a broader range of weed species, including liverworts and mosses. The application is by the pepper pot type Kerb applicator or hand granular applicator costing £55. With increasingly large areas to cover, a power knapsack type duster costing £250 looks like a better method of application. Recommendations so far only indicate two genera as susceptible to damage — *Hydrangea* and *Spiraea*, but I have not noticed any problems occurring. Ronstar has been good in polyhouses and glass until this year when it defoliated newly-potted *Skimmia japonica* liners.

These three chemicals work very well, but should not be relied on absolutely. There is still a need for labour intensive hand weeding to be carried out before seeding and residual herbicide application.

This year I set out to find an effective alternative to hand weeding especially prior to despatch.

Spray trials for the control of existing perennial weeds:

The objective of these trials is to reduce the amount of hand weeding of containerised nursery stock prior to despatch. In 1983/84 season the main problem on our site was *Epilobium* spp.

Another aim is to reduce other weeds which tend to flower and seed quickly, which cause great problems in the spring. In this category the most serious problems are caused by *Poa annua* and *Cardamine hirsuta*.

To find a chemical which will be selective enough to kill the weed and not cause any economic damage to a broad spectrum of nursery stock was not easy; my only previous experience of this kind of control was connected with evergreen nursery stock in the open ground using Kerb 50W.

The plants used in the trial were as follows:

Berberis "coccinea"
B. darwinii
Cotoneaster horizontalis
C 'Hybridus Pendulus'
C microphyllus
C 'Royal Beauty'
× *Cupressocyparis leylandii*
× *C leylandii* 'Castlewellan'
Escallonia rubra var *macrantha*
Euonymus fortunei 'Emerald Gaiety'
E fortunei 'Emerald Gold'
Hebe 'Cranleigh Gem'
Ilex aquifolium 'Argenteo-marginata'
Pinus sylvestris
Rubus cockburnianus
Sarcococca hookerana var *humilis*
Symphoricarpos 'White Hedge'

The trial was set up on the 14th of February. Four plots were laid out, one for each chemical. All are five square metres in area. Plants were chosen from the nursery beds with the highest infestation of weeds and the broadest cross section

of weed species. I found little point in conducting the trial on containers with low weed populations.

The chemicals trialed were:

i) Goal — Oxyfluorfen at 5 litres/ha.

ii) Ronstar — Oxydiazon at 4 litres/ha.

iii) R.H. 666 — experimental granular herbicide which consists of Goal/Kerb (oxyfluorfen 1.67%/propizamide 2.83%) at 600 kg/ha.

iv) Kerb — Propizamide 4% at 3.4 kg/ha.

Results were as follows:

GOAL. All weeds died off completely after 2-4 weeks but re-emergence from the crown was rapid.

Damage: Cotoneaster 'Royal Beauty' and *C. horizontalis* received slight retardation of growth. In *Escallonia* 75% of leaves dried; *Sarcoccoa* 40% of leaves died. *Euonymus fortunei* 'Emerald 'n Gold' and 'Emerald Gaiety' — both completely defoliated.

Post trial control: After 8-10 weeks complete and severe re-emergence of *Epilobium spp.*, also *Poa annua* and *Cardamine hirsuta* which were at this stage flowering and seeding.

RONSTAR. All weeds died off completely after 2-4 weeks. Re-emergence occurred from *Epilobium* at the crown.

Damage: Escallonia suffered 75% leaf death.

Post trial control: 8-10 weeks severe *Epilobium* problem returned along with infestations of *Cardamine* and *Capsella bursa-pastoris.*

R H 666. There was a complete browning of weeds early on. In April some *Epilobium* died back into the crown.

Damage: Escallonia leaves affected but regrowth soon followed.

Post trial control. 8-10 weeks later re-growth of all weeds occurred.

KERB. This was slow to act at first but by early May there was a complete burning of weed foliage, *Poa annua* and *Epilobium* dying off.

Damage. none.

Post trial control: Re-emergence of *Epilobium spp.* but all were severely weakened having an especially poor root system which enabled them to be hand-weeded very easily.

NOTE: While this trial was being conducted Kerb 50 W was applied to the main nursery container area at the 1.5 kg/ha. The spray was directed at patches of *Epilobium*, avoiding

clean batches of crop plants. This hit and miss attempt gave better control than the trial chemicals. A complete kill occurred with little re-emergence from the crown. I can only speculate about the success of this method. I think that the lower rate was taken in slowly and absorbed into the root system more efficiently.

In conclusion, Kerb 50 W for the control of existing *Epilobium* infestations applied in the winter months, can give control over a broad range of nursery stock. This range remains to be specified by further trials.

Pre-emergence trials.

After becoming very complacent with Tenoran and Simazine, I decided last month to try something new. On the 23rd June I again treated our trial plot at Spot Acre Nurseries with three of the newer pre-emergence chemicals. Here is a brief summary of the trial to date.

i) Goal/Kerb 30 gms/ 5 m^2. Looking very clean, no damage but some *Sagina procumbens* starting to cover the pots.

ii) Goal/Kerb 60 gms/5 m^2. As above.

iii) Goal liquid 2 ml/5 m^2, 2 litres of water in knapsack and washed off well. No emergence of weed seedlings but very severe scorching on all trial plants.

iv) Ronstar granules 60 mgs/5 m^2. No damage, but very many patches of germinating weed seeds.

Indications so far show that the Goal/Kerb granules are low risk and give good weed control. I understand that this granule may be on the market next year, released through P.B.I. (Pan Britanica Industries). Indications from other trials suggest a greater control over a much wider weed spectrum than oxydiazon. It also has a low phytotoxicity even at double rate to trees and shrubs, and without the need to tap off the granule.

Goal/Kerb granules: Oxyfluorfen 1.67% a.i. + Propizamide 2.83% a.i.

Hand weeding is probably the most demeaning job on the nursery and, to a large extent, can be overcome with herbicides. Like slow-release fertilisers it really is a case of trialing the chemicals and finding which one suits your own production programme.

HARDY FERNS

PETER STOKES

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I have been interested in the production of hardy ferns for the past ten years and have been producing a limited range for the last five years. These are mostly grown in 3 litre containers for sale to retail outlets.

Ferns have been around for 400 million years, so they say, but hardy ferns only became really popular with British gardeners in the last half of the 19th century. Then hundreds of types were grown by some nurseries but since 1914 interest has greatly declined.

There is certainly a place in the modern garden for hardy ferns. Many forms grow well in damp shady places and stand considerable neglect. There are attractive low growing ferns which grow well in the shaded parts of rockeries, their foliage giving a good contrast to dwarf evergreens. Some of the larger species such as the royal fern (*Osmunda regalis*) or the ostrich plume fern (*Mateucia struthopteris*) grow well in very wet conditions and make excellent marginal plants.

Propagation. Division is the simplest method of propagation. Those ferns that grow from rhizomes can easily be divided. The best time is early April as the roots are starting to grow. I pot them straight into 3 litre containers and they are often saleable in 3 or 4 months. Some of the crown-forming species can also be divided satisfactorily. A reasonable selection of hardy ferns can be produced by division, which is a simple low cost method giving quick results when it is practicable.

Ferns can be produced in large quantities from spores which are produced in vast numbers. However, it is a very slow process, taking as many as four years to produce a reasonable sized plant. Hygiene is most important in the early stages to avoid contamination by fungi, mosses, and liverworts.

After considerable trial and error, I now sow the spores on moist sphagnum peat, which has been sterilised, in sealed white plastic boxes. Spores can be collected in autumn and sown the following March. The exception is *Osmunda regale* which must be sown as soon as spores are shed in June or July. The spores germinate to produce a prothallus and these can be pricked out in small clumps into trays when they are large enough to handle, normally after four months. They must be kept moist at this stage to enable fertilisation to take place and after 2 or 3 months the first fronds should be pro-

duced. I overwinter these boxes in cold frames. The following spring the young plants can be pricked out individually into trays at a rate of about 100 to a tray. When large enough they are potted on into 3-in pots and the following year into 3 litre containers.

Some ferns produce bulbils in the axils of the fronds, which will root and produce young plants when the fronds are pegged down on a suitable compost. This method can be used for *Polystichum setiferum* cultivars, but I have yet to get consistent results with it.

Hartstongue ferns (*Phyllitis scolopendrium*), of which there are many attractive cultivars, can be produced by sowing the stubs from the base of dead fronds, cut off close to the crown, on a moist sterilised compost. They may produce a number of small bulbils that can be grown on. I have yet to obtain consistent results from this method.

I have no experience with micropropagation but the potential for hardy ferns is obvious. The main problem would seem to be one of effective marketing.

Growing on. I grow all my ferns in a netting house giving 30% shade. This gives the necessary protection from wind and sun in the early summer to produce attractive foliage. The cultivars I grow are all extremely hardy. My nursery is cold in winter. In 1981/2 temperatures were down to −20°C, but my losses of container-grown ferns in a netting house were negligible.

I use the same compost for fern production as for shrubs. This includes Aldrin, as vine weevil can be a serious pest. Generally I have had no serious pest or disease problems, apart from those in the early stages of spore production.

Species. There are very many species of hardy ferns, some attractive — others grotesque. The few I grow at present are listed below. They have been selected with hardiness and ease of production in mind.

1). *Produced by division.*

Athyrium felix-femina 'Minutissima'
Blechnum penna-marina
Dennstaedtia punctilobum
Dryopterys filix-mas 'Crispa Cristata'
Gymnocarpium dryopteris
Mateucia struthopteris
Onoclea sensiblis
Polypodim vulgare

2). *Produced from spores.*

Blechnum spicant.
Dryopteris dilatata
Dryopteris filix-mas
Osmunda regale.
Phyllitis scolopendrium

3). *Produced from bulbils.*

Polystichum setiferum 'Acutilobum'

HAMAMELIS SEED GERMINATION

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Abstract *Hamamelis virginiana* seed contains complex dormancy factors involving not only the embryo but also the endosperm and possibly the integument and testa Optimum natural conditions for breaking dormancy in fresh seed are at least 8 weeks at about 20°C, followed by at least 20 weeks below 4°C, both in moist peat Neither warm nor cold alone will break embryo dormancy, but warm in some way sensitises the embryo to react to subsequent cold While dormant, the embryo produces a lipase inhibitor which presumably diffuses into the endosperm and prevents premature mobilisation of the fatty storage reserves. For the warm treatment a soak in gibberellic acid can be substituted, but a substitute for cold has not been found.

INTRODUCTION

Hamamelis (witch hazel) seeds are shed in autumn and, under natural conditions, most of the survivors germinate 18 months later after enduring a natural cold-warm-cold cycle. Some germinate 12 months later, having had a further period of warm and cold. In the nursery, seeds of this species have been regarded as difficult to germinate because they are slow and unpredictable, and may often give very low germination percentage. However, our business demands planned production of tens of thousands of plants per annum from a limited seed supply, so a higher success rate and greater predictability are essential.

The work described in this paper began in 1979, when we made our first serious attempt to harvest and germinate seed from our own plantation. In early November about ¼ million fresh seeds were mixed in moist peat and put in a warm place; after about 8 weeks they were transferred to a domestic refrigerator, and 20 weeks later we had 90% germination. The following year a similar procedure, but with a reduced warm treatment failed to produce significant germination. A quick experiment with mixtures of gibberellic acid and Ethrel revealed a treatment which seemed capable of kicking the seeds into action. This treatment was applied to the bulk of seed and satisfactory results were achieved. But we did not know why or how it had worked and we had no confidence that it would work again next time.

We felt, therefore, that we must try to understand more about seed dormancy in *Hamamelis* and, through that understanding, develop seed treatments which would enable us to achieve some measure of control over germination. We thus embarked on two projects: 1) To look at chemical seed treat-

ments, and to see if it might be possible to shorten or eliminate either the warm or the cold stratification periods, or both, and 2) To test various combinations of warm and cold to try and find clues as to what the seeds may be doing during these periods, and thus to elucidate the nature of dormancy in this species.

A search of several computer data-bases, both in the U.K. and in the U.S.A., failed to reveal any previously published work on seed dormancy and germination in *Hamamelis*.

MATERIAL AND METHODS

1. Chemical Treatments. With seed that has been through warm and cold, yet shows no sign of germination, our results have been rather variable. We have always succeeded in stimulating germination, but best results have not always been with precisely the same treatment. In general we have found 2% Regulex[1] plus 0.02% Ethrel[2] (in water at room temperature for 24 hours) quite good. Higher concentrations of Regulex have been less effective, and there has been no advantage in increasing the soak to 48 hours. As for possible influence of Regulex soaks on subsequent seedling growth, we have found, perhaps surprisingly, no statistically significant effect.

With unstratified seed, we have found that Regulex can substitute for the warm treatment, but the normal period of cold is required thereafter. We have not found any substitute for the cold.

2. Warm and Cold Treatments. All seeds were from the same fresh seed-lot, harvested from our own plantation of *H. virginiana*, and were graded for uniformity of size. For each treatment at least 100 seeds were mixed with about 200 ml moist peat, and sealed with plenty of air in a marked polythene bag. Each bag was placed in either "warm" or "cold" as the treatment schedule required. "Warm" was in a thermostatically-controlled room with fluctuating day/night temperatures of 24/16°C; "cold" was in a domestic refrigerator at 0 to 4°C. In both environments, bags were turned and moved around at least once every two weeks; at the same time, in the warm only, bags were opened briefly for ventilation. Treatments were 0,2,4, or 8 weeks "warm", followed by 0,2,4,8, or 16 weeks "cold", followed by a further 0,2,4, or 8 weeks "warm", and a final 0,2,4,8, or 16 weeks "cold" — a total of 308 different treatments.

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[1] Regulex (ICI, Plant Protection Division) contains 10 g l^{-1} of a mixture of gibberellins A4 and A7

[2] Ethrel (Amchem Products, Inc) contains 2-(chloroethyl) phosphonic acid

At the end of each treatment we applied the following tests:

a. Fifty seeds were sown in moist peat to assess germination percentage.

b. Embryos were removed by dissection from 10 seeds and were placed on sterile oil-emulsion agar: 1) to assess their ability to grow without the influence of other seed tissues, and 2) to detect lipase enzyme activity (we thought that when the embryos were ready to germinate they might produce lipases to digest the fatty endosperm storage tissue).

c. The endosperm tissue from those 10 seeds was macerated in water which was then used, unfiltered, to irrigate 20 radish seeds on seed-test papers in Petri-dishes. This test was applied only after week 16.

d. The remaining seeds were weighed, dried at 105°C, and re-weighed to measure moisture content.

RESULTS

Treatments were identified by a series of four numbers which represent weeks in warm, cold, warm, cold, respectively: thus, 4,8,2,16 means 4 weeks warm, 8 weeks cold, 2 weeks warm, 16 weeks cold. Treatments such as 2,4,0,8, where the two cold treatments are consecutive may be referred to as 2,12. In either case, the first number indicates warm.

1. Whole Seed Germination.

a. Warm only and Cold only. Irrespective of duration, there was no germination in any of these treatments.

b. Warm/Cold. See Figure 1. At least 8 weeks cold were needed for any germination to occur. As cold increased, up to 24 weeks, germination increased, but 32 weeks appeared too long. For any given length of cold, longer warm gave better germination, although it is clear that where cold will be 20 weeks or more there can be little to be gained from more than 8 weeks warm. Where total seed-treatment time is limited, there is clearly an optimum division between warm and cold. For example, 28 weeks divided 12,16 gave 72% germination, whereas 8,20 gave 83%; 4,24 gave only 50%.

c. Cold/Warm/Cold. See Figure 2. As there is little germination below 16 weeks final cold, the results are illustrated here by 15 treatments all of which end in 16 cold. Initial cold causes greater fluctuations in germination as the intervening warm becomes longer, but there is no clear trend in the results. It is curious, however, that the top two curves are mirror-images of one another, and it is a matter for speculation

whether there may be conclusions of ecological significance to be drawn from the shape of either.

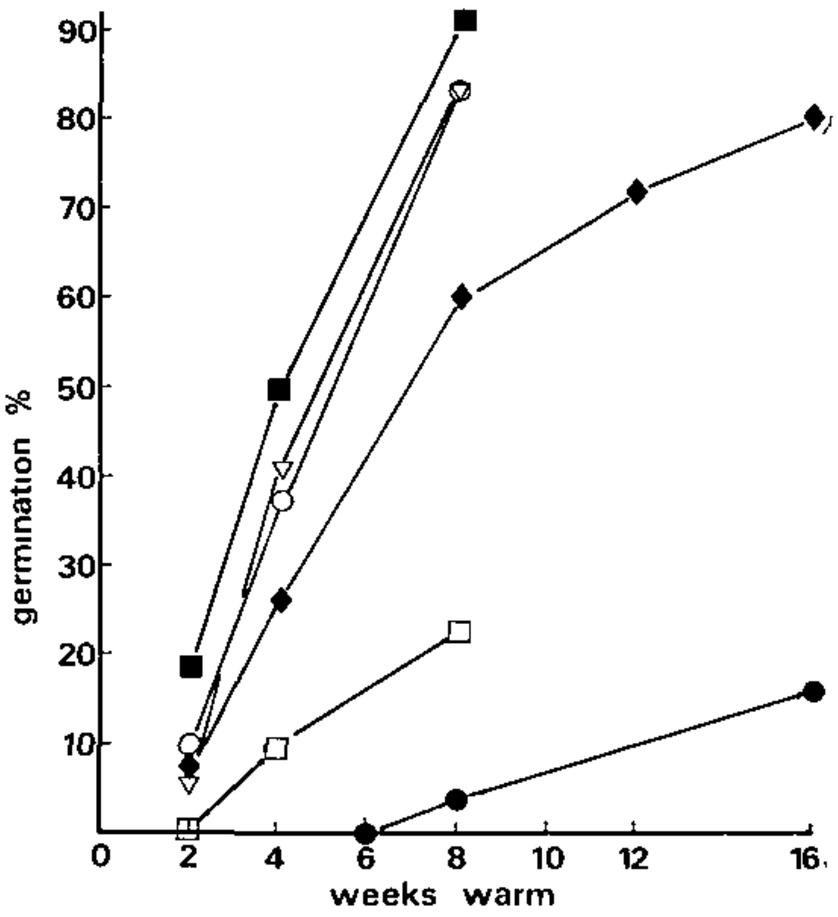

Figure 1. The effect on germination of 0 to 16 weeks warm, followed by 8(●), 12(□), 16(◆), 20(○), 24(■), 32(▽) weeks cold.

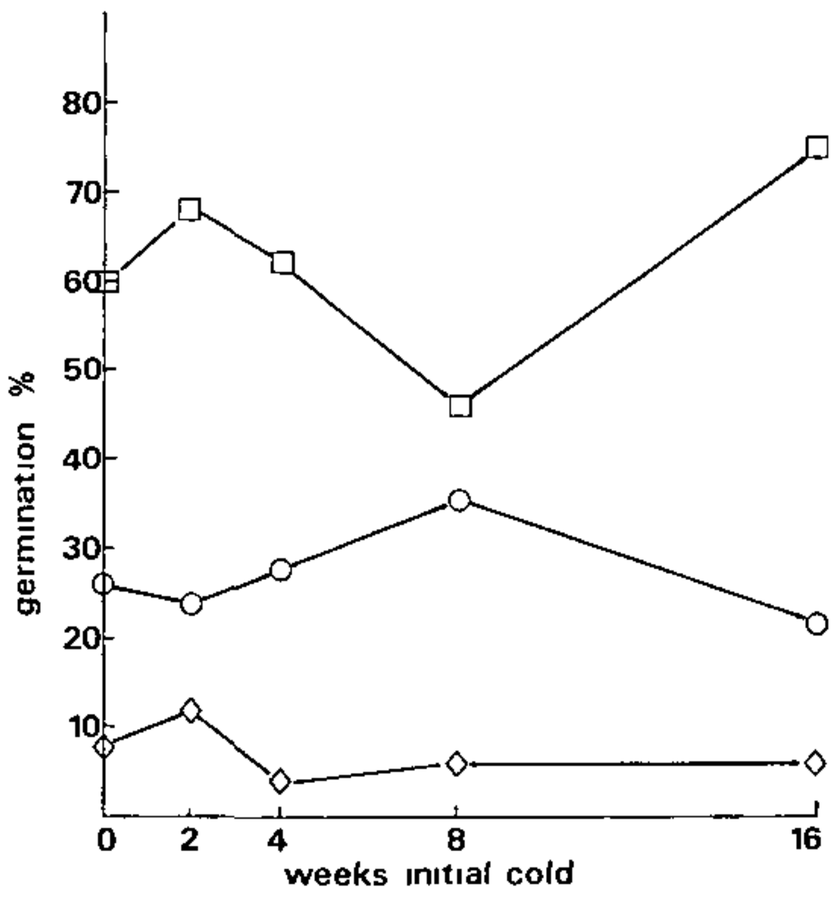

Figure 2. The effect on germination of 0 to 16 weeks initial cold, followed by 2,16(◇), 4,16(○), 8,16(□)

d. Warm/Cold/Warm. These treatments are not significant for whole-seed germination, since the final warm is equivalent to a germination test after a Warm/Cold treatment.

e. Warm/Cold/Warm/Cold. We have already seen that an extended cold period of at least 16, preferably 20 or 24, weeks is desirable, following at least 8 weeks warm. Thus this sequence of treatments effectively becomes a test of interrupting the cold with various lengths of warm at various points during the cold phase. For example, a treatment such as 8,24 can be

divided 8,8,-,16 or 8,16,-,8; while 8,20 can be 8,4,-,16 or 8,16,-,4.

The results are very clear (see Figure 3.). For 8,20 or 8,24, there is no effect on germination if the warm break occurs during the first half of the cold period, neither does the length of warm break matter. However, if the warm break is in the second half of the cold period there is a significant reduction in germination, which reduction tends to get greater as the length of warm increases. Treatment 8,16 can only be divided 8,8,-,8 (i.e. in the middle of the cold period), and here also there is serious loss of germination. Treatment 8,12 also shows reduced germination when the warm comes in the second half of the cold period, but is unique in showing increased germination from a 2 or 4 week warm break early in the cold period.

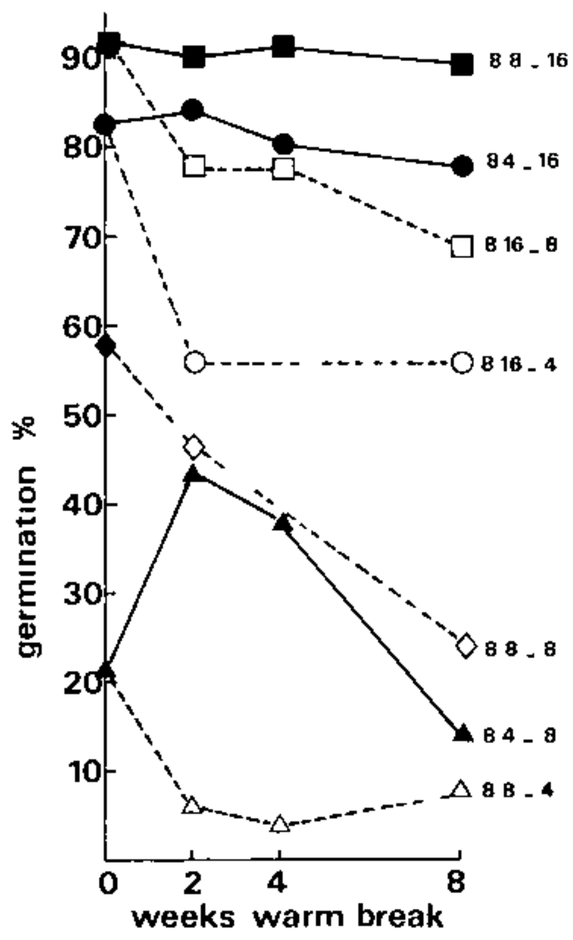

Figure 3. The effect on germination of 0 to 8 weeks warm break during the cold period in treatments 8,12(▲), 8,16 (◆) 8,20(●), 8,24(■) Warm break in either first half (_____ and solid symbols) or second half (----- and open symbols) of cold period.

2. Embryo Tests.

a. Growth. With warm only; some embryos showed a slight tendency to greening of cotyledons and extremely limited radicle growth but there was no significant visible development, irrespective of length of treatment. With cold only, there was even less tendency to development. When 8 weeks warm were followed by increasing cold, the results generally paralleled those for whole seeds. There was little activity at 4 weeks cold, but with 8 weeks most embryos developed expanded green cotyledons and significant active root growth. After 16, 20 or 24 weeks cold, 80 to 100% of embryos were very active; but after 32 weeks cold, 40% appeared dormant, while others were much less vigorous.

b. Lipase Activity. Our search for lipase activity in the embryos was fruitless, but we did discover strong evidence for a lipase inhibitor. Because our working conditions were not microbially clean, we often got bacterial or fungal contaminants on our agar plates; many of these produced lipase which digested the oil emulsion and thus produced a zone of clearing around the colony. We observed that wherever this zone of clearing approached a dormant embryo, the clearing was inhibited; there was no such inhibition from active embryos (Figure 4.). The shape of the inhibition zone suggested that the cotyledons were the source of the inhibitor.

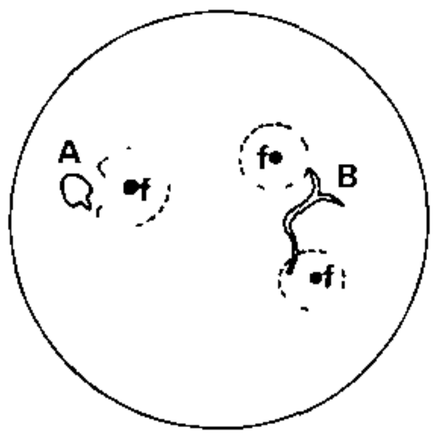

Figure 4. Diagram of one dormant (A) and one growing (B) embryo on oil-emulsion agar, with three lipase-producing fungal colonies (f) Dotted lines mark edge of cleared zones Clearing is inhibited by A, not by B.

3. Endosperm Test

This gave very clear evidence of a germination inhibitor, active against radish seeds, which was present in the *Hamamelis* endosperm after some treatments but not after others. A striking feature of this test was the very clear-cut nature of almost all the results: the radish seeds either germinated as well as the control (water only) seeds, or their germinaiton was completely inhibited.

We expected that the results of this test might correlate with those of the embryo test and the whole-seed germination test in such a way that germination would only occur if the embryo was ready for growth *and* the endosperm showed no inhibitor; either lack of readiness in the embryo, or inhibitor in the endosperm should prevent germination. In fact, this did not always happen (see Table 1.).

The first four examples in Table 1 show the expected results, where low germination correlates with either no embryo growth (2,16,2,4) or presence of inhibitor (0,16,8,4) or both (2,8,8,4), and high germination correlates with embryo growth and absence of inhibitor (8,8,8,16). The other two results appear anomalous: in 8,4,2,16 the inhibitor has failed to prevent germination, while in 8,4,8,4 there has been no germination despite positive embryo growth and absence of inhibitor. Possible explanations for these anomalies are discussed later.

Table 1. Whole seed germination, embryo growth, and endosperm inhibitor after various treatments

Treatment	Endosperm Inhibitor	Embryo Growth	Whole seed Germination
2,16,2,4	−	−	6%
0,16,8,4	+	+	4
2,8,8,4	+	−	2
8,8,8,16	−	+	88
8,4,2,16	+	+	84
8,4,8,4,	−	+	0

+ = presence of inhibitor or growth of isolated embryo
− = absence of inhibitor or no growth of isolated embryo

4. Moisture Content.

Moisture contents ranged from 45.5% to 70.0%. Excluding those treatmens which gave 5% germination or less, germination and moisture content were closely and positively related ($r=0.85$; $p<0.001$); see Figure 5. This correlation presumably relates to the conversion of osmotically inactive lipid storage materials to osmotically active carbohydrates.

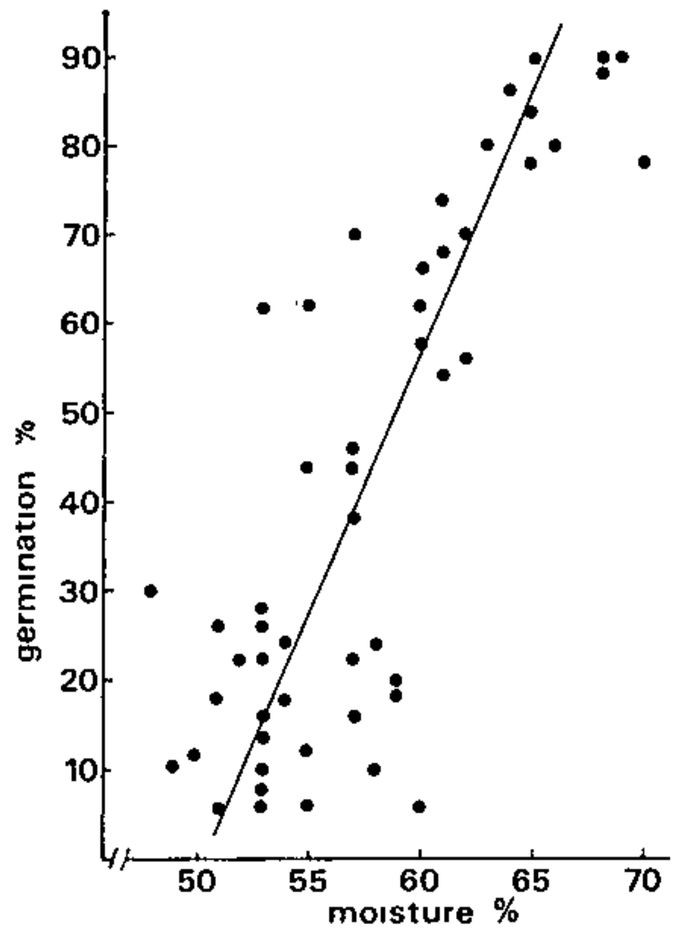

Figure 5. Correlation between germination and seed moisture content. Line fitted by regression analysis ($x=0.17y + 50\ 4$)

DISCUSSION

Before we began this work, we felt from experience that the length of the warm period might be critical, and that it might be possible for seeds to be too long in the warm period. Our results do not support this hypothesis: certainly 8 weeks warm seems to be a practical minimum, but there is no evidence that longer warm is detrimental; indeed 12 or even 16 weeks warm are beneficial if subsequent cold is sub-optimal.

Clear evidence has been presented that dormant embryos produce a diffusible lipase inhibitor, presumably acting on

lipases in the endosperm. Production of this inhibitor appears to cease only when embryos have received a suitable combination of treatments to enable them to start growth. Since the contamination which enabled us to observe this phenomenon was fortuitous, it occurred on only some plates and even then was very variable, future work would require more standardised conditions.

The anomalies in our endosperm/radish seed test need further study. Treatment 8,4,2,16 achieved 84% germination despite the apparent presence of the inhibitor; this can be explained if we hypothesise that inhibitor from a single endosperm is sufficient to produce the effect on radish. Our tests were conducted with the combined extract of 10 endosperms; if inhibitor from just one is sufficient, this could explain why we have found the test so definite in almost all cases. If none of the endosperms contain an inhibitor, the radish seeds germinate, if one or more contain an inhibitor, the radish seeds do not germinate. Our results do not provide sufficient evidence to test this hypothesis.

To explain the result with 8,4,8,4 where there was no germination despite embryo growth and apparent absence of endosperm inhibitor, requires that we postulate yet another source of inhibition, and we have two candidates to propose: the testa and the integument. The testa has been shown by colleagues at Plymouth Polytechnic, using the radish-test (S.D. Lane, personal communication), to contain one or more potential inhibitors, but we have not attempted to consider it in this study. It is often remarked that the very hard testa is perhaps a barrier to imbibition; there is however a relatively soft micropylar region and we have shown in other studies that whole seeds, cracked seeds, and seeds from which the testa has been completely removed, have identical rates of imbibition.

The integument is a membrane immediately beneath, but not attached to the testa. It is intimately connected to the endosperm and often appears to be very tough. It is quite possible that, under certain conditions, this membrane constitutes an effective barrier to gaseous exchange. Furthermore, we have often observed, outside this particular experiment, germinated seedlings which emerge with the cotyledons seemingly trapped within the integument; whether this is due to the integument's strength or to developmental incapacity on the part of the epicotyl, we do not know.

CONCLUSION

Our results have been presented largely in qualitative form because the treatments were unreplicated and most of

the information is not amenable to statistical analysis. Had we replicated, the already large number of operations would have become utterly unmanageable. Nevertheless, we have provided a practical basis on which it should be possible to achieve high germination regularly; and we have highlighted several areas, which will be of great interest to academic researchers, where further work could be done.

PROPAGATION AT BRIDGEMERE NURSERIES

BRIAN H. DALE
Bridgemere Nurseries
Bridgemere
Nr. Nantwich, Cheshire

I have worked at Bridgemere Nurseries in Cheshire for the last 14 years. I achieved the position of head of propagation some 9 years ago, due to a knowledge based purely on practical experience and advice from fellow propagators.

I have a minimal involvement in field propagation and this is limited to fruit trees and the easy evergreens, such as laurel and *Vinca* spp. The latter are propagated under low polythene tunnels on a sheltered, well-drained section of the field.

The breakdown of the 800,000 cuttings which are rooted by my department each year, is as follows: 30% shrubs, 25% heathers, and 25% conifers, the balance being split among everything from Exbury azaleas, *Pieris* spp., *Mahonia* spp., with about 5% of this balance being climbers.

The second type of propagation under my control is the division of bareroot herbaceous plants, a crop which is increasingly being home nursery produced. The reason for this is customer demand which is creating a demand for almost limitless cultivars of plants of all kinds. This means that I am constantly having to add new plants to my propagation lists, the present range covering some 750 different ones. Sadly, once the newer cultivars become popular, we have to axe some of the more traditional lines in order to keep a careful balance.

One of the few types of hardy plants which we do not propagate as yet are the alpines, but we may one day add them to our range.

Propagation Techniques. In the main, our cuttings are rooted in Macpenny mist units, which provide mist between March and October.

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Propagation Techniques. In the main, our cuttings are rooted in Macpenny mist units, which provide mist between March and October.

Having on several occasions experienced temperatures as high as 120°F without any problems, my propagation technique is to use total humidity and maximum temperature. The vital safeguard is to keep the humidity as high as possible. Until now I have never seen any ill effect on cutting material as a result of this method. On the contrary, the speed with which the cuttings will root lessens the chance of disease which can be caused by high humidity.

Throughout the winter the mist unit is turned off and the beds are covered by a tent of 150 gauge polythene which creates a microclimate around the cuttings, thus creating both higher humidity and temperature than in the rest of the house.

Certain crops are rooted in closed cases. For example, Exbury azaleas and *Clematis*. Here the cases are covered with poly-carbonate sheeting. In the case of hybrid rhododendrons however, the polythene is laid directly on the foliage of the cuttings.

The Propagation Team. There are five regular staff members in the propagation department, although this always includes one middle-year student who works about four months in each department. Another of the five is engaged for most of the year to work on climbers, as this crop remains the responsibility of my department, even to the extent of filling the relevant retail section in the garden centre.

In July and August the number of staff is usually doubled. This is due in the main to summer students being called in to help out on the climber section.

Shrub Propagation. My propagation year starts either late April or early May. The exact timing depends upon availability. The first cuttings are made from any soft material available. This is taken from liners which have been overwintered under polythene. This operation also effectively trims the liners.

This is the only forced material available as we do not have the space to force plants. The lack of space has caused us to abandon the forcing of Exbury azaleas and the propagation material now comes from liners overwintered under glass. These are kept frost-free from early March until the end of May as at this time Exburys are very sensitive and can quite easily be killed even under glass.

The Exbury azaleas are one of the few crops for which I do have a set deadline for finishing, and this is the end of May. The reason is that we need to have cuttings rooted early enough to allow extension growth to be made in the same

season. This gives a far greater chance of survival during the winter.

This growth is helped by supplementary lighting. This equipment consists of a string of ordinary light bulbs spaced four feet apart and suspended three feet above the cuttings. The cuttings are lit for a period of four hours in the middle of the night right through until the end of October.

The one vital thing needed to ensure success is that the cuttings must be vernalized (chilled) after Christmas and, as with the liners, frost protection in early spring is essential.

Once the supply of material from shrub liners is exhausted, we make use of our stock field material. This field is about four acres in size. Although is is situated about three miles from the propagation unit, it is on good light soil and has a supply of water from a bore-hole should it be needed.

We have recently planted out another stock area. I will explain about this in more detail later on.

We normally gather cuttings from the stock plants early in the morning and they are placed into cold water, drained, and then stored in white polythene bags. The cuttings are kept in the shade until they can be transferred to the propagation shed. Once there they are stored in deep crates within pallets and wrapped in white polythene to keep them cool.

The material is then kept moist until it is needed. It can be kept in the summer for up to two and a half days and up to five days in winter. This is very useful as the taking of cuttings in winter is controlled very much by the weather. Therefore, a store of ready material enables the staff to always have a supply available. This system proved itself in the recent bad winter as it enabled us to work right through.

I usually like to have the general deciduous shrub propagation finished by the end of July, although there are always certain species to be struck in August. Deciduous *Berberis* spp. for example, root best when taken in mid-August. Immediately after the deciduous propagation has been completed, we go on to deal with the evergreens in the autumn. The main groups of plants are *Pieris* spp , heathers, evergreen azaleas, and dwarf rhododendrons. The later two tend to take priority over the others as I have found the timing to be more crucial for success with both of these crops.

Azaleas and Rhododendrons. With azaleas, growth has to be ripened and I invariably find that the best material has a terminal flower bud. However, this in no way hinders rooting. This crop must be propagated before the nights get cold, otherwise leaf drop occurs in certain cultivars.

With azaleas I rely upon cuttings which have been taken with great care from saleable stock. The reason is that we have found stock plants in this case to be impractical, except when they are used for assessment and drawing comparisons between new cultivars.

Dwarf rhododendrons are rooted over a much longer period and are started before the end of August. The first to be handled are the smallest kinds, such as *Rhododendron impeditum*, gradually working through to the larger-leaved dwarfs, such as *Rhododendron* 'Scarlet Wonder'. With these cultivars timing is less rigid as they can be struck successfully through February if need be.

Heathers and Pieris. Heathers are usually started early in August and are gradually worked through by Christmas. There, again, *Calluna* spp can be taken quite successfully as late as February. On one occasion I had good success as late as April.

Pieris, I find tends to be a useful stop gap as it is a very adaptable crop which will tolerate a variety of propagation systems. *Pieris* is very important to us and we grow approximately 30,000 per year. Although two-thirds of this is *Pieris* 'Forrest Flame', we also grow a further 16 cultivars, but only in limited quantities.

Rhododendrons, Mahonias, and Elaeagnus. By late October the crops propagated tend to be the larger-leaved species and cultivars of *Rhododendron*, *Mahonia*, and *Elaeagnus*.

Rhododendrons are inserted directly into Irish moss peat, usually without any additional moisture. On some of the larger-leaved cultivars, such as *Rhododendron* 'Cynthia', it is necessary to trim the foliage before insertion.

The rooting hormone used for rhododendrons is various strengths of IBA in talc. This is usually mixed with captan so that equal volumes of 4% IBA plus captan will give an effective rate of 2% IBA.

However, I have found with several species, for example *R. caucasicum*, R. 'Pictum' and R. 'Sappho,' that a solution of only half this strength is needed, but this is very much a case of trial and error.

Too weak a hormone causes slow rooting or none at all, whereas too strong a hormone will kill the cuttings outright. When the cuttings have been prepared they are covered with 150 gauge polythene which is in direct contact with the foliage. It is then removed every seventh night to give the foliage a chance to dry out and for any dead foliage to be removed.

Mahonia is one of the few crops to be directly inserted into a pot, in this case 7 cm square. As material for this crop is always scarce, we use single leaf-bud cuttings and once these have been inserted they can either be covered by polythene directly on the foliage in a low, heated case or they can go onto the mist beds, which by this time have a polythene tent over them.

Elaeagnus × *ebbingei* cuttings have polythene directly on the foliage and the cuttings are treated in the same way as the rhododendrons, apart from being inserted into boxes. The success rate of this method is 80 to 85% rooting, which must make this a far more efficient way of producing a crop than the tens of thousands which are grafted every year, particularly in Holland.

Conifers. the only conifer I have time for before Christmas, is × *Cupressocyparis leylandii* 'Castlewellan.'

These cuttings are generally held in cold cases until February and, if necessary, can be left until April, by which time they would normally be about 75% rooted.

The rest of the conifer cuttings, some 175,000 in all, are taken after Christmas, and for this reason, I try to ensure that all other crops are finished by December.

With the exception of the junipers, which do best during the cold winters, there is no definite order in which the conifers have to be done. Although having said this, during the last bad winter I found that certain juniper cultivars seemed almost impossible to root, one in particular being *Juniperus chinensis* 'Pfitzerana Aurea'.

My only priority, therefore, is to make sure that the more difficult and rare cultivars are given the best position on the heated beds.

Propagation by division of bareroot herbaceous plants. This material is either bought in or lifted directly from our own fields. It is then split into pieces which are just large enough to make a saleable plant within three months of being potted.

With the herbaceous material we are responsible not only for the division of the plants, but also for the potting of certain species. This is either because they need careful handling, examples being species of *Pulmonaria* and *Delphinium* or, as in the case of *Paeonia* and *Gypsophila* species, the root systems make machine potting totally impractical.

To conclude, I return to a subject which I touched upon earlier, that of the new stock area which has recently been planted.

In size it measures roughly one acre and is almost square in shape. The section allocated to me is one of four adjacent walled-in plots of land which have recently been acquired by the nursery. Already we are making good use of this extra space and have planted out various shrubs numbering from 50 of certain cultivars down to as few as three of others.

This area should prove itself to be useful for testing plants of species which are unable to survive in the sheltered conditions provided by the walled in area and are not worth the risk of growing. Two of the main genera in question here at the moment are *Cistus* and *Ceanothus*, both eminently saleable plants but of questionable hardiness.

The other plus factor of this new area, is that we are now able to compare new species and cultivars side by side and to judge their worthiness for our use.

CHANGE ON THE NURSERY

D A. HUSBAND

Somerset College of Agriculture & Horticulture
Cannington, Bridgwater,
Somerset, TA5 2LS

If our I.P.P S. Conference has been of value at all, there will be some changes on the nursery as a result of our attendance. These changes need careful study to be effective, and so we will look at possible changes under five headings.

(1) In what area of business should there be changes? Changes in the wrong area could precede disaster. One guideline is, "the area where we do worst." Here, change can only improve things — or so it may seem. Another guide is, "where we are doing very well" — change in this area could shift us from the mediocre nursery to the elite nursery.

Suggestions are.

Outlets. Selling wholesale, to garden centres, instead of retail to the visiting public, — or vice-versa.

Subjects involved, or type of plant produced. Perhaps growing standards of choice ornamental trees instead of maiden fruit trees. A bigger change could be in going from bare-root to container sales. .

Sources of Stock. Beginning a stock-plant area, so that all the cutting material is completely under your own control, instead of depending on local nurseries or gardens. An addi-

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tional facet here could be the use of a stock bed some distance from the nursery.

Actual Spread of Activities. Increasing the length of time the crop is held, e.g. propagation being cut out, in favour of importing of pot-liners. Increasing sales to include sundries as well as plants. Alternatively, selling at liner stage instead of 2-year-old plants.

Logistics of the Nursery. Replacing the frame yard with standing out ground, and so widening paths to take motorised trucks instead of wheel-barrows. Altering the position of the main entrance to the nursery and thus realising space for an improved loading bay.

Overall Expansion. Purchase or renting more land. Re-building packing-shed/work-shed, and tractor shed with a larger composite facility, to include office, parking, tool store, and messroom.

Staffing. Encouraging younger staff to take on more responsibility by

a) being less involved oneself;

b) allocating specific projects of development to individuals, and giving them the responsibility to pursue this;

c) discussing all policy with them;

d) introducing a skilled foreman to take on a section of the nursery.

Communications.

a) Perhaps it is a typist we need? What about the cost of her typewriter? Does she understand what the firm is there for? Will she have to be the "office-manager" — as well as the typist?

b) Perhaps we need a computer? — for records of stock, sales, costings?

c) What about Prestel — the FARMLINK of Agriculture? Who knows how many fruit tree maidens are available next year in the U.K. How can we find out how to grow this new crop — can Prestel help? Are we prepared in our public relations to get into the computer age? Can our customers get us when they want to us? What about the cheapest source of peat, sand, fertiliser, pots, timber. What is the current price of rootstocks? Am I able to buy or sell all I need to at the correct prices?

(2) Why should there be change?

To bring in more revenue. This could be the most frequent reason for changes; it may not be the most important! It needs careful calculation to be the correct reason!

Does the cost of the change measure up to the suggested magnitude of the increase in revenue. (If not, why change?)

To increase the enthusiasm among the staff. Apathy is very expensive! To increase enthusiasm could have a large knock-on effect. Perhaps this is not thought of frequently enough by owner/managers, — and our staff are working at half-throttle because of boredom! — while we wear ourselves to a frazzle to squeeze work out of them!

To make life easier for the owner/manager. At first sight this could be a dangerous reason for change, but if father spends 90 hours a week at work, it is justifiable, — no man is an island — the family need him, — and he needs the family if he is to be the well rounded person he ought to be.

If life becomes a bit easier for the manager, he may be able to see things on the nursery in perspective — may be able to "stand back and look" — and so become a better manager.

Perhaps, taking a reduction in his weekly hours could lead him to greater contact with other nurserymen.

In fact, if he could ever go on holiday (!!!) he could well learn something of profit from nurserymen elsewhere in the world! "All work and no play makes Jack a dull boy."

To satisfy the challenge of new developments. Given the energy, this can be worthwhile — when we cross one hurdle, is it not just to see another hurdle in front of us? — and so on and so on — taking the firm with us! But we need to see it for what it is — changing to answer the challenge of new developments.

To boost ones own ego. To "make one's name a household word" may be the result of the production of the worthwhile plants — but to make it one's reason for changing things on the nursery could jeopardise the quality in some cases — many firms have crashed on this bridge.

To keep up with ones contemporaries. Although, perhaps, we would not admit to this being a reason for alterations on the nursery, a careful examination of our motives — (or of our reactions when we hear of our neighbour's latest activities) could be revealing. It may not be worthwhile.

Each change contemplated could be associated with a different reason, in our own minds.

We need to recognize the motives in our changes on the nursery. As we analyse our motives in honesty, we may be unpleasantly surprised!

Perhaps determination to progress can be motivated by personal competition — or even revenge!

To recognize the motive in our desire to introduce changes on the nursery may increase the urgency of these changes — or in fact remove the desire to change at all!

The Greek philosophical cry of, "know thyself," is very important!

(3) How much change should be introduced? This is dependent on several distinct factors — all of which must be looked at to see if the changes contemplated are affected by these factors.

Size of nursery. If at the moment it is only just "making ends meet", the changes need to be fairly certain of success. If potentially the nursery is very adequate, we can afford to speculate a little more.

Financial health of the nursery.

a) *Investment:* Have we all our eggs in one basket?

b) *Loan repayment.* Have we a lot of borrowed capital? This limits change a bit.

c) *Capital available:* If no capital can be found, then all costs of change may have to be paid back over years. Careful accounting is vital here.

Personality of staff

a) Are they easy-going? Are they happy to "have a go at something new, Guv."

b) Will the changes made make life more pleasant for them, so far as working with the rest of the staff is concerned?

c) Are they happy to listen, to try to understand, and perhaps work harder or longer temporarily, to facilitate the change?

Expertise among staff. Are the staff mainly "career" people — working to learn more and to progress in the nursery stock industry, or are they mainly "pin-money" folks? Does the nimbleness of their fingers justify asking them to be less detailed workers on a heavier job? — or vice versa? Does Johnny have the skill with a knife which will enable him to progress from cuttings to whip and tongue grafting?

Age of staff affected by change. If 50% of the workers are in their last 5 years of working life, we would need to consider carefully any change which would involve continued heavy lifts, which had not been their work in the last 20 years! — or which would "put them down" in the eyes of the other workers.

Colour of hair of the owner/manager

If *GREY/WHITE*, — and occupied with spoiling the grand-

children, it is usually more difficult to find the energy and ability for a *lot* of change! Many well laid plans go awry because this is not taken into account.

If *RED/BLACK* — and under 40 years old with a propensity to "sail near the wind" for prolonged periods, to be involved in "risky living" — then perhaps a greater amount of change can be undertaken and successfully managed.

Also, the momentum necessary to keep going through the crises brought about by the changes is more likely to be sustained if the owner/manager was born since the end of World War II.

Perhaps the rough rule of thumb of the 1960s could be considered here. This was to say that "no change should be implemented in any one year or season which constitutes more than about 15% of the nursery's activity, staffing or turnover." Some firms might still be in existence today had they followed some such rule of thumb!

Conversely, those red-headed among us would say that those nursery catastrophes could have been avoided had more change been made — and earlier!

The whole thing needs to be looked at and carefully considered by the person contemplating the changes.

(4) When should the changes be implemented?

Now — this week, month, season, year. "Striking when the iron is hot."

Many bargains are seen only after the opportunity has passed, — and the winner is the one who acted quickly. No good regretting things after the moment of opportunity has passed. Much depends on our interpretation of the current trends — if this change is possible now, but obviously will not be possible next year or ever again, then this is a strong point.

After thinking carefully. To think carefully — and then to introduce some far-reaching change builds confidence — and so does careful thinking which leads to a decision not to go ahead. Rushed decisions sometimes lead to regrets. If the changes affect others, then we shall (rightly) be blamed.

After consulting the experts in the particular field. Other folks' experience is cheaper than ours! Whether they are mistakes or successes, large or small decisions — if someone knows something, let us learn it — rather than learn by our own costly mistakes.

Experts are found everywhere — Accountants, Bank Managers, ADAS, IPPS, Colleges, Horticultural Trade Associations, our experienced friends — folks who have travelled the world

— let us consult them, and pick their brains before jumping in too far!

After discussing with one's personal mentor. Each of us has a respected senior friend to whom we look for guidance — for advice. Let us take him the proposed change, especially if it is a major change. Let us "bounce off him" so we can hear our own thoughts, and get his reactions to them — and with one's wife.

A wife is a "helpmeet" — who can often bring a different perspective to things if we let her. She know us, knows our strengths and weaknesses, and may well see benefits and/or problems unrecognized by us. If she is with us — in the changing practices, she will support us — so we need to discuss things with our life-partner, and with the staff.

Some changes will affect *all* the staff, — some will affect *some* of them — but it is a good thing to keep all the staff informed about changes we propose. They may have ideas which will enhance the changes and we will obtain their co-operation.

After praying about it. Perhaps in 1984 that sounds old fashioned — and certainly there are fewer horticultural books published today with a verse of scripture as the heading of the preface or the chapter.

Perhaps the fashion should be disregarded! Many growers can testify to the value of prayer in their business and in their life. If our prayer is to ask God, our heavenly Father, for His guidance, the changes we make (or do not make) could be the right ones. After all, He can see into the future — we cannot! James, one of the writers of the New Testament, said "If any of you lack wisdom . . . ask of God, who gives to all men liberally . . ." Turning to God in prayer could well mean a revolution in your business!

(5) For how long should the changes be tried?

The length of time we "put the new system on trial" will differ according to the kind of change we envisage.

If it is in the realm of marketing — then 2 or 3 years could well be the minimum trial period we should envisage. If new lines are introduced the same would apply. If it is a new potting system, then one sizeable crop may adequately tell us what we need to know. If a lengthening or shortening of the cropping is planned, then 3 or 4 crops must go through the system before we throw it out.

One important factor is this. All the staff habits and expertise must be fully adapted to the new system before we can say whether it is a worthwile change or not. More good ideas

have been lost by too short a trial than by too long a trial. Remember, it will be really impossible to reintroduce an idea after an unsuccessful *short* run.

Finally, *there is a price to pay for changing things.* This price may be in:

Cash if it is new equipment — a tractor, computer, prestel unit.

Interest on loans. If it is expansion in land, stock, labour, equipment

Space. For buildings, cropping, standing out ground.

Time. May be management time, or operational time.

Information. If we are to obtain and make use of extra information, we will have to give information too. If Prestel and Farmlink are to be useful to the nursery stock listing, we must put something into it. This surely is the motto of the I.P.P.S. — "To Seek and To Share."

There are some costs we must not incur! Among them are:

Relationships, among staff, between ourselves and our customers, among the family, and in the home.

Peace of mind. If the cost is an uneasy conscience or a load of worry, then it is not on.

BREEDING ORNAMENTAL PLANTS

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Auckland

It is not my intention here to discuss breeding techniques. The sheer diversity of ornamental plant material makes that impossible. Indeed, faced with such diversity, my starting point must be to ask, "What is an ornamental plant?"

A possible definition would be, "any plant that is cultivated primarily for its decorative value." Such a definition is very open-ended and really does not give a breeder much guidance. A breeder of food plants knows pretty much what is required of him. Namely, his plants should produce the largest possible yields in the shortest time with minimum cost and trouble. Once produced the product should have maximum shelf life, be easily transported and, of course, be edible. In contrast, the breeder of ornamental plants has as his raw material virtually the whole of the plant kingdom — subjects ranging in size from forest trees to ground-hugging alpines. Even more important, he or she is in an area of taste and fashion, where none of the criteria are permanent.

For these reasons, the breeder of ornamentals is much closer to a painter or composer than to a scientist. Certainly a good breeder will have a good grounding in the basic scientific principles of genetics and will keep up with the latest technical developments, but equally, good painters and composers are well grounded in the fundamental techniques of their chosen field of activity. The real difference between breeders of ornamental plants and those working with utilitarian plants lies in creativity. The breeder of ornamental plants has to have the ability to visualise what he wishes to create. This is perhaps the most important component of his work. Only when he has a clear vision can he start to devise ways to achieve this goal.

I believe it is important that people involved in the nursery and garden centre sectors of the horticultural industry, as well as in parks, see themselves as being part of an art form. Ornamental horticulture should certainly be considered an art rather than just a craft. The way buildings and everyday surroundings are complemented by plants is a very obvious statement of a people and their culture. The first impression of a country and its people is often gained on the drive from an airport to the nearest city.

It is not just a matter of saying "O.K., I suppose gardening can be considered as an art." It is important that we realise that our art form is more challenging than any other. A painter uses colour in two dimensions, while a sculptor works in three dimensions and usually makes little use of colour. In contrast a gardener works in these spatial dimensions using an infinite variety of colour and texture. However, most important, he has to contend with a fourth dimension — time. A planting is never static; its appearance changes with the time of day, the weather, and with the seasons. To maintain a planting in an attractive condition over an extended period is a great achievement and we should feel justifiably proud that we are part of this activity. When we see our industry in this light we can then start to claim our place alongside other visual arts — architecture, music, and dance.

If we now step back and look at the vast range of plant material used for ornamental purposes, we find a surprisingly small proportion has been specifically bred. Many trees and shrubs are used in the form they were found in the wild. Most variations have occurred by chance, have been spotted and have been preserved by vegetative propogation. Rhododendrons and a few other genera are notable exceptions to this generalisation, but longevity and the length of time between generations has discouraged detailed breeding of shrubs and trees.

It is also important to maintain a cultural and historical perspective. Some peoples cannot comprehend why anyone would grow plants which have no obvious utilitarian use, while others have taken an interest in ornamental plants since prehistory. The affluent have generally been able to devote time and resources to ornamental plants, while the poor have been more concerned with staying alive.

Our knowledge of what was done in the past depends on what sort of records were left. For instance, we know much more of what went on after the development of printing than before and we tend to have a better knowledge of what was recorded in European languages than in others. It is true that in most cases, where the stages in the development of a plant can be traced most often that plant will have been taken to Western Europe, developed, and redistributed from there. We should not, however, forget that ornamental plants were developed by ancient cultures in the old world, such as those in Persia, China, and Japan, and by the Incas and Aztecs in the New World, long before people from Europe "discovered" them.

The development of communication between Europe and the rest of the world and the introduction of new plants to Europe, starting in the 16th century, created great interest. From this time plants started to be grown simply for pleasure. This is reflected by the publication of books such as *Paradisi in Sole* by Parkinson in 1629, and records of "Tulipomania", the remarkable speculation in tulip bulbs which occurred mainly in Holland between 1634 and 1637.

It was from this period that the first flower "fancies" can be traced. Flower fanciers tended to be artisans who bred flowers as a hobby. In Britain, during the respective flowering seasons, competitions and exhibitions were held, often in association with a meal, at the local inn. As flower hobbyists were, until this century, known as "florists", their get-togethers were often styled "florists feasts".

By the middle of the last century the following were considered to be the main florists' flowers: carnation, pink, tulip, ranunculus, hyacinth, auricula, gold-laced polyanthus, primrose, pansy, viola, violet, chrysanthemum, and dahlia. Others with a lesser following were: double daisy, hollyhock, hepatica, pentstemon, stock, sweet rocket, sweet william, and wallflower.

As with any sport, rules were developed and ideals were set. It is clear that rapid progress was made in achieving such ideals. Taking the dahlia as an example, within 30 to 40 years of its introduction as a semi-double at the beginning of the last century, it had been transformed to a fully double and highly formal "florists' flower".

It is important to realise that this intense breeding was carried out well before Mendel started his experiments which led to our understanding of the principles of genetics. It should be remembered, though, that similar interest in the development of specific breeds of animals had been going on at the same time, with equal success. Indeed it was the close interest and association that Charles Darwin had with breeders of domestic animals and plants which helped him formulate his ideas on evolution. An understanding of genetics is a help to any plant breeder, but the practice is at least as much an art as a science, especially in the case of ornamentals. Often an experienced exhibitor, who knows exactly what he wants to produce, makes an excellent breeder.

Traditionally, with florists' flowers the flower itself was very much the centre of attraction. These were most commonly exhibited on boards. This emphasis was frequently at the expense of the plant and no interest was taken in developing plants primarily for use in garden design. It has only been

during this century, when show rules were changed, that more emphasis has been given to features of the plant such as stems, plant height, and garden worthiness. Even so, it is true, especially when the term is broadened to include flowers used in the modern cut-flower trade, that most ornamental breeding has been carried out on plants grown for their flowers rather than whole plants used in a landscape sense.

With the advent of the industrial revolution, newly-made fortunes and an interest in glasshouses, many of the florists' flowers suffered a decline. This was accentuated by the views of people like Jekyll and Robinson, who popularised natural rather than formal gardens and flowers. During such periods of decline, genetic material may be lost, as was the bizarre carnation, or may just survive in cottage gardens or in the collections of a few enthusiasts. The gold-laced polyanthus survived only by a very small quantity of genetic material being sent, in 1945, from an old-time enthusiast in England to a specialist polyanthus breeder in the USA. I have checked this story in some detail and it does appear that we have retained this characteristic or combination of genes only by the very thinnest of threads. Now with a revival of interest in florists' flowers, both amateur and commercial breeders are making use of this material.

In my own case, I realised over twenty years ago that, although the original sweet pea, *Lathyrus odoratus*, was bicoloured (i.e. where the standard petal is a distinct colour to the wing petals), all sweet peas commercially available at that time were self-coloured. Happily, Major Turral of Yorkshire, England, had collected and maintained some ancestral cultivars over many years. Shortly before his death he made these available to the seed trade and today they are listed as curiosities in seed catalogues. I have used some of these cultivars to produce a strain of sweet peas combining modern ideals of flower form and stem length with the bicoloured characteristic and strong scent of the ancestral types. Had Major Turral not made his collection it would not have been possible for me to have made this development.

Remember, plant breeders do not create new characteristics. They simply attempt to recombine what is available into the most favourable combinations. New techniques of genetic manipulation are emerging. If some of these make it possible to break down breeding barriers between species and genera this will offer great scope to ornamental plant breeders. However, such techniques are some way off for practical use and the use of tailor-made synthetic genes is futher away still. It is,

therefore, essential to preserve as wide a diversity of genetic material as possible.

This brings me to another problem facing ornamental plant breeding. Compared with breeders of food crops, fully professional breeders dealing with ornamentals are few. Most flower and bedding-plant seeds are produced by a very limited number of large companies, mainly in the USA, Europe, and Japan. Even in these companies the ratio of flower breeders to people working on other crops is low. Their aims are dictated by marketing concerns and their interest is currently directed at the production of dwarf plants, which flower very quickly from seed and which can withstand mechanical growing technology. Relatively little effort appears to be made to maintain collections of genetic material for possible future use. Presumably cost and the mobility of the breeders between companies works against this. This lack contrasts with strenuous international efforts which are being made to create gene banks of major food and fodder species. As a result, professional breeders are dipping more and more into collections maintained by enthusiasts. Most often these enthusiasts have very limited space and time, which limits the range of material they are able to maintain. If individual enthusiasts are breeding as opposed to maintaining a collection, the genetic base of their material is likely to be very limited. Taking the sweet pea as an example, the late-flowering Spencer type used for exhibition in Britain is now bred almost exclusively by amateur exhibitors. Most current show-winning cultivars have been produced by, or derived from, cultivars bred by just two people. These people have made their parentage records available to me. No more than 10 cultivars have been involved in the developments made in the last 40 years, and some of these foundation cultivars were almost certainly related. Like the professional breeder with his cost constraints, the amateur is often an exhibitor breeding for success on the show-bench. Show schedules almost invariably discriminate against certain types. Breeders will not breed material which will not be used, so the genetic pool is further diminished. Certainly crosses I have made indicate depressingly little genetic variation in the modern sweet pea.

The sweet pea is not an exception — the breeding of an increasing number of flowers is being left to amateur enthusiasts. Taking dahlias as an example, up to about 15 years ago, large dahlia nurseries with large collections bred and introduced their own novelties. Now nurserymen find it much cheaper to launch novelties bred by leading exhibitors who are quite happy simply to have their names recorded in the

catalogues. The exhibitor/breeder usually has a small garden and specialises in only one or two types of dahlia. On top of this, in Britain particularly, it is easier to win prizes with white or yellow blooms which can be sheltered from the weather without loss of colour. The result has been the introduction of many wonderfully refined white and yellow dahlias and not much else. The problem is compounded because other colours fall behind in quality and the amateur breeder is not prepared to use such material in his crosses.

Similar trends in the nursery industry worldwide, where the range of plants has been reduced but greater numbers of each type are produced, have the potentiality of making it difficult for future plant breeders. Plants widely listed only a few years ago are now hard to obtain. The extent of the problem will differ among species, but as it is becoming increasingly difficult to obtain plant material from the wild, private collections and those in botanic gardens will assume increasing importance.

Collections should not be thought of simply as repositories — they are a very important source of reference to a breeder. A good plant collection and a wide range of catalogues, both old and current, are basic plant breeding tools. While quarantine requirements make introduction from overseas troublesome, it is almost invariably easier and cheaper to introduce something which already exists than it is to breed a similar plant. A collection enables a plant breeder to observe potential parents over an extended period. People sometimes think that breeding starts with pollination. In a well planned programme, observations start several seasons before any crosses are actually made. This is why experienced exhibitors often make good breeders of exhibition quality plants — they know their plant material intimately.

We are perhaps lucky in New Zealand, in that at a time when our nurseries were starting to follow the world trend of becoming factories for a limited range of plants, horticulture in the widest sense should be looked to as a possible saviour for our flagging economy. At least a man concerning himself with flowers is not now as suspect as he was fifteen years ago!

Since the first settlers arrived, plants have been continually introduced to New Zealand. As a proportion of these settlers had lived in various parts of the world before settling in New Zealand, quite a lot of plant material was introduced directly from its country of origin. Consequently, we now have a rich heritage of plant material, some of which is unavailable elsewhere. Because a good proportion of our population has received a sound basic education over the years, we have had

quite a number of people who have between them bred a wide range of plants. Much of the detail has been unrecorded and as a country we have not afforded these people the recognition they deserve. The story of the kiwifruit and some other New Zealand fruits are now well known, but in the area of ornamentals we have, perhaps, an even richer inheritance. Camellias, carnations, orchids, daffodils, dahlias, gerberas, lilies, rhododendrons, and zantedeschia spring immediately to mind. Some of these developments have found a place on the world market, while others, although of merit, have not received the promotion necessary to compete with overseas introductions.

Breeding a good new plant is only a starting point. If it is to find a place in world horticulture, each new development must be linked with good nursery management and good promotion. In New Zealand we have an ideal climate for plant breeding. If this activity can be supported by long term planning which will put in place the other essential links in a commercial chain, we could become the horticultural Mecca of the Southern Hemisphere.

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THE LIGHT INTEGRATING METER — AN ALTERNATIVE METHOD OF MIST CONTROL

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During the summer of 1982 Lyndale Nurseries set up a propagation unit at a new site in Whenuapai. This unit consists of four 60 × 20 ft. (18 × 6m) PVC film-covered tunnel houses containing a central bed with bottom heat and a mist facility plus two side beds without heat but with mist, including a weaning option, i.e. 1/1 to 1/10 misting. All the houses

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are ventilated with louvres together with fans working under positive pressure.

The two systems initially installed to control the mist operation were:

1) A pre-set "off-on" cycle, i.e. a timer with the capabilities to operate regardless of the environment.

2) An "electronic leaf", which gives a variable "off-on" cycle dependent on the environment, i.e. 2 electrodes contained in a non-conductive substance which is placed under the mist at leaf level. At a certain level of dryness the "leaf" activates a solenoid valve.

Also used was a combination of these two systems, i.e. time-regulated mist application for certain hours, e.g. before 10 a.m. and after 5 p.m., plus the use of the "leaf" between these hours.

Despite the combinations available we were unable to maintain conditions which prevented wilting while at times giving an excessive build up of moisture in the rooting medium. This was particularly a problem in winter and cloudy periods. We felt that our weather was so changeable some days that the systems available to us were unable to be adjusted sufficiently.

We believe we now have a system which copes more efficiently with these weather changes. Firstly, we must recognise that energy input is required for evaporation and transpiration to occur and that solar energy, or sunlight, is the major source. This energy input affects the internal temperature of the leaf, stimulating stomatal openings and, therefore, raising the transpiration rate.

As available energy is influenced by:

1) time of day

2) weather - clouds, fog, rain, etc.

3) season

4) geographic location,

It seems appropriate that a misting system that relates to available energy would be more reliable in our environment.

The system we have chosen to use is a "Light Integrated Meter", which records available light energy and accordingly controls the timing of mist application.

The meter consists of:

1). a waterproof light sensor which is placed in a position out of any shade and is similar to the houses which are to be controlled.

2). a meter which records and gives a readout in calories per square centimeter; the meter has a six figure totalising counter and a four figure predetermining counter for control.

The calorie measurement used is equivalent to the quantity of light recorded in one minute on a sunny summer day. This calibration was done in Guernsey; we are finding it slightly less than one minute.

Operating the "Light Integrated Meter", The grower must decide after how many calories the mist is required — say 22 — and sets this amount on the meter, which then counts down to zero as the sun's radiation is recorded.

When it reads zero the misting system is triggered and the meter automatically resets itself to the original figure and begins counting down again.

As night falls, obviously recording stops, then recommences at sunrise the next day or, as we often experience, periods of bright sunlight dispersed with intermittent cloudy periods, the recording rate adjusts (Tables 1 and 2).

Problems (for us). To incorporate this system with our existing unit it was necessary to purchase a unit which would allow sequential watering. We chose a four-station "Irritrol" because it was the only unit readily available which could be calibrated in seconds. Through the "Irritrol" we are able to set the length of misting for each house. This varies according to crop and the type of nozzles used.

As with all misting controls the user must still determine the initial rate of mist application and, by observation, make any necessary adjustments. We feel that in using this system we are now achieving a greater degree of automation and control because of the allowance for external environmental changes.

Table 1: Seasonal and daily changes recorded by the "Light Integrated Meter".

Date	Calories	Date	Calories
Winter		Spring	
June 18	126	Sept 10	346
19	53	11	437
20	41	12	380
21	46	13	170
22	106	14	573
July 23	222		
24	239		
25	87		
26	246		
27	246		
		Summer	
Aug 8	393	Jan 10	635
9	405	11	563
10	216	12	420
16	464	13	567
22	104		
23	63		

Table 2. Daily range of recordings by the "Light Integrated Meter" (setting of 20)

Time	Calories Recorded on Oct. 8, 1984
7 30 a m	
10 00	36
12 30 p m	107
3 00	63
5 00	17

GERBERA PRODUCTION AND ITS PROBLEMS

B. TJIA[1]

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Palmerston North

For the past ten years the Transvaal daisy or gerbera (*Gerbera jamesonii* H. Bolus ex. Hook f.) has steadily become more popular, thanks to advertising campaigns that have promoted the gerbera as a cut and pot flowering plant and as a bedding plant to be used and grown in the landscape. There are presently several strains of gerberas in the trade. In the U.S.A. the earlier Jongenelen material (double), semi-dwarf

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Happipot (singles and doubles), Florist strain (doubles), Park Mix (singles), Express series (singles and doubles), Tropic, Galaxy and Ceres 2000 series, and the University of California breeding lines from Dr. Harding and his associates, are readily available.

Other gerbera sources outside continental U.S.A. are in the Netherlands, France, Italy, Japan, India, Australia, and New Zealand. Most of the commercial lines are grown and sold from seed, although some are propagated vegetatively through tissue culture means. The clonal lines are usually disease and insect free, and have gone through a rigorous selection process in terms of growth habit, substance, foliage, flower color, productivity, and uniformity. Originally gerberas were grown for cut flowers and only recently has the concept emerged to use gerberas as a florist pot crop and for outdoor use as bedding plants. A California group under Dr. Harding's supervision has developed strains that are exclusively to be grown outdoors; their major criteria in selection, therefore, are somewhat different than those intended for cut and pot specimen. Other commercial seed companies presently are breeding pot specimen and cut flower lines, mainly to be grown as greenhouse crops.

PROPAGATION FROM SEEDS.

Gerberas grown from seeds are somewhat like geraniums in terms of price, and can range from the cheapest selection costing 3.6 cents a seed to the more expensive at 90 cents a seed. Gerbera seeds usually do not germinate 100%; 70% germination is usually considered to be good. It is, therefore, not a cheap plant to start with, especially when better strains are used.

Pot gerberas are widely used in the trade for either 10 or 12.5 cm pot plants. These gerberas are also excellent for use in the landscape as bedding plants, especially where nights are cool (15 to 18°C). Seedling-grown Happipot cultivars, however, do not result in uniform growth or flowering. There will be variations in foliage size, flower color, head size or shape, and peduncle length. Flower buds of seedling-grown plants may not initiate or develop at the same time, and this time differential may vary from 1 to 4 weeks. These are not major problems, however, for the smaller grower who needs limited quantities, and no large amount of a particular flower color. It actually helps improve sales by having a wide selection of color and types. This poses a serious problem, however, for large scale producers who prefer to have entire benches of one color or shape, or benches where all the flowers appear at one time and all plants can be shipped at a specified time.

Producers that lack the facility for seed germination with controlled chambers and lights would be better off buying seedlings rather than seeds. Gerbera seedlings, once purchased, need warm temperatures for rapid growth (26 to 29°C day and 18 to 20°C night). Cold and wet soils are a sure invitation to *Pythium* and other pathogenic fungal organisms. Young, vigorous seedlings do not grow well when soil temperatures fall below 15.5°C.

PROPAGATION FROM CLONAL MATERIAL

Another alternative for growing gerberas is from tissue culture, clonal material. Clonal selection generally results in more uniform growth and flowering. These selections vary from laboratory to laboratory, hence, one must select cultivars that have the attributes that meet certain objectives. Clonal selection will depend not only on flower size and growth but also stem thickness, length, and the way the flowers face at maturity. Wiry stems are more weather resistant and tolerate rains and water stress more than cultivars with thick shorter stems. Cultivars with upward-facing flowers are ideal for landscape plants, while those tending to face one side makes them excellent for window box plantings. Some clones are best used as holiday or patio plants rather than for bedding or window boxes. These plants bear larger flower heads, have thicker stems, and are less weather resistant. Water stress often causes stem break on these clones. Plants used for cut flower purposes obviously need to have long stems, large showy flowers, and last but not least, high flower productivity. There are three ways to secure clonal (tissue-cultured gerberas). The cheapest one, but not necessarily the easiest, is to order directly from tissue culture laboratories where plants are shipped at stage 3, wherein the growers themselves separate plants from the tissue-cultured containers and transplants them in flats. *This method is, however, very risky, especially if the grower is* not set up to grow-on tissue-cultured plants. Another way is to purchase tissue-cultured plants from specialist gerbera propagators in 4 to 5 cm liners, which can be directly transplanted to 10 or 12.5 cm or larger size containers. These take approximately 8 to 10 weeks to flower compared to 16 to 18 weeks from stage 3. Another method is to purchase pre-finished plants in 10 or 12.5 cm containers with flower buds already on plants. Little growing time is required by the greenhouse operator.

Just like geraniums then, gerberas sell for a higher price compared to other pot flowering plants, such as chrysanthemum. However, as gerbera flowers are quite unique, customers seem not to mind paying the extra price for them. Gerberas

are excellent to grow in large containers, with 2 or 3 plants grouped together. It is an excellent plant to use in planters around patios, pool areas, and window boxes.

CULTURE

Soil Medium. Any pre-made artificial medium that does not contain a large percentage of *unprocessed* bark is a good medium for gerberas. It is desirable to add 20 to 30% top soil to a medium for stability, but only if steam or chemical sterilization facilities are available. Gerberas require an abundant supply of moisture, but will succumb under waterlogged conditions. A medium that has adequate pore space and yet retains substantial amounts of water should be used. Peat moss and peat-like substances (processed bark), therefore, are essential ingredients in the preparation of media for gerberas when growers mix their own. The addition of 20 to 30% soil is a good idea since it improves the buffering capacity of the medium and acts as a stabilising factor to prevent pots from tipping over, especially when the medium is dry. The soil pH should be adjusted to between 5.5 to 6.2 for optimal gerbera growing conditions. In very acid soils this can be achieved by adding either limestone or dolomite to the soil mix three weeks prior to planting.

Transplanting. The most important factor in gerbera production is *transplanting*. Problems such as crown rot can usually be traced back to improper transplanting depth. Gerberas need to be transplanted with the *crown at* or preferably *above* soil level. The crown should be visible at all times, and should be allowed to dry out between irrigations. It is not necessary to root prune when transplanting.

Fertilisation. Three kilos of slow-release fertiliser, such as Osmocote 14/6.1/11.6, plus 1 kg of a minor element additive such as Micromax™, should be mixed in thoroughly with each cubic meter of medium prior to transplanting. This should be supplemented with 100 to 200 ppm N and K at every watering, or 350 ppm twice weekly. If liquid fertiliser injectors are not available, 5 kg instead of 3 kg of Osmocote should be added to the mix when plants are ready to transplant. Fertilisers containing a high percentage of an ammonia-type nitrogen should be avoided. Fertilisation studies have shown that a high percentage of ammonium-type nitrogen (30% or more NH_4-containing fertilisers) results in reduced number of flowers and a delay in flowering. The ideal fertiliser combination for gerberas, with respect to nitrate to ammonium form, is 6 to 3. (70% NO_3 and 30% NH_4). This can be achieved by mixing equal weight of ammonium nitrate and potassiumn nitrate and

calculated to dispense either 100 to 200 ppm N at each watering, or 350 ppm N biweekly. Media incorporating slow-release fertilisers should be kept dry prior to use and should be used as soon as possible to prevent release of nutrients and build-up of soluble salt levels. Slow-release fertilisers should be mixed in with the soil *after* the soil medium is steam sterilised, *not before*.

Light, Temperature and Water. Gerberas are adaptable plants and will grow under a wide range of environmental conditions. They should be grown under full sun in New Zealand, although 20% shade may be required in the summer months. Optimum growth and yield, however, is best achieved under full sun. Under 20% shade, plants develop dark green leaves and, while flowering will not be delayed, they will develop longer petioles and have a more erect growth habit than plants grown under full sun.

The objection to longer petioles for pot plant purposes can be easily overcome by judiciously timed applications of growth regulators. Tissue-cultured gerberas will bloom within 70 to 80 days following transplanting of liners (from 5 cm containers) from spring through fall. Flowers will be 20 to 30 days later on plants transplanted late fall through late winter. A reasonable time estimate would be 10 to 11 weeks to first bloom, depending on when plants were transplanted.

There is nothing unique in growing gerberas. Most sound cultural practices for other plants apply to gerberas. Overwatering should be avoided. The soil should be permitted to dry between watering and the plants allowed to dry (wilt) occasionally. This is extremely important, especially during winter and heavy overcast weather where cold night temperatures and high relative humidity in the greenhouse prevail. Disease infestation will be less a problem when this is practiced. Plants grow best when night temperatures can be maintained no lower than 16°C and no higher than 26°C. Lower night temperatures slow growth and flowering and increase the incidence of soil-borne diseases.

Growth Regulators. Growth regulator application on gerberas is not a standard practice and plants not so treated are equally saleable and attractive. Application of growth regulators add to the expense but the benefits from them are:

(a) Plants develop darker green leaves, which enhances their attractiveness.
(b) Length of leaf petiole and flower stem are shortened, making plants more bushy and compact.
(c) Facilitates easier handling and less shipping damage.

(d) Plants can be grown with closer spacing, therefore increasing production per unit of area.

The only growth regulator effective on gerbera to date is A-Rest™ which can be applied either as a spray or soil drench. It should be applied 2 to 4 weeks after liners are transplanted into larger pots (usually 12.5 to 15 cm) at rates of 0.125 mg to 0.25 mg a.i. per pot as a soil drench to give up to 80% petiole length and 40% flower stem length reduction (flower size not affected). A-Rest™ as a foliar petiole should be applied at the rate of 33 to 66 ppm a.i. and will produce similar petiole and flower stem length.reduction. One application should be adequate. Growth regulator application has been most beneficial when applied to plants grown under 20% shade in greenhouses. A-Rest™ soil drench and spray can be prepared as follows:

A-Rest™ Drench:

Mix 30 ml A-Rest™ concentrate in 4 l of water. Apply 120 ml of this solution to 12.5 or 15 cm pot; this is the equivalent to 0.125 mg a.i./pot. If 0.25 mg a.i./pot is preferred, mix 30 ml A-Rest™ to 2 l of water and apply the same amount (120 ml) of the solution to the same size pots.

A-Rest™ Spray.

Add 480 ml A-Rest™ concentrate into 4 l of final solution. This is equivalent to 33 ppm solution. Double the amount (960 ml) to make up a 66 ppm solution. Spray evenly to foliage until it glistens. Each litre of solution should treat 4.5 m^2 of area when plants are grown pot to pot.

Insects. In general, relatively few insects attack gerberas, especially when plants are kept in a healthy, vigorous growing condition. Insects that do attack gerberas may be divided into three groups according to the damage they cause. These are sucking insects, chewing insects, and leaf miners.

Sucking insects include aphids, thrips, broad mites, cyclamen mites, and spider mites. They insert their mouth parts into plant tissue and suck the juices. Symptoms often go unnoticed for a period of time which allows the pests to become established and increase in numbers, resulting in considerable plant damage. Symptoms of sucking pests are: curled or stunted leaves, discolored (stippled or russeted) leaves, chlorotic spots on leaves.

Caterpillars are the primary chewing pest found infesting gerberas. They are the immature stage (larvae) of various moths. The most prevalent are army worms, cut worms, and loopers.

Leafminers are especially destructive to gerberas. The lar-

vae or maggot stage feeds between the epidermal layers of the leaves, leaving long meandering tunnels of blotch-like mines in the leaves.

Production and maintenance of quality plants depends on growers' recognizing the insect, mite, or other pests that infest gerberas, as well as a knowledge of their life cycle and management practices. Obviously, pest damage will seriously reduce the value of plants or render them unsaleable. Therefore, a diligent scouting program followed by prompt and accurate pest management strategies is a necessity.

Diseases. One of the most damaging diseases on gerbera is crown rot, caused by *Phytophthora cryptogea*. Crown rot is the most feared gerbera disease in culture as a heavy infestation can wipe out entire greenhouses of gerberas. This disease is prevalent only in European countries and New Zealand, and is primarily carried from plant to plant by cuttings or vegetative division.

Symptoms. This fungus causes root and crown rot and can kill gerbera plants in as short a time as 16 days. The crown deteriorates and becomes mushy. Infection is more severe at higher temperatures.

A number of other diseases affecting other plants affect gerberas as well. The most serious is bacterial blight caused by *Pseudomonas cichorii* (Swingle) Stapp. The bacterial infection and symptoms usually are not severe during the cool season but become damaging during hot weather in late spring, summer, and early fall. An infection is aggravated when plants are irrigated overhead, which aids the spread of this disease from infected to healthy leaf tissue.

Symptoms. The first sign of bacterial blight infection is the appearance of spots on the leaves. These spots are usually variable in size, circular, or irregularly shaped and are brownish-black in color. Often concentric rings form within the lesions. Occasionally, the spots may coalesce into large brown areas which can extend from the leaf margins and taper towards the mid-vein. The bacterium has recently been found to cause petiole and crown rot, which can result in plant death. Early detection of the disease, with roguing of badly-diseased plants, combined with standard control methods, helps keep the disease in check.

Botrytis blight. This disease, caused by the fungus *Botrytis cinerea*, attacks weakened or dying tissue. It is normally fa-

vored by cool, wet conditions, but can occur at times when the temperatures are warmer.

Symptoms. Initial infection causes pinpoint yellow or brown dots, which enlarge and cause extensive decay of old leaves, flowers, and flower stems. The fungus produces large spore masses and, when heavily infested plant parts are shaken, a grayish cloud of spores can be seen.

Phytophthora crown rot. Phytophthora crown rot (*Phytophthora* sp.) usually becomes established when the soil remains wet for long periods of time. Plants affected gradually lose vigor and finally wilt. When wilted leaves are pulled, the crown or part of the crown containing the younger foliage breaks off with the leaf. Infected plants die once the crown is attacked. Infected specimens should be rogued and thrown away.

Symptoms. Plants look normal, but gradually appear less vigorous and remain slightly wilted, even though the soil is moist. Leaves will eventually wilt completely and the entire crown becomes soft and is easily pulled from the other parts of plants.

Pythium root rot. The watermold fungus, *Pythium ultimum*, attacks gerberas during periods where soil temperatures remain cold and wet. An ideal situation is created during cool weather when soils are kept excessively wet or kept moist for cold protection. Roots are attacked first and gradually, as the infection becomes severe, all plant parts below the crown or at the soil line are attacked. Plants lose vigor, wilt, and eventually die. In mild infestations, a new set of adventitious roots may develop below the crown.

Symptoms. Root tips become brown and look unhealthy, soft, and watery. If an infected root is pulled, the outer layer of tissue will part away from the stele (inner tissue). If plants are pulled, the crown remains intact and usually is not affected.

Powdery mildew. Gerberas are not completely resistant or tolerant to powdery mildew, caused by the fungus *Erysiphe cichoracearum*. In most instances, gerberas are usually free of powdery mildew. There are times, however, during the cool weather in spring and fall when powdery mildew can become a problem, especially where plants are grown close together where leaves overlap and high humidity prevails, where air circulation is poor, and when foliage remains wet for long periods of time. To prevent powdery mildew from becoming a problem, plants should be adequately spaced, and leaves that overlap should be removed. Relative humidity should be re-

duced and adequate ventilation provided to facilitate air movement between leaves and among plants.

Symptoms. Powdery mildew can be easily identified by the whitish powdery-like fungal growth on either leaf surface. Powdery mildew thrives under very high humidity conditions and cool temperatures, and these environmental conditions should be minimized during the time where night temperatures naturally become cool in early spring or early winter and where condensation of water on leaves is a common occurrence.

Alternaria leaf spot. This fungus disease has been reported on gerberas for many years in Florida, becoming more prevalent in the last 10 years. Heavy infection can cause the plants to be unsaleable.

Symptoms. Leaf spots are first round to irregular shaped, later becoming larger with concentric rings within and dark brown to purplish in color. The spots may coalesce to form large areas of necrotic tissue.

Cercospora leaf spot. This fungus leaf spot disease has also been fairly common through the years on gerberas. It is most prevalent in the late summer and fall.

Symptoms. Disease lesions are tan to dark brown in color, with purple margins a characteristic symptom. The centers of the spots occasionally drop out.

Nutritional Problems. Despite monitored fertilization practices, deficiency problems sometimes develop on gerberas. Most symptoms exhibited by plants may not be due to lack of a particular mineral element in the soil but to unavailability of the element. Unavailability of elements alone, or in combination, may be caused by many factors, including culture, temperature, pH, and antagonism between nutrient ions.

Any factor(s) that contribute to root injury, such as disease organisms, mechanical injury, excess water, or high pH of the growing medium, may eventually result in the expression of a deficiency symptom(s). Growers should constantly be on the lookout for presence of pathogenic organisms that may attack healthy roots and take corrective and/or preventive measures to keep roots healthy for maximum utilization of available mineral nutrients in the growing medium. Root damage can result also by over or under watering and excessive cold or hot temperatures.

Deficiency symptoms might appear rapidly on plants grown out-of-doors during winter in containers where ambient temperatures may drop to or lower than the freezing point and

where high day temperatures often overheat the container medium.

The use of overhead irrigation with high pH water gradually increases soil pH causing mineral elements to become insoluble and thus unavailable for plant use. Another common factor contributing to nutritional imbalances in gerbera is the selection of soil media. Media mixtures for long term growing of gerberas should have high cation exchange capacities and water holding capacities, be well aerated and free draining, sufficiently heavy to anchor the plants, and have a slow decomposition rate and low soluble salt levels.

Post Harvest Handling. One of the major problems of cut gerberas with respect to the length of their postharvest life is wilting followed by stem breakage, caused by water stress. Gerbera flowers have a tendency to develop bent neck. Bent neck in gerberas is usually followed by stem break. Flower heads do not wilt severely when bent neck occurs and, even after stem break, individual florets usually remain turgid. Water stress affects the integrity of the weak, herbaceous stem 10 to 15 cm below the flower head before the flowers wilt. It is also this part of the stem that has the smallest circumference.

Experiments with flower preservatives have shown that the postharvest life of gerberas can be increased two-fold and premature bent neck and stem break prevented. Nevertheless, in order to obtain maximum postharvest life the use of floral preservatives should be combined with other procedures as noted here.

(1) Recut stems after harvest but immediately before they are placed into fresh holding solutions.
(2) To prevent crooked stems do not allow flowers to dry and keep flower stems erect.
(3) Use clean containers to hold flowers.

Author's Note: The use of trade names is solely used for example purposes only. The mention of trade names does not constitute endorsement of the product nor exclude similar products not mentioned

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PLUGS: USE AND FUTURE IN NEW ZEALAND

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Climate and lifestyle in New Zealand are very conducive to bedding plant growing. This is evident in the extensive use of flowering annuals in both public and private gardens. The production of bedding plants, until recent years, has involved a very traditional approach. Because bedding plants can be grown year-round in New Zealand there is a tendency to produce small seedlings in an open-pack to be sold at the green stage. Difficult economic times and high inflation have created an awareness amongst growers of the need to increase production efficiency instead of simply increasing prices to counter rising costs.

A need for increased productivity is shared amongst bedding plant growers worldwide. Over the past decade, some new approaches to production techniques have arisen.

Direct seeding mechanically into the final container is one such approach. This eliminates the necessity for hand sowing and alleviates the need for pricking out. Interest in this system has seen the development of several types of automatic and manually operated equipment (3,10,11,13). A manually operated vacuum type seeder has been developed and marketed in New Zealand and direct seeding with this has been extensively used. However, the one major disadvantage growers have found with the system is the extra space required at the germination stage. Because of this some have used less than adequate environmental conditions for germinating trays. Often this has led to poor germination and consequent frustration with the system.

Pre-germinated seedlings are now offered by some seed companies as a means of reducing crop time and the risk involved with germination. These pre-germinated seedlings

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Pre-germinated seedlings are now offered by some seed companies as a means of reducing crop time and the risk involved with germination. These pre-germinated seedlings

are usually sown in a lightweight polystyrene tray with separated rows for the seedlings. This "pre-finished" concept is not currently being used in New Zealand for bedding plant production. However, the idea of specialized propagators selling "liners" to other growers is a common practice here in the woody ornamental plant industry.

Containerised transplants have become widely accepted as a means of obtaining a high quality transplant. Cell-packs have been developed for the retail trade and cell trays to produce commercial vegetable transplants are being used universally. Speedling, Inc. of Florida has developed a system that combines cell culture with direct seeding to provide a highly automated technique for producing quality transplants (12). Although the true Speedling system is not being used in New Zealand, some vegetable transplant producers are growing in cell containers of some form. Some bedding plant growers are trying to introduce cell-packs for the retail trade but to date their use is limited.

The plug system of growing seedlings seems to be an evolution of the three previously mentioned production systems. Plug growing combines direct seeding and cell culture to produce a pre-finished seedling with its own containerised root system. Labour is saved by direct seeding, while space is economised by using a tray with numerous small cells. Transplanting into the final container is still necessary but because of the nature of the plug it is much quicker to transplant. The success of the plug system has been well publicized in recent years (4).

The plug system can be used by growers as a means of efficiently germinating seedlings for their own production or, a grower may choose to buy-in plugs from a specialist grower for finishing off. Listed are some of the advantages and disadvantages of plug growing that New Zealand growers should consider.

Advantages from germinating in plug trays

— plants hold longer, giving more flexibility in management
— exact amounts of seed are sown, resulting in less wastage
— spread of damping-off diseases is checked by plant compartmentalization.

Advantages from growing-on from plugs.

— transplanting time is cut by at least fifty percent
— seedling transplant shock is avoided

— the need for patching blanks is eliminated
— valuable heated greenhouse space can be saved
— production can be increased using existing resources.

Problems facing New Zealand growers.

— high capital cost of imported equipment
— unavailability of plug trays
— greater skill required for production
— high risk involved with new techniques

Despite the obstacles involved many New Zealand growers are interested in the plug system. This is especially true of those growers who have been able to use direct seeding successfully. To understand how this system can be adapted for New Zealand use, it is necessary to look at the components used in the system and the means by which they can be applied.

EQUIPMENT

The correct seeder is usually the first item of concern for a grower contemplating plug production. If growers are presently using satisfactory equipment for this purpose the seeding mechanism could be adjusted for a plug tray. There currently appears to be three suitable seeders being used in the country.

Fluid Drill, manufactured and imported from the U.K. This is the most expensive seeder available and there are only two machines currently in the country. The advantage of this model is its ability to sow pregerminated seed suspended in water.

Hamilton Natural Seeder, designed in the U.K. and imported from either the U.K. or U.S.A. This is a medium-priced seeder and two have recently been imported for plug sowing. It places seed using a modified manifold/ vacuum system. It can singulate seed down to the size of begonias.

Robinson Seeder, designed for and available from Robinson Nursery, Masterson is a manually operated vacuum type seeder in the lower price range. Several original models are in use and the manufacturer has recently introduced a new lightweight model that sells for half the price of the original. The seeder plate is not capable of delivery of very small seed such as petunia. However pelleted seed can be used for small seeded plants

Plug trays come in a variety of sizes and shapes (8). Trays with larger cells are generally easier to grow in but less efficient in terms of space utilisation. Small celled trays are economical on space but harder to grow in. The size of the cells

will effect the buffer capacity of the medium. Current regulations only allow the importation of small quantities of plug trays and, so far, the market size has been insufficient to attract plastic manufacturers. This has forced one grower, who is committed to growing plugs, into making his own trays with a small vacuum forming plant. A resultant positive effect may be a standardisation of products based upon the "273" tray.

POST-GERMINATION HANDLING

Seed Germination can be achieved in various ways. Existing facilities within a greenhouse can be used for germination (6,9,13), or space in the greenhouse may be conserved by germinating in a specially created environment in a shed. One method is to construct a frame covered with polythene film in which racks of moistened trays are placed until emergence commences. Another method is to use a specially equipped room or chamber with precise control of light, moisture, and temperature. With either of these last two techniques very careful monitoring is necessary as trays must be shifted to the greenhouse as soon as seed germination is completed.

The medium should be fine enough in particle size to evenly fill cells and hold moisture in the finer pores, yet it should at the same time, drain freely to avoid water-logging. One solution to the drainage problem is to grow on capillary mats using the mat to draw off excess water from the cell. Standard soil-less media based germination mixes already in use seem to give adequate results if the particle size is correct (1). Liquid fertiliser application of NPK nutrients seems to be the only safe and accurate method of feeding (5). A general purpose formulation can be used effectively as a constant feed with every irrigation. Application rates start at 50 ppm N. and graduate up to 200 ppm N. for finishing (6). Exact formulations and application rates must be determined to suit individual needs. Liquid feeding may be foreign to some New Zealand growers who normally rely on incorporated nutrients in the medium. Commercial preparations of liquid feed and suitable proportioning equipment are now available in New Zealand. When a constant feeding programme is used for liquid fertilisers, irrigation and fertilisation become inseparable.

Irrigation of plug trays, because of the small size of individual cells, must be both frequent and accurate in distribution. Hand watering can be effective but is very time consuming and requires a skilled applicator. Although automated circular pattern irrigation is acceptable, problems may occur in distribution and, therefore, evenness of water levels for each cell. A solution to this problem is to construct an overhead

boom system that can be automated (12). This type of application is incorporated in the Speedling system in the U.S.A. and is being investigated by at least one seedling producer in New Zealand.

Environmental control of greenhouses, especially in the North Island of New Zealand, is based upon natural radiant heat and natural air circulation via side vents for cooling. This system is possible because of a relatively mild climate and lack of extreme winter or summer temperatures. Maximisation of plug production benefits will require many seedling growers to provide a more carefully regulated greenhouse environment. The main requirements for plug growing will be adequate heating for early development of the plugs and sufficient cooling to keep mature plug plants from "stretching". Other environmental controls make use of light, moisture, and nutrients (7).

Chemical control of growth is sometimes necessary when all other possible environmental controls have been used. Two chemicals used to retard growth are available and already used in New Zealand. They are Alar® and Cycocel®. Growers should carefully check recommendations on crop effectiveness and application rates before these chemicals are used (2). The main purpose in controlling the growth of maturing plug plants is to overcome "stretching" so they can be held longer.

Application of plugs in New Zealand will be for individual grower's own finishing production until the system is mastered and someone is equipped well enough to enter this new market. One of the largest obstacles for the sale of pre-finished plug seedlings will be distribution in a country with a small, scattered population such as New Zealand. Because our growers traditionally rely on natural heating, some of the warm temperature crops, i.e. geranium, vinca, and celosia, would be excellent candiates for selling as plugs.

Transplanting of plug seedlings also has its different approaches. Once finishing trays are filled, plugs are extracted and planted in various ways. One simple method is to pull well-rooted plugs from the tray with one hand and punch them into place with the other free hand. This method is particularly suitable when planting into larger containers. Seedlings that are not well root-bound or weak in nature can be damaged by this technique. Equipment is available for predibbling holes and extracting plugs which leaves the transplanter the simple job of placing the plugs into the holes. The choice of techniques will be influenced by the scale of operation at the nursery concerned.

OTHER APPLICATIONS

The perfection of this type of culture will open up opportunities for other areas of horticulture in New Zealand — some obvious ones to consider include: seedling production of vegetables; cut flowers; indoor plants; woody ornamentals; forestry. Some areas of vegetative propagation could also benefit from similar cultural techniques used in the plug system. Perhaps the re-establishment of tissue-culture plantlets could be improved by making use of this mini-cell culture. Possibilities also exist for propagation of mini cuttings of such plants as ericas, boronias, and grevilleas, using plug trays for economy of space and easy handling.

CONCLUSION

Many growers are now considering whether plug growing will become a reality for growers in New Zealand and, as mentioned previously, already one bedding plant nursery has made a commitment to the system. For them, plug growing will become a reality if they can adapt techniques to suit their situation and innovate ways to maximise the benefits. If they are successful it is likely others will follow.

Acknowledgement. *Examples of plug growing experiences in New Zealand have been cited from information gathered at Harraps Nursery Ltd, Main Road, Napier, New Zealand*

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THE INFLUENCE OF NUTRITION ON PRODUCTION OF CONTAINER-GROWN ORNAMENTAL PEPPERS

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Abstract: Three experiments were conducted to study the influence of nutrition on the production of container-grown *Capsicum annuum* 'Fips' the first was a central composite design which examined the influence of five rates of N, P, K and lime 0 to 600 g N m^{-3}, 0 to 400 g P m^{-3}, 0 to 332 g K m^{-3} and 0 to 12 kg lime m^{-3} The second experiment was a 4 × 2 × 2 factorial with 4 rates of Mg from 0 to 450 g m^{-3}, 2 rates of P at 50 and 400 gm^{-3} and 2 rates of K at 83 and 415 g m^{-3}. The third experiment was a simple randomised block design with 5 rates of K from 300 to 700 g m^{-3} Strong responses to N and K were noted while P had a moderate influence. Lime had no apparent effect at low N rates but influenced growth significantly at high N by raising the pH from 4.2 to 5 8. There was no response to added Mg Foliage growth, plant quality and fruiting were optimal at 600 g N, 300 g P and 500 g K m^{-3} Lime at 6 kg m^{-3} was recommended (optimum pH 5 8 - 6.1). Suggested tissue composition of good quality ornamental pepper 'Fips' are given as 3 4 to 3 8% N, 0 4% P, 4 6% K, 3 4% Ca, and 1 4% Mg

INTRODUCTION

Ornamental peppers (*Capsicum* spp.) are popular pot plants providing colour for the autumn and winter months. A bonus of ornamental peppers in the home is the potential use of the fruits for making pepper sauce and flavoring food (4). The increased production of a wide range of pot plants emphasises the need for research on cultural requirements (23).

Previous studies on the nutrition of peppers were confined to chilli and sweet pepper cultivars (17). Recommended fertilizer rates in the potting medium and liquid feeding for ornamental peppers were based on standard responses of a range of container-grown plants rather than the specific requirements of *Capsicum* spp. (3,21). Studies of chillies and sweet peppers revealed a strong N response (13,20). Responses to P and K were dependent on existing soil P and K levels (6). Calcium deficiency in peppers resulting in blossom-end rots was indirectly caused by high Mg application (11) while high liming was considered beneficial (22). Magnesium deficiency is common among Solanaceous species and is often a result of high

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levels of applied K (3,21). Inclusion of $MgSO_4$ in potting mixes or in liquid feeds for ornamental peppers was advocated (8,21), although field studies found no response to Mg application (7). Studies of several Solanaceous flowering pot plants, also from tropical America, such as *Browallia speciosa*, *Brunfelsia* spp. and *Petunia* × *hybrida* revealed a strong demand for N and K, while the P requirement was relatively low (9,10,12,28).

The objective of this study was to examine the response of container-grown ornamental peppers to N, P, K, and Ca and Mg application, and to recommend appropriate rates of these nutrients in potting media used for production.

MATERIALS AND METHODS

Plant Material, Growing Environment, and Potting Media

Capsicum annuum 'Fips' plants were raised from seed in seed trays and pricked-out at the five to six-leaf stage, directly into 12.5 cm pots (0.8 liter) in Experiment A. Plants pricked-out from seed trays to 12.5 cm pots in Experiment B were older seedlings, with eight to ten leaves. Seedlings For Experiment C were raised in 5 cm pots and potted out directly into 12.5 cm pots, to minimise transplanting shock.

The experiments were conducted 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 the ambient outside temperature. Plants in experiment C, grown in the winter months, were given supplementary lighting from 4 p.m. to 11 p.m. daily to encourage growth during short-day conditions. The plants were hand-watered when required. Sprays against *Botrytis*, aphids, mites, and white flies were given when necessary. The plants were pinched at about 7.5 cm high to allow 4 to 5 shoots per plant to develop.

The potting medium used was equal parts (1:1, v/v) Mataura sphagnum peat and coarse sand (crushed shingle grit). The chemical and physical properties of this medium were described by Goh and Haynes.

Experimental Design and Fertilizer Rates

Experiment A: A central composite second order design with incomplete blocks for four factor response surfaces as described by Box and Hunter (2) was used. The factors N, P, K, and lime were applied in 30 treatments arranged in 10 blocks, each consisting of 3 sub-blocks and 10 replicates per treatment. Nutrients were supplied from Osmocote (26% N), superphosphate (8% P), sulphate of potash (39% K), and a mixture of dolomite and agricultural lime at 3:1. Nitrogen, P, K, and lime

treatment additions were all applied as base dressings with the levels given in Figures 1,2, and 4, respectively. All treatments also received a basal dressing of the following: 360 g m^{-3} "Fetrilon" (35% EDTA chelate Fe with 5% Fe), and 150 g m^{-3} "Sporumix A" (containing 1.4% B, 0.05 % Co, 1.27% Cu, 9.78% Mg, 5.46% Mn, and 0.06% Mo). The experiment was started on December 8, 1979 and harvested on March 18, 1980.

Figure 1. The nitrogen response of ornamental peppers supplied with medium rates of P, K, and lime. *Left to right*: N (in g m^{-3}): 0, 300, 600

Experiment B: A 4×2×2 factorial randomised block design with 5 replicates per treatment was used. Magnesium in the form of magnesium sulphate (10% Mg), P as superphosphate, and K as sulphate of potash, were applied as basal dressings at the rates given in Table 1.

All treatments received 450 g N m^{-3} as Osmocote (26% N), 6 kg m^{-3} of agricultural lime, and 360 g m^{-3} of "Fetrilon". No dolomite lime or "Sporumix A" were added because of the 11-19% and 9.78% Mg in these fertilizers, respectively. This experiment was run from February 8, 1960 to May 6, 1980.

Experiment C: A simple design with five rates of K, in randomised blocks, was used. There were 4 replicates per treatment which commenced on May 3, 1985 and was terminated on October 7, 1981. Potassium in the form of sulphate of potash (39% K) was added at rates shown in Figure 9. All treatments were given a basal dressing of the following: 600 g N m^{-3} from Osmocote (26% N), 300 g P m^{-3} from superphosphate (8% P), 6 kg lime m^{-3} in a 3:1 mix of dolomite and agricultural lime, 360 g m^{-3} of "Fetrilon" and 150 g m^{-3} of "Sporumix A".

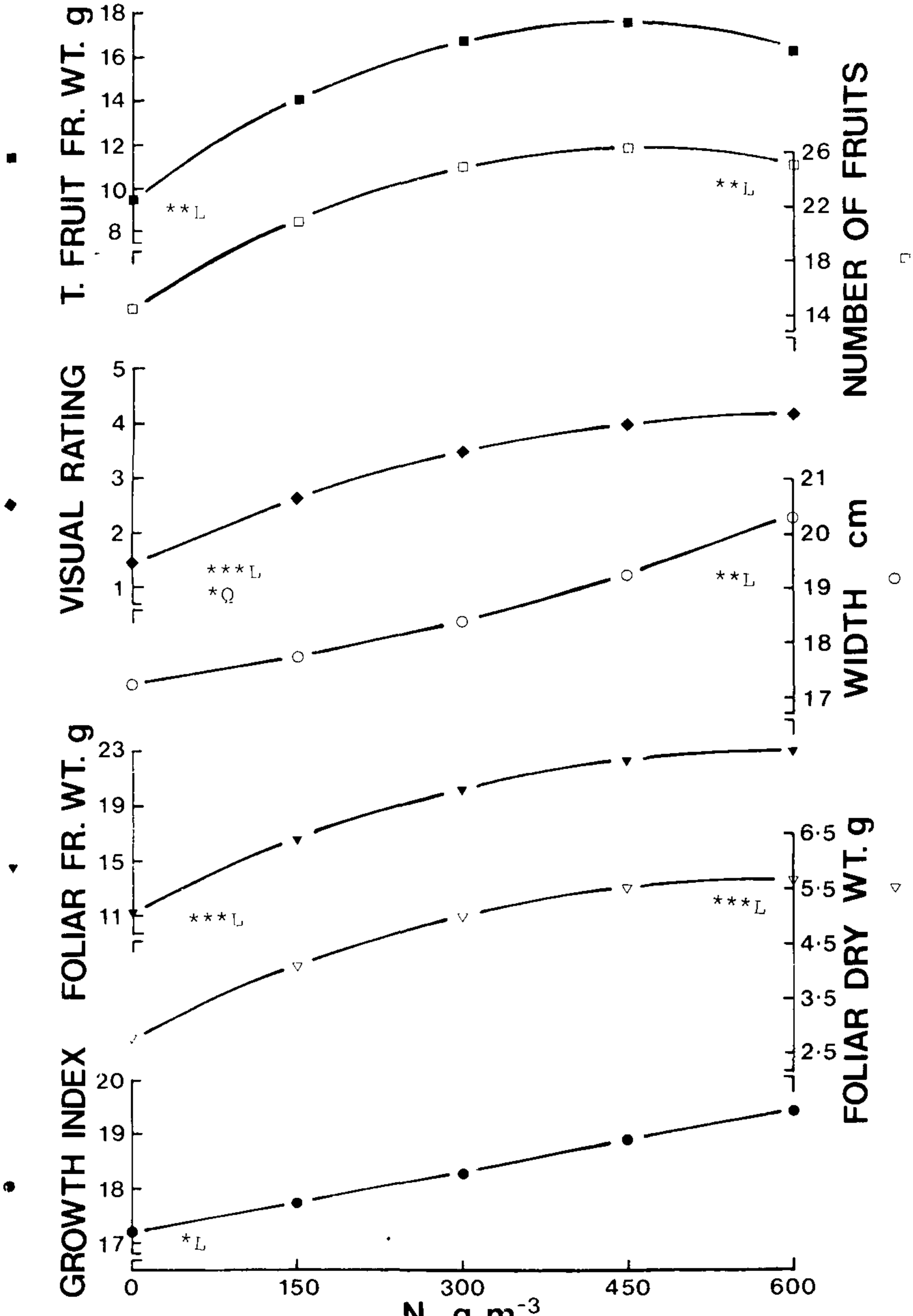

Figure 2. Experiment A Influence of low to medium N levels at medium P, K, and lime rates on foliage growth and fruiting.

(In all figures and tables L = linear and Q = quadratic with asterisks (*) used to give the level of significance.)

Table 1. Experiments A and B. Foliar analyses and media pH from composite samples of selected treatments taken at harvest and 2 months after potting, respectively.

Added Nutrients					Foliar Nutrients (% dry weight)					
g m^{-3}			kg m^{-3}	g m^{-3}						Media
N	P	K	lime	Mg	N	P	K	Ca	Mg	pH
Experiment A:										
0	200	166	6		1 90					6 4
150	100	83	3		2 92	0.27	3 0			
300	200	166	6		3 03	0.26	3 0	3 4	1.4	6 1
450	300	250	9		3 22	0 41	2 7			
600	200	166	6		3 38					5 9
300	0	166	6		0 14					
300	400	166	6		0.43					
300	200	0	6			1 5				
300	200	332	6							
300	200	166	0							4 8
300	200	166	12							6 4
Experiment B:										
450	50	83	6	0	0.25	3 5				
450	400	415	6	300	0 43	4.5				

Date Collection and Analysis

The plants were assessed for height, width, stem diameter, visual rating, total number of fruits per plant, and foliar dry weight. Plant height was measured from the soil surface to the highest point; plant width at the widest point, and stem diameter at the base of the plant at soil level. Visual ratings were obtained using a score of 0 for dead to 5 for quality plants with dark green foliage and a good display of colourful fruits. Two growth indices were calculated: growth index from the sum of height and width divided by two, and height growth index from the product of height and the square of the stem diameter (14,26). Additional assessments in some of the experiments included the total fresh weight of the fruits per plant, and the foliar fresh weight. Plants were harvested at the appearance of red fruits equivalent to when the crop would be marketed. Data collected were statistically analysed for analysis of variance and F test.

Foliar samples were taken from selected treatments in Experiments A and B to assess concentrations of N, P, K, Ca, and Mg using the methods described by Parkinson and Allen. A range of pH levels was also obtained for Experiment A.

RESULTS

Experiment A: The effects of N, P and K were highly significant as shown in Figures 1-8 and in Table 2. A strong positive response to N was observed (Figure 1). Characteristic

N deficiency symptoms of stunting and chlorosis were observed with plants receiving no N and having a foliar N content of 1.90% (Table 1). The optimum response in foliage growth and plant quality was at 600 g N m^{-3} (Figure 2) while fruiting was greatest at 450 g N m^{-3}. The foliar N content of plants receiving 600 g N m^{-3} levels was in the range of 3.22 to 3.38% (Table 1). The pH at this optimal N level was 5.9 (Table 1). Flowering commenced at the end of January.

A very marked response to P is shown in Figures 3 and 4. Plants receiving no P were severely stunted, with the young upper leaves showing an intensely dark green colouration while the lower leaves were paler with large yellow patches (Figure 5). Purple colouration of stems and leaves usually associated with P deficiency was not observed. The foliar P content of these P-deficient plants was 0.14% (Table 1). Foliage growth, plant quality, and fruiting were all optimal at 300 g P m^{-3} (Figures 3 and 4). Plants receiving this optimal P level would have a foliar P content of around 0.41% (Table 1).

Added K had a strong effect as indicated by Figures 6, 7 and 8. Potassium deficiency occurred on plants with no added K. Stunting and interveinal chlorosis leading to a bronzed colour, necrosis, and eventually loss of some leaves were observed. Such plants had a foliar K content of 1.5% (Table 1). Plant quality was apparently optimal at 250 g K m^{-3} but the responses in foliage growth and fruiting suggested a higher K requirement than supplied by 332 g K m^{-3}. It appears that plants receiving desirable K additions should have a foliar K content of greater than 4% (Table 2).

Lime had no apparent effect and plants receiving 6 kg m^{-3} lime seemingly had adequate foliar Ca and Mg and the pH of the medium was raised from 4.8 to 6.4 by lime application (Table 1).

Experiment B: Added Mg at from 0 to 450 g m^{-3} had no significant influence on either foliage growth, fruiting, or plant quality (data not shown). However, the responses to both P and K were highly significant and there was improved foliage growth, plant quality, and fruiting. Flowering was observed in early March, a month after the beginning of the experiment (as with Experiment A). Plants with optimum growth had foliar P and K contents of 0.43 and 4.5%, respectively, compared with 0.25 and 3.5%, respectively, for the plants with the poorest growth (Table 1).

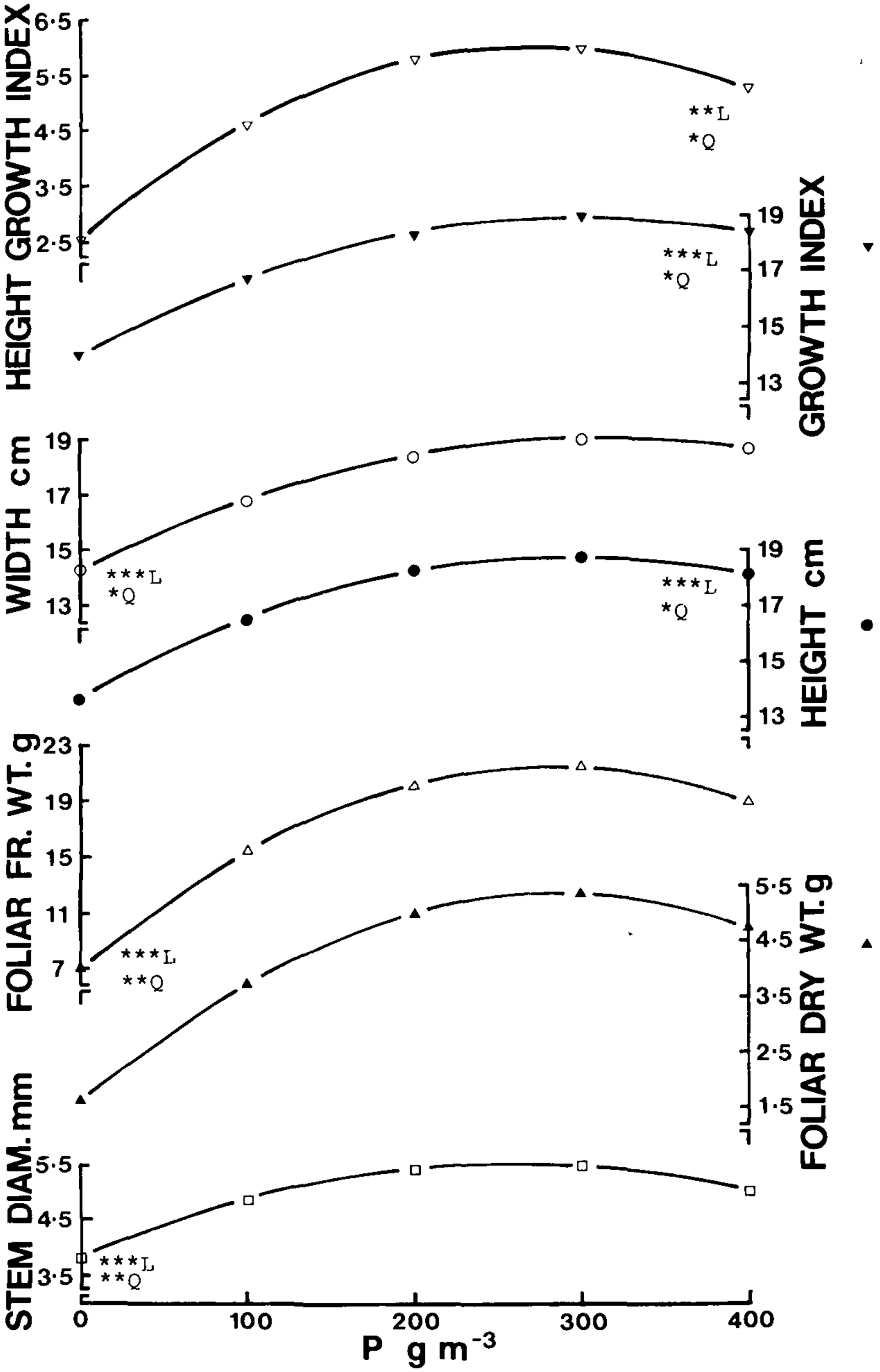

Figure 3. Experiment A: Influence of P fertilization at medium N, P, and lime rates on foliage growth.

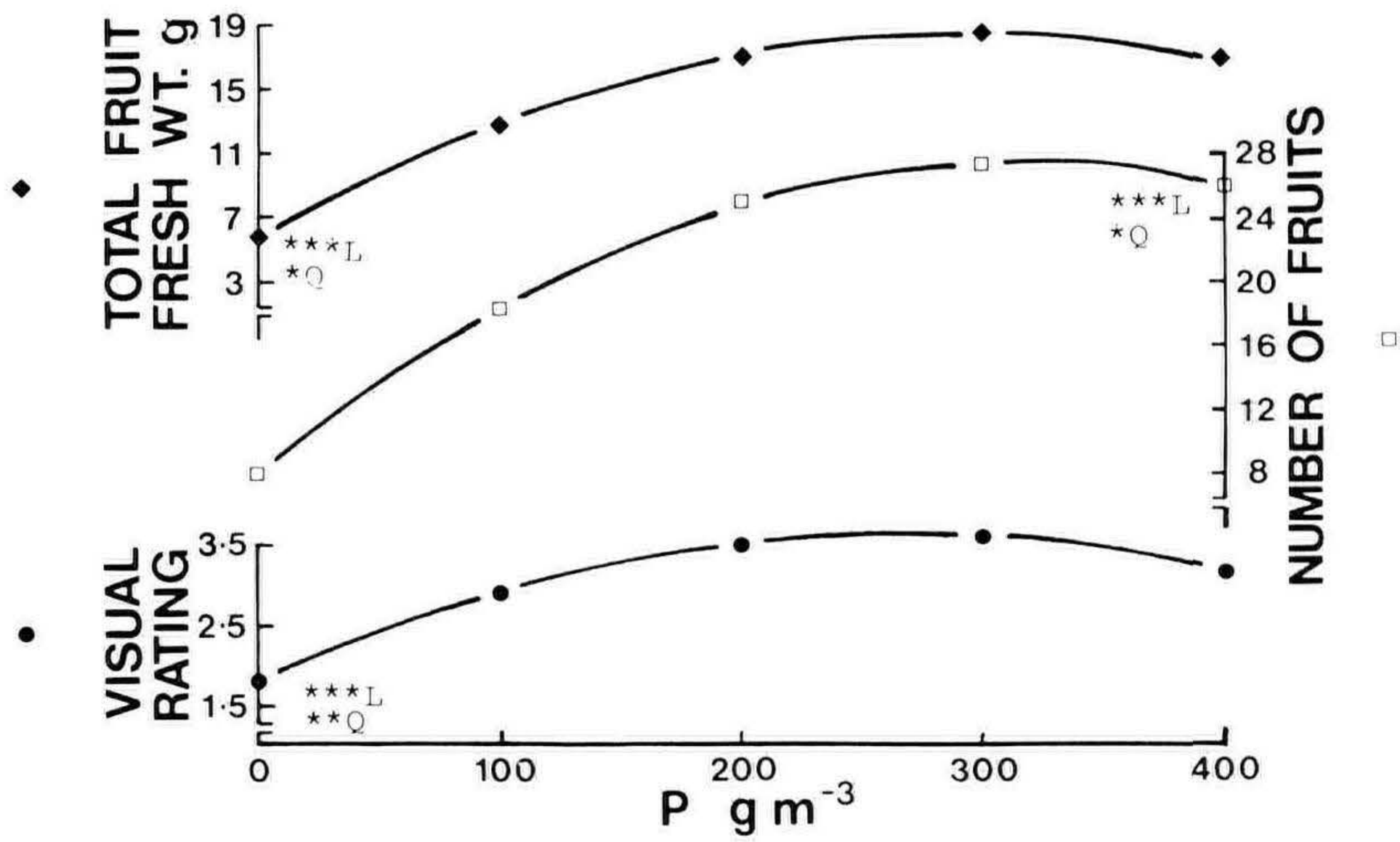

Figure 4. Experiment A: Influence of P fertilization at medium N, K, and lime rates on plant quality and fruiting.

Figure 5. The phosphorus response of ornamental peppers supplied with medium rates of N, K, and lime. *Left to right:* P (in g m^{-3}) 0, 200, 400

Table 2. Experiment B The effects of P and K on foliage growth and fruiting

Nutrient levels (g m^{-3}	Height (cm)	Width (cm)	Stem diameter (mm)	Growth Index	Height growth index	Visual rating	Number of fruits per plant	Total fruit fresh weight per plant (g)	Foliar fresh weight (g)	Foliar dry weight (g)
P levels										
50	13 4*	13 6***	5 0**	13 5***	3 5**	2 6***	5 7***	3 1***	10 9***	2 6***
400	14 8	16 4	5 5	15 6	4 6	3 5	9 6	6 1	17 0	3 9
K levels										
83	13 1**	13 3***	5 0**	13 2***	3 5**	2 6***	7 0	4 0#	12 1***	2 9***
415	15 1	16 6	5 5	15 9	4 7	3 5	8 3	5 1	15 8	3 7
LSD (05) for P or K means	1 3	1 3	0 3	1 1	0 7	0 4	1 8	0 2	1 7	0 4
Significant interactions			P × K*							
CV (%)	20	19	13	17	39	26	52	58	27	28

Figure 6. The potassium response of ornamental peppers supplied with medium rates of N, P, and lime. *Left to right:* K (in g m^{-3}) 0, 166, 322

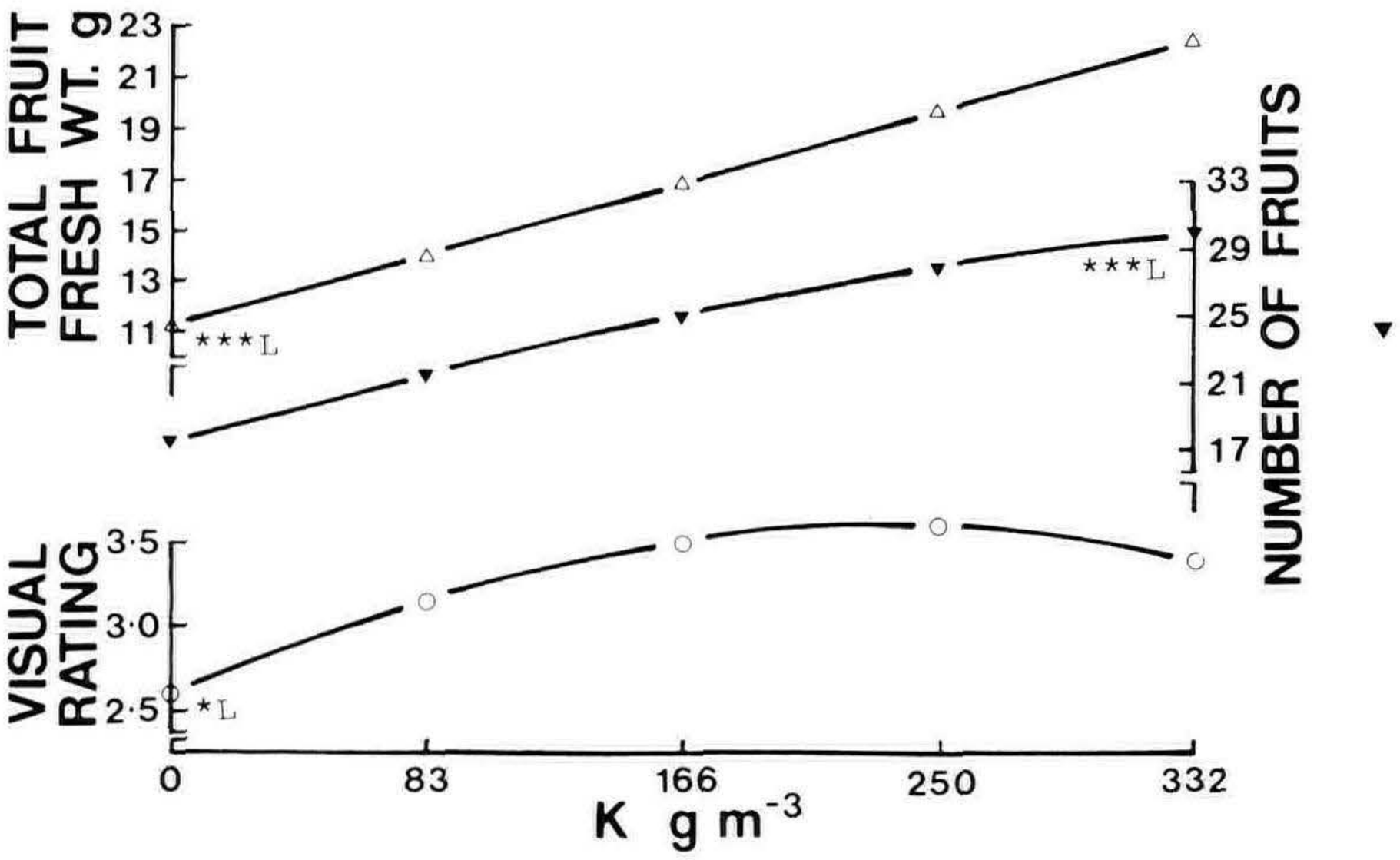

Figure 7. Experiment A: Influence of K fertilization at medium N, P, and lime rates on plant quality and fruiting.

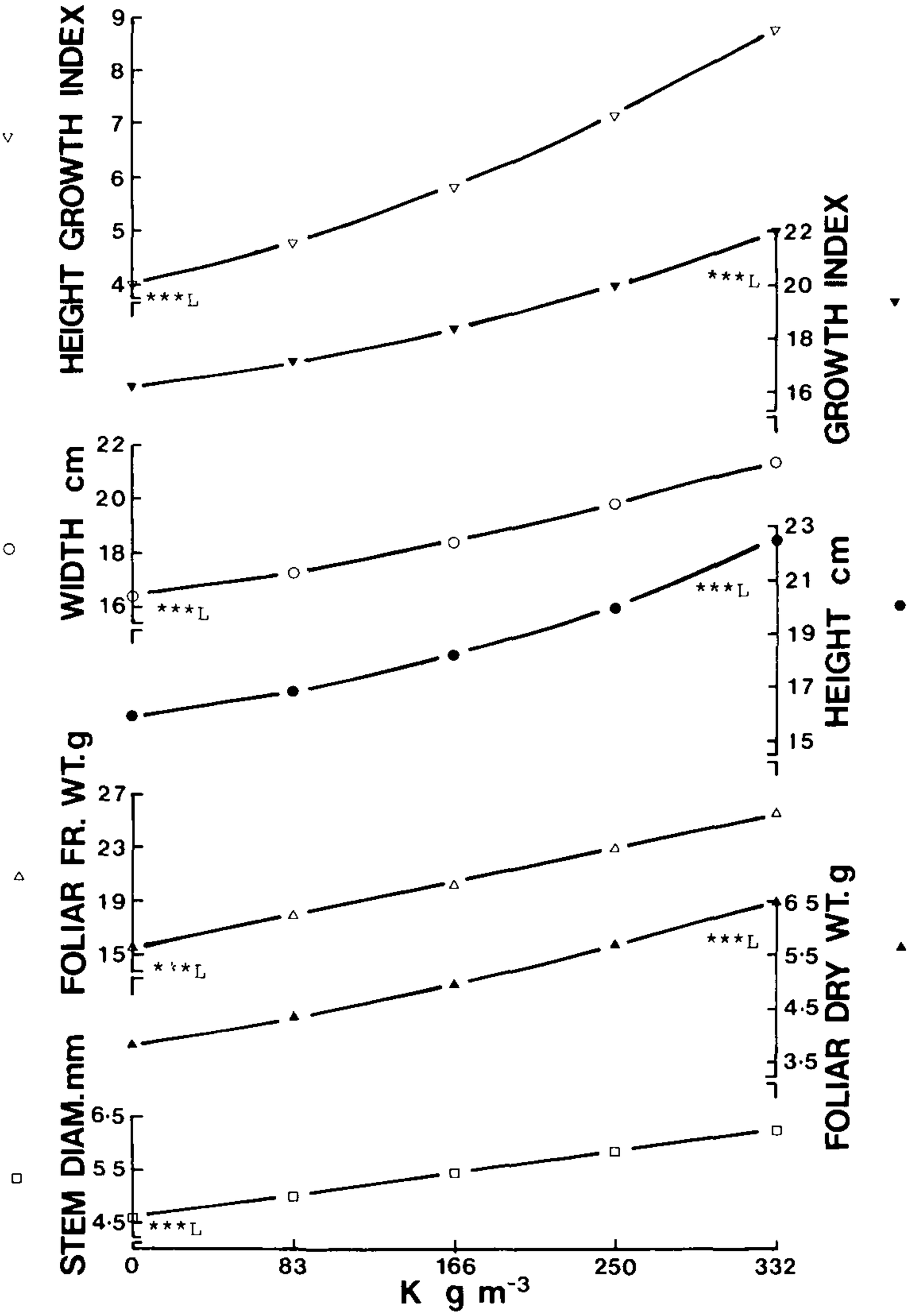

Figure 8. Experiment A Influence of K fertilization at medium N, P, and lime rates on foliage growth.

Experiment C: Responses to higher K levels confirmed the indication from the former two experiments that this species had a high K requirement; optimum foliage growth and fruiting was at 500 g K m^{-3} (Figure 9). This experiment was started in autumn and flowering was delayed until late July, taking nearly two months longer to flower than the trials conducted in summer. Growth was very slow from late May to early July and supplementary lighting was used from July onwards.

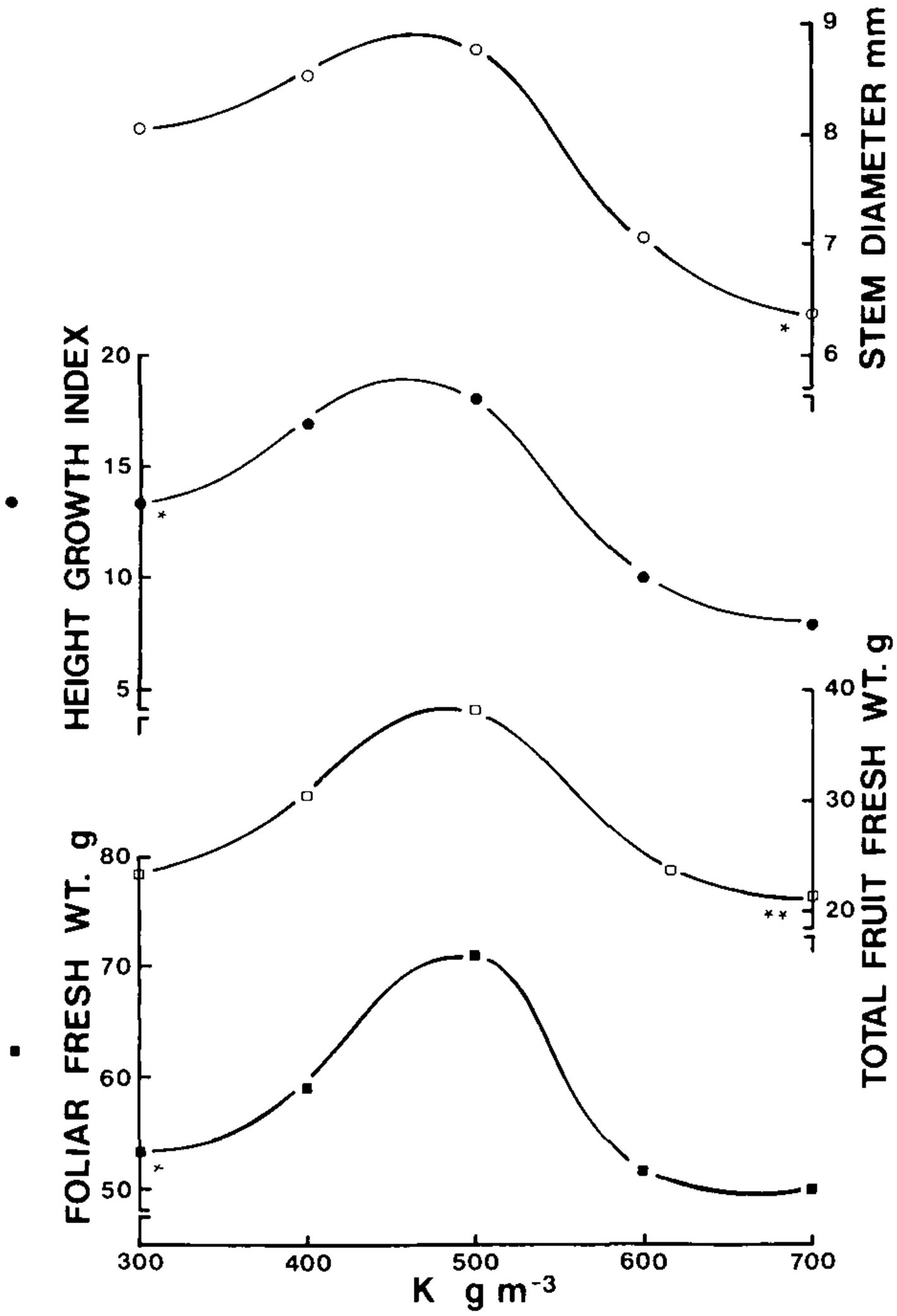

Figure 9. Experiment C Influence of medium to high K levels at medium N, P, and lime rates on foliage growth and fruiting

DISCUSSION

The strong nutritional response of ornamental pepper 'Fips' was not unexpected for *Capsicum* spp., like its Solanaceous relative, the tomato, they are vigorous plants with high nutrient requirements. Miller *et al.* (8) showed that the *Capsicum* plant could produce 54.5 g of total dry weight and absorb 1633 mg of N over a 10-week period. This compared favourably with the tomato and summer-grown pot chrysanthemum, both of which have very high N requirements (3). The loam-based John Innes No. 2 potting medium was recommended for growing ornamental peppers in Britain (8,21). This medium

contained 308 g N, 190 g P, 534 g K m^{-3}, and magnesium. Supplementary liquid feed at rates of 190 to 240 ppm N and 220 to 250 ppm K, applied weekly, were suggested. The results of the present study agree generally with these recommendations, although the optimal P and K levels were higher and lower, respectively, and Mg requirements were not demonstrated.

Nitrogen fertilization consistently increased yields of field-grown sweet peppers and chillies (13, 28). However, above the optimal N levels, fruit yields were reduced. A similar observation was made in the present study (Figure 2). Maynard *et al.* (16) had shown that increasing N levels resulted in a corresponding increase in flowering and fruit set. The increase in fruit number and the total fruit fresh weight in Experiment A would be due to the increase in flowering and fruit set (Figure 2).

Knavel (15) reported that 16-week-old sweet pepper seedlings responded best to 240 g N m^{-3}. Plants receiving less N exhibited typical N deficiency symptoms. Plants receiving no N in the present study showed similar symptoms, while chlorosis was noted at 150 g, though not at 300 g N m^{-3} (Figure 1). Chlorotic plants of the present study had foliar N content of 2.92% and below (Table 1). This value was a lot higher than that given by Miller (17) but was closer to those given by Knavel (15) and Maynard *et al.* (16). Foliar N levels of plants with optimal response in the present study were more than double the value given by Miller (17) but corresponded with those given by Knavel (15) and Maynard *et al.* (16). Sweet pepper seedlings studied by Knavel (15), when grown to maturity after being transplanted to soil beds, yielded highest in fruit weights at N levels in the range of 400 to 500 g m^{-3}. The optimal response of fruit yield to 450 g N m^{-3} in the present study would be in agreement with Knavel's investigation.

Responses to P fertilization of field-grown chilli and sweet pepper plants were varied depending on the P status of the soils in which these plants were grown (19). The P status of mineral soils is diverse, accounting for negligible to good responses to P fertilization. However, with organic soils, a good response to P fertilization was ensured by the low P status inherent in peats (3). Hence, the good response in foliage growth and fruit yield in the present study was not unexpected. The corresponding increase of foliar P content with P additions in the present study, as illustrated in Table 2, agree with the findings of Ozaki and Iley (19) and Thomas and Heilman (28). Foliar P content of plants receiving no P in the present study was higher than the 0.09% value reported by

Miller (17) for P deficiency, but less than the 0.6% given by Thomas and Heilman (28).

Ozaki and Hamilton (20) reported a good K response while Iruthayaraj and Kulanaivelu (13) found no significant response to K application of *Capsicum* spp. grown in mineral soils. The very low K content in peats, according to Bunt (3) would account for the very good response to K fertilization of peppers grown in organic soils (1), hence the good response and high K requirement shown by the ornamental peppers in the present study. A marked reduction of foliar K at high N observed in the present study was in accordance with results reported by Knavel (15) and Miller (17). Plants receiving optimum K had a higher foliar K value than that given by Miller (17).

Hamilton and Ogle (11) found that increasing Ca levels in liquid feed produced a significant increase in fruit yield followed by an equal reduction as high Ca level was added. Even at the low Ca level where deficiency symptoms of dwarfing, upturned leaf margins, and blossom-end rot of fruits were noted, good fruit yields were obtained. This could possibly explain the lack of response in Experiment A of the present study. *Capsicum* peppers were very tolerant of the low pH of 4.8 obtained from the medium which received no lime.

Field-grown peppers did not respond to Mg application even though Solanaceous species are prone to Mg deficiencies (7,19). The lack of response in the present study could be attributed to adequate Mg in the peat-based media. Peats, according to Bunt (3), have a greater percentage of Mg present than most mineral soils. Plants receiving no dolomite lime in Experiment A of the present study had foliar Mg content greater than the value given by Miller (17) for sufficiency level in the leaf tissues.

The combinations of high N, medium P, and high K fertilization for optimal growth and fruiting of ornamental peppers were comparable to the nutritional requirements of other Solanaceous species. Semeniuk (24) recommended liquid feed of N,P,K, of 20:8.7:16 fertilizer for producing *Browallia speciosa*. This ratio was very similar to the 6:3:5 N, P, K ratio obtained with the ornamental peppers in the present study. Czabajski *et al.* (5) reported that growth and dry matter yield of *Datura inoxia* were optimal with plants receiving N, P, K fertilizer with ratio of 6:1.3:5:1. The tomato, when grown with similar media, fertilizers, and environment, showed a requirement for 120 g N m^{-3} per month, 100 to 300 g P, 500 g K, and 6 kg lime

m-3 (26). The N, P, K requirements of ornamental peppers appear close to that for other Solanaceous species.

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SEED PROPAGATION OF *GENTIANA SCABRA*

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INTRODUCTION

Although the genus *Gentiana* contains many hundred species, the cultivated cut flower cultivars have arisen principally from only three: *G. makinoi, G. triflora,* and *G. scabra,* all of which are native to Japan. *Gentiana* is a very popular flower in Japan where it blooms mainly between the months of July and October. In 1979 it was estimated that approximately 278 ha of *Gentiana* was cultivated in Japan. In 1982 this had increased to 449 ha.

Until recently most propagation has been by seed. Cutting propagation is used in some districts for white cultivars, which tend to have a poorer seed germination rate than the blue and purple ones. The tissue-cultured material which is now becoming available provides the advantages of clonal multiplication but is more expensive than seedlings. Seed, available

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Until recently most propagation has been by seed. Cutting propagation is used in some districts for white cultivars, which tend to have a poorer seed germination rate than the blue and purple ones. The tissue-cultured material which is now becoming available provides the advantages of clonal multiplication but is more expensive than seedlings. Seed, available

from several Japanese seed companies, is best purchased during November and December as this is when fresh stock is available from the previous season's crop. Although some seed lines have a germination rate of over 70% it is necessary to allow for large margins of loss as the seedlings are very delicate, especially during germination and the first month of growth.

In common with many other gentians, seed of *Gentiana scabra* will germinate poorly unless it has been subjected to a prolonged period of cold temperature. Traditional Japanese gentian growers sow large quantities of seed into outside beds in autumn, then await spring germination. It has been reported that gibberellic acid (GA_3) application can be used to replace the need for a cold period (1,2).

The objective of the current study was to determine the length of chilling required, the most effective concentration of GA_3 to use, and to evaluate the influence of light on seed germination in *G. scabra*. From the results a reliable method for propagating *G. scabra* from seed has been developed.

METHODS

G. scabra seeds number approximately 19,000 per gram. In all three experiments, replicate lots of approximately 0.01 g of dry seed were accurately weighed out. All results are expressed in seeds germinating per 0.01 g of dry seed. Replicate seed aliquots were then sown onto filter paper discs moistened with either distilled water or an aqueous solution of GA_3, neutralised to pH 7.0. The fungicides, Benlate (benomyl, du Pont) and Ridomil (metalaxyl, CIBA-GEIGY), were also applied to the paper discs to suppress fungus attack of the seeds or seedlings. These two chemicals were previously determined to have no effect on seed germination in this species. Each filter paper disc bearing seed was then sealed within a clear plastic petri plate.

The plates were held in a culture room at 23°C ± 1.0°C. Light was supplied by a bank of four 40W Thorn 'Cool White' fluorescent tubes on a 12 hours light/12 hours dark photoperiod. Seed plates subjected to continuous dark conditions were held in a light-proof container within the culture room.

Germination was defined as the emergence of the radicle through the seed coat. Germination counts were taken every 3 to 4 days from the time of entry into the culture room, until day 19 in Experiments 1 and 2, and day 40 in Experiment 3.

Experiment 1: The length of cold period required to break seed dormancy.

Method: Seeds were sown on filter paper discs moistened with distilled water and stored at 2°C for between 0 (control) and 4 weeks. Following the cold treatment seed plates were then transferred to the culture room and germination counts were taken every 3 to 4 days thereafter. The results are summarised in Figures 1 and 2.

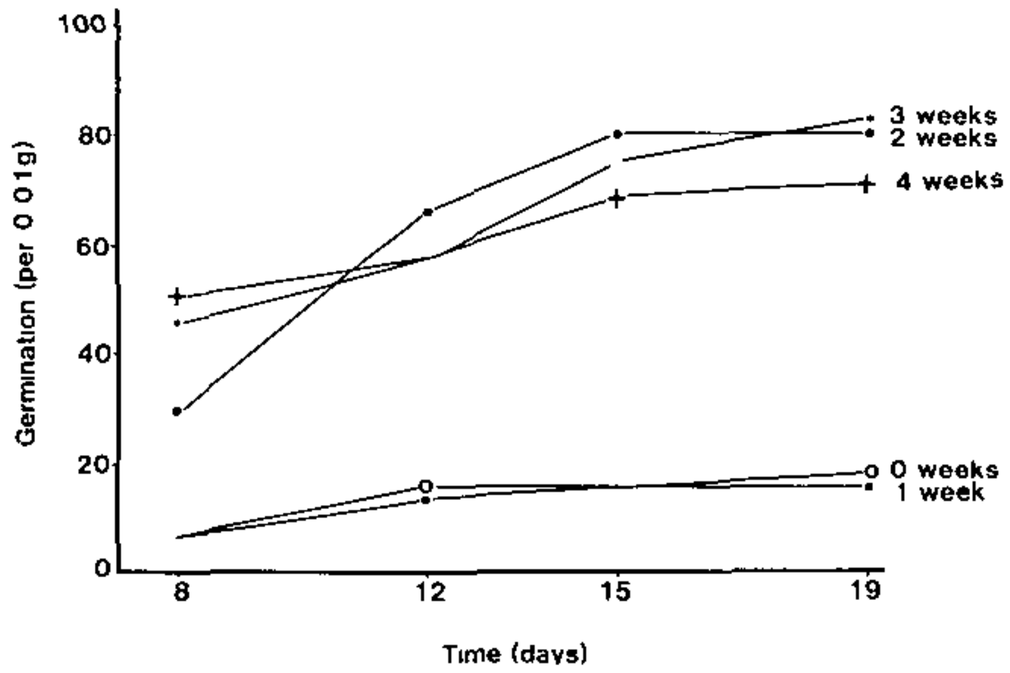

Figure 1. Progress of germination after various times of seed storage at 2°C

Results: Seed germination began between day 4 and day 8 in the culture room and was largely complete by day 19. No germination occurred during cool storage. Germination in the one week treatment was not significantly different to that in the control.

From these results it appears that 2 to 3 weeks at 2°C is sufficient to adequately break seed dormancy in *G. scabra* seed. It is important to note that the seed must remain damp throughout the chilling period.

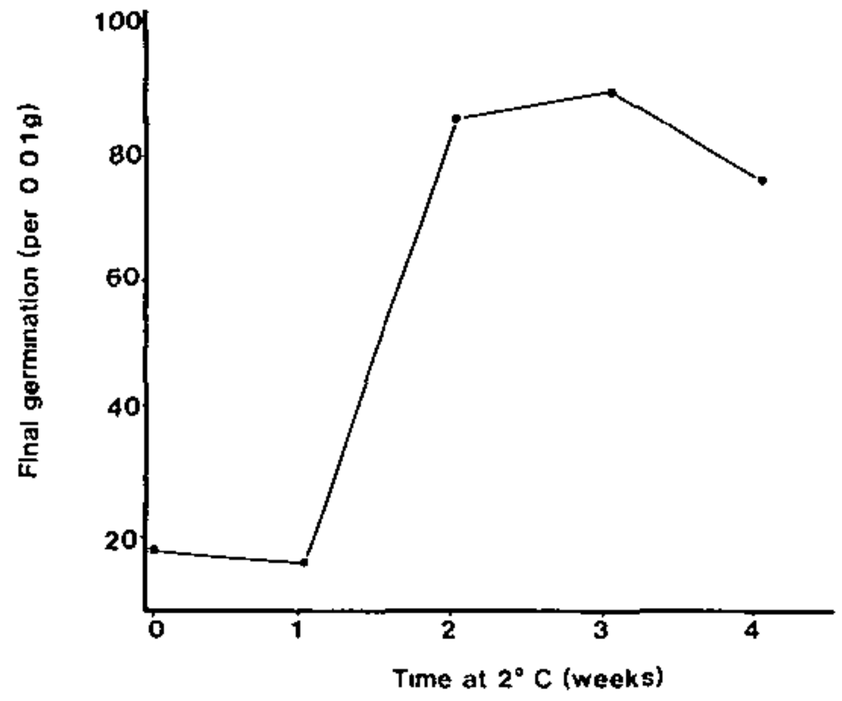

Figure 2. Final germination after various times of seed storage at 2°C

Experiment 2: The use of gibberellic acid to break seed dormancy.

Method: Aqueous solutions of GA_3 ranging in concentration from 0 ppm (distilled water) to 500 ppm, were used to moisten filter paper discs on which seeds were sown. All

solutions were neutralised to pH 7.0 using NaOH. Sealed plates were then placed in the culture room and germination counts began on day 4. Results are summarised in Figures 3 and 4.

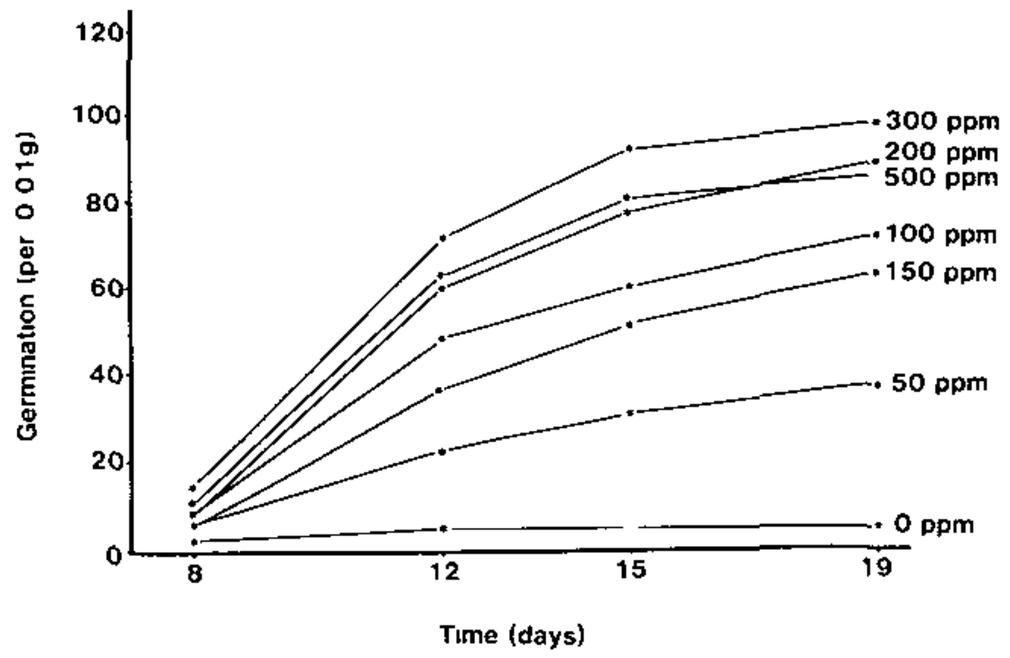

Figure 3. Progress of seed germination at various concentrations of GA_3

Results: As in Experiment 1, germination began between day 4 and day 8 and progressed up to the end of the experiment. At day 19 the highest total germination count occurred in the 300 ppm treatment (Figure 4). As the 300 ppm treatment yielded higher counts throughout the experiment than those of the 500 ppm treatment, it appears that an excessive concentration of GA_3 can suppress seed germination in *G. scabra*.

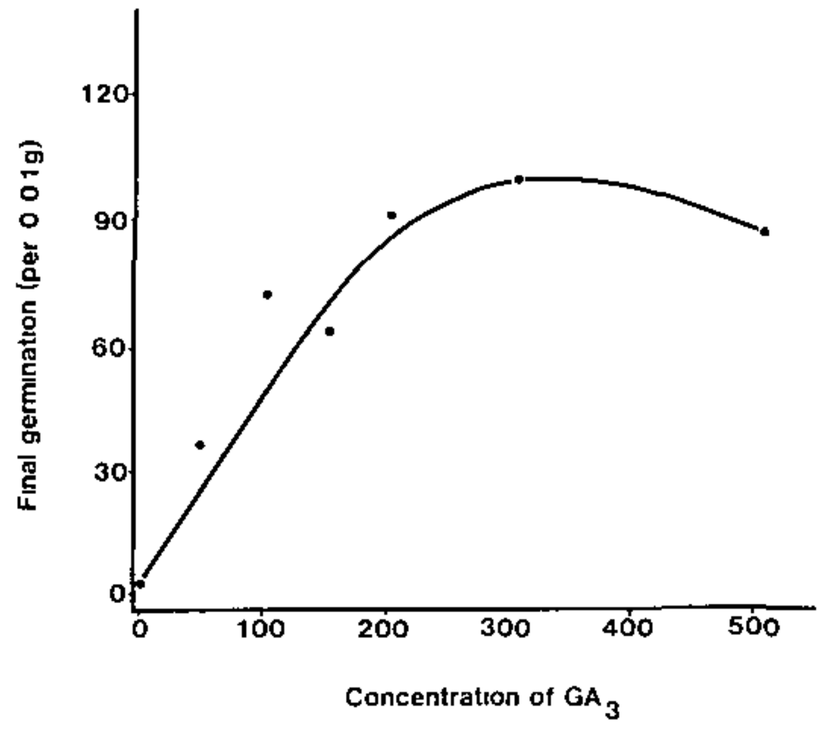

Figure 4. Final seed germination at various concentrations of GA_3

Experiment 3: The influence of light on seed germination.

Method: During the early stages of this study it became apparent that light was influencing the speed of seed germination. As a result of this observation Experiments 1 and 2 were conducted in a room in which the photoperiod and the light intensity were controlled.

To evaluate the importance of light, a third experiment was conducted. Seed was sown on paper discs drenched with a 300 ppm solution of GA_3 and enclosed within plastic petri plates as before. One set of plates was placed in the culture room under lights (in a 12 hours light/12 hours dark photoper-

iod), while a second set was held within a light-proof container in the same room. As the seeds had to be exposed to light for counts to be taken, for the "dark" treatment a separate set of replicates was used on each sampling date.

Results: Seeds kept in the dark began germinating later than those in the light (Frame 5). Throughout the period of the trial (40 days) total germination of the dark-treated seeds was less than that of the seed exposed to the light.

It is apparent that germination occurs more rapidly and more uniformly in *G. scabra* seeds exposed to light than in seeds placed in the dark.

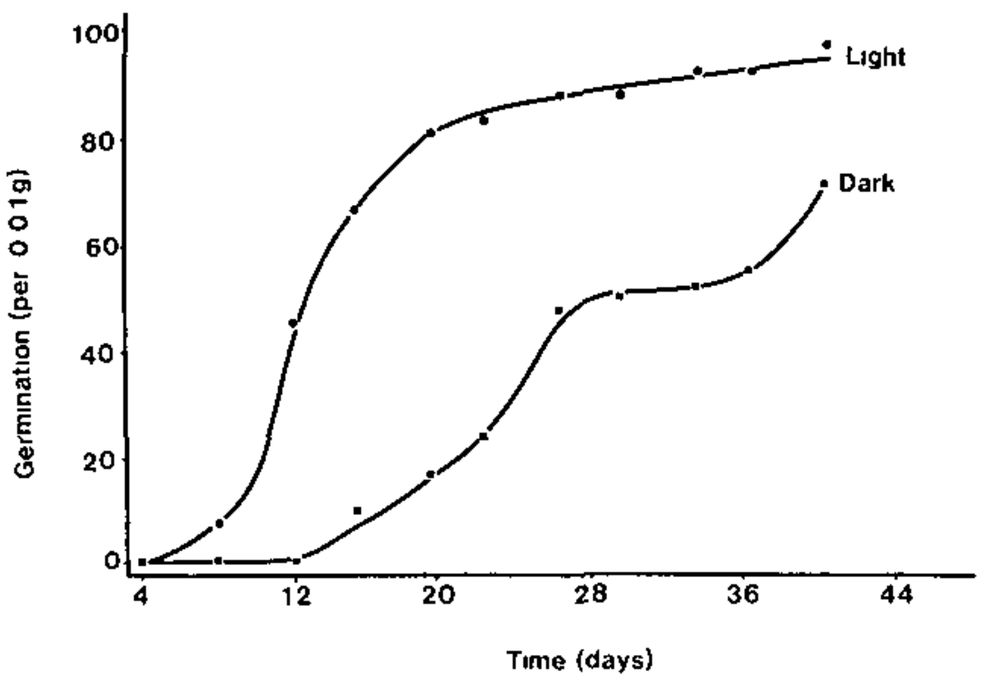

Figure 5. The influence of light on the progress of seed germination

DEVELOPMENT OF A TECHNIQUE

Gibberellic acid application is both faster and more convenient to perform than cold treatment of seeds. Furthermore, the overall seed germination from the optimal GA_3 rate (300 ppm) was slightly higher than that from the best cold treatment used (3 weeks at 2°C).

Following from these and previous findings, a method for germinating *G. scabra* seed has been developed.

Seed samples are placed into a 300 ppm GA_3 solution, neutralised to pH 7.0 using dilute NaOH. The fungicides, Benlate and Ridomil are added to the solution, both at the rate of 0.075 g/l. Air is continuously bubbled through the solution to prevent anoxic conditions developing. The seeds, which initially float, imbibe the solution rapidly and sink within three to five hours. After five days the GA_3 solution is decanted off and the seed rinsed twice in water. Seed is then stirred into suspension in water and sluiced over a prepared tray of a moist medium. As the water drains away the seeds are left on the surface. A glass sheet is then laid over the tray to maintain a high humidity about the germinating seeds. Shade cloth can be placed over the glass to prevent overheating.

The medium should be free draining and contain fertiliser at a rate similar to that used for bedding plants. The medium I have used is made up of 30% composted Fibremix (N.Z. Forest Products Ltd), 30% granulated bark, and 40% medium grade pumice. To this the following fertilisers are added per m^3 of mix:

5 kg dolomite limestone
4 kg 4-month resin-coated slow-release fertiliser (14/6.1/11.6)
1 kg superphosphate
0.2 kg calcium ammonium nitrate
0.2 kg fritted trace elements

This has proven adequate to date but may be improved upon in the future as more experience is gained with the crop.

Just prior to sowing, the mix is drenched with Terrazole (etridiazole, Olin) to suppress damping off. A second application is applied three days after sowing. Thereafter, alternating applications of Ridomil and Benlate are applied once every 3 to 4 days until the first set of true leaves have formed. Weekly applications are then adequate up to the time of planting out. The glass is slowly lifted after the plants have developed their first set of true leaves. If the seedlings are in a glasshouse under strong light, a shade tent may be required to prevent scorching. Pricking out is performed once the second set of true leaves have formed.

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1. Hayashi, T. 1983 New Techniques for the Cultivation of Cut Flowers; Perennial Plants, Vol 11 Seibundo Shinkosha, Japan
2 Ohteki, T 1982 Cut flower production — Japanese techniques *Tech. Bull* No 1. Ministry of Agriculture and Fisheries, N Z

PROPAGATING FEIJOA BY BENCH GRAFTING

IAN FANKHAUSER

Duncan & Davies Ltd.
New Plymouth

Feijoa, a native of South America, was introduced to New Zealand in the early 1900's. Since this time selections of plants with fruit suitable for export is an ongoing process with "improved" cultivars coming onto the market periodically.

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In the late 1950's, Duncan & Davies were producing named cultivars feijoa by layering. Trials have been done since then with field grafting, bench grafting, budding, and

cutting production. While cutting production produced results varying form 40% to 60%, depending on cultivar, the most successful to date has been bench grafting. This is the method I will deal with.

The main cultivars we graft are 'Mammoth' and 'Triumph', with lesser numbers of 'Coolegei', 'Robert', 'David', and 'Variegata'. We do not grow 'Apollo' and 'Gemini', as these are restricted to six nurseries granted propagating rights.

Seed of *Feijoa sellowiana* is sown in trays progressively in winter, from July through August, then pricked out in September/October (spring) into 7cm Maclons in a 1 part pumice, 2 parts peat, medium and put into a heated house for four weeks. They are then shifted into a shade house to harden off and thereafter outside. These are grown until autumn (April), given regular foliar insecticide/fungicide sprays, fortnightly liquid feeds from December through to March, and monthly fungicide drench sprays to produce clean, healthy stocks.

In April, grafting begins and carries on to early September. The first step is preparing the understock. For this we cull any unsuitable plants, remove from the pot, and cut the bottom cm off the root system to reduce root coiling then trim clean the bottom six cm of the stem. Stocks should be 5mm to 10mm in calibre at four cm about soil level. The scions should be three-noded using only matured wood. The plant is cleft-grafted at 3 to 4 cm high on the rootstock, matching up the cambium layers on at least one side and tied with a rubber grafting tie.

The propagation houses are filled to a depth of 250 mm with an unfertilized 1 part sawdust, 2 parts fibremix medium. The grafts are plunged into this burying the graft union. Bottom heat is maintained at 25°C. around the graft to induce quicker callusing.

The mist needs to be set frequently enough to maintain moisture on the leaves but not too high to make the mix soggy as this reduces the bottom heat temperatures and increases the likelihood of fungus diseases. Grafts are sprayed weekly with Benlate and Ridomil. Humidity is initially kept high but as callusing and buds develop the crop is hardened off. In the winter months this can take up to three months but with the longer days and warmer air temperatures of spring the grafts done in late winter are ready for handling within 6 to 8 weeks.

We have been doing trials with grafts under fog instead of mist. The fog is simply a mixture of water (up to 10 litres per hour) and compressed air, kept at 80 p.s.i. This goes through a mixing chamber and out a nozzle to produce a very fine water droplet size resembling fog. As the grafts callus, the amount of

fog is reduced by increasing the time off periods and reducing the water flow. To date we have had very pleasing results, with an increase in percentage take (90% compared to 85% under mist), and less time required in the propagation house. Grafts done in mid-winter needed only 8 weeks compared with 12 weeks under mist. Grafts done in early September were virtually ready for lifting 4 weeks after grafting with developed bud initiation.

When well-callused with new growth they are lifted, untied, desuckered and potted into a PB6½, and put in a polytunnel house with high light levels and air temperatures to force new growth. They remain in the polyhouses for up to 12 weeks, being trimmed to a single leader and then tipped at 30 cm to branch. The polycover is removed and replaced with a 70% shade cover to harden-off the plants — then this is removed four weeks later.

The plants are sold from April onwards, ranging in size from 60cm to 80cm, with four to six branches on the top.

In conclusion, the main reasons for Duncan & Davies grafting are:

(1) Fuller utilisation of cutting/scion wood as we get a better "take" than with cuttings.

(2) A stronger plant is produced more quickly than by cuttings, although ultimately there is no real difference between cutting and grafted plants.

PROPAGATION OF THE N.S.W. WARATAH *(TELOPEA SPECIOSISSIMA)* BY TISSUE CULTURE

JOHN F. SEELYE

Horticultural Research Centre
Ministry of Agriculture and Fisheries
Levin

INTRODUCTION

The genus *Telopea*, in the Proteaceae family, comprises four species all indigenous to Australia. *T. speciosissima*, the New South Wales waratah, is a woody shrub which produces large red blooms in the spring.

Its cultivation in New Zealand is increasing to meet cut flower market demands. However, its potential has been limited by the variable flower quality in plants raised from seed. A few clonal selections have been made in the past and vegetatively propagated by cuttings. Others are currently being eval-

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uated at this Research Centre for their cut flower qualities. Rapid propagation from the limited base stock is necessary if the local cut flower industry is to quickly realise the potential of these selections.

The procedure described here is based on studies with two *T. speciosissima* selections, clones 8 and 38. Previous micropropagation successes within Proteaceae, a family of 60 genera, have been mainly confined to the genus *Grevillea* (1,2). Shoot multiplication in *Telopea* using 6-benzyl-aminopurine (BA) in a Murashige and Skoog (MS) medium (3,4,5,6) and root development *in vitro* (5,6) have been reported.

PREPARATION AND CULTURING FACILITIES

Greenhouse-grown stock plants provided a source of explant material. The soft shoots which developed after the flowers deteriorated were removed and cut into single node segments. These were surface sterilised by dipping in ethanol, agitating for 30 min. in a 0.6% sodium hypochlorite solution and then rinsing. The segments were then surface-dried in a laminar flow hood.

The basal medium contained MS inorganics, 100 mg/l inositol, 0.4 mg/l thiamine-HCl, 30 g/l sucrose, and 7.5 g/l agar. Half strength basal medium had only the MS macro inorganic compounds reduced. The growth regulators used were indole-3-butyric acid (IBA), gibberellic acid (GA_3), and BA. The medium, with the exception of the GA_3, was adjusted to pH 5.7 and heat sterilised at 105 K Pa for 15 min. GA_3, with a similar pH, was filter-sterilized and added to the autoclaved medium; 35 ml of medium was pumped into 200 ml glass jars and closed with vented, translucent polypropylene screw lids.

The culture room temperature was 25°C ± 2°C. Cool white fluorescent tubes gave an illuminance of 2400 lux on the shelves during the 16-hr photoperiod.

SHOOT INITIATION

Single node segments were inserted into the basal medium supplemented with 0.05 mg/l IBA, 0.3 mg/l BA, and 0.1 mg/l GA_3. Removal of the outer scales from the auxillary bud hastened shoot development. Microbial contamination of some nodes necessitated repeated surface sterilising during the first few weeks.

Within one month axillary buds swelled and commenced to elongate. By 10 weeks shoots up to 20 mm long had developed.

This shoot initiation medium was also successful with 1.0 mm shoot tips aseptically dissected from the auxillary buds.

PROLIFERATION

Initiated shoots were removed, subcultured by cutting into segments, and placed on the proliferation medium comprising half strength basal medium with 0.05 mg/l IBA, 0.3 mg/l BA, and 2.0 mg/l GA_3. After six to eight weeks multiple shoots 5 to 15 mm long developed. These were removed from the basal tissue, and again cut into segments and placed onto fresh proliferation medium. By the fourth subculture, the time between subculturing could be reduced by two weeks while still maintaining a six-fold proliferation rate.

Increasing the BA levels from 0.3 to 2.0 mg/l without the presence of GA_3, resulted in a corresponding increase in the subsequent formation of fused or fasciated shoots. This was overcome by using lower levels of BA and by adding 1.0 to 3.0 mg/l GA_3. This resulted in a significant increase in the number of shoots forming from buds (Table 1), although on a medium containing 3.0 mg/l GA_3 some shoots became excessively etiolated. This elongation effect was suppressed by the higher BA levels.

Table 1. Effect of GA_3 concentrations in the proliferation medium on the mean number of visible buds and/or shoots present eight weeks after placing subcultured tissue on the media *T speciosissima*, clone 8

GA_3 rate (mg/l)	Shoots and buds	Shoots only	Shoots > 10 mm
0	2.18 a[1]	1 38 a	0.20 a
0.3	2.96 ab	2 18 ab	0.55 ab
1 0	3 56 bc	3.00 b	1 15 b
3 0	4.64 c	4 34 c	2.39 c

[1]Numbers with the same letters are not significantly different at the 5% level

With clone 8, 1.0 or 3.0 mg/l of GA_3, with 0.05 mg/l IBA and 0.3 mg/l BA, significantly increased the total number of visible buds and shoots present compared to similar media without GA_3 (Table 1). A similar but less significant trend was observed wtih the other clone. There were no significant differences in shoot proliferation rates between the two clones growing on media containing GA_3 in the range 0.3 to 3.0 mg/l.

The proliferation medium described here, containing 0.05 mg/l IBA, 0.3 mg/l BA, and 2.0 mg/l GA_3 gave adequate multiplication, consistent shoot size, and minimal fasciation (Figure 1a).

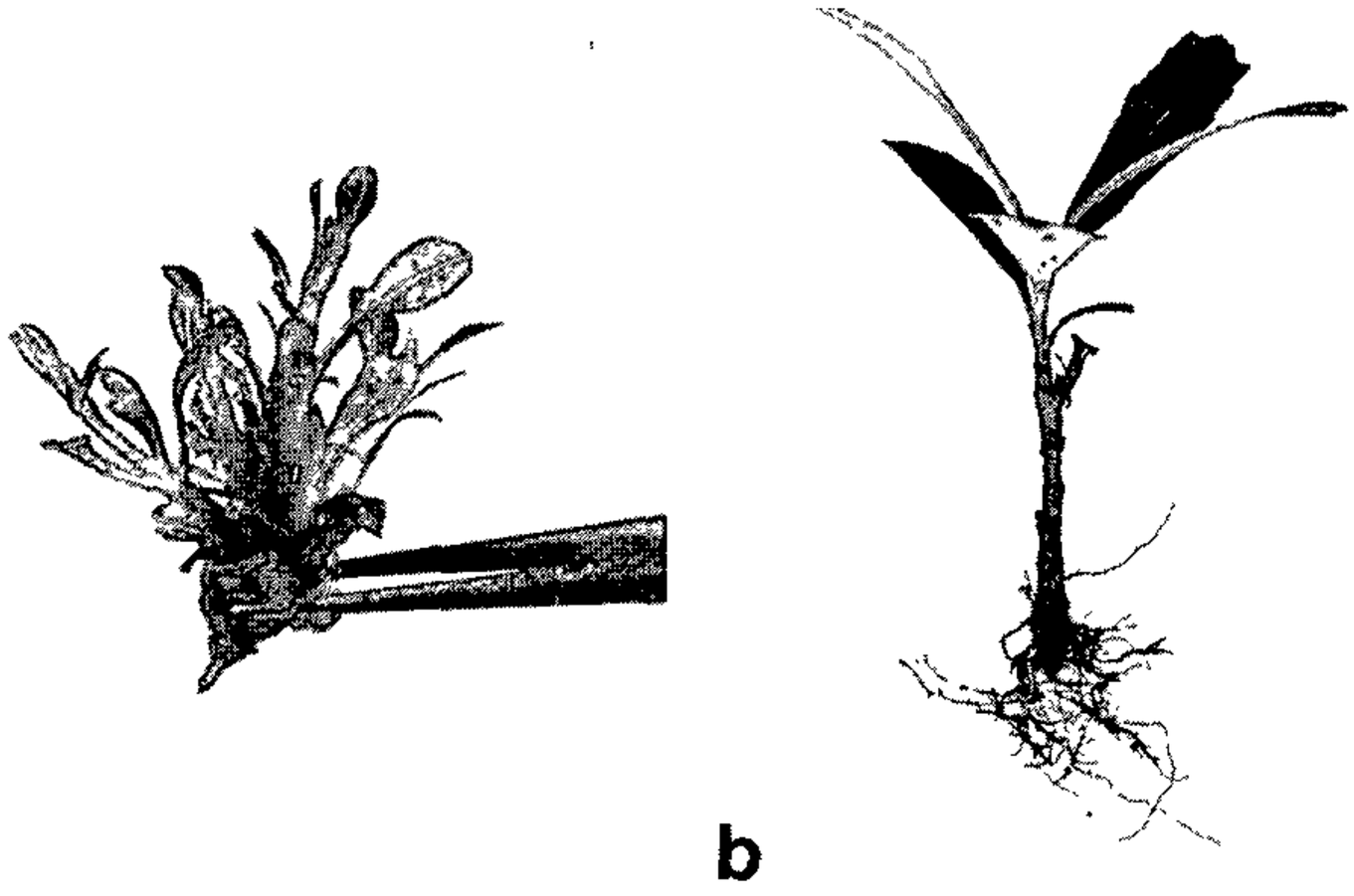

Figure 1. (a) *Telopea* shoot development *in vitro* after six weeks on proliferation medium containing 2.0 mg/l GA_3.
(b) *Telopea* plant 4 months out of culture

ROOT DEVELOPMENT

Attempts to produce rooted plants *in vitro* with IBA or NAA up to 1.0 mg/l incorporated in the basal medium were unsuccessful resulting, after six weeks, in excessive callus growth and no roots, although roots did appear many months after shoots were placed on the half strength basal medium.

When individual shoots from the proliferation medium had basal ends dipped for a few seconds in filter-sterilised 500 or 1000 mg/l IBA solitions and were placed back on to half strength basal medium, roots appeared after two weeks.

When these plantlets were moved into conventional greenhouse propagation facilities with open mist and basal heat four weeks after root initiation, they collapsed and eventually died. However, good survival was obtained when plantlets with root initials or very short roots were inserted into trays of a porous, nutrient-free, pumice medium. The trays were placed on dampened capillary matting with basal heat, and enclosed in a high humidity polythene tent. A commercial liquid-feed formulation was applied weekly. When, after six to eight weeks, roots elongated and new leaves formed, the humidity was gradually reduced. Plants were eventually potted into a standard mix with equal volumes of pumice, bark, and peat, with added nutrients in preparation for field growth (Figure 1b). Incorporating soil from mature, field-grown *Telopea* plants into this mix appeared beneficial to plant growth, suggesting a symbiotic association with micro-organisms.

Because of the importance of having a cost-effective commercial tissue culture method, with as few steps as possible, attempts are being made to establish plantlets out of culture using micro-cuttings directly from the proliferation medium. Using the pumice mix and high humidity tent, shoots dipped in 500 to 1500 mg/l IBA at exflasking had initially a lower survival rate than those undipped. Although some root development did occur, survival rates were greatly improved if IBA treatments were delayed for at least two weeks after exflasking. Root development also occurred in 20% of the plantlets which had not been dipped in IBA, indicating the IBA in the tissue culture medium may be contributing to this.

Studies based on the foregoing are continuing.

LITERATURE CITED

1 Ben-Jaacov, J and E Dax 1981. *In vitro* propagation of *Grevillea rosmarinifolia* *HortScience* 16(3)·309-310.

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6 Seelye, J.F. 1983. The rapid propagation of the NSW waratah Combined Meeting 8th Nitr Fix Workshop and 4th Biennial Meeting N Z IAPTC Palmerston North, N.Z., Abstract 47

VEGETATIVE PROPAGATION AND DEVELOPMENT OF *SOPHORA MICROPHYLLA* AIT.

STEPHEN M. BUTCHER and SHEILA M.N. WOOD

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Research Division
Ministry of Agriculture and Fisheries
Levin

INTRODUCTION

The genus *Sophora* is in the family Papilionaceae, and consists of about 30 species of temperate and subtropical trees and shrubs (1) of wide distribution. Three species are found in New Zealand, *S. tetraptera*, *S. prostrata*, and *S. microphylla*.

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S. tetraptera, J.F. Mill is a small to medium-sized tree up to 10 m tall growing from sea level to 450 m. The leaflets are large (3 cm long) and the flowers, which appear in the spring — October and November, are large and pale yellow with wings longer than the standard. This species does not have a juvenile form and usually flowers in four to five years from seed.

S. prostrata J. Buchan is a low-land bush of approximately 0.5 to 2.0 m tall. It forms a low hummock with densely intertangled divaricated orange-brown rigid branches and bears small (25 mm) orange/yellow flowers.

S. microphylla Ait. is a small tree up to 10 m tall found from sea level to 700 m. It is the most variable and hardy of the three species. *S. microphylla* usually exhibits a juvenile non-flowering phase which has been reported to last up to 17 years when grown from seed. The juvenile plant forms a dense tangled bush with small leaves and is similar in habit to *S. prostrata*. The flowers are generally large and bright yellow with wings the same length as the standard which is distinctly notched at the tip. The flowering time is variable with some plants being in full flower in winter (June or July) while others are as late as early summer (November). Two varieties within *S. microphylla* are recognised.

S. microphylla var. *longicarinata* is a tree up to 5 m tall with 10 to 20 cm long leaves each having 20 to 40 pairs of leaflets. *S. microphylla* var. *fulvida* is a small tree (up to 3 m tall) with 8 to 10 cm long leaves bearing up to 50 pairs of small leaflets. Both varieties grow true from seed and do not exhibit the juvenile form.

S. microphylla shows greater potential than *S. tetraptera* for the selection of superior forms suitable for use as specimen trees, tub and pot plants, due to its wide diversity of form and flowering times, the brightly coloured flowers and the greater degree of hardiness. A collection of ecotypes of *Sophora* from around New Zealand (and one *S. microphylla* from Chile) was obtained from the Botany Division of the Department of Scientific and Industrial Research and established at Levin by the late Mr. G.N.J. Goldie (2). One type of *S. microphylla*, grown from seed collected from Stephens Island, exhibited particularly early flowering (May) and a dwarf habit (1.5 m tall after five years). Further seed was collected from Stephens Island and the subsequent trees planted in the seedling grove at Levin. This collection shows a high degree of variability in form, habit, and foliage colour. Selections of superior forms from the grove began in 1982.

Three early selections from the ecotype grove, now named 'Earlygold', 'Goldie's Mantle', and 'Goldilocks' have been released to the nursery industry. The cultivar, 'Earlygold' has been registered for Plant Variety Rights in New Zealand. This cultivar and its seed-grown progeny are being used as the basis for further breeding programmes including inter- and intra-specific crosses and the use of gamma irradiation.

The first requirement of a selection programme is the development of a method of vegetative propagation. Goldie (2) showed that several grafting methods, as well as cuttings, could be used to propagate *S. microphylla*. The cutting propagation method described proved to be difficult to implement on a commercial scale, since a low percentage strike rate was reported. Cutting propagation has been further investigated, using propagating conditions similar to those likely to be found in commercial operations. Flowering and control of plant form in containers has also been studied.

PROPAGATION

Experiment 1: Time of taking cuttings.

Method. Cuttings 15 cm long were taken from field-grown stock plants of 'Earlygold', 'Goldie's Mantle' and 'Goldilocks' at three or four week intervals from May, 1982 to June, 1984. The cuttings were stripped of their lower leaves, given a single wound, dipped in IBA/talc (Seradix 3) and inserted 3 cm into a 50.50 "Fibremix" bark:pumice medium in trays. The cuttings and tray were then drenched with a 1.5 g/l solution of Benlate fungicide before being placed under mist with 20°C bottom heat at the cutting base. The number of dead, callused, or rooted cuttings were counted after six weeks. Those cuttings that were callused but not rooted after six weeks generally rooted after 8 to 10 weeks. The trial design was a randomised block with five replications.

Results: The results for 'Earlygold', 'Goldie's Mantle' and 'Goldilocks' are given in Figures 1, 2, and 3, respectively. Approximately 100% rooting could be achieved using this system when cuttings were taken in winter — June, July, or August. Cuttings should be semi-hard and this is dependent on weather conditions. The drop in rooting percentage during the second season was probably due to a lack of suitable cutting material. This effect was particularly noticeable in 'Goldilocks'.

The results for the three cultivars were averaged at each propagation time and graphed against monthly weather data. While rooting appeared to be poorly correlated with day-length (Figure 4), it appeared to be well correlated with dry-

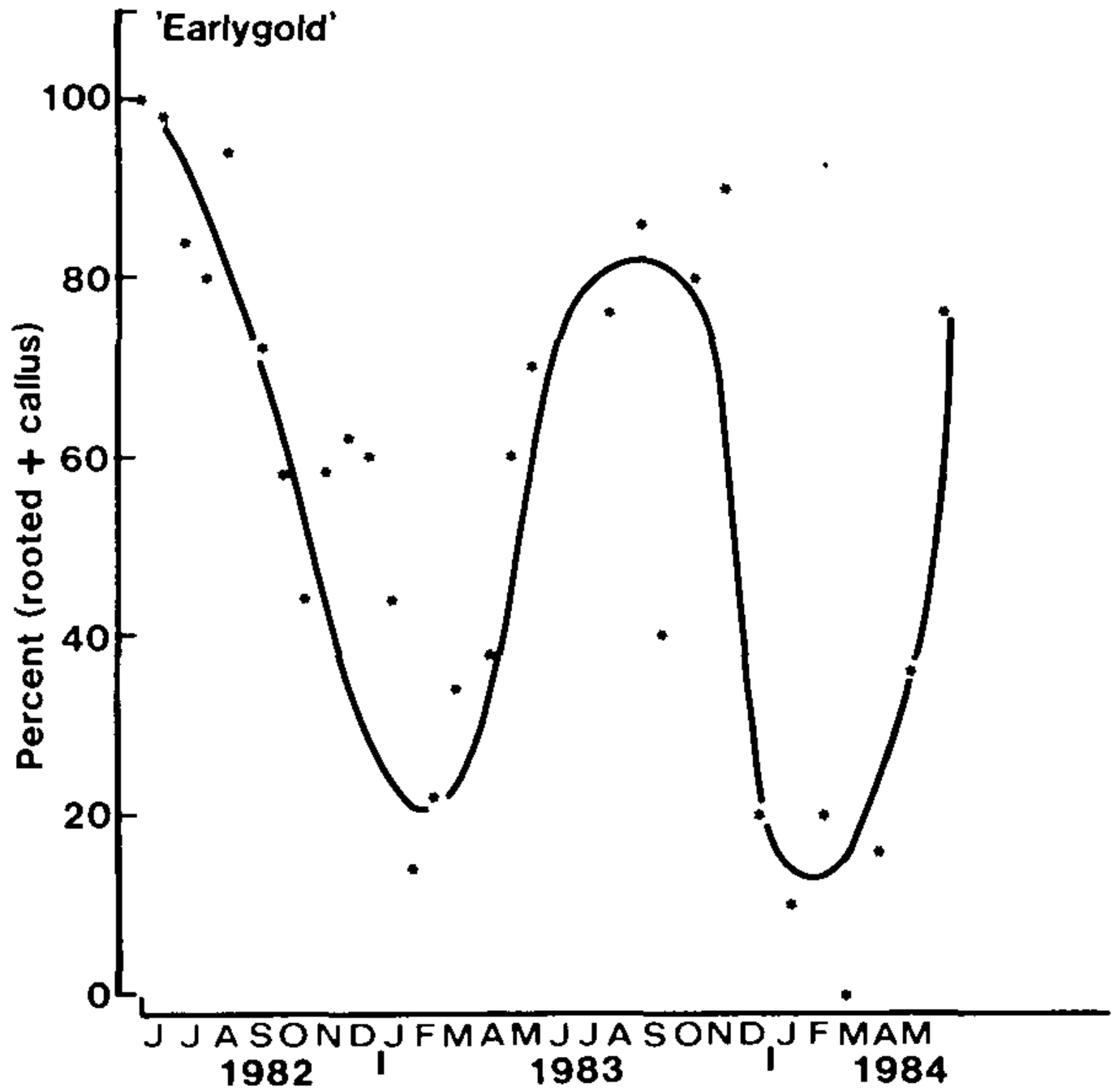

Figure 1. Percent rooted + callused cuttings of *S microphylla* 'Earlygold', versus time of taking cuttings

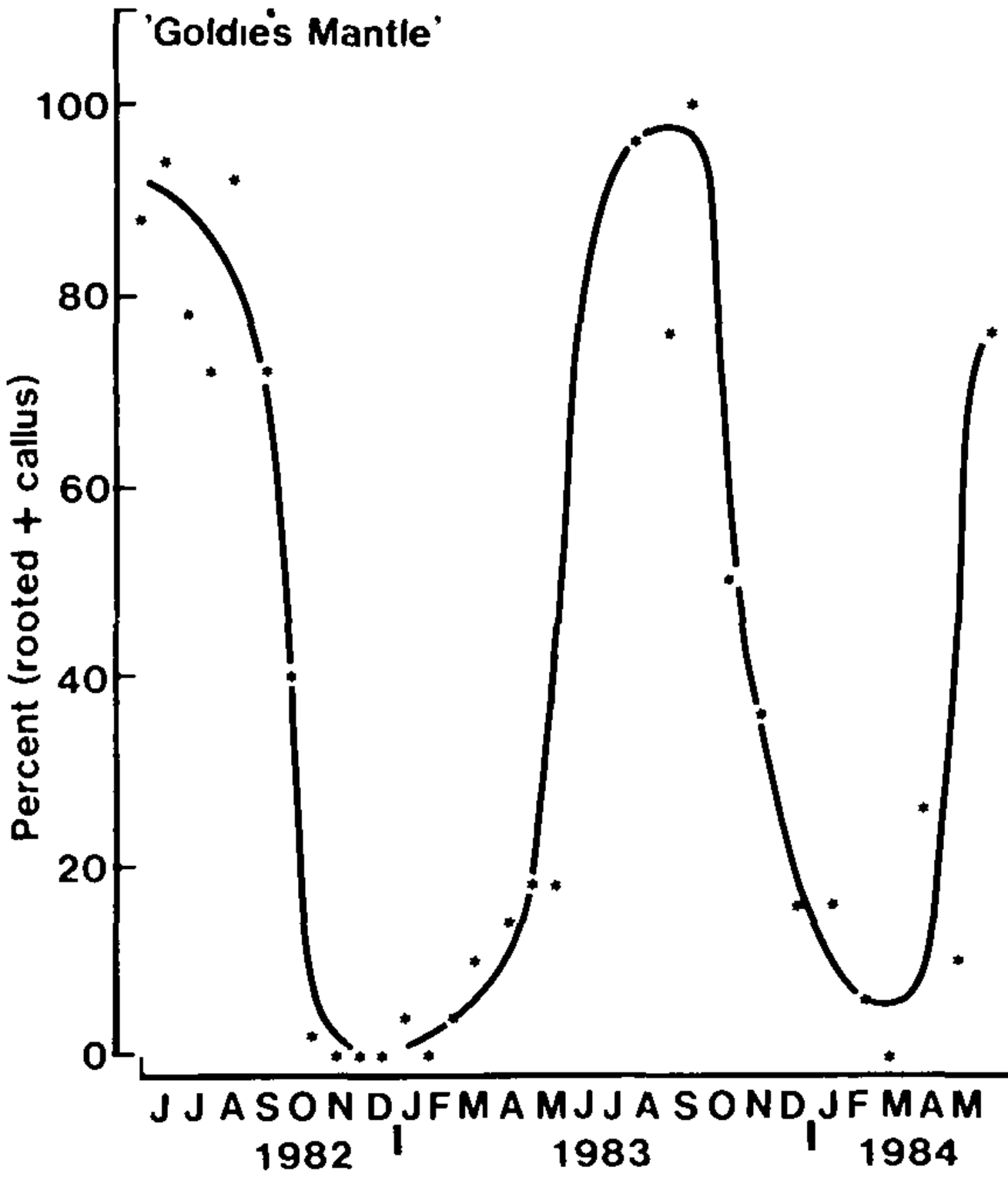

Figure 2. Percent rooted + callused cuttings of *S microphylla* 'Goldie's Mantle', versus time of taking cuttings.

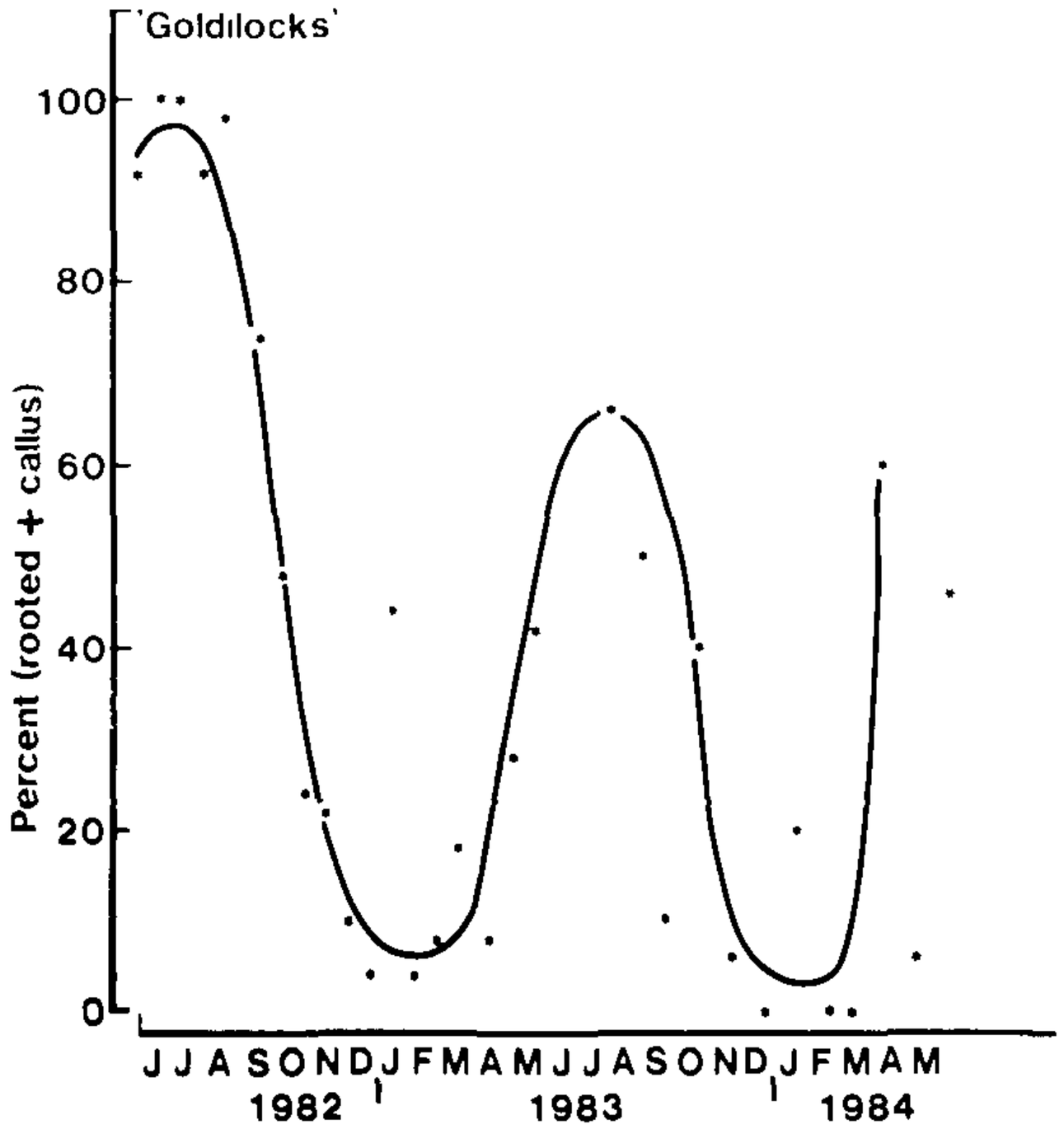

Figure 3. Percent rooted + callused cuttings of *S. microphylla* 'Goldilocks', versus time of taking cuttings.

bulb temperature (Figure 5), and the monthly total number of sunshine hours (Figure 6), but not with the monthly total radiation (Figure 7), or with open pan evaporation (Figure 8). Investigations are continuing with the aim of predicting periods of high propagatability.

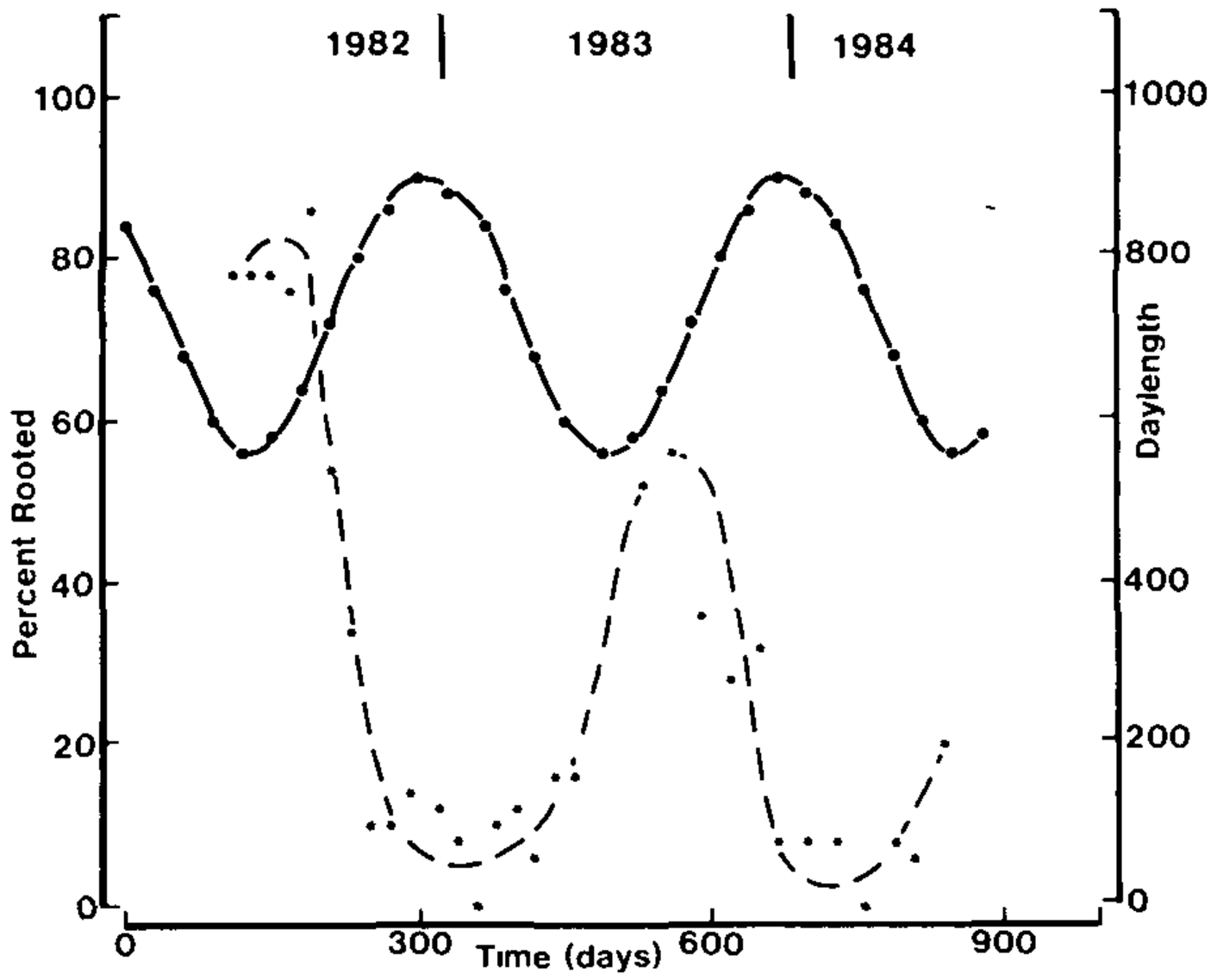

Figure 4. Percentage of *S microphylla* cuttings rooted and the day-length at Levin, versus time ● day-length, * percent rooted

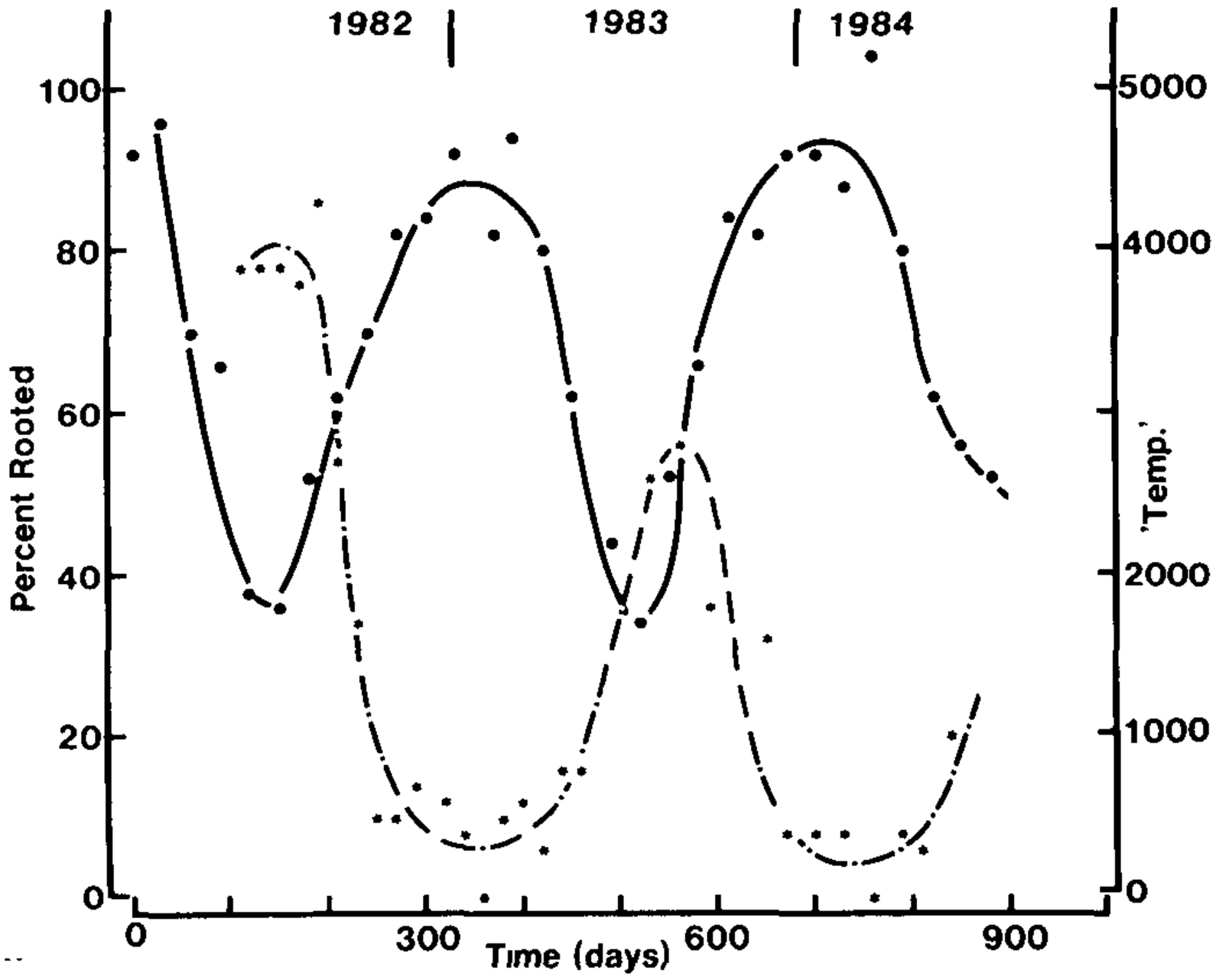

Figure 5. Percentage of *S microphylla* cuttings rooted and the dry-bulb temperature (monthly totals of the dry-bulb temperature reading at 9.00 a m every morning), versus time. ● dry-bulb temperature, * percent rooted

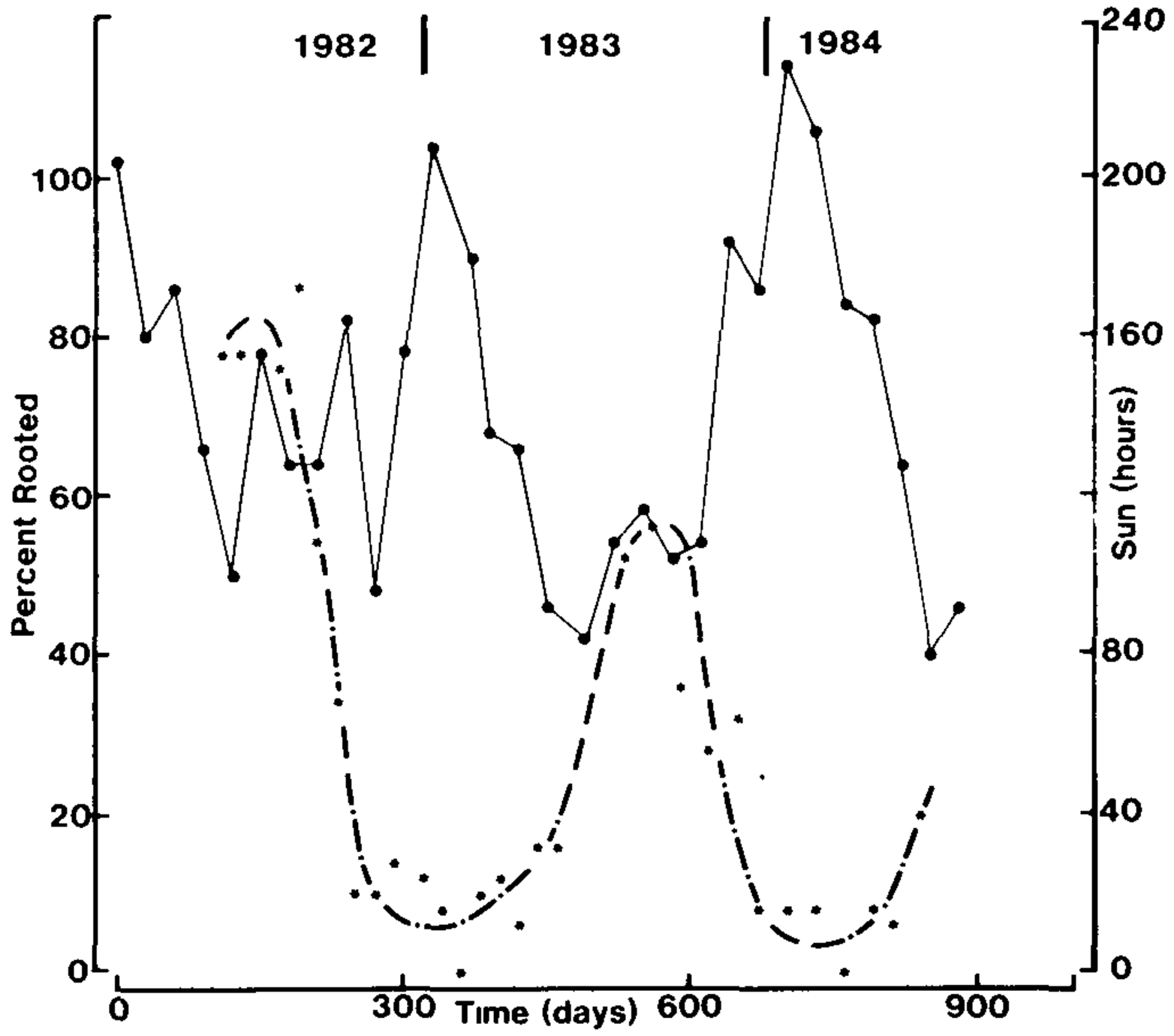

Figure 6. Percentage of *S. microphylla* cuttings rooted and the monthly totals of sunshine hours, versus time. ● monthly totals of sunshine hours; * percent rooted

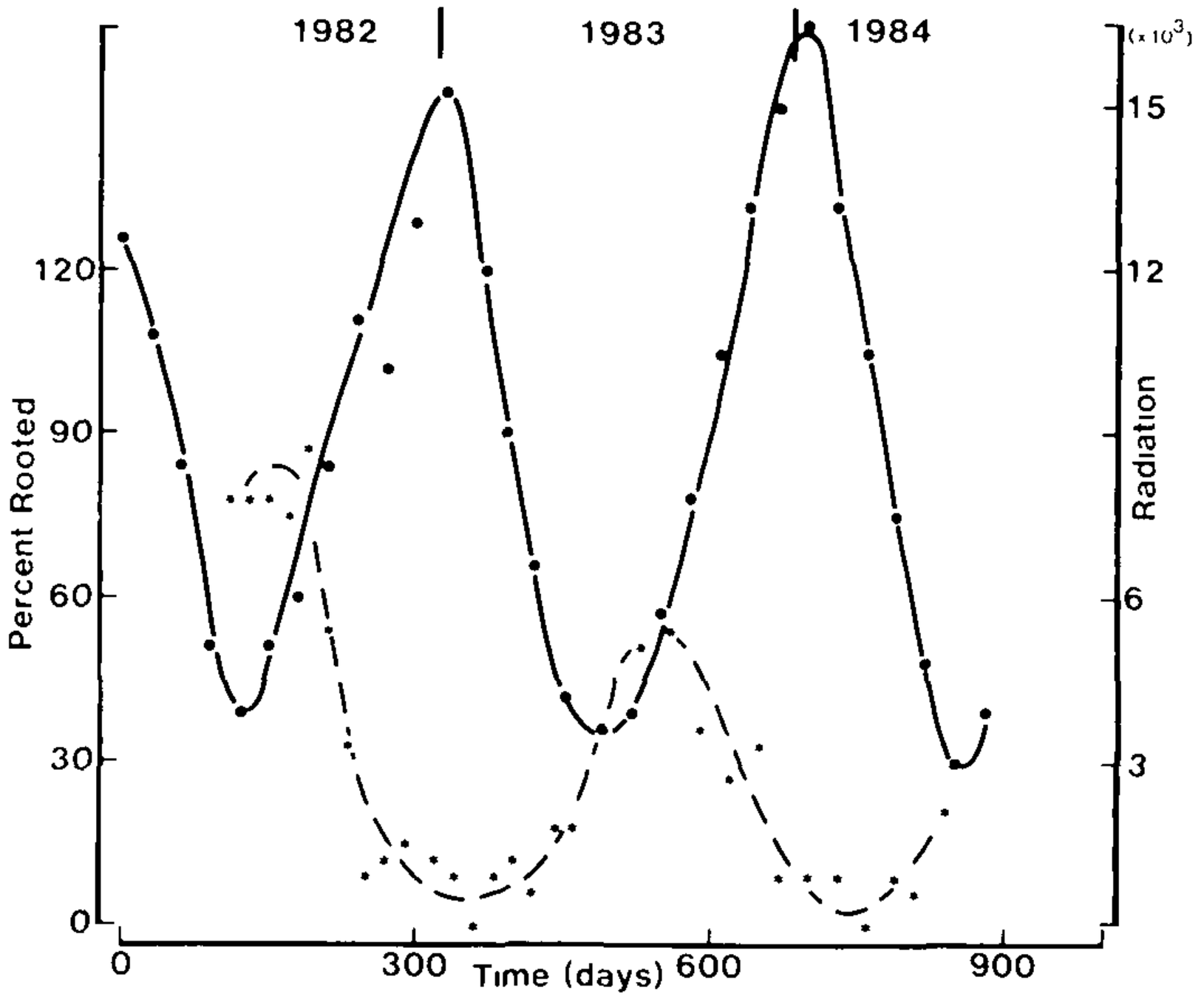

Figure 7. Pecentage of S *microphylla* cuttings rooted and the monthly total radiation levels (Langleys), versus time ● radiation totals, * percent rooted

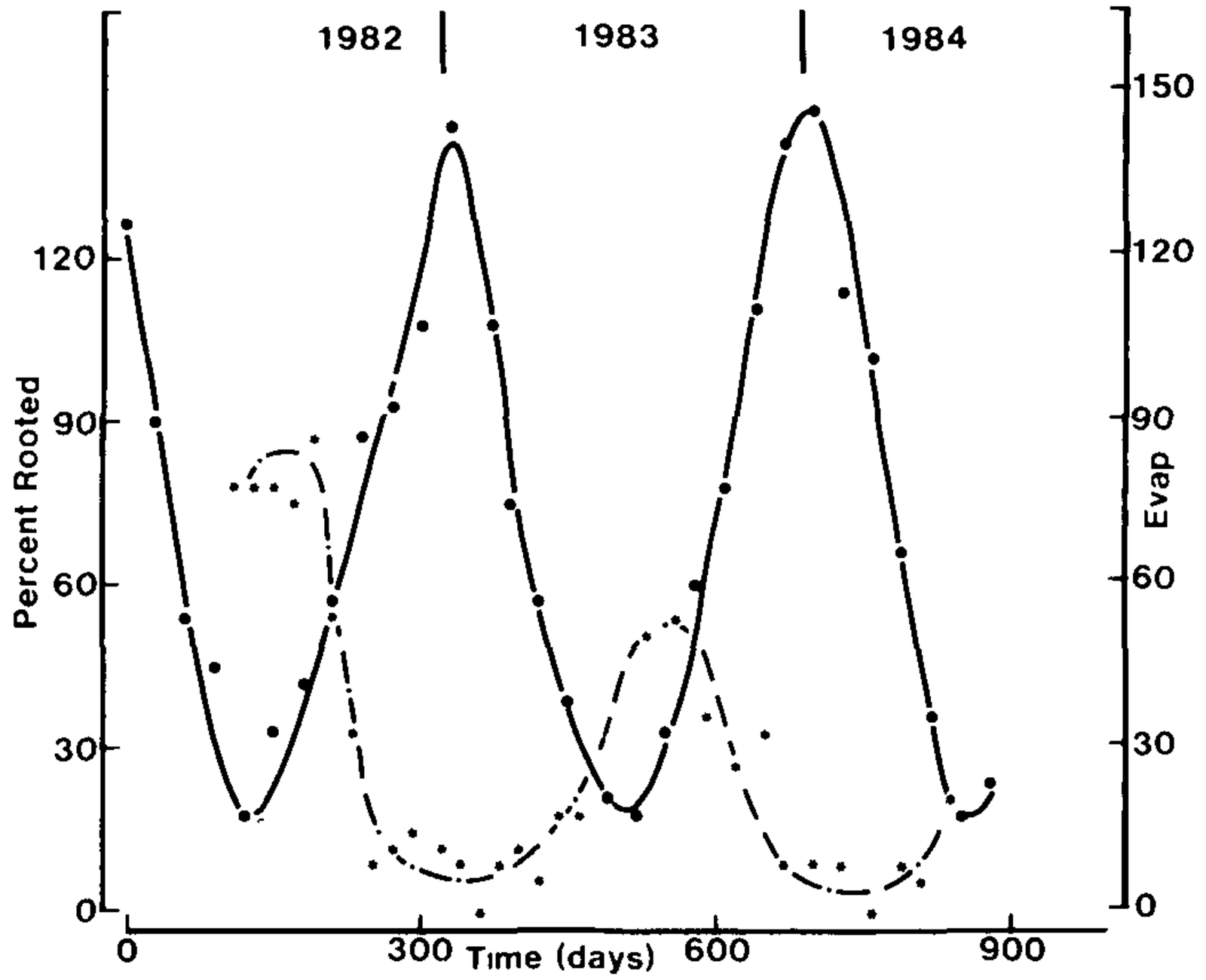

Figure 8. Percentage of S *microphylla* cuttings rooted and the monthly total open pan evaporation (× 0 1 mm), versus time ● open pan evaporation, * percent rooted

Experiment 2: Fertilised propagation mixes

Method: Cuttings of *S. microphylla*, 'Earlygold' were prepared as described previously and placed in a 50:50 "Fibremix" bark:pumice medium, containing 0, 0.5 and 1.0 times the following fertiliser regime:

	kg/m³
Osmocote 3 to 4 month (14.6 1 11 6)	4.5
Dolomite lime	5 0
Superphosphate	1 0
Calcium ammonium nitrate	0 2
Fritted trace elements	0 4

Trial design was a randomised block with five replications.

Results: No significant increases in the rooting or initial survival was found using fertilised propagation mixes.

Experiment 3: Fungicides and cutting sterilisation

Method S. microphylla 'Earlygold' cuttings, prepared as directed previously, were subjected to factorial combinations of the following pre- and post-sticking treatments:

Pre-treatments	Post-treatments	
control	control	repeated applications every seven days
50% ethanol dip, 5 sec	Benlate 1 g/l	
0 3% sodium hypochlorite dip, 30 min	Ridomil	
0 6% sodium hypochlorite dip, 30 min	Thiram	
	Sumisclex	

Trial design was a 4 × 5 factorial with five cuttings per plot.

Results: Significantly better survival of plants was achieved using no pre-sticking treatments, followed by Ridomil, Thiram, or Sumisclex rather than the control or Benlate treatments If 0.3% pre-sticking treatment was used, only Ridomil post-treatment was better than the control or Benlate treatments

FLOWERING IN POTS

Successfully rooted cuttings of *S. microphylla* will flower in the following season on very small plants (10 to 12 cm), making attractive small pot plants. Cuttings taken from floriflorus cultivars such as 'Goldilocks' make very attractive tub plants. To be a successful pot plant, the "shelf-life" of a flowering plant must be reasonably long and the plant must withstand conditions experienced in the home. Similarly, the plant form must be attractive. To evaluate the usefulness of *S. microphylla* cultivars in this regard, trials using plant growth regula-

tors to control plant form, and the "shelf-life" of flowering plants were conducted.

Experiment 4: Shelf-life of potted S. microphylla

Method. Potted plants of *S. microphylla* 'Goldilocks' were placed in a shelf-life room at 20°C and 70 to 80% relative humidity with fluorescent lighting. Floral development was assessed using a rating system for flower bud development from tight-bud to fully-open flower to abscission.

Results: Plants with very tight flower buds developed normally and gave a display life of approximately two weeks. Floral development appeared to be normal with seed pods beginning to develop. The foliage withstood the conditions well and new shoots had commenced elongating. The display period was limited by floral abscission but larger plants with more flowers should extend this.

Experiment 5: The use of plant growth regulators to control plant form.

Method: Three rates of Alar (2550, 5100, and 7650 ppm a.i.), maleic hydrazide (60, 120, and 240 ppm a.i.), Ethrel (1440, 2880, and 4320 ppm a.i.), Cycocel (2250, 4400, and 6750 ppm a.i.), and glyphosate (Roundup) (360, 1080, and 1800 ppm a.i.), plus a control (water) were sprayed on to three-week-old *S. microphylla* seedlings three times at intervals of three weeks. The height of each plant was measured initially, prior to each treatment, and three weeks after the completion of the treatments. Trial design was a randomised block with four replications.

Results: Alar, Ethrel, maleic hydrazide and glyphosate significantly reduced the growth of *S. microphylla* seedlings compared to the control or Cycocel. However, phytotoxicity was observed at the two higher rates of glyphosate and tissue damage, distortion, or leaf drop occurred when Ethrel and maleic hydrazide was used. Alar was an effective plant growth regulator on *S. microphylla*.

CONCLUSIONS

S. microphylla cuttings of 'Earlygold', 'Goldie's Mantle', and 'Goldilocks' can be successfully propagated by cuttings in a semi-hard state in late winter, corresponding to the months June, July and August at Levin. Better survival of cuttings could be achieved using Ridomil, Thiram, and Sumisclex sprays than with Benlate.

S. microphylla plants in containers make attractive flowering pot plants and respond to applications of Alar. The development of *S. microphylla* is continuing with the aim of further

improving the propagation and in controlling flowering in containers.

Acknowledgement. We wish to thank Mrs J Cunningham for the able technical assistance given in this project.

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1 Allan, H H 1961· Flora of New Zealand Vol 1, R.E Owen, Government Printer, Wellington, New Zealand

2. Goldie, G N 1976 Description and propagation of the New Zealand *Sophora* species *Proc. Inter Plant Prop. Soc* 26 356-360

MICROFOAM USE FOR WINTER PROTECTION — YOUR FIFTH OPTION

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Cold temperatures and wind are the most obvious problems of winter but when choosing our overwintering techniques there are other factors we should consider: First is the plant and its limitations in coping with fluctuating temperatures during the winter months; second is the climate and the frequency in which temperatures range above or below the average norms. Of all our problems in wintering plants the latter is the most dangerous and most difficult to handle. After examining these factors we can then choose the method or methods of winter protection best suited for our given locations.

There are five options for winter plant protection available to us today:

1. Do nothing at all.
2. Place plants pot-to-pot.
3. Place plants pot-to-pot and cover them with white poly or white poly plus shade cloth — then tack down.
4. Put plants in overwintering structures.
5. Lay plants down and cover with a microfoam insulation blanket first; follow with white poly, then seal air tight.

Why consider microfoam or an insulation blanket as a viable option for winter protection? What are its advantages and disadvantages?

There are three advantages:

1. It minimizes the range between the daily high and low temperatures within that microclimate. It accomplishes this in three ways:

   a. The insulation blanket helps moderate radiant and conduction heat losses by night — and gains by day.

   b. The system is sealed air-tight, therefore gives 100% wind protection. It is obvious this stops desiccation of plant material, but what may be overlooked is that it also stops the loss or gain of heat by means of convection due to the winds.

   c. The system utilizes the benefits of geothermal energy more than any other system in use today. Within the

enclosure the ground below provides warmth by night and helps cool the system by day. Ground temperature remains at about 57°F in our locality.

2. The system is removed from production areas after the winter season is over. There are no structures to work around during the growing months.

3. It is an inexpensive method of overwintering. Cost ranges from 4 to 16 cents per unit, depending on plant size, based on a 5-year product life. Labor to cover and uncover is included in this cost.

The two disadvantages to this method of winter production are: (1) potential buyers cannot inspect nursery stock when covered in this fashion. However, some buyers are impressed with your care of the plants; (2) one cannot inspect the plant material for potential problems without some measure of difficulty. I have found there is very rarely a need to look at the plants during the time they need to be covered. If the plants are in good nutritional condition, we have little or no leaf drop after covering.

The questions now are, "What are the potential problems or hazards when adapting this method of winter protection," and "What can be done, if anything, to resolve these problems?"

The first problem could be standing water, which would result from poor drainage on site. Wintering areas must have a good drainage capability.

The second problem could be fungi resulting from areas of poor drainage or excessive moisture on and around the plants when they are initially covered. We water thoroughly 2 days ahead, which allows almost 2 days for plants to drain. DO NOT COVER PLANTS WHEN A DEW OR FROST IS PRESENT; DO NOT COVER PLANTS ON RAINY DAYS; DO NOT COVER PLANTS WITH A GREAT DEAL OF ORGANIC LITTER ON BLACK PLASTIC. Everything should be dry but the medium in the pots. We use plastic rather than gravel. The plastic helps prevent excess humidity and condensation due to evaporation of water that seeps into the enclosure from surrounding areas.

A third problem could be rodents of various types. The use of poison baits can help if one suspects this to be a problem, but the best defense against rodents is site selection. Open areas where little or no natural cover exists is a deterrent to rodents. No self-respecting rodent is going to be caught in open areas. DO NOT USE THIS METHOD OF WINTER PROTECTION IN WOODED AREAS. During the 7 years in

which we have used this system, less than 1% of the stock lost its salability for spring shipment.

Questions that are frequently asked are: "When do you start covering?" and "When do you uncover your plant material?" There is a simple rule of thumb we use. For covering plants determine the average frost date in the fall, add 45 days, and this is the date to start covering. For example: Our average frost date is October 15, hence we can start covering December 1. The plants are dormant when we cover them, and we ship them dormant. That way they come into bloom at the normal time for the area where they are to be sold and used. The fact that they are dormant also makes shipping easier.

When we cover the plants we first make sure any leaves and litter are removed from the area. We then move plants together and lay them flat heading in opposite directions. We do not double stack. When we finish the bed size has been reduced from 40 × 52 ft. to 24 × 45 ft. We buy white poly in 28- × 100-ft. rolls, which we cut into 28- × 50-ft. pieces. The microfilm comes in 6½ × 250-ft. rolls which we cut to 6½ × 45 ft. We use 4 sheets of microfilm to cover each bed. White poly is then placed over the microfilm. We do not want holes in this as we want the entire bed to be sealed. We hold the poly with dirt shoveled over the edges, which helps keep out rodents. The plants are not damaged by snow accumulation, and there is no structure to fall due to snow or wind. We are now using a material manufactured by a company in High Point, N.C.[1] We feel we can use this material for 6 yrs. with careful handling, although costs are figured on 5-yr. life expectancy.

As to uncovering, determine what your average frost date is in the spring. Ours is April 15; we subtract 45 days from that date, which means we start uncovering around March 1. At that time we pull back the white poly, remove the microfilm and store it, and stand the plants up. We leave the poly sealed on the west side so that it can be easily pulled over the plants in case of a late cold.

In conclusion, my nursery is in the most northern sector associated with the IPPS Southern Region, and my need for overwintering using insulation blankets is greater than the average. It is not uncommon to have unseasonably warm temperatures one week and bitterly cold temperatures the next. But I do believe there are possible areas in which growers farther south may benefit from using this system. The system would be ideal for plants that are marginally hardy for your

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[1] Guilford Packaging and Fiber, Inc., Box 2643, High Point, North Carolina 27261. Phone: 919-889-7167.

location, or plants like *Ilex cornuta* whose root systems are extremely susceptible to damage from temperatures in the 20's F. It may also be helpful in preventing premature bud swelling on flowering shrubs due to unseasonable warm temperatures. It is important to consider carefully your own geographic location. If you have tried this system and found that plants do not go dormant, try covering later and uncovering earlier.

APPLYING FUNGICIDES TO ORNAMENTALS THROUGH OVERHEAD IRRIGATION

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Fungigation, the injection of fungicides into the irrigation system, has been used to apply soil drench treatments for root-rot diseases for several years. It has recently been effective against foliar diseases as reported by Lambe (1). Several forms of fungicides — emulsifiable concentrates, such as Subdue 2E; flowables, such as Daconil 2787; and wettable powders, such as Benlate and Dithane M-45, have been applied through the irrigation system with little problem.

Our application technique is simple, since we irrigate from ponds. A hole is drilled and threaded into the suction pipe close to the centrifugal pump. A ½-in short pipe nipple and valve are installed, being careful to avoid any air leakage through the valve or pipe fittings, which can cause a loss of pump prime. A pipe may connect the valve permanently to a holding tank, or a hose may be attached and simply submerged into a bucket of fungicide solution, as shown in Figure 1.

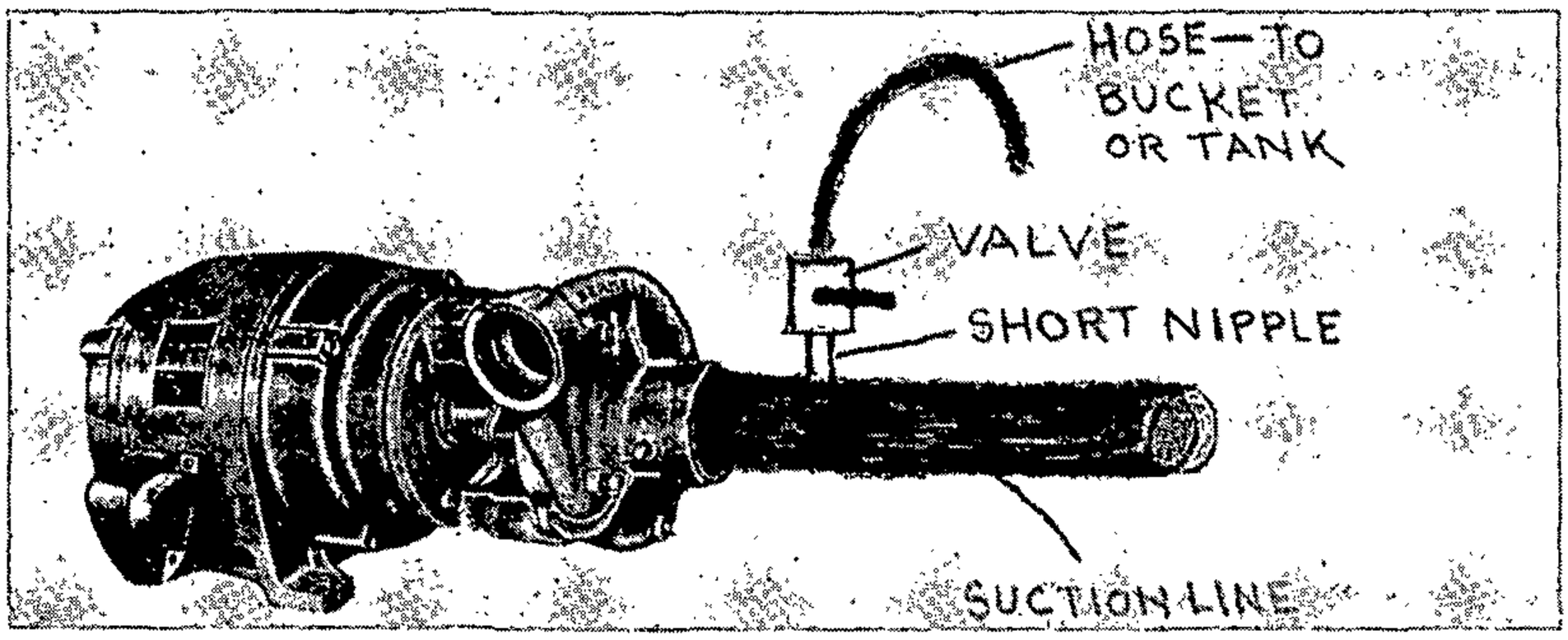

Figure 1. System used for injecting pesticides into overhead irrigation system.

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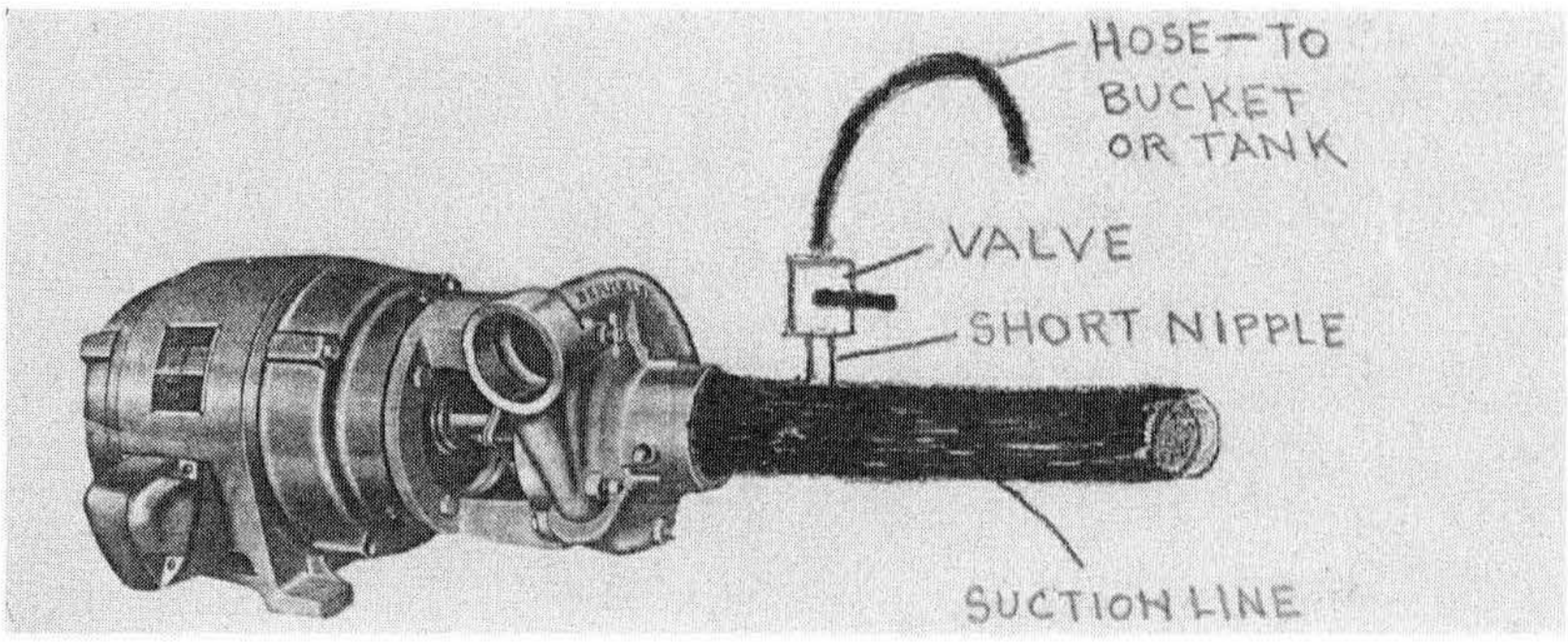

Figure 1. System used for injecting pesticides into overhead irrigation system.

Before injecting the fungicide, the pump is started and sprinkler heads are inspected for proper rotation and any blocked orifices. For smaller areas below pump capacity, the output butterfly or flow restriction valve is adjusted to prevent a back flow of fungicide to the pond. Chlorine and fertilizer injections are suspended during fungigation to prevent chemical interactions.

The measured chemical is stirred into the holding tank previously filled with water and the valve on the suction pipe is partially opened to begin drawing the solution into the pump. The flow rate is controlled over a 5 min interval to allow several rotations of each sprinkler head. The rate of rotation of sprinklers varies from 6 to 12 revolutions during this interval. The fungicide solution is constantly stirred and additional water is added to rinse all material into the pump. Care must be taken not to allow air to be drawn into the pump before closing the valve.

After all the fungicide has entered the system, samples must be taken in the field to determine when the pipes are clear of chemical. A beaker or glass jar is used to collect water samples from a specific sprinkler head. A milky solution, often with foam, indicates the presence of fungicide. With our system 6 to 10 min, depending on distance from the pump, is required to clear the lines. The change from milky to clear samples is surprisingly rapid.

Drench fungigation rates, based on the label rate per 400/ ft^2, are calculated to include roadways and perimeter areas covered by the sprinkler heads. The water samples to determine the completion of fungigation are taken from the sprinkler farthest from the pump. Because watering is recommended to wash off foliage and transport the fungicide into the soil solution, pump shut-down is not critical.

Foliar fungigation rates, based on one to 2 times the label rate per acre, are also calculated to include roadways and perimeter areas. Samples are taken from a sprinkler near the midpoint in the section and the pump is shut down promptly to prevent excessive washoff of fungicide residue.

Fungigation is an important disease control procedure compatible with modern nursery practices. Today's standards of compact quality plants, dense container populations, larger liners, and overwintering practices severely reduce air movement around plant foliage. Container-grown plants receive more frequent overhead irrigation, which increases periods of wet foliage favorable for disease development. Condensation and limited air movement in overwintering houses also produce conditions favorable for fungi and bacteria.

Fungicide sprays applied monthly by a concentrate air-blast sprayer are extended beyond their effective residual period. Biweekly sprays are needed to control *Entomosporium* leaf spot on Fraser photinia (*Photinia* × *fraseri*), and anthracnose scab caused by *Colletotrichum* spp. on *Euonymus japonica* 'Silver King', *E. japonica* 'Gold Spot', and 'Gracilis' [syn. *E. fortunei* var. *radicans* 'Argenteo-variegata']. Other seasonal diseases requiring additional fungicide treatments are *Rhizoctonia solani*, web blight, on *Ilex crenata* 'Helleri' and gumpo azalea (*Rhododendron* 'Gumpo'); and *Botrytis cinerea*, gray mold, on *Gardenia jasminoides* 'Mystery', and various azaleas.

Spray application by hand gun in tightly-packed overwintering houses is time consuming and semi-effective in controlling various foliar diseases. A biweekly fungigation has demonstrated improved disease control.

In summary, fungigation is an excellent labor-saving method to apply soil drenches. We have reduced disease problems in overwintering houses with biweekly applications. Large areas may be covered quickly when weather conditions are unfavorable to spray applications over long intervals. Fungicide residues may be effectively supplemented between scheduled sprays. Phytotoxicity of some fungicides to susceptible plants also appears to have been reduced in fungigation. It is also possible to make foliar applications. However, it is difficult to get even distribution over large areas due to differences in the distance from the source. This method can be used on concentrated small blocks of plants.

LITERATURE CITED

1. Lambe, R.C. 1984. A Comparison of foliar disease prevention on selected woody ornamentals with chlorothalonil applied either fungigation or ground spray. *SNA Research Conference*, Vol. 29.

POSTEMERGENCE HERBICIDES — WHAT WORKS?

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Weed control from preemergence herbicides is often unacceptable for numerous reasons including improper timing and rate of application, weather conditions, or excessive

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Weed control from preemergence herbicides is often unacceptable for numerous reasons including improper timing and rate of application, weather conditions, or excessive

volatilization loss. Hand labor is normally used to remove escape weeds. If weeds are not removed, they compete with ornamental plants for water, nutrients, and light. Weed competition can reduce growth of container-grown plants by 50% or more (4). An alternative to hand weeding of escape grass weeds is now available with the labeling of Fusilade (fluazifop-butyl) and Poast (sethoxydim) herbicides for postemergence application in ornamentals. Fusilade is produced by ICI Americas Inc., Wilmington, Delaware, and Poast by BASF Wyandotte Corp., Parsippany, New Jersey. Both materials control annual and perennial grasses (including quackgrass). Neither of these materials has any activity on nutsedge.

The first symptom of Fusilade and Poast activity is growth cessation, followed by death of the terminal growth points and interveinal reddening of the grass blades. Under ideal growing conditions this may take 5 to 10 days, depending on the grass species, size of the grass plants, application rate, and environmental conditions. With less than optimum conditions it may require 2 weeks for initial symptoms to appear. Grass treated with effective rates of Fusilade or Poast are generally dead no sooner than 2 to 4 weeks after treatment.

APPLICATION RATES AND NUMBER OF APPLICATIONS

In 1982 we compared split applications with single applications of Poast and Fusilade on *Taxus cuspidata* infested with common Bermuda grass. Herbicides were applied on July 29 and August 11 when Bermuda grass runners were 6 to 12 in long. Both herbicides included 1% crop oil concentrate by volume, and spray solution was applied at 20 gpa.

Grass control and phytotoxicity were evaluated 14, 30, 45, and 70 days after application. Rating for phytotoxicity was: 10 = no damage to 1 = dead plant.

For 90% control after 70 days the minimum rates of Fusilade and Poast were ½ and 1 lb/A ai (active ingredient), respectively (Table 1). A single application of ½ lb/A ai of Fusilade, or 2 applications of ¼ lb/A ai, resulted in greater than 95% control of common Bermuda grass. Lower rates resulted in initial dieback, but regrowth occurred. There appeared to be no advantage to applying a higher rate than that required for 90% control after 70 days. Cultivating several weeks after the first application will also help prevent regrowth of perennial grass (6).

Table 1. A comparison of single and split applications of Poast and Fusilade on percent control of Bermuda grass.

The effects of varying application rates				
	Pecent control			
	Days after application			
Treatments	14	30	45	70
Fusilade (single applications)				
¼ lb/A ai	38fg[z]	90a	78b	63ab
½ lb/A ai	42efg	90a	93ab	97a
1 lb/A ai	88ab	100a	98a	100a
2 lb/A ai	90a	98a	100a	100a
Fusilade (split applications)				
¼, ¼ lb/A ai	33g	100a	100a	100a
½, ½ lb/A ai	52defg	100a	100a	100a
1, 1 lb/A ai	62cdef	100a	100a	100a
Poast (single applications)				
¼ lb/A ai	28g	38c	13d	3c
½ lb/A ai	52defg	63b	58c	58b
1 lb/A ai	68abcd	90a	90ab	95a
2 lb/A ai	77abc	92a	95a	95ab
Poast (split applications)				
¼, ¼ lb/A ai	35g	97a	85ab	72ab
½, ½ lb/A ai	52defg	93a	95a	98a
1, 1 lb/A ai	65bcde	98a	100a	98a
Crop oil concentrate				
1% by volume	3h	8d	0d	0c

[z] Figures with the same letters in the same columns are not significantly different from each other at the 5 percent level by Duncan's multiple range test. There was 0 percent control in a check plot.

For annual grasses ¼ lb/A ai of either material provided excellent control when applied once at the correct stage of growth (4 to 8 inches). Fusilade has been reported to be more effective against quack grass than Poast (1) and Poast better than Fusilade against crabgrass (3). Fusilade at 2 lb/A ai provided excellent quack grass control (1).

FACTORS AFFECTING ACTIVITY

Fusilade and Poast are most effective when applied to grasses that are growing rapidly. Generally grass should be treated when 4 to 8 in high, although Johnson grass up to 18 to 24 in can be controlled with the ½ lb/A ai rate. Annual grass larger than 4 to 8 in should be treated with ½ lb/A ai. Applications to grass under stress caused by problems such as drought or excessively high temperature will result in erratic control. Also, mature weeds are more difficult to control than young, actively growing weeds.

Low spray volumes of water have been more effective than large amounts. In our research a volume of 20 gpa was used. For tall or relatively dense grass the spray pressure

should be increased, which would also result in increased volume and rate/acre if all other factors are held constant. Spray pressure of about 40 psi is adequate. With Poast the addition of a crop oil concentrate at the rate of 1% by volume is necessary for optimum activity (1¼ oz/gal, 1 qt/25 gal or 1 gal/100 gal). With Fusilade either a crop oil concentrate at this rate or a non-ionic surfactant should be added. For sensitive species the non-ionic surfactant is recommended. The non-ionic surfactant should be applied at half the rate of the crop oil concentrate or 0.5% by volume.

Fusilade and Poast are rapidly absorbed by the weed's foliage, and under ideal conditions almost complete uptake may occur within an hour. After absorption the chemicals are translocated to both root and shoot growing points. Recent work by Willis (9) showed that uptake of Poast was greater at 95°F with 100% relative humidity (RH) compared to 65°F with 100% RH. At 65°F accumulation of Poast was confined almost completely to the stem and leaves of the treated branch, while at 95°F Poast was translocated throughout all branches of the shoot. These data show that application of both Fusilade and Poast at environmental conditions that favor absorption and translocation will result in increased grass control.

PHYTOTOXICITY

Fusilade and Poast are generally safe when applied over-the-top of ornamentals. Table 2 lists many plants reported in current literature and gives their response to Fusilade and Poast. Most of the plants showing injury from Fusilade were tested with a 1% crop oil concentrate.

Some azaleas have been reported to be sensitive to Fusilade (2,5). After extensive testing it appears that the Hino group of azaleas is the most sensitive of the azaleas commonly grown. Included in this group are 'Hino-crimson', 'Hexe', and 'Hinode-giri'. In 1983 a study was conducted to characterize the effects of Fusilade 4E on growth of 'Hino-crimson' azalea. Application of Fusilade 4E resulted in phytotoxicity symptoms ranging from death of the terminal bud (¼ lb/A ai) to stem dieback 1 to 3 cm in length (1 lb/A ai) (Table 3).

Within 60 days azaleas treated with the ¼ lb/A rate were similar to the untreated plants. Also the non-ionic surfactant, Activate, enhanced the activity of Fusilade 4E. While data are not presented, the increased phytotoxicity with 0.5% Activate occurred mainly at the 1 lb/A rate. Death of the terminal buds resulted in an effect similar to pruning of the plants. Plant height and growth index were suppressed with rates as low as ¼ lb/A ai. Also application of Fusilade at ¼ lb/A resulted in

Table 2. Tolerance of some woody ornamentals to the herbicides, Fusilade and Poast.

Plant species	Fusilade		Poast	
	Safe	Injury	Safe	Injury
Information from literature citation 8[a].				
Buxus sempervirens, Common boxwood	x		x	
Chamaecyparis lawsoniana 'Allumii,'Allum lawson cypress	x		x	
Cotoneaster salicifolius, Willowleaf cotoneaster	x		x	
C. sp , 'Coral Beauty' cotoneaster	x		x	
Euonymus alata, Winged euonymus	x		x	
E flortunei 'Emerald Gaity,' Emerald gaity euonymus	x		x	
Forysythia sp , Weeping forsythia	x		x	
Ilex crenata 'Green Luster,' Green luster Japanese holly	x		x	
Ilex glabra 'Compacta,' Compact inkberry	x		x	
Juniperus horizontalis 'Hughes,' Hughes juniper	x		x	
J sp., 'Blue Pacific,' Blue Pacific juniper	x		x	
Pinus mugo, Dwarf mugo pine	x		x	
Pyracantha coccinea 'Lalandii,' Laland firethorn	x		x	
Pyracantha 'Mohave', Mohave firethorn	x		x	
Rhododendron 'Gibralter', Gibralter azalea	x		x	
R 'Herbert', Herbert azalea (Gable hybrid)	x		x	
R. yedoense var. poukhanense, Korean azalea	x		x	
R. sp , Girard's rose Exbury				
R sp., Mother's Day azalea	x		x	
Syringa patula, Korean lilac	x		x	
Taxus sp., Dense yew	x		x	
Thuja occidentalis 'Techny', Techney American arborvitae	x		x	
Information from literature citation 3[b].				
Acer rubrum, red maple	x	x (slight)	x	
Forsythia sp., Golden bells forsythia	x		x	
Hedra helix, English ivy	x		x	

Table 2. Tolerance of some woody ornamentals to the herbicides, Fusilade and Poast. (continued)

	Fusilade		Poast	
Plant species	Safe	Injury	Safe	Injury
Juniperus chinesis 'Pfitzerana,' Pfitzer juniper	x		x	
Rhododendron sp., Hershey red azalea	x		x	
R 'Roseum Elegans', Roseum elegans rhododendron	x		x	
Taxus × *media* 'Hicksii', Hicks yew	x		x	
Thuja occidentalis 'Globosa' Globe arborvitae	x		x	
Viburnum plicatum, Japanese snowball	x		x	
Information from tests at Auburn University				
Acuba sp , Aucuba	x		x	
Buxus sp , Wintergreen boxwood	x		x	
Cercis canadensis, Eastern redbud		x (marginal leaf burn)		x (marginal leaf burn)
Cornus sp., White dogwood	x			x (some burn)
Cotoneaster sp , Cotoneaster	x		x	
Euonymus sp , Burning bush euonymus	x		x	
Gardenia sp., Gardenia	x		x	
Hydrangea sp., Snowflake hydrangea	x		x	
Ilex crenata 'Hetzii,' Hetz holly	x		x	
Ilex crenata 'Rotundifolia,' Rotundifolia holly	x		x	
Juniperus chinensis 'Pfitzerana Compacta' Nick's compact juniper	x		x	
Juniperus horizontalis 'Plumosa', Andorra juniper	x		x	
J. sp., Blue Pacific juniper	x		x	
Photinia × *fraseri*, Fraser photinia	x		x	
Prunus serrulata 'Kwanzan', kwanzan cherry	x			x
Pyrus calleryana 'Bradford', Bradford pear	x		x	
Rhododendron 'Coral Bells', Coral bells azalea	x		x	
R. 'Hexe', Hexe azalea		x (terminal death	x	
R. 'Hino-crimson', Hino-crimson		x (terminal death)	x	

Table 2. Tolerance of some woody ornamentals to the herbicides, Fusilade and Poast. (continued)

	Fusilade		Poast	
Plant species	Safe	Injury	Safe	Injury
R. 'Hinodegiri', Hinodegiri azalea		x (terminal death)		
R. sp , Deleware Valley white azalea	x		x	
R. sp., Gulf pride azalea	x		x	
R sp., Pride of Mobile azalea	x		x	
R. sp., White gumpo azalea	x		x	
Taxus × *media* 'Hicksii', Hicks yew	x		x	
Vaccinium sp., Blueberry	x			x (marginal leaf burn)

[a] A crop oil concentrate at 190 V/V was used.
[b] Tolerance rating based on use of 1% crop oil concentrate.

increased shoot numbers when evaluated 12 weeks after applications, and consequently, in increased flower number the following spring. Even though azaleas treated with the 1 lb/A rate had greater shoot numbers in late October, there were fewer flowers in April. This is primarily attributed to the delayed shoot flush as a result of the stem dieback. Lateral shoots developed rapidly on plants treated with ¼ lb/A of Fusilade while plants treated with the 1 lb/A rate broke much later. As a result flower bud formation did not occur because of the late developing shoots. These data would suggest that even ¼ lb/A, if applied too late in the season, could potentially reduce flower number.

In summary, phytotoxicity of Fusilade on 'Hino-crimson' azalea has an affect similar to pruning. In fact, the symptoms are similar to a commonly used chemical pruning agent, Off-Shoot-O. If used at the proper rate, growers should not be hesitant to use Fusilade in azalea production. Timing of late season applications is under evaluation.

FUTURE MATERIALS

Fusilade and Poast are among the most recently labeled herbicides for ornamental crops, but what does the future hold for postemergence grass herbicides? Currently, there are about 8 postemergence grass herbicides in the development channels. All these new materials have the common property of rapid absorption by the plant within a few hours. Generally, absorption is equal in target and nontarget plants, but herbicidal effects are evident only in grasses. As with Fusilade and Poast, the moisture status of the targeted grass species is criti-

Table 3. Effects of Fusilade 4E on growth and flowering of container-grown 'Hino-crimson' azalea.

Treatment	lb/A ai	Phytotoxicity — days after treatment 15	30	60	Height (cm)	GI[z]	Per plant shoot numbers 1°	2°	Number of flower buds per plant	Degree of flower opening
Control	0	10.0[y]	10.0	9.9	28.9	31.0	3.6	10.0	85[x]	3.7
Fusilade 4E	¼	8.8	8.7	9.6	23.0	28.7	4.6	12.1	106	3.5
Fusilade 4E	1.0	5.0	5.3	4.9	22.3	26.2	4.3	13.6	45	2.8
Significance Linear		NS	NS	**	**	**	NS	NS	*	NS
Quadratic		**	**	**	*	NS	*	**	*	NS
Activate .25%		8.2	8.5	8.8	24.3	29.1	4.4	7.3	73	3.0
Activate .50%		7.6	7.4	7.5	25.0	28.2	4.6	8.8	88	3.6
Significance		**	**	**	NS	NS	NS	*	*	NS
Fusilade × activate		**	**	**	NS	NS	NS	NS	NS	NS

[z] Plants were treated August 2, 1983. Height, growth index $\frac{\text{height} + \text{width 1} + \text{width 2}}{3}$ and shoot number data were taken October 28, The number of flower buds and degree of flower opening data were taken April 10, 1984.

[y] Phytotoxicity rating scale used was 1 = dead plant, 2 = 3-6 cm stem die back, 4 = 1-3 cm stem dieback, 6 = necrotic leaves and dead terminals, 8 = dead terminals, 10 = normal plant growth.

[z] Degree of flower opening was rated on April 10, 1984, on a scale of 1 to 5 where 1 = no color showing, and 5 = full flower opening.

cal with respect to achieving total control. These products were initially developed for control of Johnson grass and Bermuda grass in cotton and soybean; however, with Fusilade and Poast an ornamental label was given at the same time as the cotton and soybean labels.

During 1983 and 1984 we evaluated several of these new materials with respect to grass control, phytotoxicity, and preemergence activity. Of the materials tested, Assure, Verdict, and SC 1084 have shown good grass control and some limited preemergence activity. In a 1983 test, SC 1084 provided about 4 weeks of preemergence activity; Verdict resulted in similar activity in a 1984 test.

PREEMERGENCE ACTIVITY

Fusilade and Poast are generally recognized as providing no preemergence activity (7). However, Bhowmik (1) reported that both Fusilade and Poast showed residual preemergence activity in controlling annual grasses. In 1983 Fusilade, Poast, and SC 1084 were compared for grass control and duration of any preemergence activity. *Euonymus alata* 'Compacta' plants in containers were overseeded with equal amounts of goosegrass and large crabgrass one month prior to, and again 2 weeks after, herbicide application. Grass seedlings were 4 to 6 inches in height at the time of treatment. This experiment was conducted in July and again in September. SC 1084 provided about 4 weeks of preemergence activity in each experiment, while Fusilade provided about 5 weeks of preemergence activity in Exp. 2. In Exp. 1, Fusilade provided both poor postemergence grass control and no preemergence activity. These results are contrary to subsequent work and probably reflect improper application rates.

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9. Willis, G.D. 1984. Toxicity and translocation of sethoxydim in bermudagrass (*Cynodon dactylon*) as affected by environment. *Weed Science* 32:20-24.

NURSERY MECHANICAL SYSTEMS

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Polk Nursery is located in the heart of peninsular Florida, midway between Tampa and Orlando. The operation was started in 1916 as an *Asparagus setaceus* 'Nanus' [syn. *A. plumosus* 'Nanus'] fernery and was converted 30 years ago to a wholesale woody-stem container nursery. The production today occupies 130 acres. Heated polyhouses cover 15 acres and 80 acres are irrigated for 32°F cold protection. The woody stem production is 85% blooming or showy plants in 6-, 8-, and 10-inch containers. Plants are delivered on company trucks within 200 miles. Over half of the plants are delivered within 72 hours after they are sold. The intensive care and warmth of Florida affords two turns of production with 140 employees and 130 pieces of mechanical equipment. The selection of mechanical equipment that we use was based on a 5-year payout of initial cost and maintenance. The savings may be in reduced labor, increased speed or production, improved quality, lower maintenance, or measurable job dependability. For this to be accomplished, we find that it is most important to build or purchase maintenance-free equipment, have parts and service dependability, get a machine larger than you think the job requires, and use only operators that will care for equipment.

One of the loaders and sprayers that we use has been operating for over 20 years. Our employees show more concern for equipment that does not look neglected. The Bouldin and Lawson flat filler does an excellent job. Our only wish is that this company would build heavy-duty models. It is mandatory that the 28 miles of roadways be maintained for all of the equipment. Water control also is never-ending with 50 in. of rain plus 150 in. of supplemental irrigation.

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The 6- and 8-in. pot-filling equipment that we constructed 3 years ago has performed beyond our wildest dreams with little or no wear after handling 25,000 yds of potting soil.

The system consists of a series of overhead belt conveyors that bring the soil to the containers. These are brought in on a series of trains pulled by a tractor through a 200-ft long illuminated building, which is heated in winter and well-ventilated in summer. Empty containers are positioned on the trains as they move through the building. The soil operator has complete control of the hydraulic-operated conveyor system to discharge soil over 65 ft of trailers without stopping. As the soil is leveled on top of the containers, the potters place the liners in the filled containers. When the train completes these three stations, water and herbicide are applied as plants are on their way to the field. The system is designed to handle 80,000 6-in containers per 9-hr day, 5 days a week.

Since 90% of our human resources are female, it is mandatory to find a dependable system to unload as fast as our new potting system operates, which we have set at 40,000 6-in containers per day. The machine is a large farm tractor with an extra-heavy U-shaped superstructure that supports a 40-ft conveyor on one side and an off-setting counter-weight on the other. The conveyor operator travels along the 40-ft bed and delivers the plants to the unloaders so they do not have to move over 5 ft. The system will also reverse so plants can be removed from the bed if necessary.

Probably we apply more spray per acre in a year than any woody stem nursery. This requires a most dependable assortment of spray equipment, most of which we built ourselves. It has the same extra-heavy-duty tractor with U-shaped superstructure that holds 2 outrigger booms that apply spray to the top or bottom sides of the foliage.

For 15 yrs we have shipped all of our plants on metal racks that separate into 2 parts to make loading in the field faster. The system allows for fast, efficient handling of the racks on and off the field trains, on the loading dock and onto the trucks. Easy inspection of plants being shipped as well as inventory control are tremendous extra benefits.

In summary, it seems impossible today to match the speed that our customers demand, and with reduced production costs, without the most efficient, dependable, maintenance-free mechanical devices that will complement the talent of our human resources.

DIBBLING — A USEFUL FERTILIZER APPLICATION METHOD

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Fertilizer placement studies to test the safety and efficiency of the "dibble" method of applying a resin-coated, controlled-release fertilizer to container or pot-grown plants have been conducted in New Zealand and the United States. Research trials were placed during 1981, 1982 and 1983 at the New Zealand Nursery Research Centre, Massey University, Palmerston North, New Zealand (3,4,5). Similar trials were also placed during 1982 (1) at the University of Arizona and in 1983 at Louisiana State University (2). All trials indicate the "dibble" method of applying a resin-coated, controlled-release fertilizer to new plantings of container-grown woody ornamentals is a safe and efficient cultural practice.

Also, there have been many successful grower trials conducted throughout the country during the past three years. These trials have provided substantial evidence that dibble application offers certain advantages over conventional top-dressing and incorporation methods.

Before we go much further, what is the dibble method of applying fertilizer? Webster defines dibble as "a pointed instrument used to make holes for planting seeds, bulbs, or young plants." Growers refer to the application method of placing a prescribed amount of controlled-release fertilizer into the bottom of a planting hole as the dibble method (Figure 1). The planting hole can be in a container, pot, or in the ground. After the fertilizer is placed in the dibble hole, a well-rooted liner or larger-sized plant is set on top of the fertilizer. The safety of the controlled-release fertilizer helps to insure the success of the dibble application. However, using a soluble fertilizer or a slow-release fertilizer with a large early release, is courting a crop disaster.

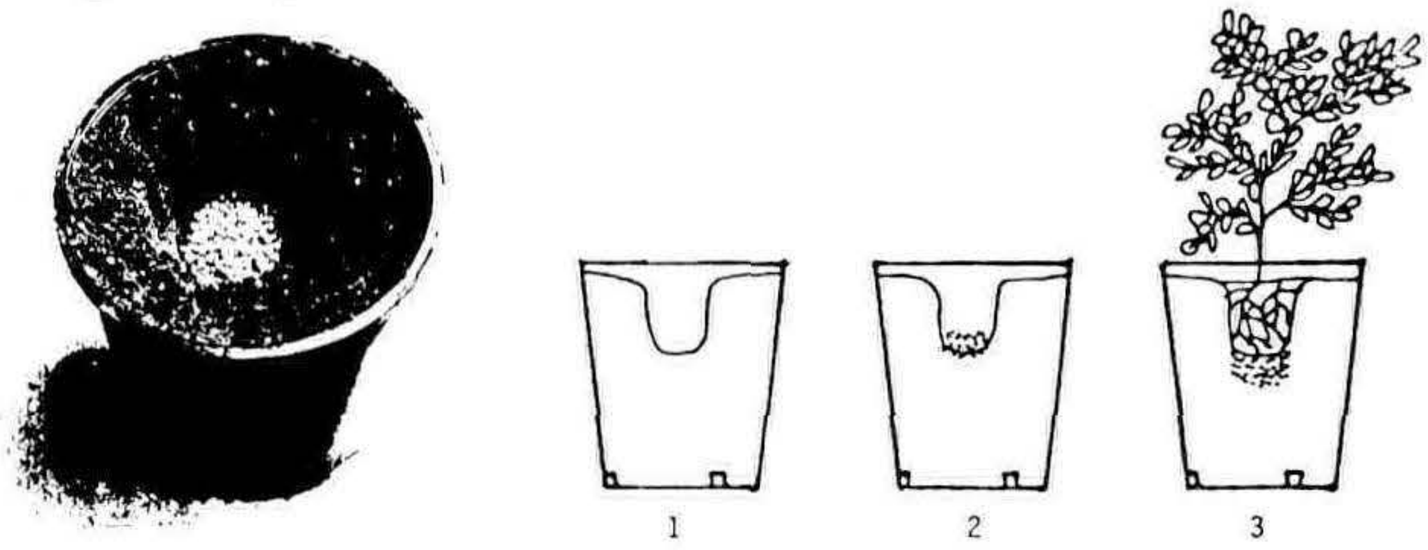

Figure 1. Placement of fertilizer and plant using dibble method of application in container production of plants.

The dibble method is employed mainly at the time a crop is rooted and shifted from the well-rooted liner stage to a 1-gal container or similar size pot. It is also possible to shift a 1-gal size plant to a 3- or 5-gal container. To date, most dibble application is used when shifting woody ornamentals or foliage plants.

At this time there is no recommendation for the dibble application on any shifting larger than a 1-gal plant to a 3- or 5-gal container. More research trials will be required to evaluate benefits derived from large plant shifting up.

Technicians with Sierra Chemical Europe have taken the dibble application method to the field where successful grower trials have been placed with strawberries, leek, Brussels sprouts, and fruit trees. In a sense, using a controlled release fertilizer in a dibble application is quite similar to banding a fertilizer into a planting slot for an agricultural crop. This is a common practice in California strawberry culture.

Sierra Chemical recommends that growers use 8- to 9-mo or longer term products such as Osmocote controlled release fertilizer (18-6-12) when utilizing the dibble application method. Eight- to 9-mo products are ideal because the resin coating is such that release of the product is gentle and gradual, which is a good safety factor in dibble application. No fertilizer with a portion of the prills uncoated is recommended for dibble application for safety reasons.

A critical management practice that will spell success or failure for the dibble system is watering. It is recommended that watering be thorough to the point of leaching immediately after planting and during the establishment period of the plant.

What are the advantages of the dibble application system?

1. Growth of the crop is uniform. The same amount of nutrition is applied to each container, pot, or under each plant in the field.

2. Application can be mechanized. Soil-handling equipment manufacturers have applicators that can be added to potting machines that will automatically apply controlled-release fertilizers in the dibble hole.

3. Fertilizer is not lost if the container or pot is overturned, flooded, weeded, or moved.

4. The availability and utilization of nutrients is optimum. Root growth around the controlled-release fertilizer insures efficient uptake.

5. Field tests indicate an extension of product life. Since the temperature is more uniform in the center of the container or pot, average temperature will be lower and nutrient release will be less.

6. Grower trials indicate success with lower rates of application than with incorporated or topdressed application rates.

7. This type of application does not feed surface weeds.

As one can see, the dibble method of application does offer the grower benefits not available with either the incorporation of fertilizer into a potting medium, or a surface application.

Progressive growers of container, pot, and field-grown crops are always seeking ways for a more effective method of growing plants in order to improve their economic benefits. Growers seeking ways to improve plant growth have been interested and have adopted the dibble application method. It might be said that applying fertilizer in the bottom of the planting hole is a spin-off of the saying, "necessity is the mother of invention."

There have been some failures. Perhaps 5% of the growers testing this practice have stunted or killed plants. Investigations of the problems indicate the use of the wrong product, too high a rate, weak planting stock, poor watering practices, or incorrect application.

We do know that several hundred container nursery stock growers in the U.S., England, and New Zealand have trialed the method. More growers become interested continually and set trials to see for themselves what benefits can be obtained.

Approximately 35% of those having tested the method are using it as a regular practice with a portion of their crop. The portion of the crop may range from 10 to 100%, with a good percentage being in the 30 to 50% range.

The list of plant species produced by the dibble method of application is long and growing daily. It is interesting to note that azaleas are popular plants to fertilize by the dibble method. As we know, azaleas range from salt sensitive to salt tolerant. I believe this plant is a good indicator of the safety of the dibble system.

Current controlled-release fertilizer longevity studies being conducted at four university research stations: University of Florida, Apopka; Louisiana State University, Baton Rouge; Auburn University, Mobile; and the University of Hawaii, Hilo, have demonstrated the safety of the dibble application method. Trials are in progress using 2, 3, and 4 lbs N/yd^3 of

soilless medium. Methods of application are surface, dibble, and incorporation.

The question is asked, "Is the dibble application method for me?" Our suggestion to growers is to set dibble trials with their crops to determine safety, cultural, and economic benefits. A dibbling decision can then be made.

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USE OF DRIP IRRIGATION IN SEEDLING PRODUCTION AND IN TRANSPLANTING ROOTED CUTTINGS

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I speak with only two full years of experience in using drip irrigation in the field. Even with this short experience I am sold on it to the extent that we are expanding its use as fast as our finances and water supplies will permit.

Before we could undertake drip irrigation we had to develop a water supply which we did by digging wells. In the mountains of Tennessee you're lucky to hit *any* water in a well, much less enough for irrigation, but we were fortunate to end up with a total of approximately a 200 gpm supply from 5 wells. These wells pump into a common underground system of 4-inch lines totaling about 25,000 ft in length, making water available to a 200 acre area. With this limited amount of water the use of drip irrigation made good sense because of this method's efficient water use.

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USE OF DRIP IRRIGATION IN SEEDLING PRODUCTION AND IN TRANSPLANTING ROOTED CUTTINGS

HUBERT NICHOLSON

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I speak with only two full years of experience in using drip irrigation in the field. Even with this short experience I am sold on it to the extent that we are expanding its use as fast as our finances and water supplies will permit.

Before we could undertake drip irrigation we had to develop a water supply which we did by digging wells. In the mountains of Tennessee you're lucky to hit *any* water in a well, much less enough for irrigation, but we were fortunate to end up with a total of approximately a 200 gpm supply from 5 wells. These wells pump into a common underground system of 4-inch lines totaling about 25,000 ft in length, making water available to a 200 acre area. With this limited amount of water the use of drip irrigation made good sense because of this method's efficient water use.

PROCEDURES

I will briefly describe five applications of drip irrigation with the pipe on top of the ground.

Five places in our production scheme where we are using drip lines are:

1) Dogwood seed planted in the fall in open fields.
2) Rooted cuttings from the greenhouse planted in the field in June and July.
3) Bench grafts potted in the greenhouse in January and moved to the field in June and July.
4) Hemlock seedlings spring-planted into the open field.
5) Trees spaced out for larger caliper size balled and burlaped production.

1) We plant our dogwood seed in November or December and cover them with sawdust. Ideally, the drip lines should go right on them but sometimes we wait and have to do it during the spring rush. Short stakes or grow-straights hold the drip line where we want it. The drip moisture next spring brings the seed up. We water them all summer and as we bud. The line stays there all winter and is used to grow out the dogwoods next year as 1-year buds.

2) In May we take softwood cuttings of *Prunus*, including Japanese cherry and purple-leaf plum. They are rooted in compartmented trays in the greenhouse under a traveling boom mister. For the past two years these rooted cuttings have been taken to the field in July in 100°F heat, drip lines put on them just as soon as they are planted and left until September. The cuttings then go dormant naturally. The next growing season we grow them on without drip because it is not really needed. However, it would no doubt have helped make larger sizes. We believe we should be getting rooted cuttings into the field a little earlier and hope we can by sharpening up our rooting operation.

3) This past winter we made whip-and-tongue bench grafts of pear, wisteria, zelkova, and flowering locust. We immediately potted them into milk cartons and put in our fog house. With no heat, and humidity at about 75% we got excellent results. They were 12- to 18-in tall by May 15. They should have gone to the field then and placed under drip, but we did not get them out until the 1st week in July. We have better than 90% livability in the field right now.

4) Canadian hemlock seedlings are hard to get started in the open field in our country because of summer heat. In July, 1983, a block of excellent quality seedlings planted in April

were dying fast by midsummer. We put drip lines on the balance and saved them. We replanted the skips that fall and kept the drip on them this past summer with excellent results. We are now of the opinion we can go to the open field with 2-yr conifer seedlings under drip and keep the soil temperature more favorable for growth and successful establishment in the field.

5) Emitters spaced 40-in apart were placed on trees transplanted to 4-ft spacing in the row for growing balled and burlaped material to larger size.

EQUIPMENT

The equipment we are using came from Shemin Nursery Irrigation Department in Atlanta. They have an engineering department that will size and lay out any kind of system to suit your needs. The make of the system is Agrifilm, which originated in Israel.

We are using 3 different spacings of emitters, 18-, 24-, and 40-inch. The closer spacings are used on seedlings and grafts. The 40-inch spacing is used on trees spaced wide apart in the row for ball and burlap production. An interesting sidenote here is the fact that we ran 9,000 ft of line with 40-in spaced emitters through a ¾-in garden hose on a temporary basis. Although we probably cut down the rate/hour, we still got good uniformity of coverage.

This coming year we plan to fertilize through the driplines and apply Subdue fungicide on dogwoods.

SOME DO'S AND DON'TS

DO always use filters and clean them regularly.

DO always use pressure regulators.

DO always walk the lines everytime you turn the water on. Plugged emitters, separated lines, and lines out of rows cut down on efficiency.

DO take the line up carefully. Keep mud and dirt out of them and flush thoroughly before reuse.

DO check the far end of the lines regularly while the water is on so you can correct problems. And you will have some.

DON'T peg down the far end of the drip line. Overnight contraction will separate the line.

DON'T make your individual lines too long. We think about 500 ft is the maximum. If your block has long rows, consider supplying from the middle in each direction.

DON'T try to force the water up hill. You won't get uniform coverage. If a slope is present, let the water run down hill.

DON'T try to hoe weeds and grass over a drip line. You'll cut it all to pieces.

DON'T let the line crawl out of the row. Through expansion and contraction the line will get off the row unless kept in place by stakes or soil on the line. The effectiveness of the water application is cut down if the line is not kept in place.

PROPAGATION OF BAMBOO BY VEGETATIVE MEANS

MICHAEL A. RICHARD
Live Oak Gardens, Ltd.
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Of the hundreds of bamboo species grown in the United States only two are native; most were introduced from Asia. Most bamboo grown by commercial nurseries is used for ornamental purposes; however, the uses seem only limited by man's ingenuity and imagination. At our nursery, located at Jefferson Island, Louisiana, we produce container-grown bamboo of both *clump* and *running* species. Specific problems or limitations exist in propagating these plants.

First we will separate and define the two classes of bamboo currently being propagated on a commercial scale.

Clump-forming bamboo typically produce late summer and autumnal growth, each successive cane developing adjacent to the preceding one. They are generally tropical or subtropical and grow constantly if moisture and temperature are right.

Running bamboo produce sprouts very early in the spring followed by underground development until late fall. Generally this type is from temperate climates. By understanding these simplified characteristics, it becomes apparent that many techniques used for one group will be unsuccessful if used on the other without modification.

Since some bamboo do not flower freely or only rarely, seeds cannot be depended on for propagation. Some species flower only once a century. In addition, most species currently in clonal production are maintained for characteristics favored for particular purposes.

Murashige at Riverside, California reports success with

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meristem culture of *Phyllostachys*. This will offer tremendous possibilities for those species currently considered to be difficult to transplant or propagate and will also provide for rapid multiplication of some clones where propagation material is scarce.

The following information describes techniques with which we have first hand experience. No laboratory techniques are used, only traditional propagation methods are employed at our nursery.

When propagating clump-forming bamboo a tremendous amount of labor and stock planting are required when the old method of hand digging and separating established clumps is used. We begin by dividing the individual rhizomes, preferably the young peripheral ones. The bare-root rhizome is taken in late spring or early summer to ensure ample growing season before winter. The cane is cut back to a foot or two, depending on the size and species.

The rhizome is then potted in a container of appropriate size. We use a standard potting mix of 5 parts ½-in grade pine bark, 1 part coarse washed sand, 10 lb dolomitic lime, 10 lb starter micronutrient blend, and 12 lb sulfur-coated slow-release fertilizer. Propagules are placed in the growing area fully exposed to the elements and watered daily. By the following spring the rhizomes have given rise to numerous small branched rhizomes with pencil-size canes up to 3 ft tall. This is when the multiplication process really begins in earnest. These plants are shaken free of medium and washed in order to better determine the best point to cut. Each culm is cut free at the narrowest part of the rhizome. These are then potted in 1-gal cans without being allowed to dry out and then cut back about half their height. With warming weather these propagules grow rapidly, and the process is repeated. If placed in a heated greenhouse, the rate of multiplication is improved dramatically. Most clump-formers are tropical and are often damaged when left unprotected in containers. Last winter our canned stock survived remarkably well with a 11°F low and with a solid freeze for 3 days. Established plantings were killed to the soil level, however; only container plants lost tips and most foliage. This may be due to conditioning and salt levels.

When more rapid establishment of a salable plant is desired and when sufficient stock is available in containers we merely remove the clump from a 5- or 10-gal container, then cut straight through the ball of roots. After each cut the halves are turned and halved again. Good 5-gal plants will easily produce 8 wedge-shaped divisions consisting of numerous

small canes. Tops are cut back, then potted and placed out in the nursery to continue growing. By the fall we have salable 5-gal plants. In addition to the starter fertilizer and sulfur-coated products, we spoon feed each can with urea formaldehyde products every 6 wks. Some of these plants will be kept to divide for the following crop.

Bambusa glaucescens culm can be cut late in autumn and individual joints inserted vertically in a ground bed, barely covering the dormant buds. By spring many of these buds will develop roots and begin active growth. It is important to note that the current season's canes have insufficient stored nutrient to produce reliable results. Canes each year should be selected. Some have reported success by covering the cane horizontally like sugar cane. We have not been very successful with this method.

Basically if culm size is kept too small by frequent division and limited rooting area, numerous culms develop rather than a few heavy canes.

With respect to running bamboo, timing is much more crucial. Running types produce a tremendous amount of above ground growth in a few weeks in early February and March. Growth of 48 in. per day has been reported from Japan; however, in Louisiana we have measured only 18 in. in a 24-hour period. This is a tremendous drain on the stored nutrient level in the rhizomes. Consequently we have on and off years. The complete culm is pushed up in a few weeks; this is followed by gradual expansion of the rhizomes until the beginning of winter. At this time carbohydrate levels begin to increase in preparation for the following spring's growth. We consider the optimum time to take parts for propagation is in February, just prior to sprouting.

We usually have two types of running bamboo, based solely on stature. Small types, less than ½ in in diameter, are propagated solely by division, whereas larger kinds are produced primarily from rhizomes.

Since the division method has been described already under clump formers, the following information applies to the large running bamboo, mainly the genus *Phyllostachys*. In order to begin a propagation program and continue it year after year without an extraordinary amount of labor, we chose to containerize the whole process.

During February, 1-year-old canes are dug from an established plant, cut back and canned in 10- or 20-gal containers. The cut back is made sufficiently high to preserve some 4 or 5 branches. One-year-old canes in full sun are best since they are adjusted to high light levels, branch lower, and are usually

easier to remove. These can easily be spotted since the protective sheath about the base remains intact only for the 1st year, decomposing before the 2nd year.

Another method which we employ involves digging 1-year-old rhizomes, which are usually barely covered by 2 or 3 in. of topsoil and leaf litter. One-year-old rhizomes are also covered by a protective paper-like sheath. Once you find a suitable rhizome, you can often rip it up like a cable 6 or 8 ft at a time. These must be kept moist before planting, or viability is seriously reduced. The heavier rhizomes produce the best results; in addition, the larger the pieces, the stronger the growth. We cut this rhizome into 1-ft sections and place on an angle in 5-gal cans for large species with ¾-in. thick rhizomes. Smaller rhizomes can be placed in smaller cans, with lengths reduced proportionate to the diameter and can size. After 2 years these plants will have produced sufficient number of rhizomes to allow removal of material for propagation.

The increase begins at this point. The plants are removed from the containers after this means destroying the container since rhizomes will have burst the can, or are so tight that you must cut the can to remove it. This is also performed in February. Now exposed, the end of the rhizome is grasped and pulled free from the ball that it encircles. If roots are too tough, hand shears make quick work of this. The rhizome is cut in 6-in. sections and potted directly while still fresh. The buds nearest the top develop. This method requires that new strong stock plants be coming on for each new crop. This stripping of rhizomes does not ruin the stock plant since only exterior rhizomes are removed. The reason for bringing in new stock is related to the root-bound condition that quickly develops. Shift up to a larger size is only practical to a point due to the excessive weight involved in healthy stock. We have used cans as large as 45-gal but feel that 20 gal is more practical. This method produces all fresh previous-year's rhizomes with tremendous nutrient level due to high fertility rates.

A major problem with this method is the tendency of the plants to escape through the drainage holes. This makes removal of the container very difficult. The major advantage is the ease with which the rhizomes are made available for propagation. When space is at a premium, many different kinds can be maintained, whereas in the soil they tend to grow together and become impossible to separate since some are almost indistinguishable from each other except when sprouting.

In summary, we may conclude that the most important element to consider when propagating bamboo is timing to coincide with the distinct growth cycle of the plant.

AZALEA PROPAGATION AND GROWING-ON AS LINERS

GARY P. TAYLOR

Chesapeake Nurseries, Inc.
Pemberton Drive
Salisbury, Maryland 21801

Chesapeake Nurseries is a wholesale grower of broad-leaved evergreens. We are located on the lower Eastern Shore of Maryland, 30 miles from the Atlantic Ocean and from Chesapeake Bay. Most of the Eastern Shore consists of farm land with a large poultry production industry, moderate seafood production industry, and a small amount of light industry. Chesapeake Nurseries has been in business for 26 years and sells mainly to metropolitan areas in and around Washington, D.C., Baltimore, Philadelphia, New Jersey, New York, and New England. At Chesapeake Nurseries we attribute our success to one thing in particular — *quality.*

My job as greenhouse manager is to produce heavy transplants and liners that are ready as soon as possible to go in the field and grow well.

PROPAGATION

At Chesapeake Nurseries we propagate azaleas, rhododendrons, *Ilex*, *Pieris*, and other broad-leaved evergreens. Azaleas, our main crop, is the topic of this discussion.

All of our propagation is done during the months of June through August. Azalea cuttings are taken from healthy, vigorous plants that will be sold later in the season. We take cuttings that have a thick caliper of the stems — not toothpick thin. With azaleas, thick stems will root much better and give us the quality we strive for. We take our cuttings in the morning while the plants are still moist and cool. Then they are placed in styrofoam coolers with ice to keep them fresh and then are sent to the propagation shed.

After the azalea cuttings arrive at the propagation shed, they are dipped in a fungicide tank containing a captan solution using 1 lb of 50% captan WP to 100 gal of water. Cuttings are then placed loosely back into the coolers to keep them from heating which would ruin them. No ice is used at this time, for ice will also burn cuttings if it touches the foliage. Every cooler contains a label indicating cultivar.

Next, our propagation crew starts pinching off the soft growth, leaving 4 to 6 leaves and stripping off the rest. They then take a handful of about 15 cuttings and cut the bottom stems at the desired length. The entire cutting usually measures 4 to 5 inches long. The cultivar determines the length.

This way, after they are rooted, all will be the same height.

The sticking crew starts sticking while the cuttings are being made up so the cuttings will not dry out. We use plastic flats measuring 14 × 19 × 2¼ in. These flats have been dipped in a disinfectant (1 part bleach and 9 parts water) and filled with a medium consisting of 50% peat and 50% perlite. With this medium we get the drainage that is so important in rooting azaleas. We do not use any hormone because we normally get 80% to 90% take. The cutting is stuck to a depth of 1½ in. Each flat contains 96 cuttings. This spacing allows for air movement and space to develop a strong root system.

As the cuttings are stuck, they are placed in greenhouses under about 50% shade. These houses have been sprayed with a disinfectant such as Physan 20, using 1 tsp./gal. water. Also, the water has been on ahead of time to build up the humidity. We have a 24-hour clock and a 30-minute clock in every house used for propagation. For the first two weeks the water comes on for 15 sec every 7½ min from 8:00 a.m. to 7:00 p.m. During the evening, 7:00 p.m. to 8:00 p.m., the water comes on for 15 sec every 30 min. This assures us that the humidity stays at a desired level (70% to 80% RH). We gradually stop running water in the evenings, usually within a 2-wk period. Also, after 2 weeks, the daytime watering is decreased, weather permitting, to 15 sec every 15 min. During this time of rooting (6 to 8 wk) we keep a check on the stems for any kind of stem rot. This will tell us if we are watering too frequently. We keep the houses vented during the daylight hours and closed during the evening. After rooting is evident, the vents are left open 24 hr a day. This helps prevent fungus problems.

Our fungicide program consists of weekly applications of one of 3 fungicides: Benlate (benomyl) Exotherm Termil (chlorothalonil) — (Smoke Bomb), or 7.5% captan dust. Each week a different fungicide is used.

GROWING AS LINERS

All of our rooted cuttings are graded before they are transplanted into flats. We check them for a strong root system; weak ones are either thrown away or restuck.

One cu. yd. of the transplanting medium that we use consists of 11% Canadian peat and 89% old pine bark, along with 5 lb limestone, 1¾ lbs phosphorus, 1½ lbs Aqua-Grow, and ½ lb fritted trace elements. The mixing is done in a 2 cu. yd. Bouldin & Lawson mixer. This mix gives good drainage.

The rooted cuttings are planted in two types of flats. One is wood, 24½ × 15 × 2¾ in. The other, plastic, called a Kadon flat, measures 20½ × 14¾ × 3¾ in. The liners are planted 3 in.

apart using a board the size of the flat with dowels making the holes. Azaleas grow well in both of these flats. After they are planted in flats, the liners go into heated greenhouses with a nighttime temperature of 55°F.

After most of the planting is done, usually by the end of November, we start taking soil samples every 3 wk to monitor the soluble salts and nutritional levels. Our liners usually grow well with a pH around 5.5.

Fertilizing is done only after we see fresh new roots started, usually by the third week. We use Peters liquid fertilizer, 20-20-20, at a low rate (1¼ lbs/100 ft^2) every 2 to 3 weeks. Then, by late February we apply Osmocote 18-6-12 at a rate of 10 lbs/1000 ft^2. Also at this time we increase our liquid rate to 1 lb/ft^2. The amount of top growth will determine the time to change.

Our fungicide program is the same as during the propagation except the applications are made every 3 weeks instead of weekly. Pesticides are used whenever necessary. We use Orthene (acephate) at a rate of 1 tsp./gal. water. This gives us good control for mites and leafrollers, our biggest problems.

By mid-April we start grading the liners before they are sent to the field where they are planted in raised beds. Grading is done by first cutting everything into cubes. Each azalea is graded as a #1 or #2, according to the amount of root, caliper of stem, and top size.

SUMMARY

We go through some extra motions and added expense to grow a top quality azalea transplant within 9 months. In our area this period includes a great deal of low temperature and low light weather conditions.

Growing azaleas or any other liners in greenhouses requires the full attention of the greenhouse manager. Observation on a day-to-day basis is necessary. Close observation will enable a grower to recognize the many little signals that a cutting or transplant gives to indicate the proper or improper level of air, water, temperature, humidity, nutrients, chemicals, or other factors. Extra care in growing a good liner will always pay off in producing a good finished plant.

AZALEA FORCING

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The forcing of azaleas is very easy as it is done every year by nature. As soon as the buds are mature and winter comes they will be cooled naturally. Sometimes they get more than they need but they usually bloom when it warms up in the spring.

We force azaleas from September to Mother's Day. The plants for September flowering are put into the cooler the latter part of June.

We produce several sizes including 5- to 6-in head in 6-in containers, 7-in head in 10-in containers, 8- to 12-in head in tubs. Production requires 12 to 18 months depending on plant size. We ship in our own trucks.

PREPARATION OF AZALEAS FOR THE COOLER

The plants are graded for bud development. If the bud can be felt or seen, it will usually cool and bloom. We grow about 40 early, late, and mid-season cultivars. They all will cool and bloom at anytime, but the later cultivars are slower and take up greenhouse space for a longer time. We prefer not to cool the later-blooming cultivars until the first of the year. They will then bloom on our schedule.

After the azaleas are graded the most important part is to drench the plants with water. This is very important in two ways. It leaches out soluble salts that tend to burn the foliage during cooling and puts plenty of moisture in the plants. This will also insure that the cooler will have 90% humidity during the cooling process. The plants will not have to be watered again until taken out of the cooler. However, if they are left longer than 4 weeks they must be checked for water. The azaleas plants are packed and put in the cooler as soon as the foliage has dried after drenching.

COOLER BUILDING

Our experience has shown that a cooler building should be built as tall as possible for the most even cooling. The coolers we now have are 9 and 10 ft tall, with a cooler under construction 18 ft tall. The original 2 coolers were built 34 × 64 × 10 ft. One is concrete block and the other is frame. The third cooler is 30 × 30 × 9 ft and is a prefabricated commercial

cooler. There are 2 in of urethane blown on the walls and 3 in on the ceiling. The concrete floor has 4 in of polystyrene under the concrete. All new coolers will be built out of concrete block; we find it to be the most economical.

All the coolers will hold a temperature of 36°F at 95°F outside temperature. Cooler space is also rented from tomato packing houses and commercial cold storage. The rentals work out quite well and would be the cheaper way to cool azaleas if it were not for the inconvenience of having them away from the growing area.

COOLING

Through the years we have experimented with many different temperatures. Higher temperatures and lights were used. We have also used applications of gibberellic acid. What we have found to be the best for the azaleas, and the most economical for us, is a temperature of 36° to 38°F. The azaleas plants are left in the cooler for 28 days. We have tried cooling 3 to 6 wks but have found that with 4 weeks of cooling we get good results, as the azaleas bloom evenly.

FORCING

The azaleas are taken out of the cooler and placed in double-poly greenhouses. We do not use any shade on the poly houses. There is 25 to 40% shade depending on the age of the poly. Too much shade will delay flowering for up to 2 wks. After spacing, azaleas are fed liquid fertilizer with a 20-20-20 solution at the rate of 500 ppm. The night temperature is held at 60°F. During daylight hours we ventilate when the inside temperature reaches 80°F.

Our spray program is minimal. The azaleas are sprayed one time with Benlate (benomyl); and Daconil (chlorothalonil), after being taken out of the cooler. Insects are a minor problem with forcing azaleas except in the spring when the temperature is above 80°F. Thrips then invade the flower beds. The best control we have found is Dycarb (bendiocarb). It does not leave any residue on the blooms or foliage nor burn the open flowers. Bayleton (triadimefon) is a very effective spray that we use to control flower blight, *Ovulinia* spp., on azaleas. Bayleton is sprayed on the buds when they are beginning to show color. Bayleton is absorbed rapidly and works systemically from within the plant. Good coverage and wetting of the foliage is necessary. Rainfall or sprinkler irrigation, after ½ hour following application does not decrease effectiveness. Bayleton leaves no residue and the flowers will last much longer with its use.

Within two weeks the azalea buds will begin to swell and another problem arises. The azaleas not only bloom but they grow vegetatively. Sideshoots start growing around the bud. With many cultivars this is no problem, but on some the shoots grow so fast that they blow out the bud — it turns brown and dies. These shoots have to be removed by hand, a very costly operation. We have found that spraying with B-Nine will slow down the growth of sideshoots. B-Nine does not burn flower petals and we have found no adverse effects from its use. We apply B-Nine when the sideshoots are about ¼ in in length. This is a very economical way of stopping sideshoots.

In summary, the parts of the operation that are very important are: Plants must be drenched with water before being put into the cooler, and a temperature of 36° to 38°F must be maintained for 28 days. If these procedures are followed, azaleas stay on a schedule for flowering very well. We are able to grade flowering azaleas the third week out of the cooler and they will all be flowering by the sixth week.

Some azalea cultivars that perform well for us are: *Rhododendron* 'Red Ruffles', *R.* 'Gloria Gish', *R.* 'Dorothy Gish', *R.* 'Road Runner', and *R.* 'Alaska'.

COMPUTERIZED PRODUCTION RECORDS

JOHN L. MACHEN, SR.
Mobjack Nurseries
Route 660
Mobjack, Virginia 23118

At Mobjack Nurseries we have approximately 7 acres of container production and approximately 50 acres of field production. Our nursery is small but still needs good records. In our nursery production records are maintained on a microcomputer which uses dBase II. Our production records consist of 3 separate but closely related inventories. They are:

1. New Plant Inventory
   A. All seedlings and cuttings we produce
   B. All liners or plants we buy to grow on to larger sizes
2. Production Inventory
   A. All plants planted in the fields
   B. All plants planted in the container in which they will be sold

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3. Salable Plants Inventory
   A. All plants deemed ready for sale

Each of these three inventories is maintained in a separate data-base file. Each data-base file consists of individual data-base records for groups of plants of the same cultivar, size, container size, and location.

In Table 1 we see a data-base record from the New Plant inventory (NP.DBF). Each bit of information (compno, vendno, quant, cost) is a data-base field within a data-base record.

The first 3 digits of the computer number denote the cultivar of the plants in the group. The next 2 digits denote the size of the plant. The last 2 digits tell the type of container the plants are in.

Table 1. Data base record from the New Plant Inventory (NP.DBF).

RECORD #	00058
COMPNO	: 0183'BR :
VENDNO	: 22:
QUANT	: 100:
COST	: 7.00:
ADATE	:F84 :
PDATE	:1184:
NAME	:ACER *palmatum* 'Atropurpureum'
SIZE	:3-4' :
SCODE	:18:
PACK	:BR :
PCODE	: 2:
YDATE	:SP88
YLD	: 35.00:
DEST1	:F :
DEST2	: :
DEST3	: :
TCOST	: 700.00:
TYLD	: 3500.00:
STATUS	:P:

The Vendno field tells the computer number of the supplier of the plants. The Quant and Cost fields are obvious. The ADate field tells when the plant will be available, whether we propagate it ourselves, or whether it is purchased. Name, size and packing are obvious. SCode and PCode facilitate sorting and listing in various reports. YDate and Yld tell us when we have projected that this group of plants will be salable and an anticipated sales price. Dest 1, 2, and 3 are used if this plant will be processed (stepped up to larger containers, or planted in fields before it becomes salable). Total Cost and Total Yld are obvious. Status is another field we use to select this record for various reports.

As indicated above, if one group of plants has reached its final growing destination, it is moved from the New Plant Inventory to the Production Inventory (PR.DBF).

In Table 2, we see a record from the Production Inventory. Most of the fields are identical, some have been dropped and a Field Data Base showing the location of this group of plants has been added. More about this later.

Table 2. Record from the Production Inventory

RECORD #	00001
COMPNO	: 0183'BB :
QUANT	: 100:
PRICE	: 10.00:
YDATE	:SP88:
YLD	: 35.00:
LOCATION	WHB :
DEST	:B/B :
NAME	:Acer *palmatum* 'Atropurpureum'
SIZE	:3-4'
SCODE	:18:
PACK	:BB :
PCODE	:21:
TPRICE	: 1000.00:
TYLD	: 3500.00:
STATUS	: :

The Salable Plant Inventory is made up of those records from the Production Inventory where the Y(ield) Date Field indicates that these plants are now salable. Salable plant inventory for spring, 1985, would contain all Production records with Y(ield) Date = S 85.

These 3 data-base files then would contain all of the plants in all stages that we deal with. From the information contained in these 3 files we have developed various reports which help us to monitor production, plan purchases, and anticipate sales income. These reports are as follows:

I. *New Plants Listed by Vendor:* The report is produced from the NP.DBF. Plants purchased go into the NP.DBF as soon as we secure a confirmation from our vendor, and plants which we propagate are entered as soon as we consider a crop of cuttings or seedlings to be reasonably certain (see Table 3). Thus, this report becomes a forecasting tool. It is monitored, updated and reprinted as changes dictate. Cancellation of orders for liners, crop failures, and changes in production schemes for new plants can all be reflected at once. The report thus gives our container-production and field-planting crews an up-to-date schedule of when to expect to process such cultivars, how many, and what size the plants will be.

Table 3. New plants (fall spring, 1984-85) listed by vendor

VNO	RNO	QUANT	NAME	SIZE	PACK	COST	AMOUNT	ADT. S
	38	0				0 00	0.00	
	123	0				0 00	0.00	
1	198	700	*Acer palmatum* 'Bloodgood'	2-4″	PT	0.75	525.00	1284
1	200	150	*Acer palmatum* 'Bloodgood'	2-4″	RP	0.60	90.00	1284
1	188	425	*Buxus sempervirens* 'Fastigiata'	2-4″	RP	0.40	170.00	1284
1	207	2900	*Cotoneaster dammeri* 'Royal Beauty'	2-4″	PT	0.60	1740.00	1284
1	210	200	*C. salicifolia* 'Scarlet Leader'	2-4″	PT	0.60	120 00	1284

II. *New Plants Listed by Destination at the Nursery:* This report, very similar to the one above, will sort all new plants according to the container size they are to be planted in. This report develops our container purchase order for each season. It also lists all plants designated for field planting and assists in planning how much new ground will be needed and where.

III. *Plants Transferred Listed by Location:* This report (Table 4) is prepared from field or container planting notes, which reflect the actual count of plants processed, not the projections. We all know these two can differ for a number of reasons. The contents of this report will be integrated into the production inventory. This report is a record of these transfers.

Table 4. Plants transfered to fields or step-up listed by new location

RNO	QUANT	NAME	COST	TCOST	YDT	YIELD	T YIELD	LOCATION
6	360	*Ilex* × *attenuata* 'Fosteri'	2 50	900.00	F88	50 00	18000 00	NEK1
7	60	*Cupressocyparis leylandi*	4.00	240 00	F87	40 00	2400 00	NEK2
8	360	*Ilex crenata* 'Cherokee'	2 50	900 00	F88	35 00	12600 00	NEK3
9	60	× *Cupressocyparis leylandi*	4 00	240 00	F87	40 00	2400.00	NEL1
10	240	*Ilex* 'Dr Kasaab'	2.50	600.00	F89	45 00	10800 00	NEL2

IV. *Plants Listed by Location:* This report lists all plants in the production inventory by location. A copy of this report, triple spaced, is used in our physical inventory count made in December and again in June (Table 5). Changes in count, size, values or anticipated Y(ield) Date or Yield are made in the field on this report. In field growing some cultivars in a group will have too many different sizes to record on this inventory sheet, so we use an inventory form (Table 6), which is keyed by code number on the inventory sheet. When the inventory is completed, the inventory sheet and inventory are updated on the computer.

V. *Projection by Yield Date:* After each physical inventory we print this report to reflect changes and updating to give an estimate as to which plants will sell, when, and for how much (Table 5). This document is used by the field supervisor and container supervisor to monitor progress toward anticipated

goals. Before the physical inventory is taken, they have already formed opinions as to whether a particular group of plants is on schedule, how many will sell at a given time, and how many we will hold to grow to a large size. Decisions can be made as to the advisability of selling or holding from the standpoint of financial management. For convenience this report is printed with plants sorted by Y(ield) Date for each *selling season.*

Table 5. Inv:Form plants listed by location.

RNO	COMPNO	QUANT	NAME	SIZE	PACK	YDATE	YIELD	LOC
668	469 3'BB	245	*Ilex × attenuata* 'Fosteri'	3-4'	B/B	F85	80.00	FAA
669	018 BB	26	*Acer palmatum* 'Atropurpureum'	000 STOCK	B/B		150.00	FAA
670	733 7'BB	41	*Pinus parviflora* 'Glauca'	000	B/B	F84	60.00	FAA
		21		7-8'		F84	65.00	
		20		8-10'			85.00	
671	442 3'BB	5	*Ilex crenata* 'Convexa' (male)	3-4'	B/B	F84	25 00	FAA
		5		3-4'		F84	26.00	FAA
672	053 3ABB	1	*Acer rubrum* 'October Glory' Delete	3-3½" CAL	B/B	F84	100 00	FAA
673	730 3'BB	7	*Pinus cembra* 'Nana'	3-4'	B/B		40.00	FAA
		4		4-5'			50.00	
		3		5-6'			60 00	
674	541 6'BB	5	*Juniperus chinensis* 'Robust Green' Delete	6-8'	B/B	F84	55 00	FAA
675	503 6'BB	5	*Ilex pedunculosa* (female)	6-8"	B/B		100 00	FAA STOCK
676	466 8'BB	3	*Ilex* 'Dr Kasaab'	8-10'	B/B		100.00	FAA STOCK

Table 6. Inventory form

Mobjack Nurseries Inv:Form Location: FAA Page No. 1

RNO	COMPNO	QUANT	SIZE	PACK	YDATE	YLD	LOCATION	NOTES
668		160	4-4½'	BB	F85	40.00	FAA 1	
		60	5-6'	BB	F85	50.00	FAA 1	
		25	6-7'	BB	F86	60.00	FAA 1	

VI. *Salable Plants Listed by Y(ield) Date:* This report lists all plants where Y(ield) date is equal to the upcoming sales season and is in fact our Salable Plant Inventory (Table 7).

Table 7. *Salable Plants Intventory Spring 1985*

RNO	COMPNO	QUANT	NAME	SIZE	PACK	YIELD	TOTAL	LOCAT
138	1134154Q	50	*Iris kaempferi* 'Gekkeikan'	15-18"	4QT	2 75	137 50	
137	1133154Q	50	*Iris kaempferi* 'Hakubotan'	15-18"	4QT	2.75	137.50	
140	1136154Q	50	*Iris kaempferi* 'Kaiohseio'	15-18"	4QT	2 75	137 50	
141	1137154Q	50	*Iris kaempferi* 'Murekorad'	15-18"	4QT	2 75	137.50	
135	1131154Q	50	*Iris kaempferi* 'Pink Lady'	15-18"	4QT	2.75	137.50	
117	1153154Q	100	*Iris siberica* (purple & yellow)	15-18"	4QT	2 75	275 00	

VII. *Price List:* The records of all the cultivars and sizes we want in our sales catalog are keyed in the Status Field, and we print our catalog using a formating program from the Sales Inventory.

VIII. *Special List:* For groups of plants too small to list in

our catalog we print a special list. As these groups usually sell out quickly this relieves some of the need to update our catalog frequently.

SUMMARY

We are well aware that "forecasting" future sales in the nursery business is ticklish and that a wide margin of error is possible. However, we feel that this system, carefully monitored and regularly updated, provides us with a plan. We feel it is essential to know well in advance what we have in the pipeline for future sales in field and container production. Knowing well in advance affords us opportunity to decide when it is most advantageous to sell our field-grown material and to select those container-grown plants that best compliment field sales to produce a predetermined gross sales income.

EUROPEAN GEMS: WHAT LOOKS GOOD

RICHARD J. STADTHERR
117 Horticulture Building
Louisiana State University
Baton Rouge, Louisiana 70808

BULBS

The Netherlands is noted for their bulbs, and many new hybrids are seen among amaryllis, daffodils, tulips and lilies. There is variegated foliage with stripes of white, maroon, or purple in species hybrid tulips as well as multiflowered stalks with up to 6 flowers on each. The best new daffodil seen was a dark yellow, large-cupped cultivar named 'Cyclops'. *Crocosmia masoniorum*, a bright orange-red montbrietia, blooms from June into September at Inverewe.

HERBACEOUS MATERIAL

'Beatrix', a beautiful rose-flowered gerbera, is outstanding in the greenhouse of Keukenhof. Two excellent members of the smartweed family are *Polygonum affine* 'Donald Lowndes' and *Polygonum bistorta* 'Superbum'; both bloom over a long period of time but are most effective in late summer to early fall. They are best when given part shade and moist soil.

In spring wallflower, *Cheiranthus cheiri*, a biennial, was seen frequently, especially in England. *Astilbe* × *arendsii* hybrids from white to pink to red make a colorful display from late summer to early fall. The Venidio-Arctotis hybrid African

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daisy is an excellent cut flower as seen in the Chelsea show. In late summer and early fall a small-flowered calceolaria hybrid was found planted with fibrous begonias, ageratum and other bedding plants. These floriferous plants in bright yellow to red shades were seen throughout the Alpine countries. There were several genera with the common name of dusty miller. They are seen most often in the British Isles where their silvery fern-like foliage is used for contrast. Most of these are *Senecio cineraria*.

SHRUBS

Forcing azaleas, 'Madame Joseph Huersel' (rose), and 'Joseph Huersel' (red), have large semi-double flowers and are exquisite. *Cytisus* × *praecox*, Warminster broom, is an irregular mass of yellow flowers in May in the Netherlands and England. Similar, but with dark pink flowers, is *C.* 'Hollandia'. The flowering red currant, *Ribes sanguineum* 'Atrorubens', is seen frequently flowering with the spring bulbs. Darwin's barberry, *Berberis darwinii*, is seen in Dijon, France in early May. *Choisya ternata* is in full bloom in mid-September in Inverewe Gardens in northern Scotland. Many cultivars of the Knaphill and Exbury azaleas give much color to the early spring gardens throughout Europe. The big-leaved, large evergreen rhododendrons flower prolifically and are tree-like in stature. One of the most attractive white-flowering shrubs is *Prunus laurocerasus* 'Otto Lyken'. This cherry laurel with lustrous green leaves is covered with pure white upright racemes about 3 in. long. 'Lord Louis', a hybrid tea rose, created quite a stir in the Chelsea show for it is reputed to be both black spot and mildew resistant. *Ceanothus* hybrid 'Glorie de Versailles' has beautiful blue, rounded flower clusters in late August and early September and attractive shiny, dark green, round leaves. The hydrangeas, with fertile center flowers surrounded by sterile ones, come in white and a dark rose pink. These were seen at the Chelsa show. A tricolor cultivar is growing in the Royal Botanic Garden at Edinburgh and flowering in September. These are probably all cultivars of *Hydrangea macrophylla*, or hybrids.

Itea ilicifolia has interesting long catkins about a foot long in late July in Villa Taranto in northern Italy. The holly-like leaves are around 4 in. long. Just a few days earlier, *Aesculus parviflora*, bottlebrush buckeye, can be seen in Heidelberg, Germany near its famous castle. *Euphorbia amygdaloides* has interesting purplish leaves near the tops of the plants. *Fuchsia magellanica* 'Variegata' is seen frequently in Europe. The plants are in bloom and are very attractive from late spring into September. A large rounded shrub with white fragrant

flowers blooming at Inverewe, Scotland, is *Eucryphia* × *nymansensis*, according to a workman. It was most attractive. Not far from this shrub is a big specimen of *Eucryphia glutinosa*, which was past maturity in flowering on September 20. This Chilean native listed for Zone 9 and 10 was growing well at Inverewe located at a latitude north of Moscow, Russia. The Inverewe area climate is obviously moderated greatly by the Gulf Stream. 'Sharoban' is a very dwarf form of *Pinus parviflora*, the Japanese white pine, which is frequently used for bonsai. *Fascicularia pitcairnifolia* is a most unusual bromeliad also seen at Inverewe. It probably would grow only in Zone 10 in the continental U.S. Another more tropical shrub thriving there is *Olearia moschata*, a member of the tree aster or daisy-bush genus. It is a large rounded shrub with grayish leaves. Eucalyptus, callistemon, and magnolia are a few other exotic plants which will grow there.

Several different cotoneasters are also there. Most interesting is *Cotoneaster fulgens*, a large sprawling bush covered with reddish fruits. *Cotoneaster bullatus* has red cherry-like fruits. This shrub is grown as a standard. Another cotoneaster, seen in a park in Heidelberg, appeared to be *Cotoneaster salicifolius*; however, no label was found on this very attractive arching shrub with bright red berries and glossy green lanceolate rugose leaves.

TREES

Near the castle in Heidelberg is a fine specimen of *Fraxinus excelsoir* 'Pendula', weeping European ash. Another weeping tree seen at Bodnant in Wales, was called *Betula pendula* 'Tristis', weeping Européan birch. However, the most spectacular tree seen is *Acer* × *heggi*. A beautiful specimen was seen in the Canterbury area, England. In early May the newly-expanded leaves are colored a yellowish-beige tinted pink on the margins. When a remark was made about the beautiful coloration, the owner replied, "You should see it in fall. It would knock your eyes out." This cultivar was not listed in Hortus Third nor in Hilliers' Manual of Trees and Shrubs. Hillier's lists an *Acer pseudoplatanus* 'Brilliantissimum' that comes close to fitting the description of these gorgeous leaves in spring. The Nikko maple, *Acer maximowiczianum*, a beautiful specimen small tree, is seen in Lucerne, Switzerland.

Throughout much of Europe, the most prevalent big flowering tree is the flowering chestnut, *Aesculus hippocastanum*. Most common are those with white flowers, but there are pinks and reds also. The only variegated-leaved specimen

was seen in the Edinburgh Botanic Garden. Probably the most unusual bark on a big tree is on *Arbutus* × *andrachnoides*, a strawberry tree, seen in Bodnant Gardens in Wales. The smooth, flaky bark is rusty-red in color. Another attractive, unusual, variegated-leaved tree is *Quercus cerris* 'Variegata'. This variegated Turkey oak with its very spreading top is seen at Inverewe. A very columnar form of *Pyrus calleryana* was seen at the Floriade in Amsterdam. It is patented and developed primarily for street-tree planting. In Paris, where many streets are lined with trees, a cultivar of *Crataegus laevigata*, a double pink English hawthorn is seen on one of the more centrally located avenues.

VINES

Finally, some unusual vines seen in Europe are of interest. *Actinida kolomitka* at Wisley Gardens has attractive multicolored leaves. *Polygonum aubertii*, silver lace or Chinese fleece vine, is seen throughout Europe in bloom in late summer and early fall. The long twining rampant stems are covered with long upright panicled racemes of white fragrant flowers. Widely seen also is the *Clematis montana* var. *rubens*. It is in full bloom in May and June with fewer flowers thereafter. Many newer clematis hybrids can be seen at the Chelsea show. They included: 'Walter Pennell', a fully double old rose; 'William Kennett', lavender; 'Mrs. Cholmondeley', a large pale lavender-blue; 'Dr. Ruppel', a burgundy red with a lavender-tinted border on each petal; 'Souvenir de Capitaine Thuilleaux', a picotee with the inner petal burgundy and a rather large white border on each petal; 'Lincoln Star', a large picotee with a reddish-purple center and a narrow white border on each petal. The smaller flowered *Clematis montana* 'Elizabeth', a pastel pink with slightly fragrant flowers, completes the picture.

These are only a few of many outstanding plant specimens seen during several trips abroad. These were the most easily identified, but if others suited an American propagator's needs, it would be well worth his time to determine precise names and sources of material.

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1. Bailey Hortorium Staff. 1976. *Hortus III*. 1290 pp. New York: Macmillan.
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ARE YOU A MANAGER OR A COACH?

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Perhaps every member of the Southern Region of the IPPS considers himself a manager of some sort; that would be only natural. We have always been schooled in the idea that, at least in the nursery production business, there are only managers, owners, and workers — never coaches!

A manager is a person charged with the control or direction of a business. He controls resources and expenditures. He directs the general activity of the business. He plans a lot for the future.

A coach is a person who trains others, either individually or as a team. He's a private tutor who gives instruction. He worries about individual effort and about making the most of individual abilities.

While there is some similarity in the duties of the two, it is readily apparent that there are marked differences also. In fact, it's hard to equate the two in view of their general responsibilities.

The Tampa Bay Buccaneers began their professional life with an initial record of 0-26. That is no wins and 26 defeats! After a few reasonably successful seasons, they fell back into losing ways last year and ended with a record of 2-14. This year they sport a losing record again. Who is to blame? What actions should be taken? The coach resigned, effective at the end of this season. Most think that is for the good, since he is responsible for the day-to-day training of the team. After all, in the eyes of the paying public, it's the team effort that counts.

The management, in their wisdom, should see to it that a more effective coach is signed as soon as possible after the end of the season. In addition, the management must protect the franchise in the sense of marketability and vigor as an organization. That's the primary function of management.

The general manager of any enterprise, be it a football team or a production nursery, must be involved with marketing, capital improvement programs, and the general team effort of personnel as seen from the total management viewpoint. He cannot and should not be directly involved in the individual workers' development, unless the organization is so small as to demand such immediate attention.

The coach, on the other hand, must recognize and develop

whatever talent is available. He must initiate and promote training programs designed to bring about the optimum efforts of those individuals for the betterment of the team effort. Just as in a college draft in football, the coach must be able to size up the potential of individuals and after hiring them, he must be able to develop them into a winning team.

What is your role? Are you a manager or a coach? Do you know? Have you taken the time to identify your role? Are you, like many, trying to be both? And with mediocre results?

A production nursery can very well have a general manager who has never stuck a cutting, or germinated a seed, or budded a single understock. That's O.K. as long as he knows how to manage. His talents can very well lie elsewhere. He may be more effective in that area than the poorly trained-for-business nurseryman.

The coach, or supervisor of production, on the other hand, should have plenty of "hands-on" experience. Otherwise how can he expect to instruct in the techniques of good propagation and production?

But, back to football for a minute. The owner looks on a team as an investment, just as the owner of a production nursery should look on his investment. The owner relies on the manager to build his investment, not just to protect what is current. The manager relies on the coach to enhance his chances to build the investment for the owner. The coach relies on many individuals and their talents as players to provide the results to further his own development, both financially and reputation-wise.

Remember this:

A group of players *always* contains a future coach or two. The same group *often* contains a general manager. That group of players *seldom* contains an owner!

An effective coach develops and retains the better employees. He provides feedback for their information. By offering constructive comments about their work, he lets them know where they stand. He isolates their weaknesses and helps them correct such weaknesses. The good coach varies the tasks of the players. He lets them experience several jobs to bring out their best talents. And he helps the players to establish goals that can bring better rewards.

A successful coach is patient, always capable of remembering that he once made those same mistakes. He is not one who says, "I thought I made a mistake once, but I was wrong!" The best coaches are fair and consistent.

The best teams are made up from good workers, not bums.

They contain eager people who are urged to concentrate on motivation, leadership, and satisfaction as goals. The financial rewards will follow if the system is properly put together.

Is it time for you to reevaluate your role in your business? Can you properly identify yourself? Are you able to determine your course of activity and then develop a program which will enable you to maximize your input and results? You are in one role or another — manager or coach, which is it? It is hard to be both.

PROPAGATION AND PRODUCTION OF TROPICAL FOLIAGE PLANTS IN THE "POLY-POT-PACK"

RICHARD W. HENLEY

Agricultural Research and Education Center
2807 Binion Road
Apopka, Florida 32703

Abstract. This is a review of work conducted on a method of plant propagation and plant production using a high quality peat-lite mix prepackaged in plastic film tailored to fit inside containers of specific shape and size. Production of foliage plants of commercial quality in these packs is shown to be feasible and offers several benefits. These include conservation of water, fertilizer, and plastic, and reduced costs of handling and shipping the finished plants. Packs will accept seeds, seedlings, unrooted or rooted cuttings, liners, and air layers to be grown to finished or prefinished sizes.

REVIEW OF LITERATURE

Nurserymen and flower growers have grown plants in a variety of containers made from a number of materials such as wood, clay, steel, plastic, asphalt-impregnated papers, wood composition, and peat. The rigid container has been and continues to be the standard of the industry. In recent years several plastic-film bags offering a range of features have been introduced to the nursery industry. Although the rigid or semi-rigid plastic and metal containers are still the most popular, there is a limited trend toward use of plastic film bags as growing containers for ornamental plants.

Development and use of improved propagation and growing media for container systems has been concurrent with the changes in container technology. Peat-lite mixes are now being formulated and marketed by several companies on a nationwide basis. Many large nurseries now purchase their potting media preblended to specifications. This trend has been pronounced during the past 5 years and is expected to continue.

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The concept of combining a tough plastic film with a high

quality peat-lite mix to form prepackaged units for plant production was initially proposed in the United States in 1966 by Boodley and Sheldrake (1). They indicated that cut chrysanthemums could be grown in 4- or 6-in. diameter polyethylene tubs filled with Cornell peat-lite mixes. In 1967 Henly (2) described growing cut chrysanthemums in a peat-lite mix contained in mat-like packages fabricated from 4-mil, black polyethylene film perforated on the top for insertion of cuttings and at the bottom for drainage of excess irrigation water.

In 1982 the term "Poly-Pot-Pack" (PPP) was coined to describe units of high quality peat mix, prepackaged in plastic film, and tailored to fit containers of specific shape and size (4). Use of the PPP for plant production has been demonstrated to be feasible for production of *Dieffenbachia* (3) and *Ficus* (4) of commercial quality. Weight of a 2-gal. polypropylene copolymer pot (C-20) was 7.37 ounces while the weight of 4-mil polyethylene film used to fabricate a PPP that fit a C-20 container was 0.67 ounces, or only 9% of the plastic used in the conventional container (4). Production of *Dieffenbachia* in 6-in. PPP irrigated with drip irrigation used approximately 40% less water than plants in conventional 6-in. standard plastic pots due to the mulch-like cover over the soil surface (3). Due to the light weight of finished plants and the soft flexible film covering over the rootball of plants grown in the PPP, plants were packed tighter than was possible with plants in conventional pots (4). This was especially true if plants were grown with very large tops in relation to the rootball size.

DISCUSSION

The concept of utilizing the PPP begins with packs containing growing medium completely sealed in plastic film. These would be purchased by potted plant growers. The film cover is perforated at the bottom for drainage and the top surface is slit for insertion of seeds, seedlings, cuttings, liners, layers or other plant propagules. The packs are then placed in supporting containers, plant material is inserted, and drip irrigation tubes are placed in the top of each pack. Plants are watered and fertilized through a drip irrigation system. At the time plants reach salable size, they are removed from the supporting pots and shipped to wholesale buyers with the film package in place. The rigid supporting containers are left for reuse at the nursery. Plants can be handled at the consumer level in several ways. Interior plants can be placed directly in ornamental containers that approximately conform to the PPP dimensions, or the plants can be placed in the large containers. When stepping plants up to larger containers, the pack sidewall can be slit vertically on 3-to 4-in. centers to permit

root penetration into the surrounding fill, or the film packaging can be removed prior to repotting. The latter two options are feasible when considering plants to be planted in the ground, indoors or out.

A summary of the potential benefits of growing plants in the "Poly-Pot-Pack" are:

1. Use of the PPP virtually eliminates all soil mixing and soil handling operations prior to potting plant material.

2. The medium in the PPP remains dry and free from contamination until it is used for plant production.

3. The PPP is a moisture conserving device with its self-mulching cover, which reduces moisture evaporation from the soil surface.

4. The self-mulching feature of the pack also excludes most weed growth during production.

5. The moisture-deflecting feature of the pack permits only a small amount of additional water from rainfall to enter the root zone and leach nutrients, thus reducing the quantity of fertilizer needed for plant production.

6. Medium in the pack tends to retain optimum aeration levels during periods of high rainfall due to the moisture-deflecting feature on the mulch.

7. The PPP requires approximately 10% of plastic used in conventional pots used for plant production.

8. Plants can be packed tighter for shipping because of reduced container bulk, flexible cover, and light weight of the finished plants.

9. The light-weight PPP-grown plants reduce labor and equipment required as plants are prepared for shipping.

10. Plants grown as prefinished items, with large tops in relation to rootball size, provide a savings during shipment because of reduced bulk and, in some cases, reduced amount of packing material needed.

11. Interiorscape contractors have the convenience of lighter weight plants that save labor and equipment requirements for plant installation.

Use of the "Poly-Pot-Pack" for production of certain container-grown foliage and flowering plants has potential. It can find most rapid acceptance when used with interior foliage plants produced for interiorscape contractors interested in cutting their shipping costs, which can amount to one-third or more of their total plant cost. Reduction of transportation cost would be especially helpful with shipments to Europe and other distant markets. The professional interiorscaper is con-

fronted with difficult logistical problems with large plants grown with the traditional heavy mixes. Use of PPP-grown plants would eliminate many of the problems presently encountered during installation of large plants indoors. Since both production and installation of large plants for interiorscapes are rather specialized professions, it is reasonable to assume that people in these professions would accept a new concept of plant production in a relatively short time.

One of the most serious obstacles to the use of the PPP with large plants is devising some systems of plant support during production. The heavy mixes now being used greatly assist in keeping large plants from tipping over in shadehouses and open field situations where wind is a factor. With a little effort effective support systems can be designed to prevent plants from tipping over in the nursery.

Acceptance of the PPP system of plant production rests with proper introduction of the concept to selected specialized producers and users of the product. Ultimate acceptability of the system is dependent upon economics of manufacturing the PPP and getting one or more of the potting media blending companies to package the product in units of the most desirable shapes and sizes.

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AN OLD ROOTING BENCH REVISITED

FRED MORRISON

Morrison's Farm and Nursery
McAlpin, Florida 32062

In 1972 Morrison's Farm and Nursery began as a hobby-type operation with the construction of a shade arbor for the rooting of plant material and a hot-house for the growing of foliage plants. We were originally in the chicken business and still do have two houses in production. From this meager beginning blossomed the present operation, which encompasses an area of 80 plus acres of production.

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During the past 24 months our nursery has doubled in size. This accelerated expansion demanded a rapid method to propagate plants in large numbers. The method chosen to accomplish this necessary production of plant liners was the rooting bench procedure. This type method allows a large number of cuttings to be placed in a small area while the rooting process is taking place.

The benches chosen for our needs contain 648 ft^2 each. Each bed is 6 ft. wide and 108 ft. long. These benches are laid out using concrete blocks for the lower portion of the bench. Each bench requires 170 concrete blocks laid loosely to allow water drainage to seep between them. These blocks are then filled level full with cypress *(Taxodium distichum)* sawdust. This sawdust allows drainage below the rooting medium and serves to collect and store heat at the base of cuttings.

The second step is construction of the rooting area itself. This section of the bench is constructed on top of the concrete blocks and contains the rooting medium. Cypress boards are used to make forms 6 ft × 7 ft × 4 in. These forms are placed on top of the concrete blocks with woven soil covering placed between the forms and the concrete blocks and sawdust. One hundred percent shade cloth could be used for this purpose. This upper section is then fitted with irrigation.

Two types of mist irrigation have been tried for these benches. The first type is a fog system consisting of Geor-Jet mist nozzles fitted to PVC risers extending 6 in. above the rooting medium. Unfortunately, these clog easily. The supply lines for this system are laid directly upon the cloth divider under the upper rooting forms. Mist nozzles are spaced on 4-ft × 4-ft settings.

The second type of mist irrigation consists of Spraying Systems brass-nozzle type heads. These heads are attached to ¼-inch steel rods, which can be lowered or raised depending upon plant material placed under them. The head is connected to the lateral lines by flexible plastic tubing. These heads are spaced on 7-ft. intervals with one line per bed.

Both mist nozzle assemblies are connected to electric valves with a 10-min. timer. This timer can be adjusted for a mist cycle with intervals ranging from 2½ sec. minimum cycle to a higher "on" time, as needed for uniform coverage.

The rooting medium consists of the following mixture:

18 ft^3 Canadian peat moss	1½ lbs. Micromax micronutrient
20 ft^3 perlite	30 lbs. dolomitic limestone
27 ft^3 raw pine bark	8 lbs. Osmocote 18-7-11

This mixture is placed inside the forms constructed and is

allowed to settle before usage. The final grade for this mixture is level with the top of the wooden forms.

Cuttings are then stuck into these prepared areas. We have been able to stick approximately 4500 to 5000 cuttings per wood-form unit. This allows each 6- × 108 ft. bench to contain 67,500 to 75,000 cuttings in an area containing 648 ft^2. We can, therefore, propagate approximately 110 cuttings per ft^2. Using this method of propagation, we can produce very large numbers of rooted liners in a limited space.

Cuttings taken for rooting in these bench areas vary in size from 2- to 6 in. in length. Cuttings such as *Ilex vomitoria* 'Nana' are the shortest in length, while cuttings such as oleander are longer. Most plant material is placed into the benches without the addition of hormone. Hormone compounds are used on plant material that may show accelerated root formation when treated. Most material will root in an acceptable length of time without hormone addition. This rooting is enhanced by the added heat supplied by the sawdust under the rooting bed. Bottom heat in propagation areas has always seemed to enhance the rooting of cuttings.

IMPROVING UNIFORMITY IN CONTAINER NURSERY STOCK

CARL E. WHITCOMB

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Abstract. Poor uniformity in container-grown nursery stock increases production and labor costs and decreases effective space utilization and customer satisfaction. Ten major factors that affect crop uniformity are discussed and suggestions are made for improvement.

INTRODUCTION

In most container nurseries poor crop uniformity is a subtle but major factor affecting production costs and customer satisfaction (5). Studies suggest that production costs in a container nursery should be assigned on a square foot of production area per month basis (3,7). With this approach some nurserymen estimate costs based on the period from planting time until sale of the first portion of that crop. However, in many cases the time between the sale of the first portion of the crop and the last may be from a month to a year or more. A more realistic procedure would be based on the time from planting until the last plants from that crop are sold and the space is

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again available for another crop. The difference in production costs between the first and last sale dates represents a good estimate of the additional cost as the result of poor crop uniformity.

DISCUSSION

Consider the following four factors: 1) A poor plant costs the same to produce as a good one. 2) Poor plants interfere with finding the good ones. 3) Good plants could have been grown in the space of the poor ones. 4) If the poor ones are sold, customers associate a poor plant with your nursery, regardless of the sale price.

There are at least 10 major factors involved in increasing or decreasing crop uniformity. In some cases, these factors are probably additive while others are independent. For example, consider a plant in a container that receives a lower level of fertilizer due to poor mixing of the growth medium, *and* is placed in a position of excessive irrigation water, *and* on the southwest side of a block of plants. It will grow poorly because of excessive leaching of the limited fertilizer. The situation is further complicated by limited root growth due to the excessive termperature. On the other hand, slight differences in container sizes or planting dates within a block of plants are more or less independent of other factors that affect crop uniformity.

The following discussion is based on numerous experiments, experiences, observations, and findings of others:

1. **Parent Plant Selection and Condition.** Always take cuttings from the *best* plants possible. One of the most common errors is in the selection of the parent plants (2,12). If the existing crop is used as the parent stock for cuttings, use the best plants rather than the poorest or last plants available. The argument is sometimes made that it is not practical to take cuttings from the best or first plants to reach marketable size. However, with imagination and planning this can be done and in a profitable manner. For example, take cuttings for the next crop from the first plants to reach marketable size in a particular size container, then shift those plants into the next larger size container, allow one more flush of growth to cover the pruning scars and sell them at a premium price.

A second alternative would be to shift the first plants to reach marketable size into larger containers before the cuttings are taken in order to provide more cuttings or to improve the condition of the cuttings, depending on the species. Never use the end of a crop for stock plants. Think positive and plan ahead.

2. **Selection of Cuttings from the Parent.** Always take the most uniform cuttings possible (6,12). Differences in stem diameter, stem length, number of leaves or buds on a cutting and the presence or absence of flower buds are obvious differences. An important factor often overlooked, however, is the position of the cutting on the plant. With many species plants grown from cuttings from lower side branches grow with a different form than plants from cuttings from the most upright branches.

A plant propagator striving for maximum crop uniformity should be ruthless in selecting cuttings. Establish a narrow tolerance for consistency and reject all others. Remember, it is much more economical to cull a cutting than the resulting inferior plant somewhere later during the production cycle.

3. **Mist Coverage, Water, and Drainage.** Always strive for the most uniform mist coverage *and* the minimum amount of mist that will allow the cuttings to root under your conditions. Most mist systems use some type of circular mist nozzle. In general, more mist nozzles closer together provide a more uniform mist coverage over a bed or bench area. Try placing a series of small containers in several spacings beneath your mist lines. After two or three days, measure or weigh the difference in water among the containers. Perhaps you need to add an additional nozzle in any dry spots.

All containers create a perched water table at the base (9). This means there are saturated conditions in the bottom ¼ to ½ of a shallow tray, bed, or small container. When overwatering occurs either due to excess length of misting or due to position beneath the mist system, air space in the rooting medium is reduced and the rate and uniformity of root development on the cuttings is decreased.

Excess misting, either due to position in the bed or length of misting time, also increases the leaching of metabolites and nutrients from the leaves (10,12). Such leaching increases the variation in growth and quality in an otherwise uniform group of cuttings.

4. **Medium Uniformity.** Always mix the components of the rooting medium uniformly (1). Poor mixing is more easily detected when fertilizers, such as Osmocote 18-6-12, are added (4). As noted under 3 above, the excess water held by the perched water table in all containers is more dramatic in shallow containers or flats. When the rooting medium is not uniformly mixed and some containers receive a slightly different mix, the water retention and aeration of the mix also varies.

Cuttings that root quickly will be much less subject to

stress than those that root slowly (8). Plants will be stunted if part or all of their roots are suffocated shortly after a cutting begins to root. This may be due to excess water holding capacity of the mix in the given depth of container or overwatering due to length of misting time.

A substantial portion of the variation in crop uniformity can be eliminated by careful attention to selection of stock plants and cuttings and improving the rooting environment. Above all, be ruthless in grading or selecting rooted cuttings for growing-on; unless the cutting meets strict standards, throw it away.

5. **Container Size.** Always keep containers of the same size together. Also, group species depending on water requirements. For example, when newly-planted, species with different water requirements can be grown together with little consequence. However, as they get larger, if the water is controlled to meet the needs of the plant with the greatest water requirement, the others will be overwatered.

A similar problem occurs when containers of different size are placed under the same watering system. The shallower the container, the more water will be retained relative to the volume of that container. Proper watering is related to size of container, needs and growth stage of the species, capacity of the growth medium to hold water, and time of year. These are important yet very difficult aspects of plant growth to measure, evaluate, or teach.

6. **Water Quantity and Quality.** Always design the most uniform irrigation system possible. Uneven watering is a subtle factor with a major effect on crop uniformity that generally goes unnoticed.

Few irrigation systems have less than a 30% variation in water applied within a given production bed (12). Consequently, if the area that received the greatest quantity of water is monitored, the remainder is under-watered. On the other hand, if the low water area is monitored, the high water area is over-watered. In most cases plant wilting in the low water areas is noticed and water applied. This means more leaching in the high water areas *and* more rapid accumulation of calcium from the irrigation water in the growth medium. Calcium accumulation from the irrigation system is a slow and subtle factor adding to the variation in crop quality. As calcium accumulates, magnesium is displaced and leaches from the container. The increasing calcium restricts the availability and absorption of iron, manganese, and the other micronutrients which, in turn, restricts plant growth and quality. With

marginal quality water this shift is more rapid than with good quality water (12).

7. **Mixing.** Always mix components of the growth medium thoroughly and uniformly. Thorough and uniform mixing of components requires considerable precision. A front-end loader can never do a satisfactory job of mixing and should not be used.

There are 3 important factors to remember when using either a paddle- or cement-type mixer: a) do not overfill; b) do not overmix; c) if sand is part of the mix, add it last along with a small amount of water. Three to four minutes is about right for most mixers.

A cement-type mixer may mix 7.5 yds.^{3} of sand, gravel and cement. However, because they are much less dense, it will not thoroughly mix 7.5 yds.^{3} of the materials used in container growth media. Perhaps the best guide is to add about 7.0 yds.^{3} of gross materials, which will shrink 10 to 15% to give about 6.0 yds.^{3} of actual growth medium.

If a mixer is run too long, especially when sand is present, the dense abrasive sand will pulverize the smaller organic particles and reduce the aeration of the resulting growth medium. A common error is to think that a long mixing time is better. Because of the density of sand, mixing too long can cause a segregation of the different materials and can result in a *poorer* mix. The best everyday analogy is the shaking of popcorn to get the lighter kernels on top and the "old maids" to the bottom.

A useful addition to a paddle-type mixer is a motor-reversing switch. An effective mixing sequence would be: a) add the organic or lightweight components with the mixer off; b) add the nutrient elements (micronutrients, dolomite, lime, etc.); c) turn on the mixer; d) add the sand or any other dense material; e) reverse the mixer briefly; f) return the mixer to normal, then dump. Remember, that unless mixing is thorough and uniform, some containers will receive too few nutrients while others receive too much; the smaller the container the more critical this becomes.

8. **Herbicide Distribution.** Always use every precaution to insure the most uniform distribution of herbicides. Preemergence herbicides, especially on container growth media, tread a fine line between killing or preventing the germination of seed of weed plants, while not injuring the crop plant. The safe yet effective rate of application of most herbicides is very precise. If the rate is too low, weed control is poor and weed competition can stunt crop growth. On the other hand, if the

rate is too high, the crop may be stunted. In either case crop uniformity is decreased.

9. **Seedling Variation.** Be ruthless when selecting seedlings for growing-on. Inherent genetic variation is a problem with most seed-grown woody plants. However, some kinds of plants are much more variable than others (11). For example, seedlings of river birch are very uniform but seedlings of most oaks and other wind-pollinated trees are quite variable.

10. **Other Factors.** Diseases associated with uneven watering, mixing, or drainage may add substantially to the unevenness of a crop.

If the bed surface around the base of each container is not capable of draining away excess water, crop uniformity will be decreased.

In summer the outside row of a block or bed of plants exposed to the afternoon sun will be much hotter than containers partially or completely shaded by foliage or other containers. In winter, plants on the outside rows, especially on the windward side, are more likely to suffer cold injury than plants within a block or bed.

Foliar insects and diseases may reduce crop uniformity in severe cases.

CONCLUSIONS

Variation in plant size and quality is a major factor limiting further mechanization, as well as improved space and labor efficiency in the container nursery industry. The ten items mentioned here may seem like minor factors influencing crop uniformity; however, collectively they can alter the time from planting to sale by many months. The additional attention and effort required to produce a uniform crop will pay big dividends in the long run. Consider the advantage when 500 plants of a species and cultivar are sold — and they are the first 500 plants on the end of a bed:

a) There would be no culls to congregate or shift to another area.

b) Plants ready to be shifted into a larger container could be easily transferred into this area or a new crop begun.

c) The distance traveled by employees and various vehicles would be dramatically reduced.

d) Perhaps best of all, the customer would be satisfied because all of the plants received were *uniform*.

Why should not a customer expect all plants to be like the best ones in the order? The nursery industry should strive for a consistent top quality product.

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QUESTION BOX

The 1984 Southern Region Question Box was moderated by Lin Taber, Glen Saint Mary, Florida.

LARRY EDWARDS: I would like more information on crop oil and surfactants. Do these materials have an effect on the chemical with which they are being used?

BRYSON JAMES: They are similar to dormant spray oils and, in general, are nonphytotoxic. They will mix with water. Vegetable oils have been tried, but crop oils are preferred. Ordinary household detergents usually do not interfere with chemical activity if they are nontoxic. Those with high phosphate content should not be used; pH of the solution makes a difference. A spreader-sticker should also be used with most tank mixes. These materials actually have a sticking effect as well as just making water wetter.

TED RICHARDSON: I have found that, in contrast to earli-

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TED RICHARDSON: I have found that, in contrast to earli-

er comments, a surfactant works just as well with Poast as a crop oil.

GARY TAYLOR: Is there a danger that herbicides will affect rooting of the cuttings?

CARL WHITCOMB: In general, those we have tested have, if anything, seemed to enhance rooting. Our tests included hollies and junipers using Lasso and Ronstar. There is a real need for more work, especially when pine bark is used for the medium.

JACK SIEBENTHALER: Is there any justification for using materials such as Terra-sorb?

CARL WHITCOMB: In one test we saw a slight benefit. However, the next two times we used it, we saw no benefit; in an extended study the control was the last to wilt.

LIN TABER: I want to comment on the importance of stock blocks. When we receive orders or foresee a coming demand, we immediately flag a block of plants. These are released for sale only after we are sure we have obtained enough cuttings to provide for our demand.

CHARLES PARKERSON: Gary (Taylor), how do you mechanically change your misting setting to adjust for the difference in requirements between night and day? It is not satisfactory for the mist to go off the time clock completely at night as the heaters dry out the plants.

GARY TAYLOR: We simply change the pins on the clocks.

LARRY EDWARDS: We have an extra gear mechanism for the clocks.

DEWAYNE INGRAM: I have a colleague who has worked out a program for a Commodore computer that gives 200 different combinations.

BOB BARRY: Toro has a gear-driven unit that puts out half as much water where there is overirrigation, such as where the spray patterns overlap. It was designed for use on athletic fields.

BILL DUTCHER: Is there a difference in the color of the light passing through white plastic vs. clear plastic covered with saran shade cloth?

CHARLIE PARKERSON: We feel that the clear plastic plus saran gives better results than the white poly.

BRYSON JAMES: The white poly diffuses the light but should not change the color.

FRED MORRISON: Could someone tell me about using the Lotus software for doing cost analysis?

HUBERT NICHOLSON: It includes a spread sheet, database file and graphics. A later package has even more features, such as word processing. It gets complicated.

JUDSON GERMANY: I would like more information on potential sodium problems. How much is too much in your water? Also, what other factors would you look for in a water analysis?

CARL WHITCOMB: Bicarbonates and sodium are the problems. We did a study using gardenias and geraniums as test plants. The geraniums were not affected but the gardenias died after about 2 weeks in the poor water.

BRYSON JAMES: There is not clear answer to your question. A measurement called the sodium absorption ratio is the one to look at. If it is less than 3, there will be no problems. This ratio relates to the balance of calcium, sodium, and certain other ions that are present in the water. The UC Manual[1] gives more information, and soil analysis labs will determine the ratio for you. This is the best we have to go by. The reading can be extremely high in some cases, which means you must be very careful in your growing practices.

JAKE TINGA: I am wondering if some of our problems are not simply a misuse of minor element formulations. These can cause serious problems in a hurry.

CHARLIE PARKERSON: We seem to be pruning our Burford holly at the wrong time. At any rate the plants seem to go dormant after pruning. The plants need to be pruned at the time we do it, so what can we do to prevent their going into dormancy?

LIN TABER: I believe this is related to heat stress more than anything.

CARL WHITCOMB: I have seen this also. If you have a flush of growth and then remove the terminal, you are removing the source of organic compounds above. If the tissue just below is at a certain stage, it just sits there. We have much to learn. At present about the only thing I can suggest is to wait until that terminal matures before pruning.

LARRY EDWARDS: I have also observed this tendency of buds to go dormant in *Ilex* × *attenuata* 'Fosteri'. However, I believe it is more than just the effect of the terminal bud.

CHARLIE PARKERSON: We are having trouble rooting aquipernyi holly.

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[1] Baker, K. F., ed. 1957. The UC system for producing healthy container-grown plants. *Calif. Agr. Exp. Sta. Man. 23.*

JIM BERRY: We did some testing with this plant. I can send you the information.

GARY TAYLOR: We used Dip n'Grow in June in Maryland. *Ilex* × *aquipernyi* is slower than 'Nellie Stevens' but does root fairly easily.

LARRY EDWARDS: I would like someone to comment on using fertigation to supplement the use of dry material. Do you need to use a balanced fertilizer, or will a single element do it?

JIM BERRY: We do use fertigation as a supplement to our dry fertilization program. We use 12-4-6 at 150 to 200 ppm.

CHARLIE PARKERSON: You need to find a reliable supplier and find out what his stock solutions are. Allied Chemical Company formulates ours since they are located nearby. Start out with a formulation around 10-0-6 or 12-4-6, then adjust it to suit your needs. We now use 10-2-6-2. The last number is sulfur, which we believe is important.

STEVE MURRAY: Has anyone taken a true microcomputer to write out invoices, deposit slips, and similar items?

CHARLIE PARKERSON: Tom Dodd, Mobile, is doing this, and we are doing everything along that line with our microcomputer. Don't try to write the program yourself. It is extremely time consuming. A machine with 64K memory will hold a lot. Buy a computer than can interface with other computers to get maximum efficiency.

TOM LETT: Why are we getting roots mostly in the bottom of bottomless pots? Can they be transplanted to the field successfully? We are using half-pint milk containers. They are good for growing seedlings.

CARL WHITCOMB: Air pruning occurs when the root gets to the bottom of the pot, and branching then takes place in a manner similar to what happens to the top when it is pruned. If you watch the seedlings, you will find there is a best time when new root growth occurs at the top of the root system and anchors the plant better. Don't leave seedlings in containers too long.

DON COVAN: We have found that on Shumard oak, golden rain tree, and others, the time of transplanting is important.

TOM SAUNDERS: Could we get someone to develop a granular slow-release fungicide?

LIN TABER: Alliete is a slow-release material.

BRYSON JAMES: It is one of the few we have found that will control water molds systematically, but it is still expensive.

GARY TAYLOR: Subdue or Ridomil are systemic but must be used as a drench.

CHARLIE PARKERSON: It seems to me that the rates of lime reported at this meeting are much lower than at other times.

GARY COBB: I feel very well satisfied with 6 lb./yd.^{3} We have found that most plants will do very well with rates varying from 2 to 15 lb./yd.^{3} Boxwood, however, seems to need the heavier rates.

TOM LETT: We are adding nothing to our peat:perlite mix.

BRYSON JAMES: Water in your area probably contains a large amount of calcium.

DON COVAN: We have found that our water can supply one ton of calcium per acre over one year's time.

SPRAY PROGRAMS AND EQUIPMENT

BRYSON L. JAMES

BRY-J Farms and Services
P.O. Box 230
McMinnville, Tennessee 37110

Safe and effective spray programs require good equipment, frequent careful inspection of plants, knowledge of pests and chemicals, and accurate records.

We do not have time nor the knowledge to give specific programs to fit all nurseries or all potential pest problems. However, we will offer some generalized examples based on experience gained in custom application and in consultation with many of the best nurseries in the South.

Many nurseries do not have effective spray programs because they do not have proper equipment or do not maintain equipment properly. We will discuss types of sprayers later but should mention here that protective clothing should be considered as necessary spray equipment.

GENERAL SAFETY INSTRUCTIONS

Anytime we discuss pesticide spraying we like to review briefly safety procedures.

— Read the label, *before* using.

— Know the pest.

— Use pesticides only when needed.

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GENERAL SAFETY INSTRUCTIONS

Anytime we discuss pesticide spraying we like to review briefly safety procedures.

— Read the label, *before* using.

— Know the pest.

— Use pesticides only when needed.

— Know what to do in case of an accident.

— Take time to explain safe use of pesticides to all employees so they will understand re-entry instructions and safe handling of treated plants.

— Check application equipment for leaks, clogged nozzles, strainers, or liners.

— Check respirator, gloves, and protective clothing frequently.

— Calibrate equipment frequently, using water.

— Never eat, drink, or smoke when handling pesticides or afterwards without first bathing thoroughly.

TANK MIXES AND PESTICIDE COMPATIBILITY

We generally use tank mixes of two or more pesticides in the spray tank at time of application. This way we effectively control both insects and diseases with one application. Some products give tank-mix instructions on the label; others are recommended by the Agricultural Extension Service or are common agricultural practice. If products you wish to tank mix do not fall into one of the above categories, their use still will not be deemed inconsistent with label if:

1. The products in the mix are applied at a dosage rate not to exceed the label instructions for use of any product in the mix used singly for the same set of pests on the same crop, and
2. The label on one or more of the products does not explicitly instruct against such mixture.

Any mixtures not on labels are applied at the user's risk with respect to effects on crops and equipment, applicator safety, and environmental effects. All the tank mixes we list later have been used many times with safety and effectiveness. Should you desire to mix products of unknown compatibility, mix proportional amounts in a gallon jug, shake vigorously, and let stand. If no gunk or sedimentation occurs, the mixture should be all right. The annually revised "Spray Compatibility Chart," published by the Meister Publishing Co., is helpful.

GENERAL INSECT AND DISEASE CONTROL PROGRAM

Our records and observations show that at least 4 or 5 sprays will be needed in a general line of nursery stock every year.

1. Dormant season spray: Apply when temperatures are not expected to be below 40°F nor above 80°F.

— Tank mix superior spray oil, Orthene, acephate; and Fermate (Carbamate), ferbam. Add oil to tank last, after thoroughly mixing the other two products with water.

2. Early spring flush spray: Tank mix Lorsban or Dursban, (cloropyrifos); Benlate (benomyl); and Dithane M-45 or Manzate 2000, (mancozeb), and a spreader-sticker.

3. Late spring, 4 to 6 weeks after No. 2: Tank mix Supracide, (methidathion); and Funginex, (triforene).

4. Summer spray: Tank mix Orthene and Daconil 2787 or Bravo, (chlorothalonil); and a spreader-sticker.

5. Early September: Tank mix Lorsban or Dursban and Dithane M-45 or Manzate 200 and a spreader-sticker.

Please note that the above are general guidelines. More frequent application often is needed for specific pest problems. When a particular pest is identified, choose a pesticide specific for that pest. Foliage plants, azaleas, Fraser photinia, and greenhouse crops usually require much more frequent spraying than the general line of woody ornamentals.

GENERAL WEED CONTROL

For field nurseries make at least two applications per year of preemergence herbicides.

1. Fall, (October-December).
   a. Needle evergreens: Tank mix Goal (oxyfluorfen); and simazine.
   b. Broad-leaved evergreens, deciduous stock and needle evergreens: Kerb, (pronamide); or Surflan, (oryzalin).
2. Spring (April-May).
   a. Needle evergreens: Goal, or simazine, or tank mix the two.
   b. Broadleaved evergreens, deciduous stock, and needle evergreens: Surflan.

Some years and at more southern latitudes a summer application may be desirable. Where needed, use Surflan.

Spot treat perennial weeds and grasses and others not controlled with the preemergence herbicides.

For general broadleaf weeds and grasses — Roundup, (glyphosate).

For nutsedge — Basagran, (bentazon), or Roundup.

For grasses only — Poast, (sethoxydim), or Fusilade, (fluazifop-butyl).

Herbicides for container weed control are seldom sprayed,

but we will give you our thoughts below on the granular products available:

1. Apply, every 10 to 12 weeks during the growing season.

2. Don't use the same product for every application but alternate with at least three products. Choices include Ronstar, oxadiazon; Scotts OH II, (oxyfluorfen plus pendimethalin); Rout, (oxyfluorfen plus oryzalin); Treflan, trifluralin.

EQUIPMENT

You cannot apply a pesticide properly or safely without the correct equipment. We apply everything except postemergence, contact-type herbicides with a mist (air-blast) blower.

Not all air-blast sprayers are suitable for nursery stock. We tested and had demonstrations with many makes before finding one that did the job we liked.

SPRAY COVERAGE

Many do not understand how or why better coverage and control of pests is obtained with low volumes of spray solution applied in an air blast than with conventional hydraulic sprayers. If you will remember that air is the carrier with air-blast spraying, it is easy to understand better coverage. Conventional sprayers frequently use 100 to 500 gal./A of water as a carrier. At our top spraying speed we use more than 700,000 gal./A of air as a carrier. At slower speeds even more air/acre is used. When properly atomized, spray solution goes everywhere the air goes.

It is important to regulate tractor speed when spraying plants with dense foliage to insure good air turbulence. To get good coverage on the underside of leaves of low-growing plants, direct the air-blast slightly downward to create bounce-back or a ground roll of air.

SPRAYER VERSATILITY AND ECONOMY

If you choose a sprayer carefully, one is enough for all field spraying, from container to large trees, with insecticides, fungicides, and herbicides. Following are some features to consider:

— *Pumping capacity* should exceed total nozzle output by 10 gallons per minute (gpm). To insure good by-pass agitation at all times, 5 gpm is a minimum.

— *Type of pump* can make a difference in maintenance costs. We find that diaphragm pumps are least affected by abrasive or corrosive chemicals. Roller pumps are the least desirable. Piston and centrifugal pumps are acceptable but not

as trouble-free, nor as easy to repair, as the diaphragm types.

— *Maneuverability* is important, especially for the smaller or highly-diversified growers. We like 3-point hitch better than pull types.

— *Blower capacity* should be adequate to create turbulence to the top of trees and laterally to the full width of areas to be sprayed.

— *Air-blast directional control* is important to maximize spray in the target ara and minimize drift.

— *Fan disconnect* feature is desirable when mixing chemicals.

— *Easy calibration* and rate changes eliminate guesswork and maximize safety and efficiency.

— *Speedy application* is important economically as well as practical. A job that can be done quickly is more likely to be done on time. Conditions usually are not favorable for spraying 24 hours per day. We spray an acre of large plants in about 5 minutes.

— *Easy cleaning* features reduce the potential for neglect and clogging problems.

— *Hose and hand-gun or boom spraying* connections should be possible. This will eliminate the need for another sprayer for directed sprays and band spraying or spot spraying for special situations.

— "*Reasonable price*" is a relative term. By comparison, we think the $5300 machine we prefer is reasonable because it has all the features above, and more. Our second choice is a sprayer that we have used one season and like. It costs under $4000. Both of these air-blast sprayers compare favorably with $7- to $15-thousand sprayers we have tried.

Please contact me if you would like more detailed information on this equipment.

CONTAINER-GROWN HIBISCUS: PROPAGATION AND PRODUCTION

MONA-MARIE KELETY

Turkey Creek Farms
P.O. Box 27224
Houston, Texas 77338

The popularity of the *Hibiscus rosa-sinensis* in the southern U.S. as a garden shrub has increased tremendously in the last few years. Hibiscus is the most popular flowering shrub in the tropics. Its unique and distinctive flower gives a lush tropical image to the surrounding landscape. The idea of using hibiscus as a color crop instead of a perennial shrub has been one of the most influential factors for the increased popularity and demand. The potential for commercial pot hibiscus production is just now being realized. Many people are unaware of the broad range of hibiscus colors, color combinations, and flower forms, and think only of hibiscus as a single red flower as so often seen. There is an almost unlimited variation in the shades of color of the hibiscus flowers.

Hibiscus may be propagated by seed (hybridizing), cuttings, grafting, or by tissue culture. Hybridizing is best done by collectors or research labs as cross-breeding hibiscus is an unprofitable method for commercial propagation. There are many factors that determine the value of commercially grown hibiscus such as uniformity, flower size and color, and bud count. It is impossible to predict the appearance or performance of hybridized plants. The first bloom should appear about 18 months after seed germination. Pink tones constitute about 80% of a progeny, followed by browns, true yellows and reds. Whites and blues are practically impossible to find.

Propagation by cuttings should begin about the time warm weather is established and the soil is warm. Cuttings may be either hardwood or softwood tip cuttings. We root the cuttings in a mix of styrofoam and peat, with Osmocote, or in Oasis Horticubes. I prefer the Oasis Horticubes because the brittle root system of the cutting often breaks off at the basal end during transplanting. The Horticubes prevent such breakage. The cubes also save time and labor as rooted cuttings can be planted directly in a 1- or 2-gal. container.

Some hibiscus cultivars root much better than others. The more exotic or fancier the hibiscus, usually the more problems rooting them. Florida growers claim you cannot root many cultivars but that they must be grafted. I do not believe that to be the case; I believe you can find a way to root them all.

One of the biggest problems is that most of the more

exotic hibiscus cultivars that come from Florida are infected with *Colletotrichum* and *Graphium*. The soft rot caused by these organisms is called anthracnose. I will talk about anthracnose later, but during hot months or during stress, anthracnose can become quite prevalent, killing most cuttings in the mist beds or after transplanted. Avoid propagation during the hottest months and use clean stock.

I use a mild liquid rooting hormone on the tip cuttings and a slightly stronger hormone on wounded hardwood cuttings. The mist should be frequent enough to keep the cuttings moist but not saturated. Cuttings root in 4 to 8 weeks depending on the cultivar. I do not recommend winter cuttings, even with bottom heat, because it could take up to 3 months or more for rooting.

Grafting hibiscus is unfeasible for commercial production because of the high labor costs involved. I recommend grafting for the hobbyist. To save time some grafters in Florida graft onto a cutting before rooting. I do not know how successful this method is.

Tissue culture may be the answer to propagating the more difficult-to-root cultivars. However, in the beginning, labs will probably have a difficult time cleaning up stock plants infected with anthracnose. But if the labs succeed, the exotic hibiscus will become more available in numbers and cultivars enticing more customers to incorporate the hibiscus in their landscaping.

A rooted cutting may be transplanted into a 2-in. liner pot, a 4-in. pint pot, or directly into a gallon container. The type of container used depends on the time of the year and desired finish date. A gallon size hibiscus finishes off in 3 to 4 months during the summer. However, by the end of the summer there are few sales for hibiscus. Therefore, the hibiscus should be finished for the spring sales. This makes the growing schedule more difficult and costly. Planting time depends on when you can transplant, the growing time, winter temperature in the greenhouse, and amount of sunlight in the winter months.

We transplant hibiscus liners and Horticube liners into gallons at the end of summer. The mix consists of peat, bark, sand, and haydite with Micromax. Hibiscus require a well-drained soil mix with a pH of 6 to 7. After transplanting we top dress with Osmocote 17-7-12. Hibiscus plants are heavy feeders and require top dressing again after a few months. I have obtained optimum growth by using Cornelius Hibiscus Food, which is a 10-4-12 formulation. Since this fertilizer should be applied monthly, it is financially unfeasible for commercial use. It is useful, however, for the hobbyist. Good

results have also been obtained using Scotts Sref and Step. We recommend spraying weekly with sequestrene iron, and monthly with a soluble 20-20-20 fertilizer. Some cultivars may need an extra foliar spray with micronutrients.

Most hibiscus require full sun, except for a few cultivars that grow better in partial shade. Too much sun for these cultivars affects flower bud number and causes bud dropping. Some growers of the florist quality 6 in. hibiscus do not use full sun, which results in the development of very dark green foliage.

Hibiscus will grow in the hot temperatures of the southern U.S. until frost. Flowering slows down if the temperature drops below 65°F. or goes above 85°F. Hibiscus is tender to frost but can often survive a mild winter outdoors if cut back to the ground and mulched over. In a greenhouse during the winter the best temperature setting is 65°F.

During summer overhead sprinklers are turned on twice a day for 40 minutes each time. Hibiscus need a lot of water in summer to remain healthy and to retain their lower leaves in the heat.

Hibiscus are susceptible to many insects. Spider mites are by far the worst problem. The mites hide up inside the cupping of the leaf between veins. We had good control with Vendex (fonbutatin-oxide) followed by either Kelthane (dicofel) or Pentac (dienochlor). Other insect problems are caused by aphids, which attack the tender growth, and grasshoppers, which chew on the leaves. Use Sevin or Orthene for most insect problems; however, never use Malathion because it causes defoliation. Some growers claim Diazinon will cause leaf drop also. If worms become a problem, Thuricide or Dipel (*Bacillus thuringiensis*) should take care of the problem.

The major fungal problems are *Colletotrichum hibisci* and *Graphium*. Their infection causes lower stem rot in cuttings, transplants, and vigorously growing plants. The most effective fungicides for this problem are Benlate (benomyl) and Daconil (chlorothalonil). It is critical that the lower stem be thoroughly wet with the fungicide during spraying. A good sanitation program will prevent introduction of this pathogen from stock plants. Careful roguing of diseased stock plants should be practiced. Also, tissue culture indexing would insure clean stock for propagation. Drip irrigation would be advantageous, especially on stock plants, since overhead irrigation splashing helps spread the fungus.

Another disease problem is bacterial. These black or brown circular or irregular shaped spots may be controlled by weekly sprays, rotating Benlate, Daconil, and Kocide, copper

hydroxide. It is important that the foliage not remain wet overnight. Cold water drops from plastic in the winter can also cause spotting.

The two main physiological disorders are leaf and bud drop. These may be caused by lack of water, sudden humidity change, and change in sunlight such as occurs when plants are moved from outdoors to indoors. Also, during mid-winter hibiscus in the greenhouse may shed some of their leaves. This is the annual leaf shedding which occurs in one or two weeks.

Selective pruning can maintain or develop a desired form on some cultivars. Hibiscus should be pruned as one would trim roses. When trimming, the cut should be made just above a leaf pointing towards the outside of the container. This helps the plant grow outward and larger instead of inward and crisscross. One should make the cut close to a node to prevent dieback of the stem and entry of diseases.

Growth characteristics vary greatly among cultivars. A plant may be compact and densely leafed, or leggy and open. Some plants grow upright while others are short and broad. In frost-free areas some plants may become 20 ft. trees while others will always remain low and drooping. Different cultivars may be more suitable for standard trees while others may do better in other forms. *H.* 'Cooper', a variegated hibiscus, does well in hanging baskets. *H.* 'Mrs. Jimmie Spangler' is a 6-in. florist type, *H.* 'New Ruffles' is a collectors item, etc. The different climates around the country will affect the growth habit of the same hibiscus cultivar.

Following is a list of those I consider to be the best cultivars:

Single red
- Brilliantissima
- Gypsy Queen

Double red
- Lamberti

Single yellow
- Butterfly

Double yellow
- Mrs James Hendry (Fullmoon)

Single orange
- Red Sheen

Double orange
- Jigora

Single white
- Ander's White
- White Wings

Double white
- Elephant Ear

Single pink
- Texas Star or
- Pink Lady (Armour)
- Seminole

Double pink.
- Fulviolaceus

Hanging basket
- Silver Queen
- Cooperi

Trees
- Brilliantissima
- Gypsy Queen

Once the plants in the containers have reached a saleable size, they are ready for a foliar chemical treatment with Cycocel. Spraying Cycocel induces budding, causes a more compact plant, and changes the foliage appearance. Cycocel causes budding on all the branches. Usually hibiscus set buds only on new growth. The flowers only last one day except for a few cultivars, where they may last two days. Therefore, as many branches as possible are needed and all branches must be heavy with buds to have a succession of flowering and an attractive plant for sale. Cycocel will induce budding in about 8 weeks during warmer months and about 12 weeks during cooler months.

Along with bud production, Cycocel causes slower plant growth which makes for a more compact plant. Depending on the strength of the Cycocel and the cultivar, plants grow much slower, or cease to grow, which effect could possibly last up to a year. I see many benefits to this growth reduction. Hibiscus then set a bud in between the nodes and, if the internode space is close, the buds will be closer also and can bloom sooner. Another benefit to the growth reduction is for the homeowner. If, normally, the cultivar grows vigorously, the homeowner may need to cut back the plants several times a year to maintain its size, thus losing several weeks of blooming time. Also, the smaller, compact plant allows space for more hibiscus plants in the garden or on the patio. Therefore, the Cycocel-treated, or dwarfed hibiscus, is more marketable and pleasing to the consumer. (Notice, I did not call them dwarf hibiscus, a term often misused since the hibiscus are dwarfed by a chemical).

Cycocel is applied when the plant has reached its desirable size. The rate of Cycocel application depends on several factors. Do you want a reduction of plant growth, or a nearly total halt to growth? Cycocel at 250 to 500 ppm will cause a growth reduction; at 750, 1000, or 1500 ppm it will stop the plant's growth depending upon the cultivar. (1 oz./gal. gives approximately 1000 ppm) The newer cultivars, especially those with heavy, waxy, wavy leaves, need a very low rate to set buds. I have seen some cultivars treated with higher levels of Cycocel that did not grow for several years; however, they did bloom well. The more vigorous plants need a heavier application to keep the plant's size under control. Different areas of the country will observe different results with the same cycocel application. A 250 ppm rate may cause bud production in some areas, such as the north, while 250 ppm in the south may just slow down growth or have no effect at all.

Some growers use several low-rate applications of Cycocel throughout the growing season. They believe these low con-

centrations start bud set sooner. This idea is very popular with the 6-in florist hibiscus.

Cycocel also affects the leaves. They turn a very dark green and have a leathery texture within a few weeks after spraying. High concentrations will cause severe cupping of the leaves and they become very brittle.

The marketing of a Cycocel dwarfed hibiscus should be much easier since the plant will be compact, dark green, and heavily budded. A hibiscus plant in bloom is very attractive and difficult for a customer to pass up. When the plant is not in bloom and showing off its spectacular flowers, it looks like an ordinary woody ornamental. In a retail store, display all the hibiscus in bloom together, or if this is not possible, pull the blooms off and display them with a label in a peg board. Display them with annual bedding plants, not with woody ornamentals. Since the plants in bloom are usually the first to sell, this allows each customer to know exactly what flower he is purchasing. It is important to label each hibiscus plant by cultivar. The label should give the name and a short description of the flower. This allows the customer to become familiar with the cultivar and become more informed. Once the homeowner catches hibiscus fever, he may return for different cultivars, rebuy the same one next spring or talk to the neighbors about their favorites.

The new sales tactic for selling hibiscus is to sell them as an annual color crop instead of a perennial garden shrub. Discourage homeowners from trying to save hibiscus through the winter. Hibiscus in the ground, cut back and mulched over may make it through the winter, but half the growing season will pass before the plant blooms. It would be a much better idea to sell a tropical colorful plant in March or April for the homeowner to enjoy until November or until the first freeze.

Often one hears the complaint about hibiscus, "I don't want to spend that much money on a plant that freezes." Compare the hibiscus to a garden mum, which blooms for a month, or to a poinsettia. No one complains about the short time these last while hibiscus will last the whole growing season.

Hibiscus may be marketed in numerous methods. Hibiscus, besides being sold as a color plant for the yard, makes an excellent patio container shrub or tree. Hibiscus can be grown as accent plants in the form of espaliers and braided trees, which are very popular. Hibiscus can be grown as a hedge or in a mass color planting in commercial or residential landscapes. The more exotic hibiscus are collector items for the

hobbyist. The 6-in. pot could be grown and available to the consumer year round.

Commercial production of *Hibiscus rosa-sinesis* has a great potential as a color crop, especially when grown as a green, compact flowering plant by the use of good growing practices and by Cycocel treatments, which enables the hibiscus to be in bloom for early spring sales, and the year around.

ROOTING HORMONE FORMULATIONS: A CHANCE FOR ADVANCEMENT

JAMES B. BERRY

Flowerwood Nursery, Inc.
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Loxley, Alabama 36551

The effects of synthetic auxins indolebutyric acid (IBA) and naphthaleneacetic acid (NAA) have been known since 1935 (8). Since that time work with these chemicals and other compounds such as 2,4-dichlorophenoxyacetic acid (2,4-D) (2), and willow extracts (6) have been reported. Commercial mixtures such as Wood's Rooting Compound (7), Rootone products, and Dip'N-Grow are successfully used throughout our nursery industry.

Flowerwood Nursery practices specific use of combinations of IBA, NAA, potassium-IBA, alcohol, water, talc mixtures and solutions, as root-promoting treatments. We find species and cultivar variations by treatment demonstrated by *Raphiolepis indica*, *Rhododendron*, *Camellia sasanqua* and almost all species that we produce. Our auxin formulation program offers opportunities for great progress for plant propagators in time, quality, and quantity of rooting.

Hormone-induced rooting of cuttings is a common practice among nurseries of all sizes. Many purchase commercially-available packaged rooting compounds. Others purchase chemical-grade auxin and formulate their own solutions. Most common is the use of crystalline IBA, diluting it with alcohol and water for desired concentrations.

Flowerwood Nursery produces 80% of all its liners from stem cuttings. Typical cuttings are from 3 to 7 in. in length. These cuttings are taken from container or field stock plants. Cuttings are bundled with rubber bands and trimmed for uniformity. Most cuttings are not stripped. All cuttings are rinsed in a fungicide solution before auxin treatments. The balance of

hobbyist. The 6-in. pot could be grown and available to the consumer year round.

Commercial production of *Hibiscus rosa-sinesis* has a great potential as a color crop, especially when grown as a green, compact flowering plant by the use of good growing practices and by Cycocel treatments, which enables the hibiscus to be in bloom for early spring sales, and the year around.

ROOTING HORMONE FORMULATIONS: A CHANCE FOR ADVANCEMENT

JAMES B. BERRY

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The effects of synthetic auxins indolebutyric acid (IBA) and naphthaleneacetic acid (NAA) have been known since 1935 (8). Since that time work with these chemicals and other compounds such as 2,4-dichlorophenoxyacetic acid (2,4-D) (2), and willow extracts (6) have been reported. Commercial mixtures such as Wood's Rooting Compound (7), Rootone products, and Dip'N-Grow are successfully used throughout our nursery industry.

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our liner production is evenly divided between division and seed.

Auxin treatment is typically a 3-sec. basal dip. Quick dips and extended dips are occasionally used. All cuttings are directly stuck into 2¼-, 3¼- or 4-in. plastic liner cups (5). Cuttings are rooted in Cave Enterprise covered gutter-connected plastic hoop houses under intermittent sprinkler irrigation. We use Ross 24 sprinkler heads. All phases of propagation except watering, pest control, and maintenance are piecework systems.

IBA-ALCOHOL-WATER SOLUTIONS

The foundation of our auxin formulation program is IBA-alcohol-water dilutions. We purchase chemical-grade IBA from Eastman Kodak Co. of East Rochester, New York. Other chemical companies have been listed as a source in a previous publication (1).

Basic Formulations:

(1) To prepare Stock solution = (10,000 ppm IBA)
mix . 5 grams IBA
1 pint 70% isopropyl alcohol

(2) To prepare 5,000 ppm IBA
mix . . 8 parts stock
4 parts tap water
4 parts 70% isopropyl alcohol

(3) To prepare 2,500 ppm IBA
mix . 4 parts stock
6 parts tap water
6 parts 70% isopropyl alcohol

(4) To prepare 1,250 ppm IBA
mix . 3 parts stock
7 parts tap water
6 parts 70% isopropyl alcohol

(5) To prepare 1,870 ppm IBA
mix . . 2 parts stock
7 parts tap water
7 parts 70% isopropyl alcohol

Uses of IBA-water-alcohol dilutions:

10,000 ppm IBA: Use on difficult-to-root species such as *Photinia* × *fraseri*, *Eriobotrya japonica*, hardwood *Ilex* × *attenuata* 'Fosteri', and hardwood *Ilex opaca* 'Savannah'. Mr. Sidney Meadows years ago advised me to root *Photinia* by using the strongest liquid treatment. Out of ignorance I treated with stock 10,000 ppm IBA and it worked. At this time Mr. Meadows was unfamiliar with IBA-water-alcohol solutions. His advice was right on target. *Photinia* × *fraseri* cuttings, with opti-

mum type wood and proper environment, will root profusely in 15 days.

5,000 ppm IBA: This treatment is seldom used at Flowerwood Nursery. Most of our cuttings are taken in spring, summer, or fall of current year wood. this strength would be of use on winter cuttings of ligustrum, pyracantha, and other species. Species that root fairly well in the summer might be slow and difficult in the winter. With this level of IBA one should see reduced rooting time and higher percentages of takes.

2,500 ppm IBA: This treatment is widely used. Response on medium-slow or medium-difficult species is great. It is commonly used on *Ilex cornuta* and species of *Ligustrum, Pyracantha, Viburnum* and most *junipers.*

1,870 ppm IBA: 1870 ppm IBA is used on fairly easy and fast-to-root items. Examples would include *Euonymus*, certain azaleas, *Ilex vomitoria* Nana (dwarf yaupon), and *Ilex crenata* 'Compacta'.

1,250 ppm IBA: There are certain cultivars that root from fallen cuttings. They root where they touch the ground and they root in the trash can. We commonly use this weakest strength IBA on these items. Most Kurume azaleas, Satsuki azaleas, *Trachelospermum* (*Rhynschospermum*), *Cotoneaster*, and *softwood Lagerstroemia* all fall into this category. The advantages of using treatments on the easy cultivars are shortened mist time, reduced disease pressures, and reduced intensive care time of long duration rooting. Quality and quantity of roots are also enhanced.

As a general rule, the harder the cutting wood, the higher the auxin concentration should be.

IBA — NAA — ALCOHOL WATER SOLUTIONS

A very successful propagation program can be designed using only IBA. However, several species respond dramatically to IBA-NAA combinations. Five years ago I began to investigate IBA-NAA combinations. In 1980 my first discovery was that *Raphiolepis indica* cultivars had very specific responses to IBA-NAA levels. This held true as I worked on *Camellia japonica, Camellia sasanqua, Rhododendron*, and many other species.

Basic formulations:

(1) To prepare 10,000 ppm IBA + 3,000 ppm NAA
mix . 1.43 grams NAA
1 pint IBA stock solution

(2) To prepare 8,000 ppm IBA + 2,500 ppm NAA
mix . . . 8 parts IBA stock solution
1 part 70% isopropyl alcohol
1 part tap water
1 19 grams NAA
(3) To prepare· 2,500 ppm IBA + 2,500 ppm NAA
mix . . . 1.19 grams NAA
1 pint of 2500 ppm IBA
(4) To prepare 5,000 ppm IBA + 1,500 ppm NAA
mix . 0.71 grams NAA
1 pint of 5000 ppm IBA

My experience shows that NAA at 2,500 ppm can be toxic. I do not use NAA at levels greater than 3000 ppm.

There exist great opportunities to those who become familiar and comfortable with IBA-NAA mixtures. Commercial mixtures do not give me the latitude to design specific optimum auxin treatments to accommodate cultivar variances.

OTHER FORMULATIONS

K-IBA. K-IBA is the potassium salt of indolebutyric acid. It is highly water soluble while IBA itself is not. We selectively use K-IBA solutions as auxin treatments where alcohol sensitivity is present.

To prepare 3,000 ppm K-IBA
mix . . . 1.43 grams K-IBA
1 pint H_2O

To prepare 3,000 ppm K-IBA + 3,000 ppm NAA
mix . . . 1 pint H_2O
1 43 grams K-IBA
1.43 grams NAA

The most dramatic effect of K-IBA is for treatment of *Ilex crenata* 'Helleri', *Ilex vomitoria* 'Nana,' and *Berberis thunbergi* 'Atropurpurea Nana.' When using an alcohol-based solution, all of these species at times will have basal flaming, a result of alcohol burning, immediately after auxin application.

IBA-talc-fungicide. We formulate our own talc mixtures. We find greater response with those mixtures than to solution treatment only in a few cases (*Elaeagnus*, *Rhododendron*, and certain *Ilex* species).

To prepare: 2% IBA-talc-fungicide
mix 2 grams IBA
8 grams Benlate
90 grams talc

Any commercial baby powder talc will suffice. To change the percentage IBA one has to manipulate the IBA-talc ratios.

SOME SPECIFIC OPTIMUM AUXIN TREATMENTS

IBA

1. *Rhododendron* (satsuki group) 'Shinnyo-no-Tsuki': 1250 ppm IBA
2. *Cotoneaster salicifolius*: 1250 ppm IBA
3. *Euonymous japonica* 'Aureo-marginata': 1870 ppm IBA
4. *Gordonia lasianthus*: 2500 ppm IBA
5. *Pyracantha* 'Navajo': 2500 ppm IBA
6. *Photinia* × *fraseri*: 10,000 ppm IBA

K-IBA

7. *Berberis thunbergi* 'Atropurpurea Nana': 3000 K-IBA
8. *Ilex crenata* 'Helleri': 3000 ppm K-IBA

IBA-Talc

9. *Elaeagnus pungens* 'Fruitlandii': 2% IBA-talc

IBA-NAA

10. *Nandina domestica* 'Purpurea': 1250 ppm IBA + 1500 ppm NAA
11. *Ilex cornuta* 'Rotunda': 3750 ppm IBA + 750 ppm NAA
12. *Camellia sasanqua* 'Yuletide': 6000 ppm IBA + 2500 ppm NAA
13. *Camellia japonica* 'Warrata': 8000 ppm IBA + 2500 ppm NAA
14. *Ilex latifolia*: 10,000 ppm IBA + 1500 ppm NAA

METHODS OF EXPERIMENTATION

There remain many discoveries to be made in regard to auxin treatments and practices. New product lines at Flowerwood Nursery are initially propagated by our best reasonable guess. Difficult items are tested with a wide range of application methods, auxin levels, and auxin combinations. Currently we use 15 different treatments to do auxin experimentations. We constantly study responses and analyze our results. We feel that many factors affect rooting abilities, but a primary factor is the auxin treatment. Our research is headed in the direction of higher IBA concentrations, as well as use of aryl esters of IBA and indoleacetic acid (3).

Auxin treatment of cuttings is an integral part of Flowerwood's accelerated cropping systems. The essence of accelerated cropping is to maximize plant growth and development beginning with the cutting. We avert stress. If we cannot avert it, we try to minimize stress. Use of auxin treatment, we feel,

greatly accelerates rooting and liner development helping us in our race to the market place.

LITERATURED CITED

1 Dirr, M A 1981 Rooting compounds and their use in plant propagation. *Proc Inter. Plant Prop. Soc* 31.472-479

2 Ellyard, R K 1981. Effects of auxin combinations on rooting *Persoonia chamaepitys* and *P pinifolia* cuttings. *Proc Inter. Plant Prop. Soc.* 31·251-255.

3 Haissig, Bruce E 1979. Influences of aryl esters of indole-3-acetic and indole-3-butyric acids on adventitious root primordium initiation and development *Physiol. Plant* 47 29-33

4. Meadows, S B 1975. Personal communications

5. Meadows, S B 1981 Developments in direct rooting *Proc Inter. Plant Prop Soc* 31.655-658

6 Proebsting, W. M. 1983. Willow water and rooting rhododendron cuttings. *Proc Inter. Plant Prop. Soc.* 33:79-81

7 Woods, Edsal A 1981 New horizons in rooting hormones. *Proc. Inter Plant Prop Soc* 31 116-118

8. Zimmerman, P W and Frank Wilcoxon. 1935 Several chemical growth substances which cause initiation of roots and other responses in plants. Contrib Boyce Thompson Inst. 7 209-229.

DEVELOPMENTS IN DRACAENA PRODUCTION

JOE CIALONE

Tropical Ornamentals
5346 Woodland Drive
Delray Beach, Florida 33445-1198

Dracaena fragrans and *Dracena fragrans* 'Massangeana' are two of the most important plants used in interiorscaping. These plants are native to tropical Africa but are known to have been under cultivation in Europe since at least the mid-1700's. Currently, these plants are available in bush, cane, tree, and stump forms. They are used extensively in interiorscapes because of their aesthetic impact and because they perform well under low light conditions with very few insect and disease problems.

This paper will focus mainly on the production of this plant in the cane form and will introduce some new techniques which could have a significant effect on how cane is produced and grown.

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Until the 1960's most cane was collected in Central and South America and shipped to the United States for growing. During the past 25 years extensive acreage of cultivated cane has greatly increased both the total volume and diversity of

sizes, and made cane available 12 months of the year. Cane is normally harvested and processed in a 10-day period and shipped to final producers. This process usually includes cutting the cane into 1-, 2-, 3-, 4-, 5- or 6-ft. pieces, waxing the top end, treating with indolebutyric and (IBA) and eventually shipping in climate-controlled containers.

In south Florida the most commonly-grown configurations are canes of staggered heights as follows: 8 or 10-in. pots having a 3-ft., 2-ft., and 1-ft. cane; 10 or 12-in. pots having a 4-ft., 3-ft. and 2-ft. cane; and 12 or 14-in. pots having a 5-ft., 4-ft., 3-ft. and 2-ft. cane. Normally from one to three lateral buds develop at the top of each cane, thus producing the tufted look that we expect in normal cane production.

The development of the lateral buds at the top (apical) end of the cane are of both horticultural and botanical interest. Dracaenas are botanically monocotyledenous plants. This group includes other major plants such as grasses and palms. Most of the herbaceous (leafy type) members of the monocot group are quite different from the dracaenas in that they do not exhibit secondary cambial growth. In this regard, the dracaena group is more like the dicotyledenous plants, such as *Ficus*, *Quercus* (oaks), and many other common plant species. Dracaenas have a secondary cambium, which allows for lateral growth or thickening of stems, as well as vascular bundles within the stems. A cross examination of a dracaena stem will show that there are a series of leaf scars around the stem, each containing a lateral or axillary bud. The fact that only the top buds develop on cut cane is due to what is referred to as apical dominance.

The concept of apical dominance is well known in horticulture. Many plants exhibit this phenomenon, which is the inhibition of the development of buds located below the apex or tip of the plant. When certain plants are pinched or pruned, non-apical buds often develop and, thus, the plants branch or become bushier.

Nowhere is apical dominance more evident than in the growing of *Dracaena fragrans* 'Massangeana' in the cane form. In almost all cases 1 to 3 buds develop at the apical end of a 'Massangeana' cane, while buds below this point are inhibited and remain dormant.

The possibility of artificially inducing additional buds to develop in this plant without sacrificing the apical heads has been the goal of many people in our industry. This response would allow a myriad of new possibilities, including:

1. Promoting more apical heads. Often only 1 or 2 develop while 3 or more is most desirable.

2. Promoting a bushier look at the base of the pot. Often 1- or 2-ft canes will develop only one head.

3. Promoting head development along the length of taller canes to give a fuller look or to develop heads in selected areas to give a more decorative look, such as the poodle cut.

4. Promoting branching during field propagation to produce plants that have more character.

It is generally accepted that non-apical buds do not develop because of growth hormones produced at the apex (top) of the plant that move downward and inhibit non-apical (lower) bud development.

It has been observed many times that when cane is injured, buds below the injury will sometimes develop. Additionally, in a branched cane, each branch develops independently. An apex on one branch, even if it is shorter than another, will develop apical buds. This indicates that the inhibiting hormone travels mostly downward.

After considerable research[7] it seemed that the answer to the problem of inducing lateral buds to develop without affecting the top buds was to isolate a bud or buds from the influence of more apical buds. After applying this reasoning, it remained to develop a technique to accomplish this goal. We have found that cutting deeply into the cane results in the development of lateral buds below the cut area. This is not a new idea. Reed and Holme did this in 1919 with lemon trees. A bud or buds will develop anywhere from directly below the cut to a distance of 5 or 6 in. below it. This distance is related to the location of buds on the side of the cane that is cut. *Dracaena fragrans* 'Massangeana' buds form in the leaf axils of the developing plants. Since the leaves are formed in whorls, it follows that the buds are present in a whorled pattern around the cane. We have observed that 3 leaves complete approximately a 360° circle, with the center of each leaf being 120° apart, each bud being progressively further up or down the cane. The vertical distance between buds is related to growth factors that affect the rate of growth and vigor of the plant.

We have also found that by cutting in selected areas of the cane, it is possible to promote a specific bud or buds to develop (Figure 1). The location of a cut on old or new wood on the cane seems to make no difference in terms of success rate, and the development of these lateral buds has no detrimental effect on the growth of apical heads or on root growth. Five-foot canes have developed up to 4 lateral buds when properly cut. Several of these have been grown to salable size and sold to the trade.

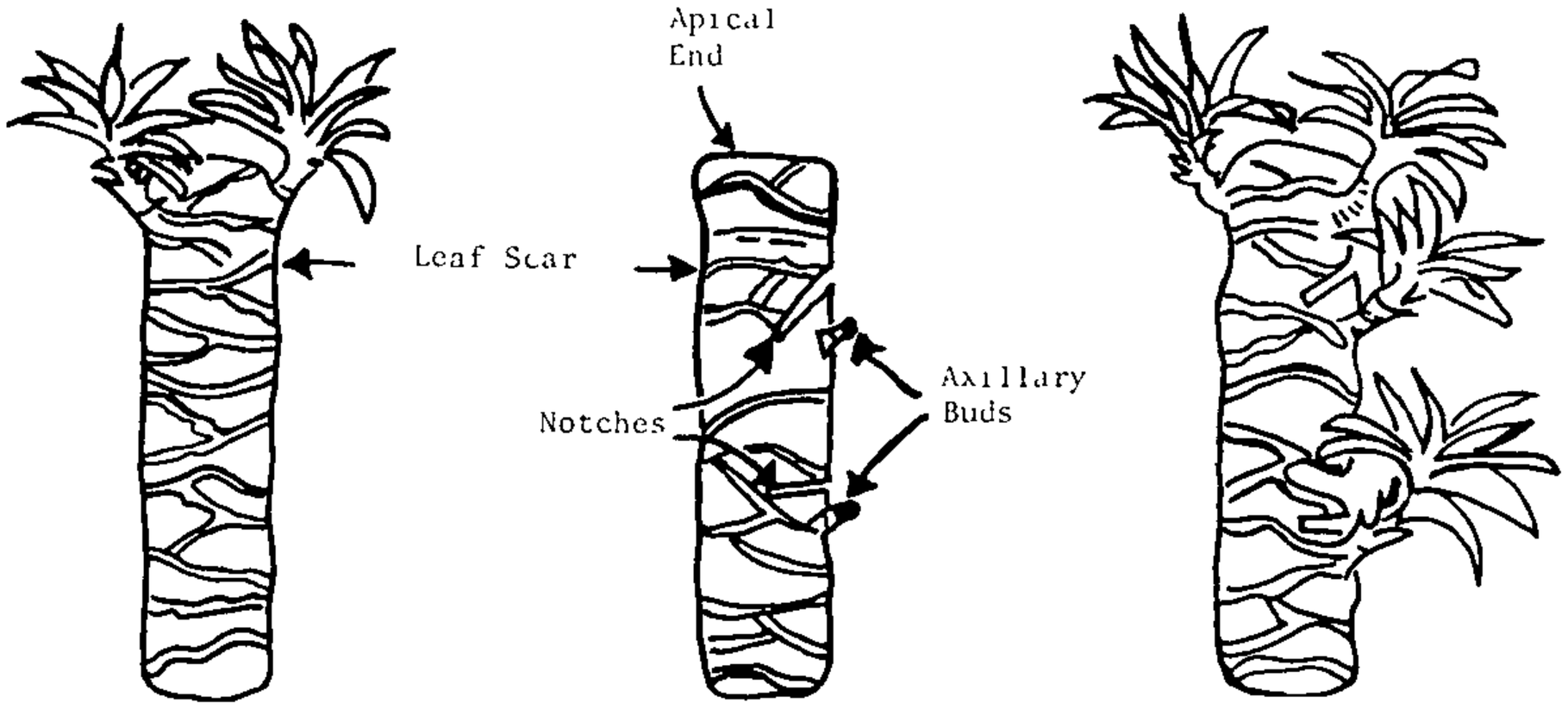


Figure 1. Technique for promoting lateral bud development in dracaeana canes *Left* Typical unnotched cane *Center*: Cane following notching *Right* Notched cane producing lateral buds.

It is sometimes observed that a bud will begin to develop near the apex and then stop dêveloping and end up as a stub. This is probably due to hormone production in buds that are more advanced, or more apical (further up on the cane). We have found that a deep cut above such a bud will result in full development. Currently, our work has been done with cuts ⅓ to ½ of the way through the cane. We are experimenting with the minimum depth of cut to assure bud development.

These research efforts are only in their beginning stages. We are very excited about the possibility of making a very good plant even better. We are currently working with *Dracaena marginata* and *Dracaena deremensis* 'Warneckii', and results to date are very promising.

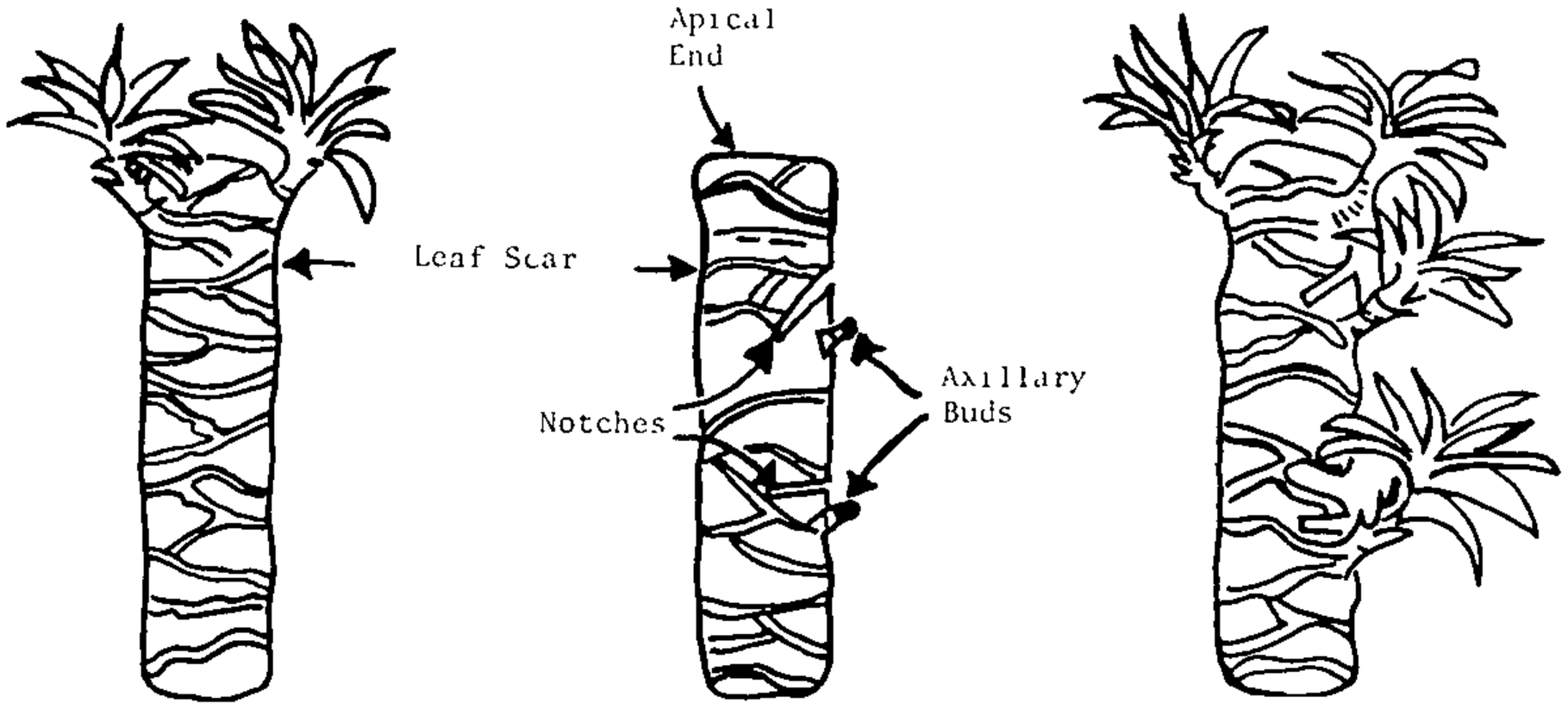
JAPANESE STYLE WORK GROUPS AT CYPRESS CREEK NURSERY, INC.

JAMES DOUGLAS RYAN

Cypress Creek Nursery, Inc.
8055 Conroy Road
Windermere, Florida 32786

After a study of Japanese style management groups by Leiser Colburn, it was decided by the management team[1] at Cypress Creek Nursery to set up a trial program in one department of the nursery to see if such methods would prove beneficial in the company. The propagation department was selected for two reasons:

[1] Management team: Bill Colburn, Bill Mincey, Doug Ryan, June Sunday



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1. Under Cypress Creek Nursery management structure, the department functioned virtually alone. It was headed by a foreman who was a working member of the 10-member group. Its productivity could be objectively measured and was not dependent upon the performance of any other group within the nursery.

2. The cost of production in the department was at an unacceptable high level, and long-term production schedules for finished liners had never been met. Conventional management techniques were not improving performance. It was the opinion of the management team that the situation in the department could not get any worse. The Quality Circle concept was to be implemented as a measure of last resort prior to radically restructuring the department.

The plan was that beginning August 24, 1981, one half-hour each week would be set aside for an unsupervised employee group meeting at which time members of the group would be expected to identify and solve problems contributing to their unacceptable production record. Lieser Colburn, who was not a member of the CCN management structure, would meet with the group to help them develop communication skills and encourage them to think creatively about the work they were doing. She was to be the liaison between the group and management, providing for the group the statistical data necessary for them to evaluate their own performance and securing the support of management for the improvements suggested by the group. The group was to be given as much information as it could assimilate concerning its own job; how that job related to and influenced other departments within the company; and how the company related to the nursery industry. In addition, educational programs were to be scheduled to increase group understanding of basic horticultural practices.

Within a short time management was able to detect improvement in the performance of the group. Some of the improvement, such as increased morale and greater cooperation with other departments, could not be evaluated statistically but was to prove extremely beneficial to the company. For instance, in our company, inventory figures begin with the weekly count turned in by each member of the propagation department, who is then paid a piece-work rate.

We were obtaining an accurate count numerically, but there was extreme carelessness in reporting species and cultivars. A session was scheduled with the office manager who explained the inner workings of her department to the group and stressed that accuracy for them depended upon the cor-

rectness of the propagation department reports. The group, with new understanding of the importance of its work, responded by exercising greater care in reporting what it had previously perceived as useless information.

By January, 1982, management was able to report to the group that the September through December production had increased by 233,033 units over the same 4-month period the previous year. In addition, a higher percentage of the cuttings taken had rooted, the quality of the liners had improved, and there were fewer weeds in the propagation areas.

The group had correctly identified and dealt with the problems that were impeding efficiency. The changes they had made in their procedures were as simple as assuming responsibility for ordering supplies before they ran out and cooperating within the department on the use of carts and other equipment. A team spirit had developed as the group became more aware of overall goals, while at the same time, individual efficiency had increased.

As production schedules were met, the group used slack times to visit other nurseries and observe their propagation techniques. This produced lively discussions of the strengths and weaknesses of our program and seemed to heighten the group's awareness of their position in the company and the industry.

We feel the program was very beneficial and have implemented it to a more limited degree in other areas of the nursery.

IMPROVED TECHNIQUES USED IN PRODUCING BUDDED CITRUS NURSERY TREES FOR COMMERCIAL FRUIT PRODUCTION

WILLIAM G. ADAMS

Adams Citrus Nursery, Inc.
Haines City, Florida 33844

Since the introduction of citrus fruit to the Western world by Spanish explorers, citrus trees have been produced by squeezing out the seeds and planting them in the ground. The trees grew slowly and were usually 10 to 20 years old before reaching a fruitful maturity.

In the late 19th century grafting and budding techniques began to be used by some growers to reproduce quantities of desirable fruit types. Other advantages soon became apparent as growers now had the abilities to improve cold hardiness,

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adapt trees to poorer soil types, and also produce larger quantities of better quality fruit without several years' wait for scion maturity.

Satisfied with these developments, growers and researchers spent the next several decades improving fruit quality by developing new cultivars and rootstocks, using cross pollination techniques.

With the invention of the orange concentrate process the Florida citrus industry rapidly grew in size and so did the demand for citrus trees. Nurserymen, in an effort to fill this growing demand, soon resorted to the improved production methods of more irrigation, more intensive fertilization, and other cultural practices that made the trees grow faster but seriously increased the risk of cold injury. When fuel oil for outdoor heating began to increase in price, it became apparent that new growing techniques would soon be required. The improvements made in the last ten years are the text of this paper.

In modern citrus production the rootstock holds equal importance with the scion cultivar. The best rootstock cultivars are screened for freedom from various pathogens, assigned registration numbers, and distributed to the industry for further multiplication.

When the mature seed fruit is harvested, it is run through a device with rapidly spinning fingers that tears the fruit apart and exposes the seed and pulp within. A flood of water carries the resulting seed-pulp slurry into a rotating cylinder screen which separates peel from the seed and sends the peel out a conveyor to the dump.

The loose seed is collected, along with small pulp bits, and placed in a digester tank for cleaning. This process, developed about ten years ago by Drs. Barmore and Castle, University of Florida, is simply a speeded-up fermentation or rotting process, which destroys all the solids and leaves the seed coat intact.

Simply put, the process is as follows: A large 50 gal. tank is constructed. The bottom is removed and a gate valve placed in the bung for seed removal when the process is complete. About 40 gallons of equal parts seed slurry and water are added to the tank. Two ounces of "Kleerzyme 200", a pectolytic enzyme from the wine-making industry are added, with about 8 oz. of sodium bicarbonate, to bring the pH to 4.5. An agitator provides continuous stirring and a heating element brings the temperature to 85°F. Within 8 to 12 hrs. the digestion is complete. Clean seeds are removed, dipped in a fungicide, and dried with warm air. When dry, the seed is packaged

(in 2-lb. quantities) and placed in cold storage at 34° to 38°F. Viability has been maintained for up to 2 yrs. by this method.

For planting, the seed is removed from cold storage and soaked in water at 90°F for 16 to 18 hrs. Planting consists of single seeding in 3 and 5 in. deep "Speedling" trays with suitable soil mix such as Pro-Mix. Planted trays are then moved to a greenhouse at 90° to 95°F. for seed germination. When 80 to 90% of the seedlings have emerged (20 to 30 days), temperature is reduced 10°F. Liquid fertilization is commenced immediately on transfer to the greenhouse.

Seedlings are of satisfactory size to transplant to greenhouse Citripots in about 80 to 90 days from planting. About 30 days are allowed for hardening off before transplanting in the open field.

At a height of 6 to 7 inches the seedling is ready for transplanting to a larger Citripot. Soil temperature is maintained at 80° to 85°F and fertilization is provided weekly in irrigation water. Depending on cultivar, 60 to 90 days are required for the seedlings to achieve a size for budding, ⅛ to 3/16-in. caliper.

The greenhouse Citripot is a 4-in. square × 14-in. deep plastic pot with a hole of approximate diameter of 2½ in. on the bottom for air pruning of roots. The volume of approximately 3 qts. is adequate for one year's intensive greenhouse growth.

For budding, a very small bud is used with the inverted T-bud method. Wraps remain on for 14 to 21 days, followed by a 5-day resting period after unwrapping. Various methods of forcing the bud can be used, but we find the most suitable is to roll or bend the top of the seedling just above the bud down beside the pot, then wedge the pots together to hold the top down. Bud eyes emerge a little slower, but once out, seem to grow faster without the shock of lopping.

Once growth from the new bud has reached a height of 6 to 7 in., a small steel stake is placed in the pot for training a straight trunk. The stake stays with the tree when planted in the grove. A label stating scion and rootstock, and all identification numbers, as well as the budding date, is attached immediately after budding so that the identity of each plant is never lost.

When seedlings are placed in the greenhouse for budding, they become part of an assembly-line growing process so that, as they grow, they are moved slowly across the greenhouse on a dolly and track system devised for this type production. At the end of the growing period, about 8 to 9 months later, the plants are graded for shipping sizes and moved on the same

dollies into a truck for delivery to the final purchaser.

The controlled greenhouse environment has proved to be quite a satisfactory method of citrus tree production, enabling the nurseryman to increase or decrease available light in the summer and alter temperature and humidity during the winter. The total production time of 10 to 14 months from seed compares quite favorably with the 30 to 36 month production time required for 100% field production. In addition, the serious danger of extreme cold is eliminated, although the problem of cooling-power failure does exist to some extent in the summer months. Total production costs favor the greenhouse plants over the field grown, with the big advantage being removal of cold hazards.

The greenhouse or Citripot tree has many advantages over bare-root production that are quite beneficial to the citrus grove owner. The primary advantage is that, since the plants are in containers, they can be held in a shaded holding area or barn for several days before planting, allowing the citrus grower to use his own, usually cheaper, labor for transplanting. Transplant shock is eliminated and a simple hole dug with a post hole digger is suitable for planting. The tree is mudded in from a water tanker and, with low volume irrigation, does not have to be watered again. Dry fertilization can be done the same day and, thereafter, with irrigation water. The pot in which the plant has been grown is inverted over the tree to provide protection from hungry rabbits, sand blasting, and sunburn. Some research indicates a small degree of cold protection from the inverted pot.

Field performance of trees produced in a controlled environment have equalled or exceeded conventionally-produced outdoor, bare-root citrus trees. The fact is strongly confirmed by the large number of growers now insisting on purchasing only the greenhouse-grown trees.

AN INSULATED PALLET TO REDUCE LABOR COSTS AND TEMPERATURE STRESS IN CONTAINER PLANT PRODUCTION[1]

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Abstract. An insulated pallet system was devised and tested for handling and summer and winter temperature moderation Handling labor is required only twice instead of 6 to 9 times Since plants could not blow over, the weight of the growth medium could be reduced by 50% or more by eliminating sand as a component Plant growth and quality was increased by reduced root zone temperatures in summer Plants overwintered with the pallet system had no detectable root injury compared to moderate injury with a single layer poly-covered structure or with straw, and severe injury or death with no protection Ten advantages of the system are discussed.

INTRODUCTION

Labor is the greatest expense in producing container nursery stock (2,4,6). Individual containers are handled from 6 to 9 times during the production cycle (9). This does not include the additional labor involved in standing plants up after a windy day, or fastening plants to the soil with stakes or by wires attached to the top. A system that prevents plants in containers from blowing over substantially reduces labor costs, and could be very cost effective.

Stress from temperature extremes are major problems associated with container plant production (9). Roots of container-grown plants are not in their natural environment and are subject to temperature extremes. To prevent low temperature injury, the nursery industry is currently using many different techniques: a) bunching plants together or laying them down, b) bunching with paper wind barriers around the perimeter (5), c) improving nutritional practices to prepare plants for winter (7), d) mulching with straw (1), e) constructing single- or double-layer poly houses with or without a layer of poly or microfoam over the plants inside the houses (1,5), and e) laying plants down and covering with microfoam or microfoam and poly (3).

High temperature stress also restricts plant growth in containers. White containers reduce root injury and stimulate plant growth, but are generally not practical (8). Early planting of large liners reduce high temperature stress by developing a

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[1] Journal series #4748 of the Oklahoma Agriculture Experiment Station, Stillwater, Oklahoma.

[2] Professor and former undergraduate student, respectively

plant canopy over the container before summer's heat (9). Spacing plants so that the top of one plant shades the adjacent container from the intense afternoon sun aids growth (9).

After numerous studies in each of these areas (9), it appears that an insulated pallet system could solve several problems: 1) reduce labor, 2) prevent plants from blowing over, 3) reduce high temperature stress, 4) protect roots during overwintering, 5) reduce early spring growth, 6) reduce cost of bed preparation and maintenance, 7) provide a re-usable container shipping mechanism, 8) be adjusted to different production schemes, 9) potentially decrease soil-borne diseases, 10) eliminate weeds in drain holes, and 11) insure that containers are clean at shipping time. This is a summary of several related studies and a discussion of their potential.

PROCEDURES

During the summer of 1981, a study was conducted to measure the effects of three root environments on plant growth. Green #1 containers (approx. 3.5 liters) were compared, second — with the same container painted glossy white, and third — with the sidewall of the container shielded from any direct light by lightweight aluminum sheeting. All plants were grown in a mix of pine bark, peat, sand, 3-1-1 (v:v:v), with Osmocote 17-7-12, Micromax micronutrients, and dolomite @ 14, 1.5, and 8 lbs./yd.^{3} (8, 0.9, 4.75 kg/m^3), respectively. The 6 species (see Table 1) were grown in full sun and watered by overhead sprinklers as needed. Temperatures in containers were monitored every 2 hours during the period July 5 to 15, using thermocouples placed 3 in. below the surface and 1 in. in from the south side.

The highest temperatures recorded were at 5:00 p.m. The average high temperatures on 7 sunny days during August were 107°, 101°, and 96°F (42°, 39°, and 35°C) for green, white and aluminum covered containers, respectively, when the air temperatures averaged 97°F (36°C).

At the end of the growing season differences in top and root weights and, for some species, number of branches and visual grade, were greatest where the sides of the container were shaded by the aluminum (Table 1). Plant response was intermediate with the white container and poorest in the green containers. Azalea and elaeagnus benefited most from the aluminum shading; however, all responses measured for all species were greatest with the aluminum shading (Figure 1).

During the winter of 1981-82 and 1982-83, two studies were conducted to evaluate the insulating effect of a pallet on

Table 1. Effects of container, exposure, and color on plant response.

Plant and parameter measured	Aluminum covering	White container	Green container
Hetzi Japanese holly			
Ilex crenata 'Hetzii'			
Top wt. (g)	52 b[z]	37 a	43 a
Root wt. (g)	101 b	83 a	81 a
No. branches	25 b	16 a	17 a
Visual grade	8.5 b	5.8 a	6.2 a
wintercreeper			
Euonymus fortunei			
Top wt. (g)	46 b	27 a	32 a
Root wt. (g)	80 b	65 a	64 a
No. branches	8.2 b	6.0 a	6.2 a
Visual grade	8.9 b	4.6 a	4.8 a
Nellie Stevens holly			
Ilex × 'Nellie R. Stevens'			
Top wt. (g)	217 b	75 a	71 a
Root wt. (g)	131 b	113 a	109 a
No. branches	8.7 b	7.2 ab	
silverberry			
Elaeagnus macrophylla			
Top wt. (g)	93 c	55 b	38 a
Root wt. (g)	86 c	69 b	48 a
No. branches	9.3 c	6.0 a	5.2 a
Visual grade	8.9 c	5.4 b	2.2 a
Hinodegari azalea			
Rhododendron × 'Hinodegari'			
Top wt. (g)	45 b	31 a	24 a
Root wt. (g)	45 b	41 b	26 a
No. branches	24 b	16 a	14 a
Visual grade	8.9 c	4.8 b	3.3 a
red top or Fraser photinia			
Photinia × *fraseri*			
Top wt. (g)	84 b	64 a	57 a
Root wt. (g)	69 a	65 a	47 a

[z] Averages followed by the same letter are not significantly different using a protected LSD test at the 1% level.

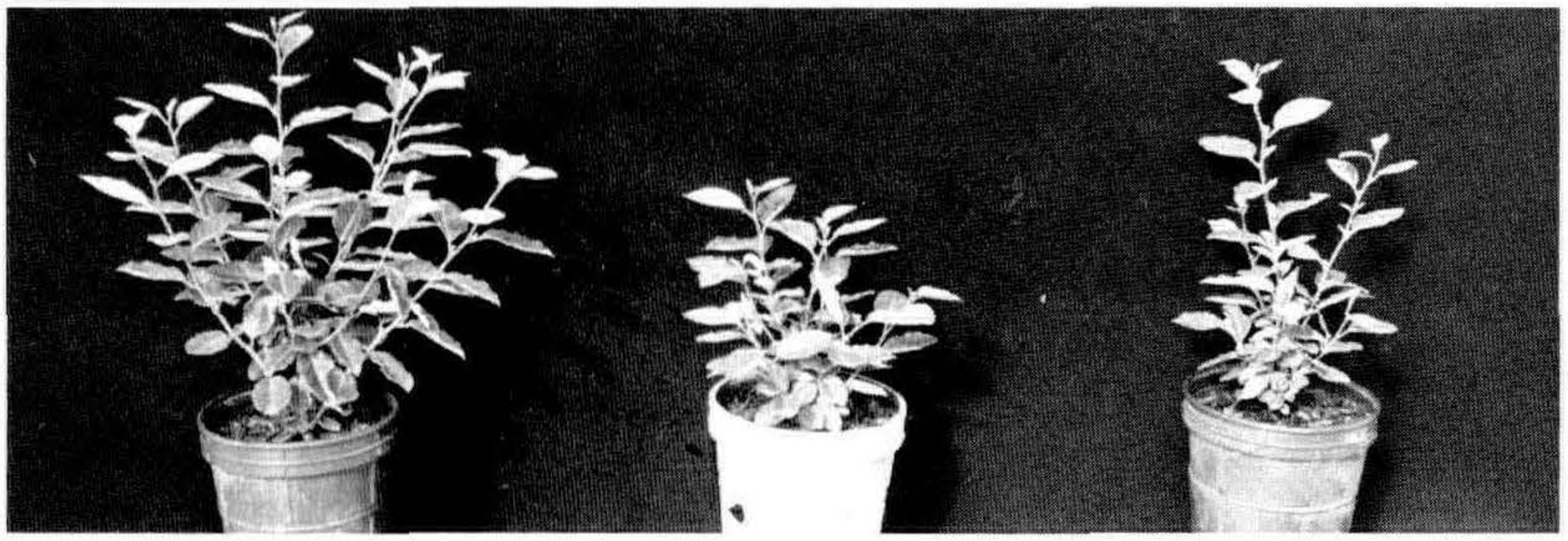

Figure 1. Growth of *Elaeagnus macrophylla* after one growing season in *(left)* container in aluminum pallet, *(center)* white container, and *(right)* green container, all exposed to direct sunlight.

root survival. For the winter of 1981-82 insulated pallets were constructed from solid 4-ft. × 8-ft. sheets of styrofoam, 2 in. and 4 in. thick (Figure 2). A special tool was made from sheet metal to taper holes for a snug fit of individual #1 containers. When the containers were in place, the sides of the pallets were covered with 2-in. styrofoam for additional root protection. Four species were used: *Euonymus fortunei*, evergreen wintercreeper; *Ilex crenata* 'Hetzii', Hetzi Japanese holly; *Ligustrum* × *vicaryi*, golden vicaryi privet, and *Juniperus procumbens*, Japanese garden juniper. A mix of 3 parts ground pine bark, one part sand, and one part peat was used as the growth medium. Four treatments were used: 1) 4-in. styrofoam pallet, 2) 2-in. styrofoam pallet, 3) heavy wheat straw mulch, and 4) no protection (plants bunched together). All treatments were replicated 4 times with 2 subsamples. The experiment began on November 17, 1981, with uniform plants of all species. All treatments were subjected to 3 natural levels of cold as follows: a) When temperatures reached 9°F (−11°C), two plants from each replication of each species were removed and placed in a heated greenhouse and evaluated for root injury. b) When the temperatures reached −4°F (−20°C), the second group of plants was removed and transferred to a heated greenhouse and evaluated. c) The third group remained outdoors throughout the winter; however, −4°F was the coldest temperature experienced.

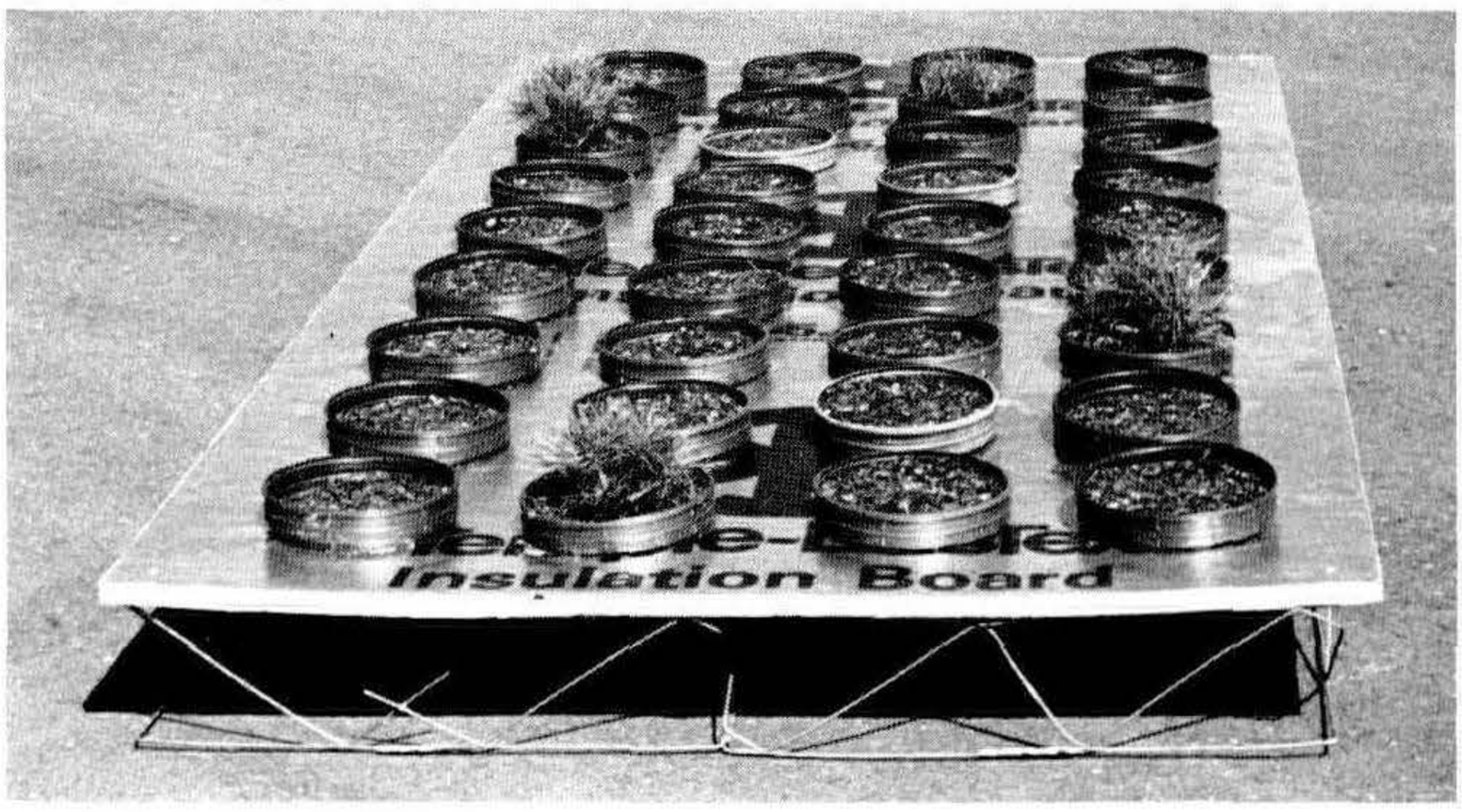

Figure 2. The insulated pallet system with 36 equally spaced containers. Plant roots in the containers are insulated from summer's heat and winter's cold when insulated on the sides, cannot blow over, and can be handled in units as opposed to individual containers.

Temperatures were checked in containers in the pallets throughout the winter and were found to be substantially warmer than pots that were jammed together, unprotected, or mulched with straw. The lowest temperature recorded for containers in either insulated pallet was 24°F (−5°C) during a period when outside temperatures reached −4°F (−20°C).

Marked differences were observed in root weight, top weight, and root counts, or visual root grades. In all cases results from the use of insulating pallets were superior to those from the straw mulch or those from exposed containers at the end of the winter (Table 2).

Table 2. Effects of root protection treatments on top and root weight and a visual root grade of golden vicary privet

		4 in styro-foam	2 in styro-foam	Straw mulch	Bunched but no protection
Date 1 (9°F)	top wt	157	143	163	167 NS
	root wt	71	77	86	91 NS
	root grade	7	6	6	6 NS
Date 2 (−4°F)	top wt	113 b	120 b[z]	103 b	22 a
	root wt	70 c	58 bc	44 b	17 a
	root grade	6 c	6 c	3 b	2 a
Date 3 (all winter) (−4°F)	top wt	54 b	72 b	52 b	dead a
	root wt	41 b	63 b	53 b	dead a
	root grade	8 c	8 c	6 b	1 a
	root count	44 c	48 c	25 b	0 a

[z] Averages followed by the same letter are not significantly different at the 5% level using a protected LSD test. NS = not significantly different

Only the privet data are presented since all species responded similarly, except that tops of the unprotected holly plants were killed on date 2. There was little difference in the protective properties of the 2-in. and 4-in. styrofoam; the 4-in. material provided no additional protection, and during extreme temperatures was colder than the 2-in. pallet. This was probably due to the prevention of earth heating of the container. Some foliage discoloration occurred with the euonymus, but with the first flush of spring growth plants were full and attractive. Even with a hardy juniper, significant differences in root grade and in living root count were noted. These were readily visible when roots of plants that were overwintered in the insulated pallet were compared to those with straw mulch or with no protection (Figure 3).

During the 1982-83 winter, treatments consisted of a) plants in a single-poly covered structure, b) a pallet using ¾-in. urethane as an insulating top, c) straw mulch, and d) bunched plants, all using the same species. Growth medium was the same as the previous year. Winter conditions were somewhat milder overall, with a minimum temperature of 6°F (−15°C).

All plants survived the winter except the unprotected holly. However, spring top growth of the plants in the poly structure and in the insulated pallet were larger, reflecting less root injury than the straw mulch, or the unprotected plants.

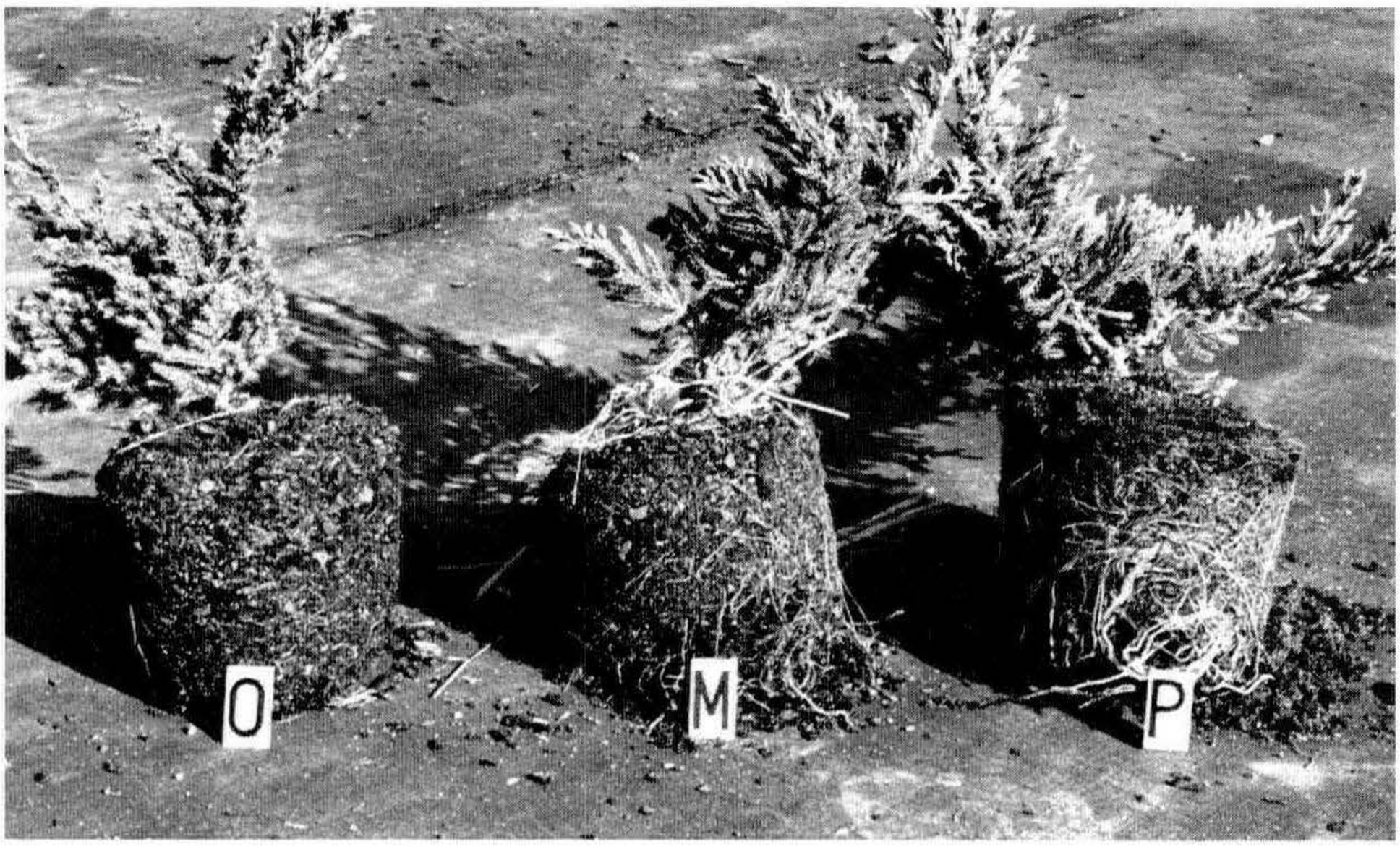

Figure 3. *Juniperus procumbens* plants after the winter *(left)* with no root protection, *(center)* heavily mulched with straw, and *(right)* with insulated pallet to protect the roots. The size of the spring flush of growth reflected the root injury.

DISCUSSION AND CONCLUSION

We envision this as part of a year-round production system for container nursery stock (Figure 2). In more northern areas, marginal plants may need additional protection of the top. Protection of the root system against cold injury could be adjusted to fit the geographic area by increasing or decreasing the insulating capacity of the top of the pallet. With a lightweight growth medium, this pallet system could quickly and easily handled by a lightweight fork lift. This system has the potential to reduce or eliminate many problems associated wit the production of container nursery stock and, at the same time, reduce labor costs.

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contact Elton Smith, who is our program chairman for next year.

I will now turn the program over to the moderator for the morning session, Harrison Flint.

PRODUCTION OF THE IPPS *PROCEEDINGS* AND *THE PLANT PROPAGATOR*

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Publishing the *Proceedings* and *The Plant Propagator* constitutes the largest outlay of funds by the Society and these two publications are mainly what the members receive for their annual dues.

One of the problems we face is the ever-rising cost of publishing books. In any college bookstore it is common to find textbooks at prices ranging from $30 to $100 each. To avoid increases in our annual dues, we keep trying to hold our publishing costs down, principally of the *Proceedings*.

The primary controlling factor we have in avoiding cost increases is to hold down the book size. With material from our six Regions, it would be easy to allow the size of the book to greatly proliferate, becoming more and more expensive. So we have set a limit of 10-double-spaced typed pages including tables and figures, for manuscripts submitted for the *Proceedings*, which translates to about 5 printed pages. The length of the average article in the *Proceedings* has been less than this. We are trying to avoid those extremely long articles with large tables of raw data.

Another goal is to get the *Proceedings* mailed out to the membership as rapidly as possible. The main delay is waiting for manuscripts from the speakers. These are supposed to be handed to the Regional Editors at the time of the meetings — but there are always substantial numbers who do not and this can delay the *Proceedings* by weeks or months. We never receive some papers and the *Proceedings* is published without them.

Some important suggestions in preparing articles for publication in the *Proceedings* are:

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[1] International Editor

1. Study and follow the direction sheets mailed to all speakers by the Program Chairmen or Regional Editors.
2. Study articles in recent issues of the *Proceedings* to see the format and style used.
3. Keep within the 10-page *double-spaced* typewritten limitation. Never, never, type articles single-spaced! There is no room for editorial corrections.
4. Avoid lengthy tables of raw data. Condense data into concise tables. Lengthy, complicated tables are costly to typeset. Set up tables in a vertical rather than horizontal format. These fit the dimensions of the printed page better. Preferably, the data should be analyzed statistically. This gives more credence to the conclusions. Any list of plant names should always be in alphabetical order and by *scientific names — not common names.*
5. Use sharp, glossy, black and white photos to illustrate your message. These are relatively inexpensive to use and add to the appearance of the *Proceedings*. Often a photo will show what you cannot explain in words. Take outdoor photos in light shade rather than full sun, if possible. This avoids distracting shadows.
6. When graphs are used, include the original with your manuscript, not a photocopy, which is often fuzzy and difficult to read. Lettering is important. Remember, a reduction is usually made to fit the graph on to the printed page. If letters are too small, they will tend to disappear after reduction. Likewise very fine lines will disappear after reduction.
7. For *Literature Citations* at end of article use the format found in articles in the *Proceedings*. Use complete citations. Do not omit name or date of publication, volume, or page numbers, or the publisher, in case of books.
8. Use complete mailing address, including — in the U.S. — the zip code, under your name at the beginning of article. Galley proofs are sent to authors and this cannot be done without a proper address.
9. Have someone else read your manuscript for clarity and meaning before it is submitted. If HORTUS III is available, use this to check your plant names for accuracy.

It is a constant goal to maintain and improve the quality of the *Proceedings*. The Regional Editors first edit the papers, making sure they are not over the page limit and that all *components* — all pages, figures, graphs, literature citations — are properly included. The International Editor then receives

and further edits the papers, preparing them for the printer with notations as to type size, headings, placement of illustrations, etc. Our two botanical editors, Warren Roberts and Andy Leiser, then go over all papers for the correct botanical nomenclature. This is very important. Our Society should be a leader in using correct nomenclature. You may note that we use the modern term "cultivar", rather than the less precise term, "variety" in IPPS publications.

Manuscripts then go to the printer in Sacramento, California — Region by Region — for printing of the galleys.

Galley proofs are returned to the authors and Regional Editors for further checking. Authors should not try to rewrite their papers in the galley proof stage. This becomes very expensive and costs are billed to the authors. After return of all corrected galley proofs, the printer prepares the page proof which the International Editor checks over for any errors or problems. The corrected page proof, along with the Index — prepared by the International Editor — is then returned to the printer who prepares the final silver proof, which is again checked over for the final time by the International Editor, just before publication of the book.

The Plant Propagator is issued four times a year and goes to all members. Mailings are in December, March, June, and September. Preparation of these issues are finalized for the printer about six weeks ahead of these dates.

We welcome research papers or any news items of interest to propagators for publication in *The Plant Propagator*.

A recent trend toward the encouragement of our younger plant propagators in school has been the submission to *The Plant Propagator* by their major professor of joint papers describing results of research projects in their graduate studies. We also receive many papers from overseas IPPS members who are in countries with no IPPS Regions and cannot easily attend meetings.

Our constant goal is to improve quality and usefulness of the Society's two publications and suggestions to accomplish this are always welcome.

PROPAGATION, COSTS AND SYSTEMS

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Before speaking about propagation, costs and systems, it might be well to define certain terminology which shall be used frequently. We will begin with what is meant when we refer to "propagation," and categorize the different types of "propagators" we will be talking about.

Some people would say that propagation is merely "putting roots on cuttings"; but more correctly, it entails the entire process from start to the finished liner. For example, a juniper cutting is really not finished in propagation until it is potted in a pint container. Similarly, the direct stuck pachysandra, or any other groundcover in flats, is not finished in propagation until the cuttings are rooted and are sufficiently established to sell.

We talk about being a propagator, and about all propagators doing the same thing. However, we are not the same, and we are doing the same thing only to a point, and within very different parameters. Propagators can be divided into three groups:

1) Commercial propagators
2) Horticultural propagators
3) Scientific propagators

The goal for the commercial propagator is to propagate plants in large quantities and at the lowest possible cost. Often he has a very specific upper limit beyond which his cost must not go. If the costs go above that limit, then that particular operation is not generating enough net profit and it is not worth doing. It must be improved or scrapped. If another commercial propagator can provide you with liners cheaper than you can grow them yourself, you should buy them and propagate something else at which you are proficient. Commercial propagation is, in other words, business.

The goal for the horticultural propagator is to propagate a certain limited quantity of a plant. This can often be as many as possible of a specific cultivar. The cost of the end product is of much less concern for the horticultural propagator than for the commercial propagator. The important thing is not cost but to get a certain plant propagated. The horticultural propagator would usually work in botanic gardens, arboreta, schools, and similar institutions. Sometimes though, the commercial propa-

gator will switch and become a horticultural propagator when he obtains a new plant and needs to produce as many as possible, as fast as possible.

The goal for the scientific propagator is to develop new methods of propagation, such as tissue culture. Even though he also must work within certain budget limits, the cost of the end product is not of concern. The important thing is to make the system work. Later the commercial propagator will worry about the cost.

The best way to approach commercial propagation is to look at it as a manufacturing process. We can learn a lot from our friends in manufacturing — we are not nearly as unique as we may think we are.

PROPAGATION SYSTEMS

In order to do any kind of mass production, we must develop and build a system. Mass production of uniform units can be done as a continuous process, such as the gasoline flowing out of a refinery, or it can be done as a batch process, such as molding 100,000 2-gal. plastic pots, and then switching to 1-gal. pots. Often what the commercial propagator does fits well into the batch process definition, such as when he makes 50,000 juniper cuttings and sticks them. However, when a propagator sticks pachysandra in June and ends in August we could more properly call it a continuous batch process. The commercial propagator will normally develop a basic system, then derive variants of this for different crops. You can propagate broadleaf shrubs and conifers in the same facility, just as you can make cars and pickup trucks on the same production line. You just need to change and adjust a few things.

What is in a system then? All of the following would be parts of a system to produce 3 in. pachysandra plants:

1) Facility: Quonset greenhouses with shadecloth cover
   Mist line
   Mist controls
   Drainage
2) Field-made cuttings
3) Fungicide dip
4) Cooler
5) Hormone
6) Soil mix
7) Flats with 24 3-in. pot cells
8) Flat filling
9) Direct sticking, 2 cuttings per pot
10) Transportation to quonset greenhouses
11) Misting
12) Rooting
13) Hardening off
14) Fertilizing
15) Pruning
16) Finished pachysandra ground cover

You may vary some of these parts a bit in your system, just as Chrysler assembles cars a bit differently than General Motors. This particular system will propagate many other plants than just pachysandra. As we shall see in a bit, we can propagate many crops in a very few systems.

A somewhat different system would be the following for propagation of conifers. Again, this system could propagate other crops.

1) Facility:
   Quonset greenhouse with double plastic
   Sand benches in ground
   Hot water pipes under bench
   Mist system
   Mist controls
   Drainage
   Boiler
2) Field-made cuttings
3) Fungicide dip
4) Cooler
5) Disinfection of sand beds
6) Hormone
7) Stick in sand beds
8) Misting
9) Heat
10) Rooting
11) Fertilize
12) Harden-off
13) Dig rooted cuttings
14) Soil mix
15) Pint pots and flats
16) Pot in pints
17) Place in quonset greenhouses with shade cloth
18) Irrigate
19) Harden off
20) Fertilize
21) Grow
22) Prune
23) Grow
24) Finished liner

Even small changes in such an intricate system can affect many parts and final success. Therefore, changes should never be made at random, but only after sufficient testing has shown the effects of the changes. We need consistency and predictability. We get that in an organized system with specific identifiable segments. That is, when we can start pinpointing costs.

COSTS

An efficient and well functioning propagation system is only halfway to our goal as commercial propagators. Our goal is to make a net profit on each unit we propagate. To achieve that we need to develop a system to keep an account of the costs during propagation. A standard manufacturing cost accounting system can easily be adapted to work for us. Again, we are not nearly as unique as we think we are.

In cost accounting we talk about direct cost and indirect cost. For a propagation grower situation, direct cost would be: labor, plants, materials.

Indirect cost, or what we often call overhead, would be anything we can not fit into the three direct categories. This theory is all well and good, but how do we implement it? Three things must be done:

1) The plants propagated must be divided into *crops*.

2) A method of *collecting data* must be developed.

3) A system for *processing the data* must be developed.

Crops. In order to limit record keeping it is advisable to divide production into crops. Crops would be groups of plants with production similarities from a cost standpoint and would be considered the same.

A crop is really a batch in the production process. Therefore, it is also tied to a year. Examples would be: 3-in pachysandra 84, 2-in. *Euonymus fortunei* 'Colorata' 84, conifer cuttings 84, and deciduous cuttings 84.

The way you divide your production into crops will depend on your operation. There are no set rules. But the aim is to get all your different plants into a limited number of groups or, as we call them, crops. All costs incurred are then allocated into these crops.

Collection of data. Collection of data must be done both in the propagation area and in the office. In the propagation area only two documents are used:

1) Labor time ticket.

2) Production reports.

Each worker will write daily on his time ticket what job he did. At the end of the week before turning in the time ticket his foreman will crop code the entries on the time tickets. Daily the foreman or manager will keep a record of his production on production sheets, which are turned into the office weekly.

This is all that is needed from the propagation area, and since most of such records should be kept anyway, it is really a manageable job. The office, in the course of normal bookkeeping, collects additional needed data but, again, this is done anyway, so it is not extra burden.

Processing the data. This is where most of the extra work comes. There is no way around it — it is a lot of work. But how can we be commercial propagators and not know what our production cost is? All the data must end up on each of the crop sheets.

The unit cost at the far right is what we are after. That number is the reason for doing it all. The processing can be done manually or electronically, i.e. with a computer.

In a manual system the end of month functions for the cost accounting clerk would be the following:

1) Distribute labor from time tickets to crop sheets.

2) Based on production sheets:

— calculate overhead based on figures from general ledger and distribute on crop basis.

— from inventory cards collect monthly sales and current inventory, and post to crop sheets.

3) Calculate unit cost and post.

Electronic Data Processing (EDP). With this the function of the cost accounting clerk would be somewhat different:

1) Labor would be fed weekly from time tickets into the system and automatically flow to both crops and payroll.

2) Production from the production sheets would be fed weekly into the system and automatically go to crops and inventory.

3) Since overhead is a function of certain ledger expenses, and space used by the crop and sales, and inventory is automatically current, the monthly update of each crop sheet with its unit cost can be produced by the push of a few buttons on the computer keyboard.

It is obvious that enormous amounts of time can be saved with the EDP system. Information will also be available faster. However, it is also important to keep in mind that the end-of-month unit cost is what we are aiming for, and it is not better or worse whether it has been produced manually or electronically.

The computer of today gives the commercial propagator and grower fantastic possibilities. But he must get organized as he should be anyway. With a lot less effort and at much lower cost, we can get the information needed to make the right decisions. We must ever keep in mind that what we are doing is pretty basic production and business. We are not that unique. We must look to bigger industries and the systems and methods they have developed at great cost. We, in our little industry, would never have the resources to do the same. But we can learn from them, take their systems and adapt them to our particular business and profit greatly from it.

The selection of the right computer system is probably the most difficult and frustrating experience a small business can have today. We have been through this in our business in the

past year, going from the worst to the best. There is a right computer system for any size business today and there is a way of finding it. We went the wrong way and then the right. If any of you are looking for computers, I would be glad to share my information and experience with you.

DECIDUOUS AZALEA PROPAGATION: AN OVERVIEW OF OLD AND NEW TECHNIQUES.

ANNA J. KNUTTEL
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Deciduous azaleas with their vibrant flower colors should be an important plant for the landscape. However, there is a negative response to them in the nursery industry because of foliar problems. The most common cultivars, such as 'Old Gold', 'Golddust', and 'Orangeade', are highly susceptible to powdery mildew and from mid-summer on, the foliage of susceptible cultivars begin to look unattractive unless treated every 2 weeks with a fungicide.

There are other cultivars, however, such as 'Royal Lodge', and 'Visco Sepala', 'Sunset Boulevard', 'Satan', 'Crimson Tide', and 'Pink Jolly', that are not affected by powdery mildew and have attractive fall foliage. These plants would be a welcome addition to any garden and be saleable in both spring and fall. Clearly this type of cultivar should be selected for production by the commercial propagator.

To propagate deciduous azaleas by stem cuttings, we made use of a program at Knuttel Nursery that was described by H. C. Nienhuys of Roadview Farm Nursery in Gloucester, Virginia, at the 1980 meeting of the Southern Region, International Plant Propagators' Society (1). I will only describe this method briefly, including minor variations.

During late fall we leave our stock plants outside, exposed to the cold weather, so that they become completely dormant. During the third week of December, we bring these plants into a large greenhouse that is heated to approximately 40°F. We allow the plants to thaw out gradually, slowly increasing the temperature to 70°F by the beginning of March. The plants are usually in full flower by mid-March.

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We begin to take cuttings during the first week of April. Cuttings are taken from herbaceous shoots approximately 6 in. long. The optimal cutting should be hairy and slightly firm. To insure crispness of the cuttings we take the cuttings early in the morning and only take enough to process by noon. The cuttings are 3 to 4 in. long. The apical tip is removed and the lower leaves are stripped, leaving 3 to 5 leaves. The cutting is wounded on one side approximately 1 in. and treated with a hormone. The hormone powder consists of three tablespoons 1% IBA (indole-3-butyric acid), two tablespoons Dithane M-22 (maneb, Rohm & Haas), one tablespoon Benlate (benomyl) and a pinch of boric acid. The cuttings are planted in beds filled with a fine consistency Canadian sphagnum peat. The peat is moist but not soggy. We mist these cuttings with a mist nozzle at the end of a hose. With careful regulation, we prevent the peat from becoming too wet. The rooting medium is maintained at 73°F with forced hot air underneath the propagation beds.

In 4 weeks the cuttings begin to root. We then fertilize weekly with a combination of one tablespoon 23-19-17 (Rapid-Gro-Co.) and one tablespoon of Dithane M-22 per 3 gal. of water. Around June 15, the cuttings are then planted into 1½ gal. containers and placed in shaded hoophouses for the rest of the summer.

This method of propagating deciduous azaleas is highly successful for us. We generally have 80 to 85% rooting and the plants are usually a saleable size after 1½ years.

The traditional method of stem cutting propagation has a serious drawback in that it takes many years to get new cultivars into production. With cultivars that show a tendency towards difficult rooting such as 'Cecile' and 'Ballerina', it makes serious marketing of these plants nearly impossible. Tissue culture, on the other hand, allows quantity production more rapidly for all types of deciduous azaleas.

Charles Addison's tissue culture procedure makes use of dormant shoot cuttings taken from November to April. These shoots can be stored under refrigeration until July, which allows for continuous production for 9 months. Unlike that used in many other tissue culture labs, this procedure utilizes dormant buds. This enables the use of more concentrated sterilization materials.

Under a dissecting microscope, the dormant bud is opened and the well-protected meristematic point, which is approximately 1 mm in length, is extracted. The tip is then floated on a sterile liquid medium in a test tube.

In a primary growth room, utilizing proper lighting and heating techniques, the tiny growth tip increases to approximately 5 to 6 mm in 3 weeks. At this point, the tissue is transferred to a container with solidified agar supplemented with essential nutrients and a cytokinin, either 2iP or zeatin. Occasionally, a few tenths of a milligram of IBA may be added for increased proliferation. The ingredients of both the liquid and agar media are similar to the woody plant medium developed by McCown and Lloyd (2) at the University of Wisconsin.

As growth continues and the containers fill with increasing tissue mass, the clumps are divided and transferred to new containers for further proliferation. When adequate growth has occurred and significant numbers have been attained, the plantlets are then transferred to a container with a new medium. This modified medium has activiated charcoal, little or no cytokinin, a higher IBA content, and reduced inorganic nutrients.

After 3 to 5 weeks the plantlets are harvested. These plantlets are then transferred into either a peat/sawdust or peat/milled sphagnum mixture in trays. These are then placed in a secondary growth room which has high humidity and provides bottom heat. In 4 to 5 weeks rooting usually occurs. At this point they are hardened off and transplanted into 2¼ in. mesh pots for growing-on in a greenhouse.

With this method of propagation, thousands of plants can be produced within a year or two. This allows new and difficult-to-root cultivars to be produced and marketable in a much shorter period of time than with the traditional method of stem cutting propagation.

Using either of these two methods of propagation the nursery industry should concentrate on selecting and propagating cultivars of deciduous azaleas with powdery mildew resistance. The attractive foliage of these deciduous azaleas would make them better landscape plants and would extend the market time of these beautiful springtime plants into the fall.

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REVITALIZATION OF HERBACEOUS PERENNIALS BY "REPROPAGATION"

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The word "repropagation" is not found in the dictionary and it is not normally used in the nursery industry. The word "repropagation" may be used to describe a technique useful in revitalizing plants that have been under stress as a result of improper shipping, packaging, storage, or from having been under poor growing conditions.

The principles of repropagation for herbaceous perennials have been in use for over a half century in the nursery industry. An early application was when many plants were shipped to the U.S. by ocean freight from Europe and other countries. In addition to the long trans-ocean crossings there were always delays during the inspection at port of entries and delays with domestic transportation. Therefore, the amount of time plants and plant parts were under shipping conditions varied from several weeks to a month or more. Even cross-country shipments of plants and plant parts had problems because of poor shipping conditions and delays. By the time shipments arrived at their destination, the plants and plant parts were often covered with mildew, or parts of them were rotting. To salvage those plants that exhibited life, repropagating techniques were employed.

In recent years, the need for applying repropagating practices have surfaced because of an increased number of summer-dug plants being shipped from south to north during the growing season. Rots and mildews are not infrequent despite efforts to control them with fungicides, bacteriacides, and improved shipping containers. Although our transportation systems have improved, over-heating — especially in parcel-service trucks and on loading platforms — is not uncommon. For security reasons the trucks are often kept locked and when parked in full sun, temperatures within these trucks often reach 125 to 150°F within an hour or two. Because many of the plants and plant parts are packaged in plastics, the humidity surrounding the plant tissues is high which makes conditions ideal for the growth and development of rot and mildew causing organisms. Although many nurseries dip their plants in fungicides and bacteriacides prior to packaging, these chemicals do not provide permanent protection. Therefore, knowing the principles of repropagation can be beneficial for salvaging

shipments of plants that would otherwise be lost. This is especially important if they are one-of-a-kind.

Repropagation can also be used as growing storage. Bare-root herbaceous plants that have been shipped in the spring according to schedule, but cannot be planted because of weather conditions, can be stored under repropagating conditions. The repropagation of these plants will result in heavier root systems and avoid the problems often associated with spring cold storage of plants that have broken dormancy.

To prepare plants for repropagation, it is important to remove all decayed and damaged tissues. Feeder roots must be pruned closely and occasionally totally removed. The tops must be cut back hard, and frequently they must be pruned off. After all pruning is complete, the roots must be washed thoroughly under pressure to remove all dirt. The propagating bench or boxes should be at least 6 in deep and the bottom should have widely spaced narrow boards covered with mesh for optimum drainage. They should be filled with new horticultural grade perlite; it is sterile (heated to 3300°F) and will not hold excess amounts of water. The roots should be planted at their original planting depth in the perlite. To reduce stress, a light shade should be applied over the beds or boxes and the roots should be watered in lightly. The perlite should be kept moist but not wet. Although a greenhouse is often preferred, repropagation can be done outdoors providing the repropagating area is protected from heavy rain by shading with saran shade cloth or screen.

The perlite should be irrigated lightly only when necessary; there is no need to apply fungicides because the perlite is sterile and drains freely. Generally a light application of a low-nitrogen, water-soluble fertilizer is recommended within 1 week after planting. Within 3 to 5 weeks, depending on temperatures, the plants will have developed a large mass of feeder roots, the tops will have started to grow and they are ready to be planted.

Certain species may require special handling procedures. For example, oriental poppies should have all feeder roots and tops removed then placed 2 to 3 in apart in 3 in wide rows. Daylilies should have all fleshy roots over one year old removed, feeder roots pruned to within 2 to 3 in, tops cut to within 4 to 6 in and spaced 4 to 6 in apart in 5 to 6 in wide rows. Root and top growing characteristics of each species must be considered.

Since the facilities and the basic procedures are the same for normal propagation, repropagation requires no additional outlay. This is not presented here as a new method but as a

different and practical application of known methods used to: revitalise plants following shipment, provide growing storage conditions that can result in improved plant quality, and as an intermediate stage between propagation and field planting to increase survival.

PRAIRIE RECONSTRUCTION AND PLANTS

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A prairie can be described as a meadow. So simple a definition describes the part of our country that is responsible for the soil that produces so much of the world's food. The pioneers broke the sod with their primitive implements and discovered some of the richest agricultural soil in the world, soil created by thousands of years of decomposing plant roots that extend as much as 10 ft deep. This breaking of the sod doomed the prairie.

Recently there has been a tremendous interest in not only preserving the remaining remnants of original prairies but reconstructing them, too. The Chicago Botanic Garden Prairie is a reestablished prairie of approximately 11 acres. Two acres, containing 155,000 plants, will be a mesic or tall grass prairie, the dominant type in Illinois where corn and soybeans are now planted.

All the seeds for this reconstruction were collected within a 200 mile radius of the Chicago Botanic Garden during the summer and autumn of the previous year. The seeds were cleaned and stored under refrigeration until sowing in late March. Mesic prairie plants propagated from seed in 1983 are shown in Table 1. Slow growing species, such as legumes, were sown first and the fast growing prairie grasses and silphiums were seeded last. Seeds are sown in either Jiffy strips or Rootmaster pots and put in a cool greenhouse for germination. Young plants were hardened-off outside several weeks before planting.

Site preparation is an important component in prairie reconstruction. The weedy vegetation is first destroyed by using the herbicide Roundup. Several weeks after Roundup application, the area is tilled several times. To control erosion on steep slopes, Curlex, an excelsior fiber blanket covered with a photodegradable nylon netting was used. Strips of Curlex al-

Table 1. Mesic prairie plants propagated by seed — 1983.

Allium cernuum
Amorpha canescens
Andropogon gerardii
A. sullivantii
A. tuberosa
Anemone patens
Aster azureus
A. ericoides
A. laevis
A. novae-angliae
A. sericeus
Astragalus canadensis
Baptisia leucantha
B. leucophaea
Bromus kalmii
Cacalia suaveolens
C. tuberosa
Ceanothus americanus
Cirsium discolor
Coreopsis palmata
C. tripteris
Desmodium canadense
Dodecatheon meadia
Echinacea pallida
Elymus canadensis
Eryngium yuccifolium
Filipendula rubra
Gentiana alba [G. flavida]
Gentiana andrewsii
Gentiana saponaria [G. puberula]
Heliopsis helianthoides
Heuchera richardsonii var. *grayana*
Hierochloe odorata
Iris virginica var. *shrevei*
Lespedeza capitata
Liatris pycnostachya
L. spicata
Lilium michiganense
Lobelia spicata
Monarda fistulosa
Oxypolis rigidior
Panicum virgatum
Parthenium integrifolium
Pedicularis canadensis
Petalostemum candidum
P. purpureum
Phlox pilosa
Physostegia virginiana
Potentilla arguta
Prenanthes racemosa
Pycnanthemum tenuifolium
P. virginianum
Rosa carolina
Rudbeckia subtomentosa
Ruellia humilis
Silphium integrifolium
S. laciniatum
S. terebinthinaceum
Solidago riddellii
S. rigida
S. speciosa
Sorghastrum nutans
Spartina pectinata
Sporobolus heterolepis
Thalictrum dasycarpum
Tradescantia ohiensis
Valeriana ciliata
Vernonia fasciculata
Veronicastrum virginicum
Zizia aurea

ternated with a row of bare soil seems to work well. Planting through the Curlex is time consuming as the nylon netting must be cut and excelsior fibers parted before a hole can be dug. Excelsior fiber makes an excellent nesting material for rodents and therefore rodent control methods must be used. Despite its disadvantages, Curlex is an excellent erosion control material and will continue to be used.

Prairie plants here at the prairie garden were planted on 1 sq. ft. intervals. Planting boards marking the intervals have been designed. This method of planting results in a very unnatural looking grid pattern. However, untrained volunteers find it easier to distinguish prairie plants from weeds knowing that prairie plants occur at one foot intervals.

Burning is an important tool in weed control. As soon as the new prairie can produce enough hay to support a fire, burning is recommended. In the Chicago area trees are begin-

ning to encroach on areas that are no longer burned. If not for the fires, the landscape of Illinois would have been woodland, not prairie. Fires are not only detrimental to woody plants but also to Eurasian weeds (which do not have the deep root system of our native prairie plants). Many Eurasian weeds are cool season growers and, therefore, resume growth in the early spring. Consequently early April in Chicago is the best burn time. In only a few short weeks growth begins anew.

ACCELERATED GROWTH OF *PIERIS JAPONICA* GROWN FROM SEED

EVERETT VAN HOF

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Propagators' efforts are not always richly rewarded. Sometimes we have failures which are beyond our control. For example, in June we had temperatures from 95° to 99°F, with equally high humidity, which caused us to lose about half of our *Pieris japonica* crop due to heat stress. This crop is the subject of my presentation today.

Pieris japonica seed capsules are gathered the first part of November. After the capsules open, the seeds are screened from the capsules. The seeding medium is prepared by mixing one 6-cu ft bale of peat moss with two 4-cu ft bags of coarse peat moss. Flats (20×14×3 in) are filled with this mixture and lightly pressed down to ½ in below the top of the flat. The flat is then filled with screened peat moss and leveled.

The flats are now ready for sowing. One level tablespoon of pieris seed is used per flat. After sowing, flats are watered well and a polyethylene cover is placed over the flat to retain moisture during the germination period.

After about 3 weeks the seeds have germinated and the poly cover is removed. Watering of flats is done as needed and, with every other watering, the seedlings are fertilized with Peter's 20-20-20.

In February seedlings are transplanted into flats (20×14×4 in) using Fafard No. 3 mix at the rate of 140 seedlings per flat. The same watering and feeding program continues. In April seedlings are trimmed the first time. After trimming, the seedlings are about 3 in tall. The second trimming is done in July. After the second trimming the seedlings are about 5 in tall. At

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this time feeding is discontinued. The third trimming is done just prior to bed planting in the first part of September.

Planting out beds are 5½ ft wide and are prepared by tilling in peat moss. Ten seedlings are planted per row, mulched with well composted sawdust, and covered with 50% lath shade. In April the lath shade is removed and plants remain in this area for two growing seasons. The plants are fertilized twice during the first growing season with urea and once in the fall with Peters 15-15-15, and trimmed once to a height of 12 in.

During the second year in the beds, plants are fertilized 3 times and trimmed twice to the height of about 18 in. In September, some will be lined out in our nursery and the rest will be sold as liners.

CHARLIE PARKERSON: What is your sowing time?

EVERETT VAN HOF: We gather our seeds in November and sow in November.

TOM MCCLOUD: Do you pinch by hand or by chemicals?

EVERETT VAN HOF: All by hand — with hedge shears. We have not tried chemical methods.

ED MEZITT: Do you give supplementary light to seedlings in November?

EVERETT VAN HOF: No.

VOICE: Do you pick your own *Pieris* seed — and do you have trouble germinating the seed?

EVERETT VAN HOF: We pick our own seed and have no problem germinating the seed. We used to think that we had to wait until after a frost, but that does not make any difference.

VOICE: Do you use any fungicide?

EVERETT VAN HOF: No, except if we see some *Botrytis*, and then we use Benlate and Captan (1:3, v/v).

ED LOSELY: What is your Peter's fertilizer rate?

EVERETT VAN HOF: 200 ppm.

MARGERY HANDCOCK: What is your transplanting mix and the pH of the growing-on beds?

EVERETT VAN HOF: Fafards No. 3 mix is the transplanting mix. I do not know the pH of the growing-on beds.

ROOT GRAFTING OF OAKS

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Each year after attending our Eastern Region, International Plant Propagators' Society meeting, I am motivated to try some of the ideas and procedures that are either presented or generated through personal contacts. Sometimes these applications may be far-fetched and slow to take hold. However, in 1983 a new procedure was initiated immediately because of necessity.

After returning from the 1983 meeting, I found that we did not have enough *Quercus robur* rootstock suitable for clay rosepots. Seeing all those well-branched root pieces, that had to be trimmed-off for the understocks to fit the pots, caused me to think that those root pieces might be the answer to my shortage problem.

Having just heard Moser (4) speak on root regeneration of oaks and also recalling papers by Lumis (1,2,3), and other articles and talks on hard-to-transplant tree species, led me to experiment with some of the same principles on *Q. robur* root pieces. While both authors mainly used auxins to stimulate root regeneration, it was brought out, especially by Lumis (1), that soil temperature was important. Since increased temperature is used by propagators to gently bring the rootstocks into growth, I decided to try the same technique with *Q. robur* root pieces.

On December 15, 1983 we potted 100 well-branched root pieces of *Q. robur* into our regular light potting soil using clay rose pots. The potted root pieces were placed together with the normal seedling understocks in the grafting house. The root pieces were covered with peat except for the very top. In addition a piece of opaque plastic was used as a cover. Temperature in our grafting houses ranges from 12°C at the start and is increased to 18°C weeks later. All understock pots are placed on peat, with root growth starting after 3 weeks. In the fourth week, we commence grafting with the evergreens and finish with deciduous material, such as *Fagus* and *Quercus*. On February 13, 1984 we grafted both understock and root pieces with *Q. robur* var. *fastigata*. The scions were 6 to 8 mm thick with 3 to 4 buds and were from the lower end of the current year's growth. Their size closely matched that of the understocks and root pieces.

A side veneer graft was employed on both the seedlings and the root pieces. We covered the finished grafts with damp peat and, in the case of the root pieces, the whole root piece was covered. There was considerable callus growth on the top of the root pieces at this time and good new roots were visible in the pot. The grafting case is covered with glass sash and shaded during sunny weather. The temperature is kept between 18 and 24°C.

The grafting case is kept closed for the first 14 days. Thereafter, it is aired for one hour daily to start, with the airing time being increased daily until, after 4 weeks, the sash is kept open. It is important to protect new growth against mildew.

We noticed that the scions on the root piece grafts sprouted very uniformly and with more than one bud, which is better than the seedling understock grafts. Also, the root ball of the root piece grafts had nearly filled the pot which does not occur with seedlings.

We planted 100 root piece grafts out at the end of May. The root portion was planted deep enough so that the root portion did not dry out. Little regrowth occurred but this is typical for one-year-old grafts of oaks and all piece root grafts survived. Up to this point there has been no suckering of the root pieces and I do not expect any suckers to develop as they often do on seedling stocks.

Our initial success with *Q. robur* led us to try *Q. rubra* and *Q. palustris* piece root grafts in April, 1984. A dismal failure was the result. There was no callus growth and the scionwood was near the bud breaking point. I believe that timing and callusing are essential in *Quercus* root piece grafts. New trials which incorporate auxin treatments are under way with *Q. rubra* and *Q. palustris* root pieces.

In summary, the advantages of *Q. robur* piece root grafts include uniform growth, better root development, and no suckering.

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WAYNE MEZITT: Why do you put your root pieces in pots if they regenerate so well?

JOERG LEISS: Because they have to be potted up after they sprout and it is easier to graft in a pot.

PETER VERMEULEN: How are you going to apply the auxins to your root pieces?

JOERG LEISS: Dip the bottom of the root pieces where I want the roots.

VOICE: How long after potting are they grafted?

JOERG LEISS: They were potted on December 15th and grafted on the 13th or 14th of February.

VOICE: How long were the new roots?

JOERG LEISS: We graft when new root growth is present on the outside of the pot.

AIR LAYERING OF NATIVE WOODY PLANTS[1]

DONALD R. HENDRICKS

The Dawes Arboretum
7770 Jacksontown Road, S.E.
Newark, Ohio 43055

Since 1971, the Hayes Regional Arboretum in Richmond, Indiana, has been searching for a way to propagate its 181 native woody species in such a way that:

1) Single specimens can be collected without the aid of expensive greenhouses or facilities.
2) The original plant is not destroyed or altered where it is growing.
3) The genetics of native material could be duplicated.
4) Propagation could be done at the site where the plant grows.

In 1981, there appeared in the *Journal of Arboriculture* a reference to an article published on the air-layering of water oak cuttings by Dr. Robert C. Hare, Plant Physiologist of the Southern Forest Experimental Station, USDA Forest Service, in Gulfport, Mississippi (3). His technique involved the use of peat rooting cubes as aerial, *in-situ* chambers. Other species tried by Dr. Hare were slash and loblolly pine, southern red oak, sycamore, and sweetgum (1,2,5,6).

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A program was initiated to try and duplicate this technique on woody plant species native to Indiana and Ohio.

MATERIALS AND METHODS

Talc was mixed with two auxins and sucrose. No fungicide was added because prior research did not show any benefit (6).

A 1-1-20 mixture was made with indolebutyric acid (IBA), 1-phenyl-3-methyl-5-pyrazolone (PPZ), and 10× confectioners' sugar (6). One gm IBA and one gm PPZ were dissolved in 80 ml of anhydrous acetone, then mixed with 80 gm talc (Baker USP) in a bowl. The slurry was stirred constantly in a hood over gentle heat and under a gentle air stream until completely dry. The powder was ground and sifted down to 45 mesh. Twenty gms of confectioners' sugar was added, then ground with mortar and resifted. The mixture was sealed in a container, and stored at a cool temperature (4).

Over a two-year period (during April, May and June), tests were run on 25 species representing 16 families of native woody plants. Each specimen was air-layered on two branches which had a southern exposure.

As soon as leaves on the tree were fully expanded, a girdling cut, approximately 1 cm in width, was cut around each of the two selected branches at a point where second or third year growth occurred. All phloem and cambium was removed from the cut. A small amount of moistened rooting powder was immediately applied tó the distal part of the girdle. The girdle next was encased in a wet Oasis rooting cube that covered the entire cut area. A piece of Parafilm M was wrapped around the cube and then aluminum foil was wrapped around the film to slow solar heat buildup. The cubes were left on the plants for a period of 4 to 5 weeks (7).

If, after 4 weeks, the roots had penetrated the cube and the parafilm, the rooted layers were severed at the bottom of the cube and immediately put in a holding nursery. If the layered plants showed callus tissue but no root activity, they were allowed to remain on the parent plant for up to 8 weeks. Callused air-layers not rooting after 8 weeks were rooted in the nursery.

RESULTS AND DISCUSSION

Of the 25 species tried, only 4 did not produce roots or callus tissue (Table 1). If adequate care was taken with calused stock, there was no difficulty in rooting them in the nursery. A 70% success rate was achieved the first year with the 25 species and, with additional care and improved tech-

niques, an 85% success rate was accomplished the second year. Reasons for lack of success include: branches not in the best location (southern exposure), layering performed too late in the season for rooting to occur, failure to remove all phloem and cambium, all 2nd and 3rd year wood not used, cubes dried out, branch too thin to support weight of cube, woodpeckers, vandalism, and rotting.

Table 1. Response of certain native woody species to air-layering.

Species	Family	Rooted	Callused	No Growth
Acer. saccharum subsp. *nigrum*	Aceraceae	X		
Aesculus octandra	Hippocastanaceae		X	
Amelanchier arborea	Rosaceae	X		
Asimina triloba	Annonaceae	X		
Carya laciniosa	Juglandaceae		X	
Ceanothus americanus	Rhamnaceae			X
Cephalanthus occidentalis	Rubiacea	X		
Dirca palustris	Thymelaeaceae			X
Hydrangea arborescens	Saxifragaceae			X
Juglans cinerea	Juglandaceae		X	
Juglans nigra	Juglandaceae		X	
Juniperus communis	Cupressaceae	X		
Lindera benzoin	Lauraceae	X		
Liriodendron tulipifera	Magnoliaceae		X	
Lonicera prolifera	Caprifoliaceae	X		
Magnolia acuminata	Magnoliaceae	X		
Populus grandidentata	Salicaceae	X		
Populus tremuloides	Salicaceae	X		
Prunus americana	Rosaceae	X		
Quercus shumardii	Fagaceae	X		
Rhamnus lanceolata	Rhamnaceae		X	
Salix bebbiana [S. rostrata]	Salicaceae	X		
Sassafras albidum	Lauraceae		X	
Spiraea alba	Rosaceae			X
Ulmus thomasii	Ulmaceae	X		

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VICKI GINGAS: Did position of the air layer on the plant alter the percent rooting?

DON HENDRICKS: That was difficult to evaluate with as few air layers as we were taking.

BRIAN DECKER: What about using your technique for rooting younger specimens, such as 5 to 6 ft magnolia plants in a nursery? Could you stagger them along one branch? Have you tried one-year and much older wood?

DON HENDRICKS: Yes, you can do it with younger plants. We have not tried staggering them but it is a good idea. We have tried 1, 4, 5-year, and older growth but have had poor results.

SEED DISPERSAL AS IT CONCERNS THE PROPAGATOR

ALFRED J. FORDHAM

898 Clapboardtree Street
Westwood, Massachusetts 02090

In nature's scheme of things, many remarkable methods have been evolved for dispersal of seeds. Study of these methods is fascinating and sometimes essential to those involved in collecting seeds for propagation. To understand these methods allows one to collect seeds after they are properly developed for propagational purposes but before they are lost through natural agencies of dispersal.

Although the seeds of some woody plants are dispersed in late spring and throughout the summer, most do not ripen until autumn, rightly considered the time of fulfillment in nature — a season of natural abundance. As ripening occurs, changes come about in the appearance and character of fruits, and many plants become dispensers of food. Fleshy fruits containing seeds dependent for dispersal upon animals and birds become palatable and change to a wide variety of colors attractive to those responsible for their distribution. The pulp furnishes food to the bird or animal which, in turn, carries the hard-coated seeds about in its digestive tract until they are passed unharmed in its droppings, and thus are scattered about the countryside. Migratory birds may carry seeds far away from their point of origin.

In late summer, when the nesting season has passed and birds have reared their young, some species congregate in multitudes. These flocks roam the countryside, feeding on fruits and seeds as they ripen. Trees and shrubs that are

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In late summer, when the nesting season has passed and birds have reared their young, some species congregate in multitudes. These flocks roam the countryside, feeding on fruits and seeds as they ripen. Trees and shrubs that are

heavily laden with fruit can be virtually stripped clean after one visit from such flocks. Removal is often so thorough that large trees bearing countless thousands of fruits one day can be denuded the next.

FRUITS TAKEN BY BIRDS

Since autumn is a season of plenty, birds can exercise preferences. Some favorites are Asiatic sweetleaf *(Symplocos paniculata)*, sassafras *(Sassafras albidum)*, dogwoods *(Cornus species)*, blueberries *(Vaccinium species)*, and magnolias. These plants must be watched closely so fruits can be collected before they are taken.

Fleshy fruits which develop on plants exhibit a wide range of colors. Birds which feed on them, however, have failed to show color preference. For example, fruits of mountain ash (*Sorbus* spp.) appear in red, orange, white, brown, and yellow, with many intermediate shades of each — yet the same birds pass from one species to another to take fruits as they ripen. Ripeness obviously has been the factor that determined which fruits appealed to birds, while color seemed of no consequence. The observations which follow will just scratch the surface of this vast subject.

Magnolia species. *Magnolia* fruits are highly favored by birds; the fruits ripen and are ready for collection about mid-September. Dispersal of these seeds is most interesting. They are contained in chambers within colorful cones. At ripening, the chambers open and the seeds emerge and dangle on slender cords called suspensors. In this way they are available to birds while still on the tree. Those that fall from the trees can be eaten by rodents and dispersal is thereby defeated. Species of *Euonymus* and *Celastrus* also have this same dispersal adaptation.

Sorbus species. Large flocks of starlings and robins descend on the mountain ash trees in early autumn and the ripe fruits quickly disappear. They must be collected just prior to their final stage of ripeness.

Cornus species. Many species of dogwood are favorites of birds. Fruits of a number of species ripen erratically and birds make daily visitations to collect those that are ripe. Giant dogwood *(C. controversa)* has been noted as bearing ripe fruits from August 8 through September 7, while Korean dogwood *(C. kousa)* seeds ripen erratically from August through October. Flowering dogwood *(C. florida)* is a great favorite of birds. Fruits ripen about mid-September and disappear quickly. In 1964, a prolific year for this species, all the fruits in the Arnold Arboretum had been taken by October 1.

Fruits of cherries (*Prunus* species), spice bush (*Lindera benzoin*), viburnums and the like, must often be collected just prior to their final color change. At this point the seeds will have developed enough to be viable but the fruits will not have reached the stage where they would appeal to their carriers.

Symplocos paniculata. Asiatic sweetleaf, with its beautiful display of intense blue fruits, is another favorite of birds, such as starlings, robins, catbirds, and bluejays. Its fruits ripen about mid-September and can disappear in a day so, when seeds are needed for propagation, the fruits must be gathered before they are fully ripe.

Viburnum species. Many *Viburnum* species produce fruits that ripen erratically over a span of time and birds make daily visitations to take those that are ready. Seeds of these species must be collected before they are fully ripe.

Fruits of Sargent cranberrybush (*V. sargentii*) and of *V. dilatatum* have a disagreeable odor and perhaps are distasteful, for they are usually ignored by birds. However, during times of deep snow, starlings, house sparrows, and pheasants have been seen feeding on them, perhaps in desperation.

Cedrus libani. In the Boston area pollination of cedar of lebanon takes place about mid-October and the female cones start to develop the following spring, reaching maturity in mid-August of the second year. The cones which are vertical in position start to shatter at that time and the winged seeds are carried off in the wind.

Cercidiphyllum japonicum. Trees of the katsura tree are dioecious; the female trees bear heavy crops of many-seeded pods each year. The pods are borne in clusters on short stalks and resemble miniature hands of bananas. In autumn, when the trees are shedding their leaves, the pods turn from green to dark purple. A split which starts at the upper end of the pod opens the top of the cylinder-like structure from which the small winged seeds are then dispersed by the wind. Seed collection is best done just as the leaves are starting to fall.

Aesculus species. Most horsechestnut and buckeye fruits are ripe about the last week in September and are taken and buried by squirrels; this is the normal method of dispersal for seeds of this group. The squirrels sometimes carry horsechestnuts great distances to soil suitable for easy burying. It was not uncommon to find numbers of horsechestnut seedlings coming up in the Dana Greenhouse nursery of the Arnold Arboretum, although the closest trees are several hundred yards away.

Juglans nigra. Fruits of black walnut start to ripen and some of the nuts drop about mid-September; others remain on

the trees until after the leaves have been shed in mid-October. Squirrels gather them from the trees or ground and carry them away to be buried, which is the normal dispersal method for this subject. As any country boy knows, walnut husks contain a highly persistent staining substance which cannot be removed from the hands. In fact, this material is used in the manufacture of walnut furniture stain. Faces of squirrels that gather walnuts become darkly stained and they can always be spotted by this blemish.

Albizia julibrissin. Natural dispersal of silktree seeds take place during late fall and into winter. Pods, which develop in clusters, are firmly attached to the tree and require high winds to tear them loose. This method of dispersal allows wide latitude in time of pod collection. The suspended clusters of pods can be gathered quickly, a handful at a time.

Abies koreana. Pollination of Korean fir takes place in spring and the cones shatter to disperse the seeds about mid-September. Collection should be made about the first week in September.

Pseudolarix kaempferi. Golden larch, is a superb coniferous tree that produces seeds erratically. Patches of male and female flowers appear on separate parts of the trees in spring. Seed production varies enormously from tree to tree and from year to year. Shattering and dispersal of seeds by the wind takes place about mid-September.

ELWIN ORTON: What was the species of *Aesculus* whose seeds germinate immediately in the fall?

AL FORDHAM: *Aesculus parviflora*.

Tuesday Afternoon, December 11, 1984

The afternoon session was convened at 2:00 p.m. with Mike Young serving as moderator.

SOFTWOOD CUTTINGS TAKEN FROM DEVELOPING HARDWOOD CUTTINGS

T. MURRAY ALWARD

Riverbend Farms
P.O. Box 31
Port Burwell, Ontario, Canada NOJ 1TO

The rooting of softwood cuttings from hardwoods began at Riverbend Farms in December, 1980, in a 96 × 27 ft. double polyhouse. We use a hot-water boiler for heating our benches with wood from our farm as the main fuel source. The heated benches are located in the front half of the polyhouse and are used for propagating evergreen cuttings and grafting. The space at the back of the polyhouse on the floor is reserved for propagating deciduous hardwood cuttings. Two additional polyhouses supply further space and storage for pot liners.

In December, 1980, I utilized the space past the heated benches to stick hardwood cuttings in flats, as listed in Table 1. The cuttings were approximately 4 to 5 in. and the media, our favourite, was a 6 sand, 4 peat, 3 perlite, mixture.

Table 1. Species from which hardwood cuttings were prepared

Cornus alba 'Elegantissima'	*P. parvifolia* 'Gold Drop'
Forsythia × *intermedia* 'Spectabilis'	*Spiraea* × *bumalda* 'Anthony Waterer'
Kerria japonica 'Variegata'	*S.* × *bumalda* 'Gold Flame'
Lonicera japonica 'Halliana'	*Symphoricarpos orbiculatus*
Philadelphus coronarius	*Weigela florida* 'Bristol Ruby'
Physocarpus opulifolius 'Dat's Gold'	*W.* 'Minuet'
Potentilla fruticosa 'Abbotswood'	*W.* 'Variegata'

In March, 1981 the hardwood cuttings started to flush, and to form a small root ball. After the cuttings had developed a small root ball and had a good flush of new growth we potted them into 7 oz styrofoam cups.

In April, I tried the very soft young cuttings from the new pot liners. The cuttings, which usually have four leaves; were treated with Hormodin #1 and stuck in the bench or in flats, wherever space permits. We continue taking softwood cuttings as the various species flush. Taking softwoods from hardwoods can produce a double or triple crop in one season, before traditional softwoods in June, July, and August.

The softwood cuttings receive no mist, only occasional hand watering. The day temperature in early spring is warm but not hot. Roots develop quickly with some spirea cuttings rooted in 2 weeks. By May we were potting up our rooted softwood cuttings.

Before the end of summer, both the original crop of hardwood cuttings and the bonus crop of softwood cuttings were lined out. We like the heavy, well-branched plants harvested from our pot liners in the following 1 to 2 years. Grading is greatly reduced because the finished plants are uniform.

At Riverbend Farms we have utilized limited space, equipment, heat, water, and labor to produce softwood cuttings from developing hardwood cuttings. Utilization of early spring propagation also leaves more time during the summer to keep our nursery clean, to prune our evergreens, and to organize our inventory.

PROPAGATION OF *ILEX OPACA* BY CUTTINGS

KATHRYN K. MERCHANT

Many Oaks Nursery
Bagdad, Kentucky 40003

I will attempt to explain the procedures for propagation of *Ilex opaca* by cuttings that we have found most successful and profitable.

Cuttings are taken from healthy plant in mid-to-late December after a good freeze, prepared, and stuck in greenhouse benches filled with perlite and heated with bottom heat. When taking the cuttings, we try to make them at a finished length of 8 to 10 in., to reduce handling. Cuttings should be taken when the temperature is above freezing. This may be important. I lost about 100 cuttings this past year due, perhaps, to the "wind chill" factor. That is the only variable that was different in all the groups of cuttings. The actual temperature was about 36°F, but with a wind chill of 10 to 15°F. Of 105 cuttings taken under these conditions, only two rooted.

The cuttings are stripped, wounded, and dipped in the appropriate hormone solution. We strip the leaves on the lower 3 in. of the cutting. The bottom ½ to ¾ in. of the cutting is then wounded on two sides with a short piece of worn hacksaw blade. The wounded cuttings are then dipped in concentrated Chloromone for about 5 sec., followed by Hormodin #3.

I have been advised to use Chloromone on *Taxus baccata* 'Repandens' by Leonard Savella about 3 years ago. I also tried it on several other subjects, including holly. The Chloromone-treated holly cuttings rooted about 20% better than the untreated group.

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After the hormone has been applied, the cuttings are stuck in a bottom-heated bench, filled with perlite. We try to keep the heat in the bench between 68° and 72°F. At present, we are considering going back to sand. The perlite seems to break-down and hold too much water after 2 or 3 years. The cuttings are stuck about 25 to 30 per sq. ft. They are watered in by hand and then, as needed, to keep the medium slightly moist to the touch and to keep the foliage moist.

During the period the cuttings are in the bench, they are drenched about three times with a Benlate solution (½ table-spoon to a gallon of water) to help prevent leaf drop.

About late May or early June the cuttings are potted, set in a lath house for one or two years, and then lined out.

EVERETT VAN HOF: How much Benlate did you use?

KATE MERCHANT: One-half tablespoon/gal warm water. This is drenched over the cuttings.

PETER VERMEULEN: What was your bench temperature?

KATE MERCHANT: From 68° to 72°F.

ELWIN ORTON: What was the air temperature?

KATE MERCHANT: We do not try to heat the air. What-ever it is that day. We just heat under the bench. Last year, in a cold period, we had ice on the inside of the greenhouse walls, but the cuttings rooted well.

ELWIN ORTON: If you could keep the air at about 50°F and the medium at 70°F, you could up your percentage to 100%.

TOM MCCLOUD: Are your cuttings under mist?

KATE MERCHANT: No, hand-watered. We water the cut-tings in well when we stick them, and then water as needed to keep the foliage damp.

ROOTING CUTTINGS IN OUTDOOR MIST BEDS

ROBERT J. GOUVEIA
Jackson Nursery, Inc.
217 W. Main Street
Norton, Massachusetts 02766

We have been using outdoor mist beds at our nursery for 5 years. They are an alternative to a costly greenhouse struc-ture and the use of an expensive energy source.

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The beds are made of cement blocks, mortared together, and set into the ground 16 in., or the depth of 2 blocks. The medium is coarse sand filled to the top of the first block. In 1982, we insulated one bed with 1 in thick rigid foam (polyisocyanurate. R = 7.2 at 68°F.) (1). The bottom insulation was sloped toward the middle with a 3 in space for drainage. The sides have 16 in. of insulation. Sand is used to grade the slope level. Lead cable is then laid down 4 in. apart on the sand and ¼ in. mesh hardware cloth is laid over the cable to help disperse the heat and protect the cable. The temperature controls for the medium give us 70°F at the root zone. In 1984, it took 676 kilowatt-hours to heat 225 sq ft of bed at a cost of $67.60. Collection of cuttings for narrow-leaved evergreens begins at mid-April and must be completed before growth starts. Seven *Thuja* cultivars are taken first and are stuck in a bed without bottom heat — since they root readily in summer without heat. Thirteen cultivars of *Taxus* are taken next, followed by 15 cultivars of *Juniperus*; both are stuck in a heated bed.

The mist system is made of ¾ in PVC pipe and Flora Mist nozzles. The pipe runs the length of the bed and is controlled by one 24-hour clock and one intermittent clock.

Rooting takes place in 7 to 10 weeks, but the cuttings are not lifted until September 1st. Beginning 3 weeks before lifting, the cuttings receive two applications of liquid fertilizer (Peters 20-20-20) at the rate of 200 ppm at 10-day intervals. The *Taxus* and *Thuja* roots are trimmed, planted in outdoor beds, and shaded with lath. At first, we mulched after planting, but experienced lower stem splitting, especially on *Thuja*. Now, mulching is delayed until late November, and we have no damage.

We feel that by moving *Taxus* and *Thuja* in early September, the cuttings have enough time to produce roots in the fall with little heaving. We have observed that *Taxus* 'Densiformus' (*T. cuspidata* 'Densa'? Bot.Ed.) cuttings, when rooted in winter and planted in spring, produce a growth flush of ½ to 1 in., but cuttings rooted in the summer and planted in September put on 6 to 7 in. of growth the first growing season. The *Juniper* cultivars remain in place all winter and are covered with pine branches for shade. They are potted into 1-gal containers in early spring.

Softwood cutting propagation begins the first of June and the cuttings are stuck in a deep bed or cold frame. This bed is 3 ft deep, 6 ft wide, and 50 ft long. The medium is sand and perlite (1:1, v/v). This bed has no bottom heat but is covered with a 4 mil white poly film left over from winter storage

houses. A frame of ¾ in. water pipe is used to hold the poly. The tent has doors and louvers at each end. White poly is used to avoid heat build up. White poly does not inhibit rooting; in fact, the cuttings root very well (2).

Almost all of the softwood cuttings remain in place for the winter. We put 2 layers of ¼ in. microfoam over the tops of the cuttings and then cover the bed with sash made of filon. This is then covered with another layer of polyfoam, followed by white poly that is nailed to the sides. We maintained a temperature of 32°F at the top of the cuttings when the outside temperature was −17°F. In the summer of 1983 we stuck 1,670 *Cornus florida* 'Rubra' cuttings and potted 1,420 the next spring.

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VOICE: How do you keep your plastic pipe from sagging and your nozzles from dripping after they shut off?

ROBERT GOUVEIA: We have a series of 2 × 2 in. oak boards that go across and the pipe sits on them.

RALPH SHUGERT: *Berberis thunbergii* 'Atropurpurea Nana' [*B. thunbergii* 'Crimson Pygmy'] cuttings are left under the mist for how long?

ROBERT GOUVEIA: It depends on how soon they root. We watch them and take them out as soon as they are well rooted. They do not do well under prolonged mist. The time averages 8 to 10 weeks.

JIM SAMPSON: Do you have any special tricks for transplanting *Stewartia* cuttings in spring? We experience tremendous losses.

ROBERT GOUVEIA: We keep them in the flat until we see leaves. I do not get excited about moving them too quickly. We also pot them up in the greenhouse and watch them closely.

JIM SAMPSON: We wait until we have leaves, but we still have losses. We have had some luck with the fungicide, Subdue.

ED MEZITT: We had trouble with hot water heat in our outdoor beds and finally gave up on heating. Do you find any difference in rooting without heat?

ROBERT GOUVEIA: Yes. *Taxus* cuttings the first year did not have heat outside and by September they were not ready to transplant.

ED MEZITT: I was talking about deciduous softwood cuttings.

ROBERT GOUVEIA: They do not have bottom heat.

RICHARD WOLFF: Did you find any effect of reduced light? We have a similar set up and observed no effect.

ROBERT GOUVEIA: The reduced light does not appear to be a problem.

CAMERON SMITH: Polybutylene, used as a piping for hot water in beds, is specifically made not to be damaged by freezing. This is not so for polyethylene and PVC.

WILLIAM STUDEBAKER: How often do you change your sand.

ROBERT GOUVEIA: We take it out every 2 years.

HARDWOOD CUTTING PROPAGATION AT MCKAY NURSERY

BERNARD FOURRIER

McKay Nursery Company
P.O. Box 185
Waterloo, Wisconsin 53594

Propagation by hardwood cuttings is an important part of the propagation procedures at McKay Nursery. Hardwood cutting propagation has several important advantages over other methods;

1. It is the second most economical method of propagation — after seedlings.

2. Liners from hardwood cuttings are larger than those from softwood cuttings.

3. The cuttings do not require special handling in storage.

4. The cuttings are more easily transplanted.

A limiting factor is the many stock plants necessary to make large numbers of hardwood cuttings.

Our hardwood cuttings are prepared and stuck at two times of the year — fall and spring. We prefer fall cuttings as

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they perform better, and many of them callus before the soil freezes. Some species, however, suffer bark splitting when stuck in the fall, so cuttings of these species are stuck in spring.

FALL CUTTINGS

We start making fall hardwood cuttings as soon as the wood is ripe. The cutting material is ready when you can remove the leaves without tearing the bark. This is usually around September 15 in Wisconsin. Current season vigorous shoots are cut from 2-year-old field-grown plants. They are then stripped and sawed into 8 in. cuttings with a band saw. We usually make 2 to 3 cuttings per cane. The tops, which are not mature enough, are discarded. With some species and cultivars, the position of the cuttings on the cane is recorded and cutting batches are kept separate, because the rooting percentage varies depending on whether it is the first, second, or third cut. The cuttings are then counted, bundled with elastic bands, waxed on the tops (mainly to indicate the orientation of the cuttings) and stored until planted. Table 1 lists fall-propagation hardwoods.

Table 1. Plants propagated by hardwood cuttings in the fall and special treatment required.

Lonicera × *xylosteoides* 'Clavey's Dwarf'	
Populus species	
Potentilla cultivars, except 'Katherine Dykes'	
Prunus × *cistena*	2500 ppm IBA quick-dip
Prunus glandulosa 'Sinensis'	Soaked in 1000 ppm IBA solution for 16 hours then dipped in Benlate powder
Rosa × *rugosa* 'Belle Poitevine'	
Rosa × *rugosa* 'Theresa Bugnet'	
Ribes alpinum	
Salix species	
Spiraea × *bumalda* 'Anthony Waterer'	
Spiraea × *bumalda* 'Froebelii'	
Spiraea × *bumalda* 'Goldflame'	
Spiraea × *vanhouttei*	

Preparation of the soil to receive the hardwood cuttings begins the previous spring. Fertilizer is applied at the rate of 160 lb. N, 35 lb P_2O_5, and 130 lb K_2O per acre. Following plowing, sudex is sown at the rate of 30 lb/A. When the sudex reaches 5 to 6 ft, it is chopped. We usually chop two or three times before plowing under by mid-August. At plowing time we apply 100 lb/A of urea.

At planting time the land is worked and leveled with a Niemeyer power harrow. Cuttings are placed in paired rows, 9 in. apart, separated by 48 in. aisles to facilitate cultivation and

digging. Trenches to receive the cuttings are made with two knife-like chisels mounted on a 130 Farmall tractor.

Cuttings are stuck 7 in. deep, 1 in. apart in the trenches and firmed by stepping along the rows. They are then sprayed with Devrinol at the rate of 5 lb, Ai/A and covered with marsh hay to keep them from freezing too hard and subsequently heaving. This year we are trying some cuttings without hay and covered completely with soil.

SPRING HARDWOOD CUTTINGS

These are divided into 3 subgroups.

1) Easy-to-root — which are handled in the same manner as the fall-planted hardwood cuttings.

2) Cuttings which require special attention, such as shading, warmer soil, or watering. These include: *Potentilla*, *Ligustrum*, *Philadelphus*, and *Cornus alba* 'Elegantissima'.

3) Cuttings which will be planted directly in the field for finished plants. For these we use heavy cuttings since the subsequent growth is directly related to the size of the cuttings. These cuttings are planted 1 ft apart in the row, 48 in. between rows, and include *Sambucus*, *Cornus*, *Physocarpus*, *Spiraea* × *bumalda* '*Froebelii*', and *Salix*.

The spring hardwood cuttings are prepared in February from wood collected in early December in the field and from plants in storage. Proper care should be taken to keep the wood from desiccating. We also collect some wood in March if we are short and there are no signs of winter injury.

The cuttings are prepared in the same way as the fall cuttings, except for a few which, because of long internodes or because they perform better, are cut by hand under a bud — or set of buds — at the proximal end of the cutting. Such is the case with *Cornus*, *Hydrangea*, *Philadelphus*, *Forsythia* and *Weigela*. After processing, the cuttings are stored in a 50/50 mixture of peat and wood shavings, and put in a cooler until ready to plant (See Table 2 for plants propagated by hardwood cuttings in the spring).

The spring cuttings are not mulched. Success with spring cuttings depends a lot on the weather. If we are unable to get the ground ready early enough and the temperature rises from 60 to 80°F in a very short time, buds may break dormancy before the cuttings have a chance to form roots. After sticking, we apply Surflan at the rate of one quart per acre. If necessary, the cuttings are fertilized during the growing season with 100 lb/A of urea.

Table 2. Plants propagated in the spring by hardwood cuttings and special treatments required. (Treatments given prior to sticking)

Cornus — dipped in Fermate powder
Cornus alba 'Elegantissima' — Rootone 10 + Fermate
Forsythia — 2500 ppm IBA + 1000 ppm Ethrel, quick-dip
Ligustrum — Rootone 10
Philadelphus — 2500 ppm IBA + 1000 ppm Ethrel, quick-dip
Potentilla cultivars — Rootone F
Sambucus
Spiraea
Symphoricarpus
Weigela — 2500 ppm IBA + 1000 ppm Ethrel, quick-dip

The rooted cuttings are dug in the fall with a modified potato digger and put in a cooler where they will be graded, counted, and trimmed for planting in the field the following spring.

MIKE DODGE: Have you had any success with lilacs from hardwood cuttings?

BERNARD FOURRIER: Yes with *Syringa* × *chinensis*

STOCK PLANT ETIOLATION FOR IMPROVED ROOTING OF CUTTINGS

NINA BASSUK, DIANE MISKE, AND BRIAN MAYNARD

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Abstract. The practice of stock plant etiolation, whereby dormant plants are grown under severely restricted light levels and then allowed to green up while shoot bases remain etiolated, using a covering of black adhesive tape, produced significantly better rooting of cuttings. Rooting was improved from 5% to 68.5% for *Fagus sylvatica*, from 15% to 42.5% for *Carpinus betulus*, and from 53.3% to 83.3% for *Pinus strobus*. Cuttings from 6 hybrid lilac cultivars also showed improved rooting with prior etiolation and, moreover, the period over which lilac cuttings could be propagated successfully was lengthened considerably.

INTRODUCTION

Using etiolation or, the exclusion of light, in the stimulation of adventitious root growth is a well established practice. As early as 1537 there is mention of light reduction having a favorable effect on the rooting of apple cuttings (3). The practices of stooling and other types of layering routinely use this

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principle when mounding soil around the portion of stem to be rooted. Even when we insert the base of a cutting into an opaque rooting medium we are achieving this same effect.

Technically, etiolation refers to plants grown in total darkness; however, as this term has sometimes been used in propagation, it may refer to plants grown in a heavily shaded condition with some low level of light present. It is important, however, that the distinction be made between etiolation and the practice of blanching where stock plants are grown initially in the light and then shaded either entirely or in a localized area, usually the base of the stem (6).

Within the last ten years, the practices of etiolation and/or blanching have been investigated with renewed interest, primarily due to the work reported by Howard and co-workers at the East Malling Research Station in England (6,7,9). Their first success with this technique was with the difficult-to-root apple rootstock, M9, where prior etiolation of the stock plant increased rooting of softwood cuttings from 11% to 78%, on the average (6). Other researchers have also had success with the following difficult subjects for cutting propagation: *Tilia* spp. (9), *Acer platanoides* 'Crimson King' (9), *Pinus sylvestris* (5), *Syringa vulgaris* cvs. (8), *Mangifera indica* (1), and *Persea americana* (3), among others.

The purpose of this work was to etiolate such poorly rooting species as *Fagus sylvatica*, *Carpinus betulus*, and *Pinus strobus*, as well as 6 cultivars of *Syringa vulgaris* for the purpose of increasing their rooting percentages and, in the case of the lilacs, to lengthen the period of time over which cuttings could be successfully propagated. Hybrid French lilac cuttings are quite variable in their rooting response and propagators who have been successful attribute their success largely to choosing the correct timing for cutting collection, usually a brief period during initial shoot growth (2). Due to differences among the growth rates of lilac cultivars, variations in seasonal weather patterns from year to year, and stock plant growing conditions, choosing the optimal time for cutting collection can be a tricky endeavor.

METHODS

The method used to etiolate these plants was first developed by Gardner (4), modified by Howard (7), and further expanded for this report (Figure 1). Just prior to bud break, dormant stock plants, either in-ground hedges or container-grown plants, were covered by black plastic stapled over a frame which allowed for adequate new shoot growth. Light readings under the black plastic showed an average of 99%

light reduction, as slits were cut in the plastic for ventilation. The white pine plants, however, were grown in a 70°F day/ 62°F night greenhouse under 92% shade saran cloth.

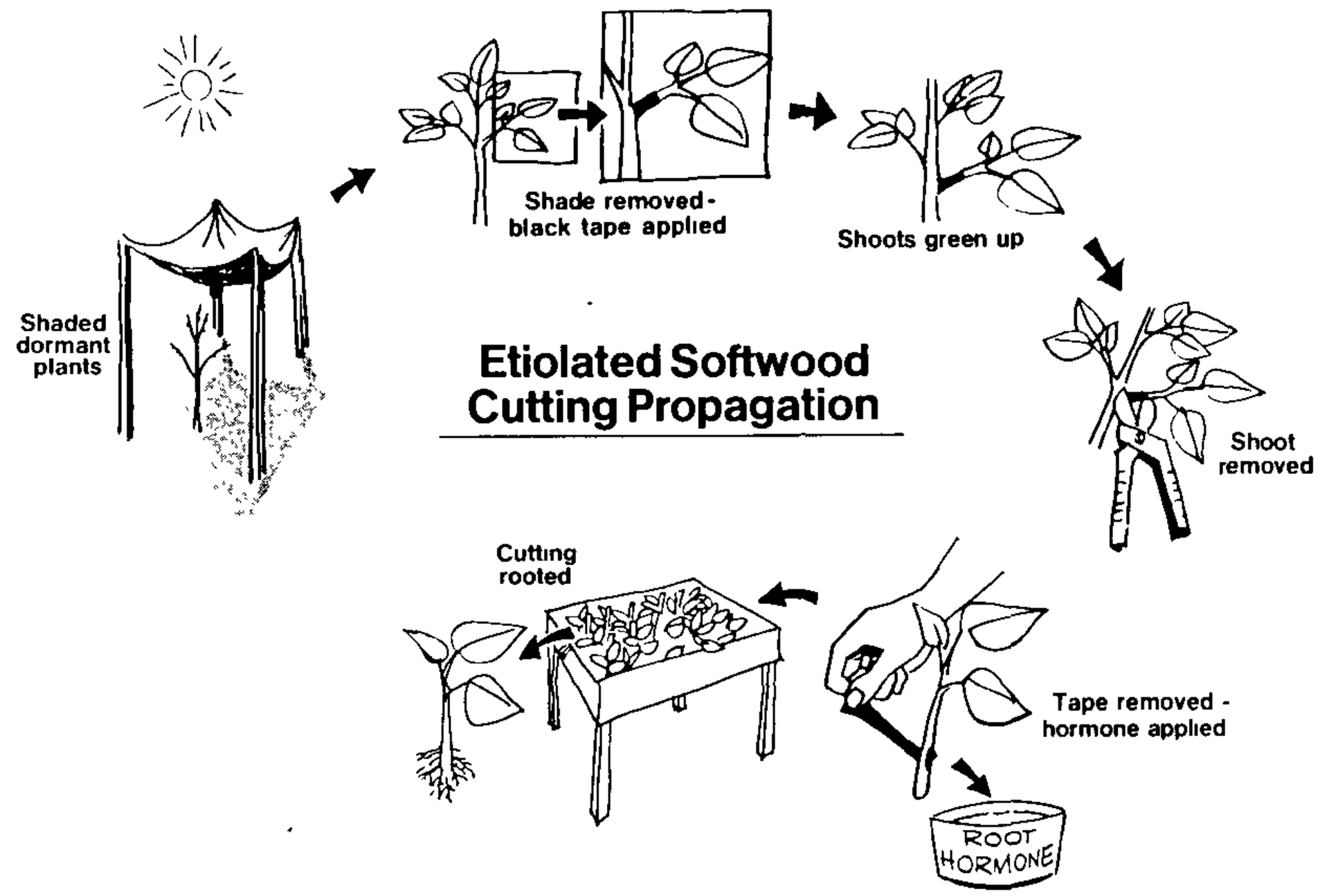

Figure 1. A graphic representation of the stock plant etiolation method

After new growth reached approximately 6 to 8 cm in length, the north side of the enclosure was removed to begin weaning the greenish-yellow, soft shoots to the sun. Also, at this time, some shoots were banded at their bases with black adhesive tape to keep the future rooting zone of the shoot in an etiolated condition while allowing the shoot tips to green up. All black plastic shading was removed within one week and, after another week of greening-up, cuttings began to be collected. Collection continued at set intervals up to 12 weeks after shade removal in some cases. After shoots were collected, banded shoots had their tapes removed and then all cuttings were treated as normal softwood or greenwood cuttings, i.e. IBA was applied and the cuttings were rooted under mist in the greenhouse.

RESULTS

Cuttings from etiolated hedges of *C. betulus* and *F. sylvatica* showed a striking improvement in rooting over their respective controls (Table 1). Cuttings were collected at 2 and 8 weeks after banding, treated with 3000 ppm IBA in talc, and rooting assessed after 5 weeks in the mist bench.

Table 1. Effect of etiolation and banding on rooting of *Fagus sylvatica* and *Carpinus betulus* cuttings.[1]

	Percent rooting		
	+Shade+Band	+Shade−Band	−Shade−Band
Fagus sylvatica	69	42	5
Carpinus betulus	43	0	15

[1] 20 cuttings per treatment

Greenhouse grown *Pinus strobus* cuttings were collected at 4-, 8-, and 12-week intervals after shading was removed and/or banding applied, and given a quick dip with 4,000 ppm IBA and 25% Captan in 50% ethanol. Rooting percentages were averaged for all collection dates after cuttings were in the mist bench for 3 months. Etiolation or banding without prior shading improved rooting significantly (Table 2).

Table 2. Effect of etiolation and banding on rooting of *Pinus strobus* cuttings.[1]

	Percent rooting	
	+ Banding	− Banding
Etiolated	83	84
Light grown	79	53

[1] 36 cuttings per treatment

Cuttings from 6 hybrid lilac cultivars were collected 2-, 5-, 8-, and 12-weeks after shade was removed and/or banding applied. All cuttings were treated with 1,000 ppm IBA in talc and rooting assessed after 5 weeks in the mist bench (Figure 2). For 'Charles X', rooting of the control (−shade −band) was fairly high, 60%, at 2 weeks but dropped to 10% by 5 weeks, and remained low thereafter. The full etiolation treatment (+shade +band) began as did the control at 2 weeks, but improved to 80% at 5 weeks, before dropping to a steady 30% at the 8 and 12 week dates. With intermediate treatments, blanching (−shade +band) showed a small improvement over the control although not up to the levels of the full treatment. Initial shade minus banding gave no improvement over the control. A similar pattern of treatment responses is seen for 'Michel Buchner.' Control plants (−shade −band) rooted poorly at 2 weeks, gradually rising to 60% by 12 weeks. The full etiolation treatment began similarly to the control at 2 weeks but by 5 weeks was rooting at 80%, rising to 100% at the 8 and 12 weeks collection dates. With the 2 intermediate treatments, blanching (−shade +band) again showed a favorable, if more variable response, than the full treatment, and initial shading alone without banding showed little improvement over the controls.

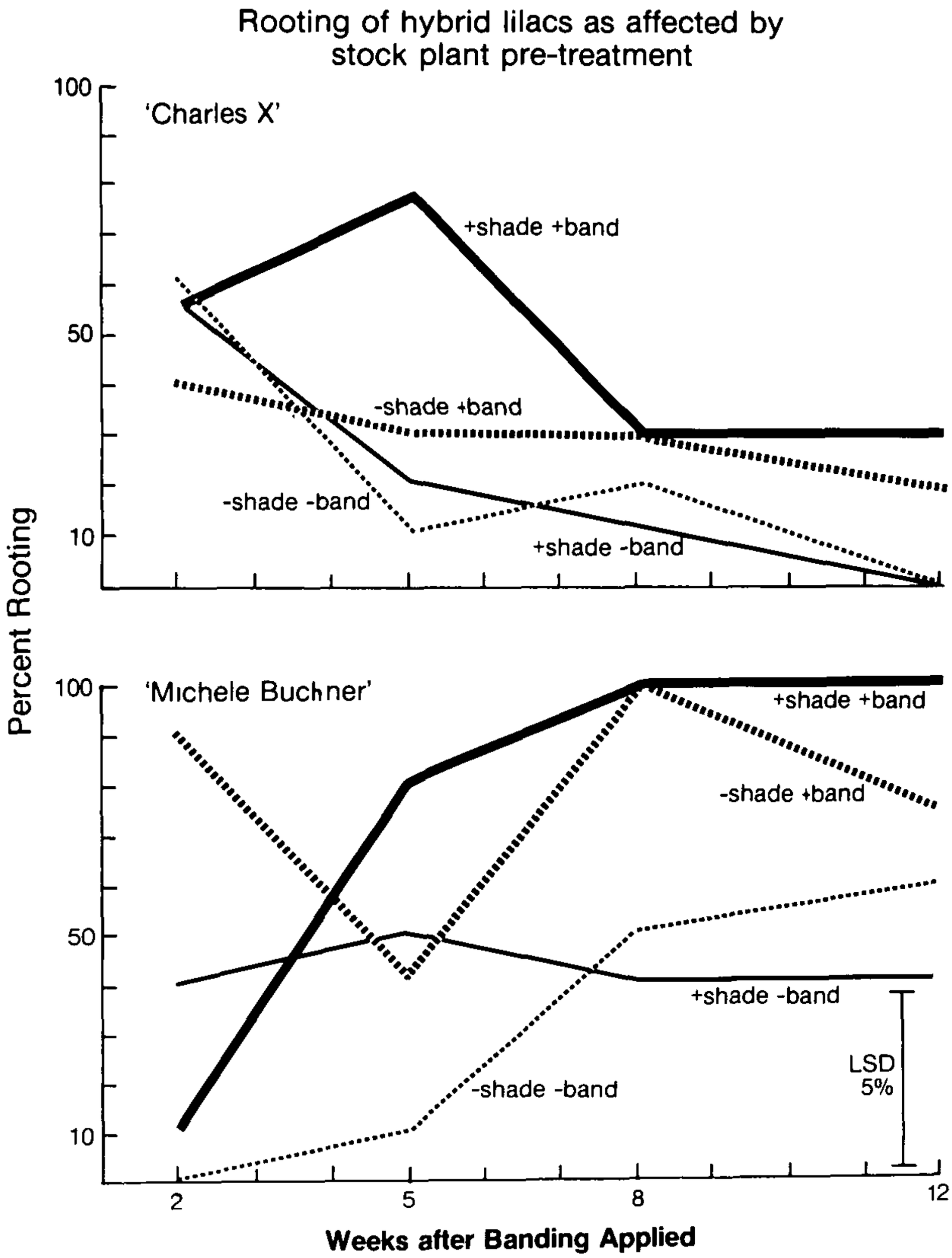

Figure 2. Rooting of hybrid lilac cultivars as affected by etiolation, banding, and date of collection

Stock plants of 4 other lilac cultivars were also given the full etiolation pre-treatment (Figure 3). With these cultivars, etiolation also improved rooting; however, the results were less consistent. 'Madame Lemoine' is noted to be a particularly shy rooter, at best rooting only at 30 to 40% (2), yet etiolated cuttings collected 12 weeks after the shade was removed and banding applied, rooted at 80%. Unfortunately, there were not

enough shoots on control plants to make a true comparison. 'President Grevy', also a shy rooter, showed only slight improvement with prior etiolation, while etiolated 'Belle de Nancy' and 'Charles Joly' showed significant improvement over their respective controls.

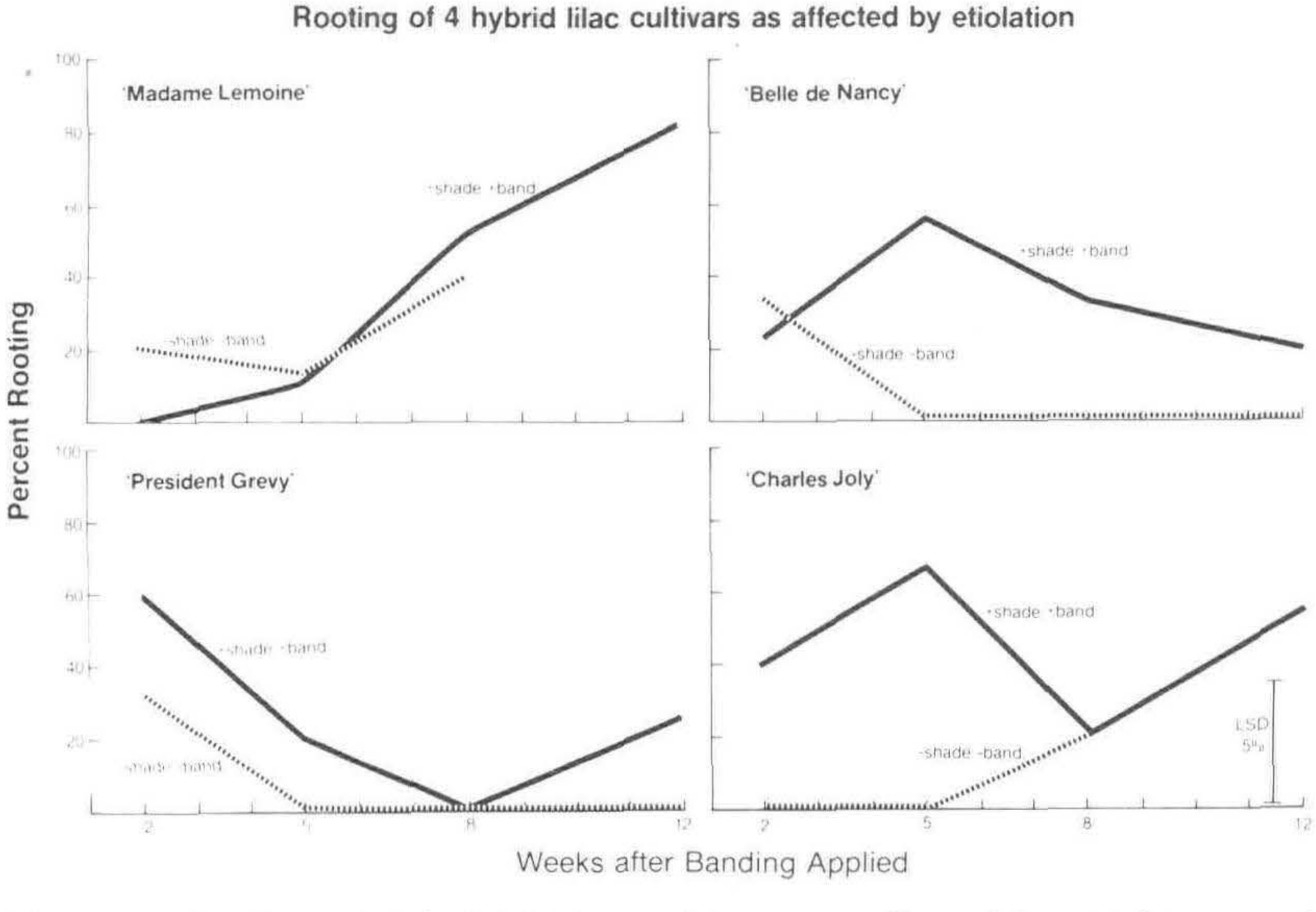

Figure 3. Rooting of 4 hybrid lilac cultivars as affected by etiolation and date of collection.

DISCUSSION

It is apparent that prior etiolation of cutting material and the related treatment of blanching are capable of improving rooting in a diverse group of plants. *Pinus strobus* cuttings responded positively to both shading or banding, either treatment achieving a 25 to 30% increase over the control cuttings. With this plant, localized banding was not necessary to keep the base of the etiolated shoot in a shaded condition while the shoot was greening-up as long as the shoot was initially grown under shaded conditions.

Etiolated *F. sylvatica* and *C. betulus* shoots showed a dramatic increase in rooting ability over their respective controls. Additionally, with *Fagus*, but not *Carpinus*, shading without subsequent banding also gave a noticeable improvement over the control.

Although all lilac cultivars showed a positive rooting response to etiolation plus banding, the magnitude of their respective improvements was cultivar dependent. Previous re-

ports stating that 'Madame Lemoine' and 'President Grevy' were poor rooters (2) were borne out by this study; however, for 'Me Lemoine' there was potentially a 4 week period (between the 8 and 12 week collection dates) where the etiolated cuttings rooted over 60%. 'President Grevy', the poorest in this trial, also reached 60% rooting success with prior etiolation at the two week collection date. Neither of these two cultivars' controls ever reached acceptable rooting levels. If we continue to arbitrarily use a 60% rooting level as being acceptable to commercial propagators, then 'Belle de Nancy' and 'Charles Joly' also reached that level for one and two collection dates, respectively, compared to none for their controls. With the case of 'Charles Joly', which has been reported to be an easy rooter with 75% or more rooting (2), the fact that we did not see this may be due to an inadequate level of IBA (1,000 ppm) used in this study, and a troubling frequency of decay in the bench as no fungicide was used. IBA concentrations of 3000 to 8000 ppm have been used by others on lilacs (2).

With the better rooting cultivars, 'Charles X' and Michel Buchner', not only was rooting significantly improved by stock plant etiolation, but the period over which cuttings could be successfully collected was lengthened considerably. Other propagators reporting variable success using etiolation with lilacs may not have witnessed its effectiveness due to having had only one collection time (8).

Again using the 60% rooting criteria as acceptable, etiolated 'Charles X' could potentially be rooted successfully at the 2 week collection date through to the fifth week or longer, while the control only rooted successfully at the first collection date. Etiolated 'Michel Buchner' cuttings could potentially be rooted at better than 60% for even longer — from the fifth week collection date, through to the twelfth week date, while its control rooted acceptably only at the last collection date.

It appeared to be essential that lilac shoots be grown in an etiolated state and then banded to exclude light from the future rooting zone of the cutting to achieve large improvements in rooting. Overall levels of lilac rooting may be further improved by the use of higher IBA levels and a fungicide in the mist bench.

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BILL FLEMER: The name of the second lilac clone is incorrectly spelled. It is 'Michel Buchner'.

PETER VERMEULEN: With *Carpinus* you had 0% with the intermediate treatment. Do you have a reason for that?

NINA BASSUK: It appears that it required both etiolation and localized banding to get the 40%.

RALPH SHUGERT: Did you use 1000 ppm IBA on all your cuttings?

NINA BASSUK: No, we used 4000 ppm plus 25% Captan in talc on *Pinus strobus* and *Carpinus*, and 3000 ppm on *Fagus.*

RALPH SHUGERT: For lilacs, 1000 ppm seems light. How did you determine this?

NINA BASSUK: The 1000 ppm was based on results from greenhouse-grown plants. In retrospect they appear to have been more sensitive than outdoor grown plants. If I did it over again, I would use a higher concentration of IBA.

NEW FINDINGS IN THE STORAGE AND SHIPMENT OF UNROOTED CUTTINGS[1]

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Shipment and storage of unrooted cuttings has changed dramatically over the past 10 years. In this time period cutting production has shifted to specialist propagators who are normally located long distances from final growers. Given that this is the case, then one must accept that cuttings are going to be shipped for longer periods without adequate environmental controls.

Production shifts have been noted because of either financial considerations or need to improve the cutting production environment. When plant material is produced in warmer climates, heating costs are reduced and elaborate growing structures are generally not necessary. In addition, labor in most instances is less expensive, especially overseas. A grower can also relocate to an area with limited rainfall which, in many cases, will reduce the severity of foliar diseases, when stock plants are grown outdoors.

With these changes, new problems have surfaced. The major problem is related to postharvest physiology. Unrooted cuttings that are shipped for long periods often show foliar yellowing when received. In addition, cuttings that may appear green can show reduced rooting rates and develop disease problems which are not as serious with directly rooted cuttings.

We, at the University of Illinois, are attempting to understand these shipping problems. Our first priority is defining the shipping environment. Once this is defined, cutting quality can be correlated to specific environmental parameters. Our second objective is to understand why these problems occur on a physiological basis. The experiments presented in this brief paper are part of a 5 year project formulated to understand why any plant material yellows during shipping and/or storage. Based on preliminary experiments a shipping hypoth-

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[1] This work has been supported by Oglevee Associates, Horticultural Research Institute, The Fred C Gloeckner Foundation, American Florists Endowment, Fischer Pelargonium, and Illinois State Florist Association

[2] Assistant Professor, Graduate Student in Postharvest Physiology, and Graduate Student, Extension Education, respectively

esis has been formulated. The hypothesis follows this line of reasoning:

1) Unrooted plant material is shipped for long distances, generally without adequate environmental controls.

2) Poor environmental controls close stomates.

3) Once stomates close internal ethylene builds-up.

4) High levels of internal ethylene reduce cutting quality.

Results from 2 experiments will be presented. Each project was designed to verify points in our hypothesis. Data will first be presented defining the shipping environment which will be followed by an examination of stomatal fluctuations during specific handling procedures.

Monitoring the shipping environment was the first step to understanding why cuttings yellow during shipment. It is recommended that unrooted geranium cuttings be stored at 3°C (37°F). In order to examine temperature patterns during shipment a Ryan temperature monitor (available from Ryan Instruments, Inc., P. O Box 599, Kirkland, WA. 98033) was used. This recorder allowed us to obtain a constant record of temperature during the complete shipment period.

Several experiments were conducted that examined packing materials, box types, fungicides, precooling, and the incorporation of ice into boxes. Shipment times varied from 72 to 108 hr. Plant material originated on the Canary Islands and was air-freighted to Munich, Germany; Miami, FL.; Chicago, IL; and finally to Urbana, IL. The data presented in this paper is from a 72 hr shipment with several geranium cultivars. Each box contained 1000 cuttings which were divided into four groups of 250, wrapped in moist newspaper and placed in unsealed plastic bags. All cuttings were treated with a fungicide prior to being shipped in either a cardboard or a styrofoam box. One styrofoam box treatment contained ice. Each box contained a Ryan temperature recorder.

When temperature graphs were examined the cardboard box and styrofoam box without ice showed few differences (Figure 1). Temperature inside the styrofoam box fluctuated, but at a slower rate when compared to the cardboard box. The temperature extremes were similar. The significant finding was that the styrofoam box with ice maintained a cooler temperature for the first 32 hr when compared to the other treatments.

When plant material was evaluated, cuttings from the styrofoam box with ice were greener and showed less foliar decay than the other treatments Results from this work indicate that maintaining lower shipping temperatures for the first

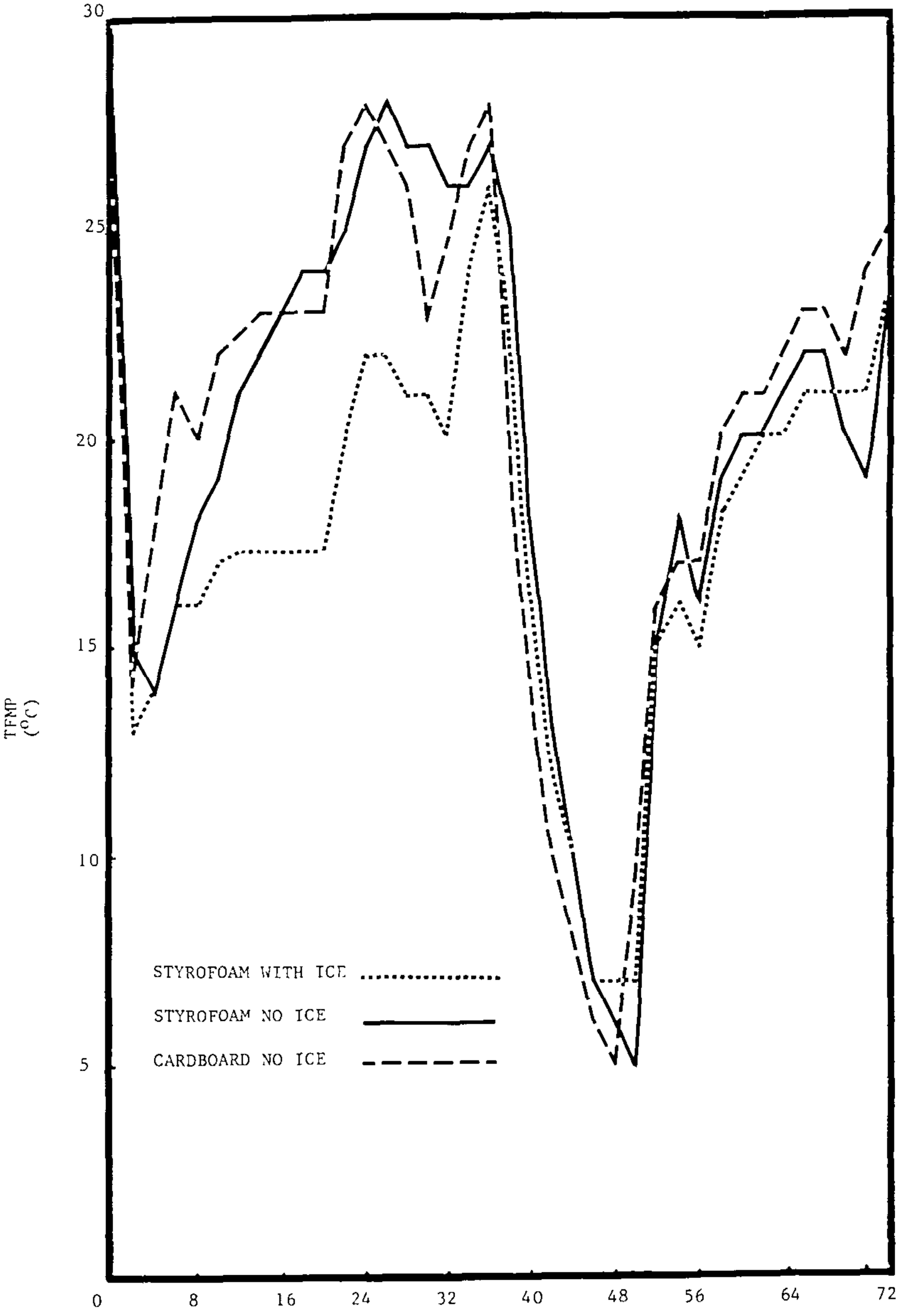

Figure 1. Internal box temperatures during shipment of unrooted geranium cuttings in styrofoam and cardboard from the Canary Islands to Urbana, Illinois

24 to 36 hr can signficantly improve the quality of unrooted cuttings even if temperatures substantially exceed recommendations later on during handling procedures.

Another interesting finding was that the cuttings from the styrofoam box without ice appeared to be in better condition than those from the cardboard box. One advantage of using a styrofoam box is that it is air tight. The natural respiratory activity of the cuttings increased carbon dioxide to levels high enough to inhibit ethylene action. Ethylene is one of many factors that can cause leaves to yellow and eventually die. From the previous work, it become evident that commercial cuttings do not receive adequate temperature control during shipment.

The second phase of the total project was to understand why temperature fluctuations reduced cutting quality. Work was then initiated in the areas of stomatal conductivity and internal ethylene levels.

Stomates are pores in leaf tissue that provide the main pathway for gas exchange between the external environment and that within the leaf. When literature in this area was reviewed, it became obvious that factors which cause stomates to open and close are similar to those encountered during shipping and/or storage.

Ethylene is one compound within a plant that passes outside through the stomates. Ethylene is also known to cause leaf yellowing and is produced in greater quantities at higher temperatures. If stomates close during shipping (low stomatal conductivity), then no gas exchange can occur and ethylene builds up inside the leaf. If our hypothesis is correct, then cutting quality will be reduced.

Three simulated shipping experiments were conducted to examine how stomates react to various shipping environments. The first experiment examined differences between two geranium cultivars, 'Sincerity', a good shipper, and 'Salmon Irene' a poor shipper. The second study involved storing 'Sincerity' cuttings at three constant temperatures 3, 10, and 27°C (37, 50 and 81°F) for 72 hr. The last experiment was conducted at 3°C in the absence, or presence, of light

In each study, terminal cuttings were taken from stock plants grown at the University of Illinois, treated with Daconil and placed in loosely sealed opaque plastic bags for 72-hr periods. Stomatal conductivity was measured using a Li-Cor steady state porometer at the temperature cuttings were stored. Stomatal conductivity data is from the upperside of the lowest leaf on the cutting and is the average of several replications.

'Sincerity' cuttings exhibited higher rates of stomatal conductivity when compared to 'Salmon Irene' for the first 24 hr of monitoring (Figure 2). After 48 hr of dark storage, no differences in stomatal conductivity were detected. In several instances, internal levels of ethylene were monitored. Regardless of treatment, ethylene was always extractable from 'Salmon Irene' cuttings, but not from 'Sincerity'.

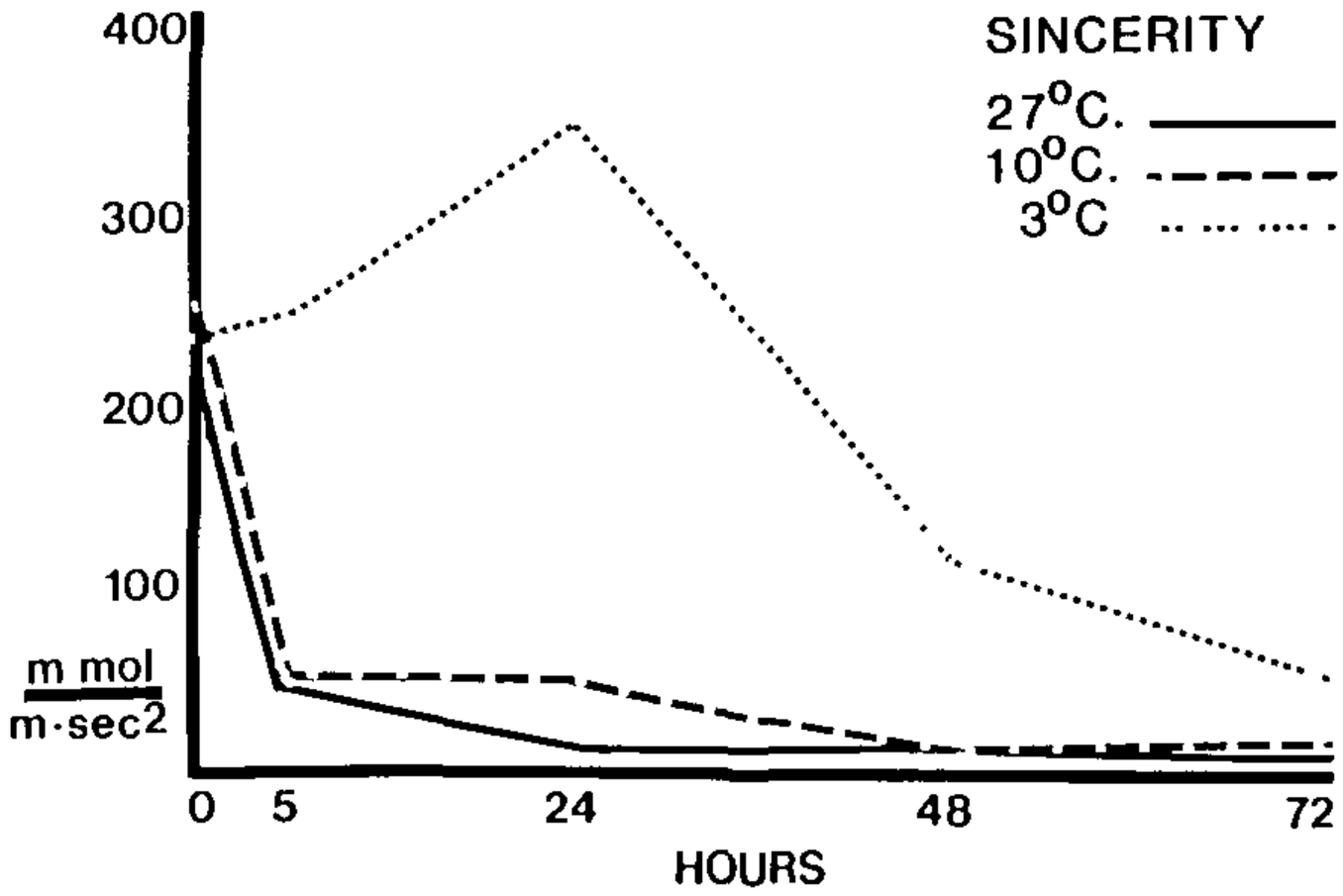

Figure 2. Stomatal conductivity levels from leaves of unrooted cuttings of 'Sincerity' geranium during 72 hr of dark storage at 3, 10, and 27°C

In order to determine if proper temperature storage allowed for greater stomatal conductivity, cuttings were stored at the proper 3°C, a reasonable temperature of 10°C, and an unacceptable 27°C. 'Sincerity' cuttings stored at 3°C showed higher rates of stomatal conductivity when compared to similar cuttings stored at 10 or 27°C (Figure 3). These differences were maintained during the entire 72-hr period. In addition, 'Sincerity' cuttings stored in the light showed higher rates of stomatal conductivity when compared to cuttings in the dark (Figure 4).

These results indicate that conditions during commercial shipment of unrooted geranium cuttings lead to reduced stomatal conductivity. A lack of light and improper shipping temperatures, which are encountered during shipping all proved to be factors that decrease stomatal opening and can led to poor quality cuttings.

Findings from these two series of experiments have aided in our understanding of why cuttings yellow during shipment. Once quality is lost, it is nearly impossible to regain. Therefore, it is the shipper's responsibility to establish improved handling practices, even if it means an added expense. Work is in progress identifying the factor that causes stomates to close,

as well as in the area of post-shipment treatments to regreen cuttings.

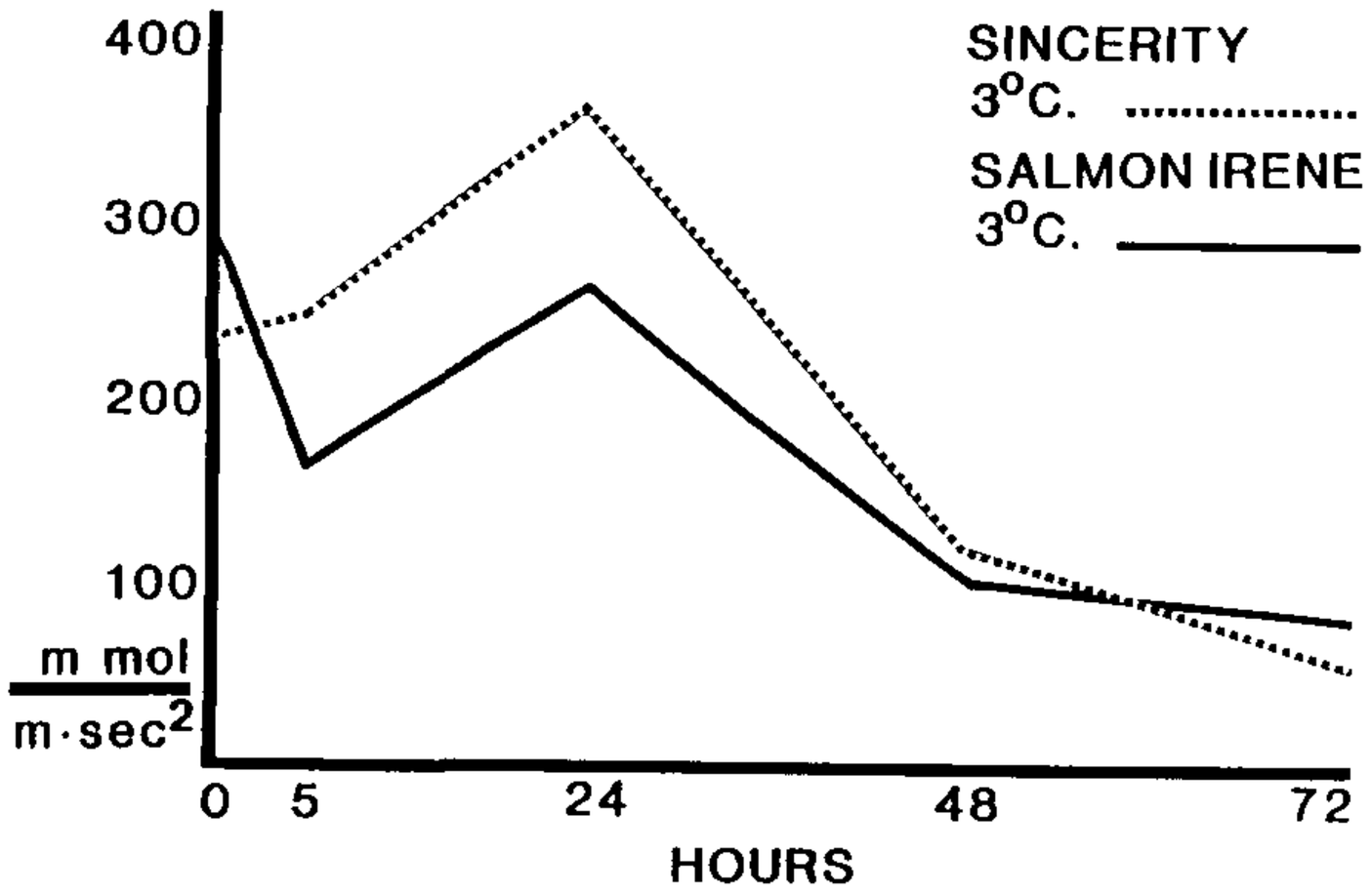

Figure 3. Varietal comparison of stomatal conductivity levels from leaves of unrooted cuttings of two geranium cvs., Sincerity, and Salmon Irene, during 72 hr of dark storage at 3°C

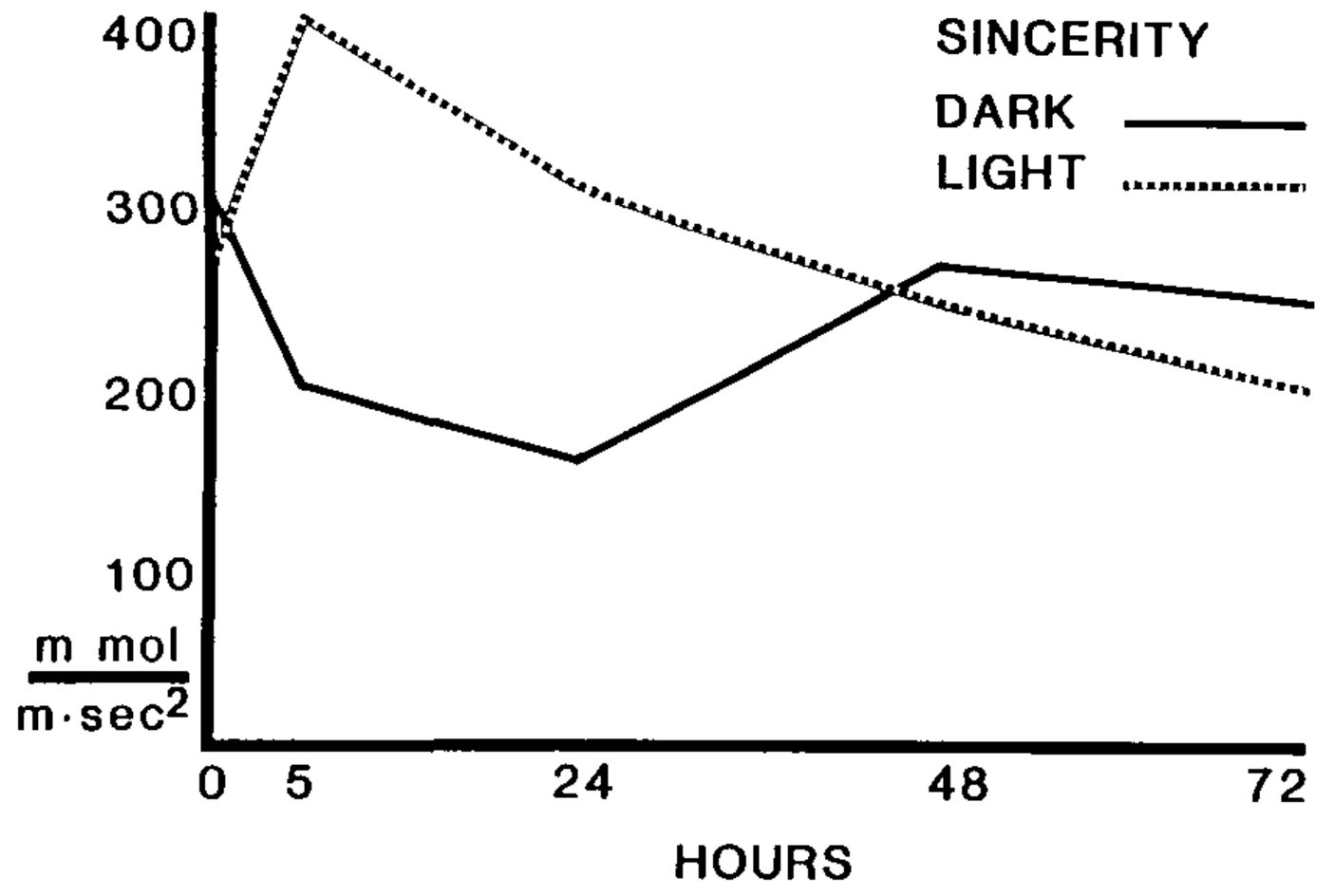

Figure 4. Stomatal conductivity levels from leaves on unrooted cuttings of 'Sincerity' geranium during 72 hr of light or dark storage at 3°C

VOICE: I wonder why you did not reduce the number of cuttings as a first step, because anytime you get yellowing it is because cuttings are packed together and high heat aggrevates the problem.

BARRY EISENBERG: I did not have time to report on all of our experiments. Regardless of how many cuttings put in the box the key is cooling them down. I did not have time to present the information on the gas atmosphere in the styrofoam boxes. Those boxes are air-tight and, after 96 hr, the CO_2

is up to 6 to 8%, O_2 is down to 10%, and there is a little ethylene. One of the benefits of the tight boxes, we feel, is the high CO_2, which should reduce respiration.

Tuesday Evening, December 11, 1984

Dave Beattie moderated the Educational Program. The following paper by Dave Williams was part of that program.

USE OF A SPRAY PATTERNATOR TO DEMONSTRATE LOW-PRESSURE PESTICIDE APPLICATION

DAVID J. WILLIAMS

University of Illinois
100 Ornamental Horticulture Building
Urbana, Illinois 61801

The selection of the proper pesticide to control a known pest is only the first step in implementing a spray program. It is essential that the pesticide be applied properly to insure that the desired pest control will occur in an efficient manner without waste or environmental contamination. More pesticides are applied with low-pressure sprayers than with any other kind of equipment. These sprayers apply chemicals to control weeds, insects, and diseases in field, nursery, vegetable and fruit crops, and turf. Tractor-mounted, pull-type, and self-propelled sprayers are available in many models; however, these may not be available to the classroom teacher or be too cumbersome to use for demonstration purposes. The use of a portable spray patternator allows the instructor to demonstrate the concepts of proper pesticide application in a limited area. The spray patternator, due to its portability, is also useful for extension meetings.

All low-pressure sprayers have several basic components: a pump, a tank, an agitation system, a flow-control assembly, and a distribution system. Spray pressures range from almost 0 to about 200 psi and application rates can vary from 10 to over 100 gal/A.

The spray patternator can be used to demonstrate the effects of pressure, boom height, nozzle placement, and nozzle type on spray patterns. The use of a strobe light behind the spray pattern illuminates the pattern so that it can be easily seen by the audience. Plans for the construction of a portable spray patternator are available from the author.

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The spray patternator is an effective teaching tool for studying spray distribution systems. The following is a discussion of distribution systems that should prove useful to instructors and pesticide applicators.

All hoses and fittings should be of a suitable quality and strength to handle the chemicals at the selected operating pressure. They should be chosen on the basis of composition, construction, and size.

A good hose is flexible, durable, and resistant to sunlight, oil, chemicals, and general abuse, such as twisting and vibration. The hose must be resistant to the chemical action of spray materials. The outer coating of the hose should be chemically resistant because spray may occasionally contact it. Two widely used materials that are generally chemically resistant are ethylene vinyl acetate (EVA) and ethylene propylene dione monomer (EPDM). A special reinforced hose must be used for suction lines to prevent collapsing.

Peak pressures are often encountered that are much higher than average operating pressures. These peak pressures usually occur as the spray boom is shut off. For this reason, the sprayer hoses and fittings *must be in good condition* to prevent a possible break and the operator being covered with the spray chemical.

Spray lines and suction hoses must be the proper sizes for the system The suction hoses should be air-tight, noncollapsible, as short as possible, and as large as the pump intake. A collapsed suction hose can restrict flow and "starve" a pump, causing decreased flow and damage to the pump or pump seals. When you cannot maintain spray pressure, check the suction line to be sure that it not restricting flow.

Other lines, especially those between the pressure gage and the nozzles, should be as straight as possible, with a minimum of restrictions and fittings. The proper size of these lines varies with the size and capacity of the sprayer. A high, but not excessive, fluid velocity should be maintained throughout the system. If the lines are too large, the velocity will be so low that the pesticide will settle out and clog the system. If the lines are too small, an excessive drop in pressure will occur. A flow velocity of 5 to 6 ft/sec is recommended. The suggested hose sizes for various pump rates are listed in Table 1.

Boom stability is important in achieving uniform spray application. The boom should be relatively rigid in all directions. Swinging back and forth, or up and down, is undesirable. The breakaway hinge arrangement of the boom should be dampened so that the boom is rigid in the fore and aft direc-

Table 1. Suggested hose sizes for various pump sizes

Pump output (GPM)	Hose sizes — Suction Pressure (inches)	
0-1	½	¼
1-3	½	⅜
3-6	¾	½
6-12	¾	⅝
12-25	1	¾
25-50	1¼	1
50-100	1½	1¼

ion. The boom should be constructed to permit folding for transport. Check for interference of the folded booms with tractor cabs and roll bars. The boom height should be adjustable from about 1 to 4 feet above the ground.

Certain commonly used chemicals will react with some plastic materials. Check with the sprayer manufacturer and the chemical manufacturer for compatibility.

NOZZLES

The proper selection of nozzle type and size is the most important part of pesticide application. The nozzle determines the amount of spray applied to a particular area, the uniformity of the applied spray, the coverage obtained on the sprayed surfaces, and the amount of drift. You can minimize the drift problem by selecting nozzles that give the largest drop size, while providing adequate coverage at the intended application rate and pressure. Although nozzles have been developed for practically every kind of spray application, only a few types are commonly used on low pressure sprayers. These types are described below.

Regular Flat-Fan Nozzles. Regular flat-fan nozzles are used for most broadcast spraying of herbicides and for certain insecticides when foliar penetration and coverage are not required. These nozzles produce a tapered-edge, flat-fan spray pattern, and are available in several selected spray-fan angles, although 80-degree spray-angle tips are most commonly used. The nozzles are usually on 20-in. centers at a boom height of 10 to 23 in. The boom heights for various spray-angles are shown in Table 2.

When applying herbicides with flat-fan nozzles, keep the operating pressure between 15 and 30 psi. At these pressures, flat-fan nozzles produce medium-to-coarse drops that are not as susceptible to drift as the fine drops produced at presssures of 40 psi and higher. Regular flat-fan nozzles are recommended for some foliar-applied herbicides at pressures from 40 to

Table 2. Boom heights for various spray angles

Spray angle (degrees)	Boom height, 20-in spacing (inches)
65	21-23
73	20-22
80	17-19
100	10-12

60 psi. These high pressures will generate fine drops for maximum coverage on the plant surface.

Because the outer edges of the spray pattern have tapered or reduced volumes, adjacent patterns along a boom must overlap in order to obtain uniform coverage. For maximum uniformity, this overlap should be about 40 to 50% of the nozzle spacing.

The LP or "low-pressure" flat-fan nozzle is available from the Spraying Systems Company. This nozzle develops a normal fan angle and distribution pattern at spray pressures from 10 to 25 psi. Operating at a lower pressure results in large drops and less drift than the regular flat-fan nozzle designed to operate at pressures of 15 to 30 psi.

Even flat-fan nozzles apply uniform coverage across the entire width of the spray pattern. They should be used only for banding pesticides over the row, and should be operated between 15 and 30 psi. Band width is determined by adjusting nozzle height. The band width for various nozzle heights are shown in Table 3.

Table 3. Band width for various even flat-fan nozzle heights

Band width (inches)	Nozzle height	
	80-degree series	95-degree series
	(inches)	
8	5	4
10	6	5
12	7	6
14	8	7

Flooding Flat-Fan Nozzles. Flooding flat-fan nozzles produce a wide-angle, flat-fan pattern, and are used for applying herbicides and mixtures of herbicides and liquid fertilizers. The nozzle spacing for applying herbicides should be 60 in. or less. These nozzles are most effective in reducing drift when they are operated within a pressure range of 8 to 25 psi. Pressure changes affect the width of spray pattern more with the flooding flat-fan nozzle than with the regular flat-fan noz-

zle In addition, the distribution pattern is usually not as uniform as that of the regular flat-fan tip. The best distribution is achieved when the nozzle is mounted at a height and angle to obtain at least double coverage or 100% overlap

Flooding nozzles can be mounted so that they spray straight down, straight back, or at any angle in between. Position is not critical as long as double coverage is obtained. You can determine nozzle position by rotating the nozzle to the angle required to obtain double coverage at a practicable nozzle height.

Hollow-Cone Nozzles (Disc and Core Type). Hollow-cone nozzles are used primarily when plant foliage penetration is essential for effective insect and disease control, and when drift is not a major concern. At pressures of 40 to 80 psi, hollow-cone nozzles produce small drops that penetrate plant canopies and cover the undersides of leaves more effectively than other nozzles. If penetration is not required, the pressure should be limited to 40 psi or less. The most commonly used hollow-cone is the two-piece, disc-core, hollow-cone spray tip. The core gives the fluid a swirling motion before it is metered through the orifice disc, resulting in a circular, hollow-cone spray pattern.

Whirl-Chamber Hollow-Cone Nozzles. Whirl-chamber nozzles have a whirl chamber above a conical outlet. These nozzles produce a hollow-cone pattern with fan angles up to 130 degrees, and are used primarily on herbicide incorporation kits. The recommended pressure range is 5 to 20 psi.

Raindrop° Hollow-Cone Nozzles.[1] Raindrop° nozzles have been designed by the Delavan Corporation to produce large drops in a hollow-cone pattern at pressures of 20 to 60 psi. The RD Raindrop nozzle consists of a conventional disc-core, hollow-cone nozzle to which a Raindrop can has been added. The RA Raindrop nozzle (a whirl-chamber nozzle with the Raindrop cap) is used for herbicide incorporation, and the RD Raindrop nozzle for foliar spraying. When used for broadcast application, these nozzles should be rotated 30 to 45 degrees from the horizontal to obtain uniform distribution.

Nozzle Tip Materials. Nozzle tips are available in a wide variety of materials, including hardened stainless steel, stainless steel, nylon, and brass. Hardened stainless steel is the most wear-resistant material, but it is also the most expensive. Stainless steel tips have excellent wear resistance with either corrosive or abrasive materials. Although nylon and other synthetic plastics are resistant to corrosion and abrasion, they are

[1] Registered Trademark

subject to swelling when exposed to some solvents. Brass tips are the most common, but they wear rapidly when used to apply abrasive materials such as wettable powders, and are corroded by some liquid fertilizers. Brass tips are probably the most economical for limited use, but other types should be considered for more extensive use.

Thursday Morning, December 13, 1984

The Thursday morning session was convened at 8:00 a.m. with Ralph Shugert serving as moderator.

CUTTING PROPAGATION OF SOME SHADE AND FLOWERING TREES

DOUGLAS J. CHAPMAN and CHARLES W. MARTIN

Dow Gardens
Midland, Michigan 48640

The specific objectives of this paper are to review: 1) reported shade and flowering trees that can be commercially propagated by softwood cuttings, and 2) the morphological characteristics of the growth stage at which these softwood cuttings are most likely to root.

One advantage of propagating trees by cuttage lies in the fact that ease of propagation would stimulate the introduction of regionally-oriented cultivars from superior trees. An important consideration in selecting regional cultivars is the provenance expression of these plants for characteristics such as winter hardiness. As one moves farther north, trees are more photoperiodic responsive. Photoperiod affects vegetative growth, carbohydrate storage, abscission, the onset of dormancy, and overall winter hardiness, to mention a few responses for northern temperate zone trees.

Other characteristics one is searching for when selecting cultivars include disease resistance, environmental tolerance (air pollutants, chlorides, and high water tables), and unique phenotypic expression (habit, flower color, and fruit color and size). Trees selected and propagated with identifiable desirable characteristics could lead to new cultivars for use in park, street, home, or commercial landscapes.

There are several morphological characteristics for *Acer*, *Malus*, *Aesculus*, and *Magnolia* which have consistently indicated the stage at which to take cuttings to be successful. Chapman and Hoover (6) reported that elongation of new

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There are several morphological characteristics for *Acer*, *Malus*, *Aesculus*, and *Magnolia* which have consistently indicated the stage at which to take cuttings to be successful. Chapman and Hoover (6) reported that elongation of new

growth should essentially be complete or that the new growth be hardening off. In addition, small terminal buds should be developed. Yawney (12) reported similar observations for *Acer* in that the shoots should be stiff and the terminal buds slightly visible. Also, he reported that for optimal rooting of sugar maple softwood cuttings the leaves should just have reached full size with slightly reddened petioles and pronounced lenticels. Lastly, he noted that large cuttings rooted better than small cuttings (12). Burd and Dirr (4) reported good rooting of different *Malus* species or cultivars when propagated by softwood cuttings.

It should be noted that cuttings taken from mid- to late May in Illinois (reported by Burd) are at a similar stage of growth as mid-June cuttings in Midland, Michigan (by Chapman) and in Vermont (by Yawney) (6,7,12).

There are several additional considerations that should be kept in mind when propagating by cuttage. Flemer (8) reports that some clones propagate easier than others. Yawney (12) supported this, suggesting that each individual tree will have varying potentials for rooting from 0 to 100%. Further, the tree's ability to root is consistent year in and year out (12). Brotzman (3) suggested that clonal selections should be made by their ability to root, as well as by the other desirable characteristics. In addition, Brotzman's results indicated that cuttings should be taken only from current season's wood (3). Table 1 lists some species of trees that have been propagated from cuttings.

At Dow Gardens we use softwood cuttings that are washed, disinfected with sodium hypochlorite, and treated with a hormone, such as Hormodin No. 3, Wood's Rooting Compound, or IBA crystals. The cuttings are then placed in an intermittent mist propagating bench that contains a medium of perlite and peat moss (1:1, v/v). To be commercially successful, one should achieve at least 65% rooting of the cuttings. Table 2 gives the results of our 1984 tests with *Malus* and *Ostrya*.

From the above literature review and our 1984 results, it becomes clear that many crabapple cultivars, a significant number of maples, and several difficult-to-grow native trees, e.g. American hophornbeam and pin oak, can be propagated by cuttage. This propagation technique should stimulate selection, development, introduction, and use of new cultivars. In addition, propagation by cuttage should support use of native trees in the landscape. Clonal introduction of native trees allows nurserymen to introduce superior trees that are tolerant to

disease, low-oxygen soils, chlorides, and exhibit regional provenance.

Table 1. Some tree species that have been propagated by cuttings

Species	Optimal time for taking cuttings	Reference
Acer buergeranum	late June	1
A campestre	June and July	5
A carpinifolium	late June	11
A ginnala	mid-June	5
A griseum	late June	9
A palmatum	June	9
A platanoides	mid-June to mid-July	6
A rubrum	mid-June to mid-July	5
A saccharum	June	12
A saccharum subsp *nigrum*	mid-June to mid-July	6
A tegmentosum	July	3
Aesculus hippocastanum	late May to mid-June	6
Cornus florida	mid-June to July	1
Magnolia kobus	June	2
M × *soulangiana*	June	2
Malus 'Donald Wyman'	mid-June to mid-July	7
M hupehensis	mid-May to June	4
M 'Mary Potter'	mid-June to July	6
M 'Profusion'	late June to mid-July	7
M 'Red Jewel'	mid-June to mid-July	7
M sargentii	late June	7
M 'Selkirk'	May and June	4
M 'Snowdrift'	mid-June to July	6
Ostrya virginiana	late June to mid-July	7
Quercus palustris	mid to late July	6
Tilia cordata 'Greenspire'	mid-June to early July	8

Table 2. Rooting results with cuttings of *Malus* and *Ostrya* species and cultivars, 1984 trials

Species			Dates cuttings stuck		
			June 14	June 28	July 12
Malus sargentii		Decayed	6%	—	12%
		Rooted	8	17%	6
		Callused	3	—	6
M	'Red Jewel'	Decayed	1	—	1
		Rooted	7	11	23
		Callused	16	14	1
M	'Donald Wyman'	Decayed	3	—	—
		Rooted	20	25	22
		Callused	—	—	1
M	'Profusion'	Decayed	2	2	7
		Rooted	9	20	18
		Callused	—	—	—
			June 22	July 5	August 30
Ostrya virginiana		Decayed	18%	3%	25%
		Rooted	1	11	—
		Callused	6	10	—

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PROPAGATION TIPS ON SOME LESS WIDELY GROWN PLANTS

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These wide ranging comments will include nothing spectacular or particularly new to anyone who is regularly propagating the particular plants mentioned but might be useful to those of you who may one day meet up with these same plants at your propagation bench — or they might be useful as something to try on some other plant which might present a similar type of obstacle to commercially acceptable success.

If, as is usually the case, we are propagating a specific cultivar, the most important part of the successful effort is the *selection* of the specific wood for propagation so that we achieve exact reproduction. However, in our rush to get on with it, we may very well spend a lot less time and care on wood selection than would be called for by its relative importance.

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If, as is usually the case, we are propagating a specific cultivar, the most important part of the successful effort is the *selection* of the specific wood for propagation so that we achieve exact reproduction. However, in our rush to get on with it, we may very well spend a lot less time and care on wood selection than would be called for by its relative importance.

There are two main considerations in the selection of the wood to be propagated:

1) Ease of rooting — and the percentage of success.

2) Success in obtaining exact duplication.

Let us first consider ease of rooting. If the particular plant roots so readily that the new roots may break off as you are sticking the cutting, this factor is not of significance. However, if the plant is not so easily rooted, the selection can be very important, especially when one is working with semihard or hardwood in the fall or winter, as is the case in our own nursery. For example, in the case of *Rhododendron* 'Purple Gem' the selection of cuttings is not all that important since almost any healthy growth, including the last shoots of the season on container-grown plants, can be utilized. However, with *R. carolinianum*, or *R. minus*, or their hybrids, like *R.* 'Windbeam', *R.* 'P.J.M.', or *R.* 'Dora Amateis', consistently higher rooting can be obtained if the smaller, thinner shoots from the shady side of the plant are used. Our experience suggests 85 to 95% rooting rather than the 65 to 75% rooting achieved without careful cutting selection.

Sometimes a really difficult-to-root plant will put out roots quite readily if the whole plant from which the cuttings are taken is well shaded when in growth. *Kalmia latifolia* 'Myrtifolia' is a good example of this type.

The more hardy Eastern native *Arctostaphylos uva-ursi* presents some propagation problems not encountered with West Coast forms. Years ago, we went through all of the variables plus a number of special prayers. We even used as a medium sand from underneath native stands as well as regular sand "seeded" with debris from beneath large stands in the wild. All of this experimentation ceased when we quit using the most tempting long end runners and tried the very short side branches from the middle of the plant. Now we get 95% rooting. This plant does have a mycorrhizal association but this needs to be taken into account in transplanting — not rooting. One way to achieve successful transplanting from the propagation bench into another type of medium is to:

1) Do any top and, especially, root pruning in the propagation bench, and put the pruned cuttings right back in the propagating medium for a few weeks until the pruned roots develop laterals.

2) Take along and transfer as much as possible of the propagating medium to the new growing medium.

3) Try to moderate the extremes of the environment, in-

cluding irrigation, until the plants have had a chance to get established.

Leiophyllum buxifolium and its variety *prostratum* from Grandfather Mt , may be easier to propagate by softwood cuttings than by hardwood cuttings in fall or winter. Take hardwood cuttings as early as possible, in October if you can, and take only the short side shoots from near the main branch terminals, which tear off easily with a small piece of heel when you pull downward. Propagation by seed works fine on the species and, if taken from a well isolated plant, will reproduce the variety, *L.b. prostratum.*

In fall propagation of *Kalmia angustifolia*, you will do much better if you use the same upper side shoots, as with *Leiophyllum.*

The genus *Daphne* provides quite a number of worthy and quite saleable woody ornamentals. *Daphne* × *burkwoodii* and its cultivars, 'Carol Mackie' (a variegated sport) and 'Somerset', *D. caucasia, D. cneorum*, and *D. tangutica* are particularly noteworthy.

As those of you who have visited the Sheridan Nurseries in Canada know, the species *D. cneorum* roots well from softwood cuttings under double shade without mist. If you have reason to try later in the year, take cuttings in early October if possible. If later, try to use cuttings from the more succulent container-grown plants. Rooting of hardwood cuttings of the almost deciduous species appears to be in direct proportion to the number of leaves on the cuttings when taken. On semi-hardwood cuttings taken in October, the thinner inside cuttings or those from a shaded plant or shaded side of a plant will give better results.

An extra well-drained propagation medium is important with *Daphne.* We use perlite with just a touch of peat to give a little tougher root than develops in straight perlite. A wound is beneficial. This can be just a razor blade slit on the stem. Transplanting the rooted cutting is the key to successful propagation of *Daphne.* Try to do this in stages so that only one ingredient is changed at any one time. Do not cut the roots and change the surrounding environment at the same time

Let us turn now to the other main reason for care in selection of cutting wood — success in obtaining exact duplication. Some of our best dwarf forms of woody ornamentals present real problems in achieving this objective of exact duplication

Chamaecyparis, especially *C. pisifera* and its squarrosa cultivars, will give great variation from a single plant even if

you carefully select the tiny, tight little fans or tufts. For example, even with great care *Chamaecyparis pisifera* 'Compacta' (or its smaller version 'Nana') you will still have two or three significantly different rates of growth in a given crop.

Ilex crenata has what I consider to be instability, but this may be a poor word choice. In any event the end shoots have greater vigor than basal shoots. If you follow the natural human tendency to clean up and prune the stock plant when taking cuttings you will end up with faster growing forms. *Ilex crenata* 'Helleri' is one example. There are several distinctly different plants in commercial trade. A more extreme example is the very dwarf form, 'Dwarf Pagoda'. If you take the heavier end shoots (the easiest to see and take) you will change the plant completely in a couple of generations. This may be what happened to 'Mariesii' which, in the old descriptions, sounds just like 'Dwarf Pagoda'. Instead, take only the very short stubby side spurs which are a little harder to handle but there are plenty of them and they root just as readily.

There are other plants where it is better to clean off the strong odd ball shoots *before* taking any cuttings for propagation Another clear cut case in point is the prostrate forms of *Cotoneaster microphyllus*. If you take the strong upward shoots, each generation is likely to be less reliably prostrate.

Those of you familiar with the prostrate and low spreading forms of conifers will know that selection of wood for grafting has been used to achieve habits of growth other than evidenced by the parent plant. One such as *Abies pinsapo* 'Glauca' which, in our trade, has no leader. *Pinus flexilis* 'Pendula' is probably the result of selection from low side branches. There are a number of low growing *Abies* which presumably originated by this same selection of wood with little or no apical dominance.

There are also examples of unintentional differences in the progeny because of the type of wood selected for grafting. Grafts of *Picea pungens* 'Compacta' produce remarkably similar progeny in a given crop whereas great variation exists with grafts of *P. pungens* 'Montgomery', a similar plant. Tom Dilatush of Dilatush Nursery in South Robbinsville, New Jersey, proposed that all of the strong central shoots in each cluster on 'Montgomery' have strong apical dominance whereas those taken from most anywhere on 'Compacta' do not have any tendency to put up a central leader.

The dwarf forms of *Picea abies* are so unstable or variable that you can find several distinct foliage forms on a mature plant. In any event, to retain these they should only be propagated as cuttings. Grafting is very likely to produce a much

faster growing, but less compact growth habit. Most often we speak of the vigor of the understock pushing through into the scion. If you listen to the keen observations of Tom Dilatush, you will conclude that many of the dormant buds of dwarf Norway spruce have reversion tendencies and that the vigor of the understock activates these. In very young grafts you do not always notice this difference until it is too late.

The wounding of cuttings has been a subject of considerable discussion in the *IPPS Proceedings*. It is not always worth the extra labor on species which give high quality root systems with no wound, or where the regular procedure for stripping away the foliage provides the equivalent of an intentional wound.

There are some cases where a wound does not appear to achieve the expected response but, nonetheless, is well worth while. The so-called brooms or Scotch brooms, *Cytisus* and *Genista*, provide an excellent example of this phenomenon. The low-to-prostrate forms generally root easily, but the very popular upright growers like *Cytisus* × *praecox*, the Warminster broom, are more of a problem in that cuttings typically send down a couple of fleshy, brittle roots right to the bottom of the medium with little or no side branching. A light wound, like a ½ in razor blade slice, will not produce roots along the wound but will somehow cause a beautiful, fully packed circle of roots from the base that gives a high quality, easy to transplant, rooted cutting.

It can be difficult to achieve consistent high quality rooting with *Gaylussacia brachycera*, the box huckleberry, thought by some to be the world's oldest living plant. You can get roots but they are variable, sparse and poorly attached. We tried everything including cutting type, timing, medium, hormone, etc., but could not get consistent results. However, once we used a light wound with a razor blade we obtained consistently good rooting year after year regardless of other factors.

Vaccinium vitis-idaea var. *minus*, the mountain cranberry, readily develops roots but their adherence is poor. The razorblade slit wound remedies this and all but eliminates transplating losses.

Although pruning the rooted cutting is not considered part of propagation in the strictest sense, pruning often needs to begin before the plants leave the propagation area. There are plenty of instances where early or timely pruning is essential for a high quality branch structure. In some cases, regular pruning clearly shortens the time until the plant is saleable, even though it may not actually accelerate growth. The pre-

viously mentioned *Cytisus* and the evergreen *Cotoneaster* are good examples.

There are also plants where pruning accelerates or encourages continuation of bud break and growth. If the tips are pruned off of *Gaylussacia brachycera* just as each flush is fully extended, you will achieve several season's growth in one. *Daphne* has similar characteristics. The rooted cuttings are always slow to make that first break but this time can be made up quickly if the tips are pruned just before the flush of growth hardens off. Unlike the evergreen *Ilex* or *Kalmia latifolia*, you do not need to wait for dormant buds to form and mature to get multiple breaks.

A contradictory example is *Cassiope mertensiana*, the so-called mountain heather, from Bruce Briggs' country (the Pacific Northwest). You will achieve a better branched plant with more flowers at the end of the first season if you withhold all pinching or pruning. *Vaccinium macrocarpon* 'Hamilton', a delightful very dwarf form of cranberry, responds in similar fashion.

PROPAGATING *ACER GRISEUM* FROM CUTTINGS

DIXON P. HOOGENDOORN

Hoogendoorn Nurseries, Inc.
Middletown, Rhode Island 02840

Acer griseum, the paper bark maple, is possibly one of the most beautiful and interesting small trees available to our trade. The leaves are trifoliate while possessing a delicate soft green texture. In certain locations, leaves will turn a good red color in the fall. The bark curls back to reveal the coppery trunk underneath on trees more than a couple of years old.

It has been reported that a definite flowering sequence problem exists with this particular tree which results in many sterile embryos. Therefore, most of the seed produced is nonviable. This is one reason that *Acer griseum* remains a relatively rare tree today. Grafting this species has been impractical, if not impossible.

Many years ago, my father, Case Hoogendoorn, became very interested in *Acer griseum* and purchased 500 two-year seedlings from Gulf Stream Nurseries, Inc., Wachapreague, Virginia. They were planted in a stock bed with the intent of using these plants for vegetative propagation purposes. We usually prune the stock plants in March to initiate vigorous

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growth. As I mentioned, the stock plants are seedlings and there seems to be large clonal variations among the plants. This is most noticeable when plants are breaking dormancy in the spring.

Acer griseum is the first plant we propagate in the greenhouse approximately the third week of June. Timing is very important in the success or failure of this particular species. If you wait too long the cutting wood will become hard and poor results can be expected. The propagating bench is prepared with a coarse sand medium 6 in. in depth, which is firmed with a wooden pounder. In our experience a loose medium will generally lead to poor results. It may also be necessary to apply shading to the greenhouse at this time since the sun's rays can be very intense.

Cuttings are collected in the early morning hours, when the temperature remains relatively cool, and are put in wet boxes to prevent desiccation. While we are collecting the cuttings we hold them in the same direction in order to speed up the process. They are then taken to our refrigerated storage, watered thoroughly, and kept at 50°F to ensure the cuttings will be in a turgid, workable condition.

The following morning the cuttings are brought to the work area and prepared for sticking. The soft terminal tip is removed while the top two sets of leaves remains on the cutting. I might add that leaves are not cut during this operation due to their relatively small size. The cutting is made approximately 8 in. in length. In our experience, wounding has not proved beneficial. Cuttings are dipped in Hormodin #3 (0.8% IBA).

Cuttings are stuck in the medium to a depth of approximately 3 in. with 1½ in. between the cuttings and 2 in. between the rows. When a relatively large area has been completed the cuttings are watered in. An automatic mist system is turned on after all the cuttings are stuck. We set the mist control clock to come on at 8:30 a.m. and shut off at 6:00 p.m. The mist operates for 12 sec every 10 min. This gives the foliage a chance to dry before darkness to reduce disease problems. We apply Benlate and captan on an alternating spray schedule at the rate of 1 tbls/gal water. The solution is applied at daybreak with an Ortho Spray-ette proportioner (a portable sprayer that connects to a garden hose). The fungicide must have a sufficient time to dry before the mist is put on.

Greenhouse ventilators remain open during the daylight hours when the mist system is operating. However, during the night hours the ventilators are closed. Leaves of *Acer griseum*

are very tender and could burn if subjected to a substantial wind.

Cuttings should be rooted in approximately 8 to 10 weeks. They are lifted very carefully with a spading fork as the newly rooted cuttings have a very soft root. We usually attain approximately 60% rooting. The rooted cuttings are potted in 2¼ in. clay pots in soil, peat, and sand (1:1:1, v/v/v) mixture and set pot-to-pot in a greenhouse to reroot. We syringe these plants and give them bottom heat during cool periods as needed until rerooting has occurred. The pots should be checked for proper moisture content periodically. Cuttings remain in the greenhouse until they have rerooted sufficiently, which is usually toward the middle of October.

Potted cuttings are then moved to our deep pit storage house for the winter. They are set pot to pot and covered with approximately ½ in. peatmoss and watered in. This process enables potted cuttings to hold adequate moisture levels for extended periods of time. We find that 2 or 3 waterings are usually all that is necessary during the winter months under normal conditions. We like to keep dormant plants on the dry side. We reach a minimum temperature of 28°F in our deep pit storage house which is ideal for sensitive plants. The pit house provides the proper dormancy period and the plants respond by breaking extremely well in the spring. We open the door during mild periods to air the house. The potted cuttings are periodically checked for proper moisture content.

As the days lengthen and the outside temperatures rise, it is necessary to increase ventilation procedures. We have a 3 ft fan set in one end of the house for this purpose. However, it is necessary to remove four staggered filon panels on each side of the storage pit to increase air circulation. They are replaced with 50% lath shades. The remaining filon panels are sprayed with shading paint to break the intensity of the sun's rays. This enables the cuttings to be properly hardened off prior to transplanting.

By early June the rooted cuttings are ready for planting into outdoor nursery beds. If the cuttings are small or not particularly well rooted, it may be advisable to leave them in the pot for a year before transplanting. The cuttings are planted 6 to 8 in. apart and protected with 50% lath shade for the first year. After the third year they are harvested for our lining out stock trade or transplanted into field rows. They are planted on 3 ft rows with 2 ft spacing between the plants in the row. Plants are harvested for our ball and burlap trade after three growing seasons.

In conclusion, I would like to say that *Acer griseum* has been quite a challenge over the years. In the future we would like to develop a clone with outstanding characteristics, such as exceptional peeling bark and a desirable growth habit, which would propagate easily by cuttings.

SELECTING DAYLILIES WITH COMMERCIAL VALUE

DARREL A. APPS
Longwood Gardens
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Selecting daylilies with commercial value is a perplexing problem for plant propagators because of the large number of registrations and introductions each year. In 1983 alone The American Hemerocallis Society (AHS) registered over 800 daylilies. Annual registrations since the society's formation in 1946 now include over 20,000 named cultivars (1).

In actuality only a very few of the plants registered become important commercially. There are several reasons for this: 1) many are not commercially superior to those previously introduced; 2) most breeder-introducers are not effective in marketing new plants over an extensive geographical area; 3) some hybridizers assign names for the convenience of breeders and friends, and do not consider their plants to have commercial value; and 4) slow plant increase has kept some cultivars off the market long enough so that they are rapidly superseded by newer and better cultivars.

With the advent of micropropagation, new cultivars can now be propagated rapidly and distributed in a short period of time (3). This method encourages judicious selection to avoid wasting expensive growing space and capital investments on inferior plants.

At present The American Hermerocallis Society has in place an awards and honors system to recognize the most outstanding cultivars (2). Basically the system has four steps: Junior Citation, Honorable Mention, Award of Merit, and Stout Metal. These awards are based on voting by AHS approved awards and honors judges. In 1984 the 4,500 member society had 445 judges.

The primary purpose of the award system is to recognize new daylilies with several desirable attributes such as: good foliage; graceful flower scapes, bright colored, heavy-substanced flowers; consistent flower form and size; and plants with overall distinction. Unfortunately, it is difficult to quanti-

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tate these characteristics and judges do not agree on uniform standards. That aside, those daylilies receiving the highest number of votes by the awards and honors judges are distinctive and often have commercial potential.

The two most significant society awards are Honorable Mention and Award of Merit. The Honorable Mention Award is important because it is presented as early as 2 years after introduction and is based on votes from at least 4 of the 15 regions. A negative aspect of this award is that it only requires 12 votes of the 445. However, voting records are presented in each winter *Daylily Journal* and it is possible to select two or three with the greatest number of votes. Growers in areas of the country with very low winter temperatures should be cautious with award winning evergreen daylilies because some are not hardy.

The Award of Merit is a more trustworthy designation. The award requires votes from half of the regions and is given to the ten plants receiving the most votes. With few exceptions, the top one or two of this group climb to the top of the popularity poll and have high commercial value. These two awards recognized daylilies with distinction (see Figure 1 — distinction side).

Growers can further determine commercial potential by screening AHS award winners through various steps shown in Figure 1 (see monetary side). Cultivars with commercial value possess the qualities listed in the descending hierarchical order. They need to be winter hardy, increase rapidly, stay in bloom for at least 3 weeks, have good foliage all season, be insect- and disease-free, and not set seed (seeding decreases plant vigor and may produce unwanted new forms).

There are other reasons why a cultivar may or may not succeed in commerce. Trends in color preference are the most important. Today greenish yellows are most popular, then pinks, reds, whites, pastels, and finally orange. Flower size is also a significant factor. Gardeners generally prefer large-flowered types (5 in. and over) to the small-flowered (3 to 5 in.) and miniatures (under 3 in.). Finally, growers need to consider flowering time. Most daylily cultivars bloom in July in the mid-western and eastern part of the U.S. With care in selection, a sequence of bloom will continue from mid-June to the end of September. Generally each cultivar will bloom only about 3 weeks.

Combining the distinction and monetary screening sides of this system it is possible to select distinct daylilies with potential commercial value. Because of continued improvements by breeders new cultivars need to be added frequently and older

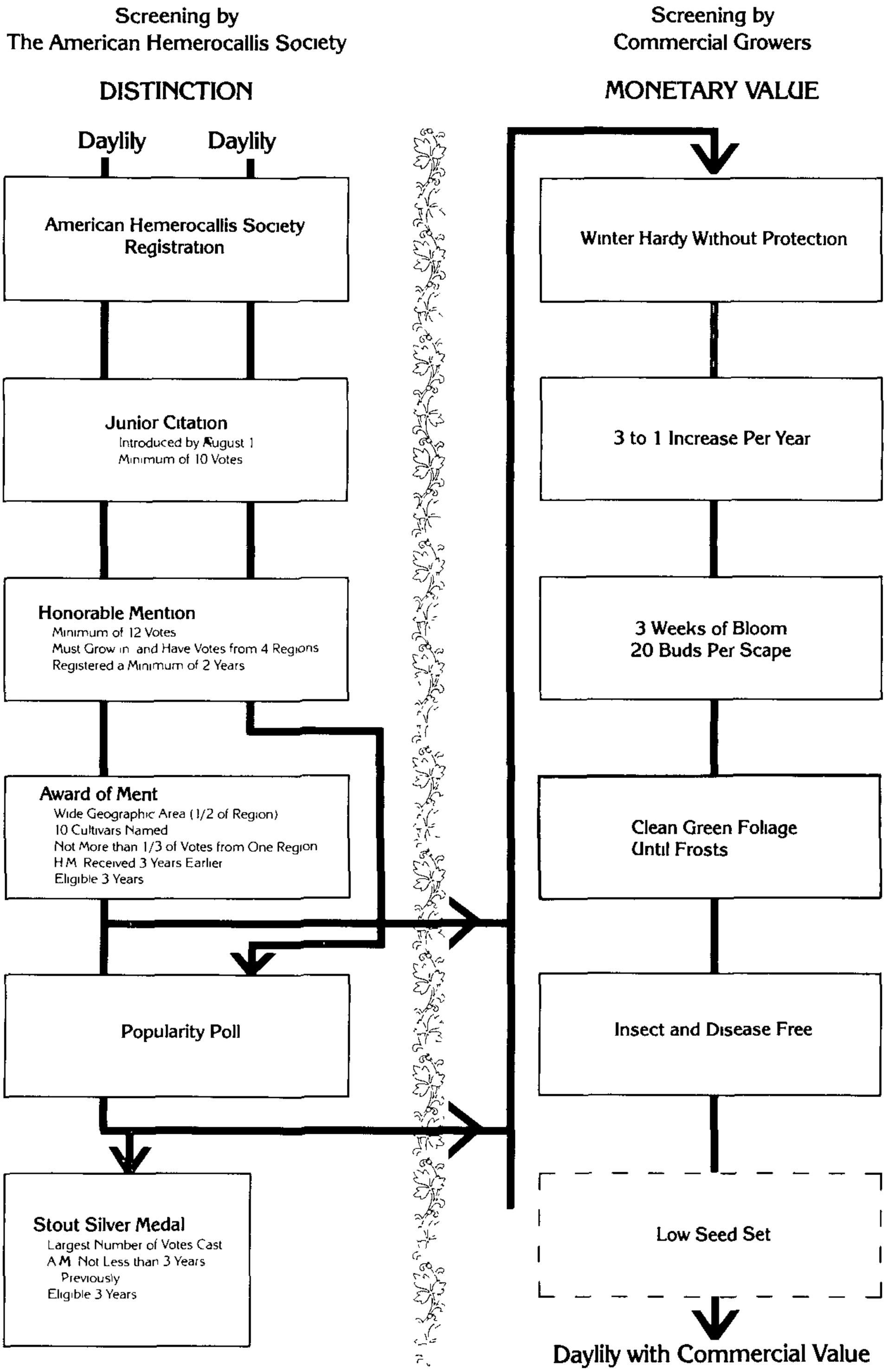

Figure 1. Selecting daylilies with commercial value

Table 1. Examples of daylilies from various color groups that have commercial potential.

Cultivar	Dormant, evergreen, semi-evergreen	Color shade	Flower size (in.)	Season of bloom	Height (in.)
		YELLOW and GOLD			
Bitsy	Evergreen	Canary yellow	2½	Early and repeats	20
Butterpat	Dormant	Medium yellow	2½	Midseason	20
Green Flutter	Semi-evergreen	Canary yellow	3	Late midseason	20
Mary Todd	Semi-evergreen	Buff yellow	6	Early-midseason	20
Stella de Oro	Dormant	Gold	2¾	Early-midseason to late	15
Wynnson	Dormant	Green-yellow	4½	Early-midseason	24
		PINK			
Elizabeth Yancey	Semi-evergreen	Light pink	5½	Late-midseason	28
Yesterday Memories	Dormant	Deep pink	6½	Midseason	20
		RED			
Apple Tart	Dormant	Bright red	6	Early-midseason	28
Ed Murray	Dormant	Black-red	4	Midseason	30
Red Rum	Semi-evergreen	Rusty red	4	Midseason	15
		NEAR WHITE			
Hope Diamond	Evergreen	Very light yellow	4	Early-midseason	14
Joan Senior	Evergreen	Near white	6	Early-midseason	25
		PURPLE			
Little Grapette	Semi-evergreen	Grape	2	Midseason	15
Russian Rhapsody	Semi-evergreen	Violet-purple		Midseason	30
		LAVENDER			
Prairie Blue Eyes	Semi-evergreen	Lavender/blue-eye	5¼	Midseason	28
		ORANGE			
Bertie Ferris	Dormant	Persimmon orange	2½	Early	20
Ruffle Apricot	Dormant	Apricot	7	Early-midseason	28

ones dropped. The cultivars listed in Table 1 are examples of daylilies from various color groupings that have passed through the various screens of Figure 1 and would have commercial value. Commercial sources of these *Hemerocallis* cultivars can be obtained by writing directly to Sandy Goembel, Secretary of The American Hemerocallis Society, Route 5, Box 6874, Palatka, Florida 32077.

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PREPARATION AND DEVELOPMENT OF AUSTRALIAN NATIVE PLANTS FOR PROPAGATION

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Many Australian plants have been difficult to propagate and many still are in that category. In this paper I do not intend to try to tell you how to propagate all Australian plants, but rather how selection and development of different species has given way to better results in propagation.

We are conducting experiments on Sid Cadwell's property 200 km west of Sydney. Mr. Cadwell's property is situated in a very dry area which receives approximately 300 to 350 mm of rain per year. Summer temperatures reach 40°C and winter temperatures are below 0°C.

Propagation material, such as grevilleas, has been collected with careful attention paid to selection of parent materials from all over Australia. Cutting material is harvested in very early morning or late evening during spring, summer, and fall (October to April). It is recorded and packed in plastic bags with very little water. In most cases cuttings are wrapped first in clean white paper, then packed in styrofoam boxes and air-freighted to their destination.

Propagation takes place either under mist with bottom heat, or in a small glasshouse without mist or bottom heat.

ones dropped. The cultivars listed in Table 1 are examples of daylilies from various color groupings that have passed through the various screens of Figure 1 and would have commercial value. Commercial sources of these *Hemerocallis* cultivars can be obtained by writing directly to Sandy Goembel, Secretary of The American Hemerocallis Society, Route 5, Box 6874, Palatka, Florida 32077.

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PREPARATION AND DEVELOPMENT OF AUSTRALIAN NATIVE PLANTS FOR PROPAGATION

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Many Australian plants have been difficult to propagate and many still are in that category. In this paper I do not intend to try to tell you how to propagate all Australian plants, but rather how selection and development of different species has given way to better results in propagation.

We are conducting experiments on Sid Cadwell's property 200 km west of Sydney. Mr. Cadwell's property is situated in a very dry area which receives approximately 300 to 350 mm of rain per year. Summer temperatures reach 40°C and winter temperatures are below 0°C.

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Propagation takes place either under mist with bottom heat, or in a small glasshouse without mist or bottom heat.

After rooting, the liners are planted out in the field. Their start in life is rugged as they very often only receive the one watering at planting time. Water is in very short supply on this property. However the results have been good.

Under these conditions a *Grevillea* from the Northern Territory grows up alongside one from Victoria, Western Australia, New South Wales, or Queensland. In their natural state this does not occur because thousands of miles separate one from the other. Hence many different Grevillea selections are planted together as are other plants such as the callistemons.

In 2 to 3 growing seasons quite strange things happen; because such plants would never have been grown near one another and now find themselves in the same bed so to speak; natural hybrids occur as seedlings under the parent plant.

When plants are taken into cultivation from the wild and vegetative propagation takes place one of two things is likely to happen. The first, of course, is an unconscious selection for individual clones which are often easier to propagate, and elimination of other members of the group that are difficult to propagate. Many species are self incompatible and out-crossing occurs. In our situation we aim to collect more vigorous selections for nursery production.

Many selections of our flora have come about in this way. Foremost among these are Dave Gordon's *Grevillea* 'Robyn Gordon', the Cadwell, Mason, Payne, and Poorinda hybrids, and the hybrids of Mervyn Hodge in Queensland, and George Lullfitz in Western Australia. Seeing how these plants came about encourages us to support Sid Cadwell in planting out as many species as possible and play the waiting game. Selections from these plantings were made, plants propagated, and assessments made for flowering, growth, and suitability for container production.

Some of these plants have peculiar characteristics. For instance, the Grevillea hybrids 'Robyn Gordon', 'Royal Mantle' and 'Superb' have beautiful flowers but produce no seeds. At the start some of these plants proved difficult to propagate. However, after cuttings were harvested, plants grown, and cuttings taken off these plants and they, in turn, were grown and cuttings taken from the third generation, many plants became much easier to propagate.

These hybrid types or selections, whether they occur naturally or not, have much more vigour and their flowering is not only improved but often extended. Some, like 'Robyn Gordon', flower 8 to 9 months of the year. Others are prized for their foliage, especially in the florist trade. Some examples are

Grevillea longifolia, *G. asplenifolia*, *G. hookerana* and *G. johnsonii*. Some of the genus *Banksia* also fit into this category.

World-wide hybridization and research with many Australian species suitable for the floral trade is under way. Long stems, individual flowers, and attractive foliage of some grevilleas like 'Misty Pink' and 'Sandra Gordon' are being improved in breeding and selecting programmes in North America, Israel, and Holland. Banksias are also being improved in Hawaii. The kangaroo paw (*Anigozanthos*), Western Australia's floral emblem, has been hybridised many times and most selections are available in tissue culture. There are forms for both the floral trade and home gardener.

Australia, being the size it is, makes it impossible to keep wandering all of one's life. However, as a member of IPPS, Australian Region, I am privileged to travel to a different state each year and visit many interesting growers and collectors of plant material. By placing all the selections in one area one can quite easily observe many thousands of plants from all over Australia.

The genus *Banksia* is worthy of mention. There is a form on the east coast of Australia, *Banksia ericifolia* 'Port Wine', that has very striking red flowers borne on long stems, mostly on the outside of the bush. This plant was developed by Sid Cadwell. This form propagates well from soft tip cuttings. More recent development has produced a dwarf form suitable for small gardens. All the banksias and grevilleas are great for birds in the garden and this has helped in the sales of these plants.

Telopea speciosissima, waratah, is much valued for its flowers. Selections of this plant have been planted and many of these are being propagated by cuttings. If one wishes to have these plants for flower production then they had best choose vegetative propagation methods, especially for the white and pink waratah. The white waratah is one of Australia's most endangered plants. There are plant propagators interested enough to endeavour to improve or select from the stock already on the market. This stock, I suspect, has come from more than one parent plant and variations in growth and flowering do occur.

Macadamia, the Queensland nut tree, is an example of the selection and hybridization that has been based very much on the type of planting I have described. I do not deny some cultivars have been deliberately crossed and bred for better production.

Plant propagators have real winners as the markets they grow for cover such wide areas of interest that new plants and improved forms, with the right promotion, are readily accepted.

The indoor plant field and the material available from our rain forests is about to be discovered in real terms as our 1985 meeting in Rockhampton, Queensland, will show. The flowering hoyas have been hybridized and spectacular plants are coming on the market. Native cissus have found their place in similar programmes all around the world. The interesting part about the hoyas is their ability to be propagated by tissue culture.

Whilst in parts of Australia the summers are very hot and winters severe, the spontaneous sports or natural hybrids seem almost to thrive. In fact, one may well be led to believe that they are bred for the area in which they find themselves. Other observations show that these plants do well in most climates. Why this is so I am unable to answer other than to say that if they are hybrids there is extra vigour.

Grevillea 'Bronze Rambler' is a classic new ground cover developed in Victoria. It is similar to 'Robyn Gordon' with spectacular foliage. The plant is about to come on the market because it will be readily accepted and should become a good plant to propagate.

Not all the hybrids are sterile. Steven Du Pee did his Masters Degree on *Grevillea* hybridization at Sydney University. His work on this group of plants is well worth studying in Research Report No. 9, Sydney Department of Agronomy and Horticultural Science.

What all of this work has led to, of course, is other standard propagation methods being used, such as approach grafting of grevilleas, resulting in weeping standard trees with ready sales. Seedling rootstock of *Grevillea robusta* for weeping standard plants is mostly used.

Grafting of *Prostanthera* onto *Westringia* is done for difficult areas, soil types, and *Phytophthora* resistance.

Two carnivorous plants almost extinct until a few months ago have been preserved by propagation in tissue culture. One is a Western Australian rare wildflower, the wongan triggerplant (*Stylidium coroniforme*). This is an example of what plant propagators can and are doing. *Sarracenia*, pitcher plant, also from Western Australia, has proved to be a great novelty that also has been propagated through tissue culture. Both of these plants sell well in the nursery trade as novelties.

The need to change lines of plant material brings the plant propagator under pressure to keep coming up with plants of high quality and performance. Table 1 contains a list of the more prominent selections and hybrids. Native plants are in this situation. The craze for selling these has been dampened by selling too many untried plants from different regions of Australia and the customer subsequently finding them to be unsuccessful in this area.

Table 1. Some of the more prominent selections and hybrids of Australian native plants

Anigozanthos hybrids
Callistemon 'Captain Cook', selection
C 'Endeavour', selection
C 'Hannah Ray', selection
Chamaelaucium-Geraldton wax flower There are selections of red, purple, white, and pink for cut flowers
Grevillea 'Boongala Spinebill' (*G bipinnatifida* × *G caleyi*)
G 'Bronze Ramble'
G 'Cadwell's hybrid'
G 'Sid Cadwell'
G 'Ivanhoe' (*G asplenifolia* × *G caleyi*)
G 'Jessie Cadwell'
G Mason's hybrid, also known as Kentlyn hybrid and 'Ned Kelly'
G 'Misty Pink' (*G. banksii* × *G. sessilis*)
G. Poorinda Hybrids, more than 50
G 'Robyn Gordon' (*G. bipinnatifida* × *G. banksii*)
G. 'Royal Mantle' (*G Laurifolia* × *G willisii*)
G 'Sandra Gordon' (*G pteridifolia* × *G sessilis*)
G 'Sid Cadwell'
G 'Superb'
Hoyas hybrids — many new ones not yet on the market. For climbing indoor flowering plants forestmost is the rich red *H macgillivrayi*
Macadamia hybrids
Thryptomeme paynei

The Australian Nursery Industry, in presenting its submission to the Australian Rural Adjustment Unit Workshop on Rural Research, listed no less than 13 areas for research in the nursery industry. The number one area on that list is the breeding and selection of native flora with respect to decorative appeal and ease of culture.

Again in the Sydney University Department of Agronomy and Horticultural Science Report No. 9 for 1980-81, Professor Michael Mullins reports on the development of the waratah. *Telopea speciosissima* forms have been collected from the wild and are being selected for desirable traits.

In this same report other native genera mentioned are: *Clianthus*, *Blandfordia*, *Grevillea*, *Isopogon*, *Pandorea*, *Persoonia*, and *Verticordia*. Both the waratah and *Blandfordia* are

being worked on in tissue culture at Sydney University by Professor Mullins

PREPARATION OF CUTTING MATERIAL

1) The material should be selected from late spring to late autumn (November to May), as new growth starts to mature. However, the cuttings must still be soft. In Australia, stock plants must be cut back to produce the most viable material.

2) Cuttings should be made about 20 cm in length and given a basal wound approximately 2 cm in length by removing a sliver of bark in order to expose the cambium.

3) Hormone treatment should contain IBA and NAA in approximately equal parts applied at the rate of from 2,000 to 4,000 ppm, depending on the type of growth.

4) The medium should be well drained, e.g. 25% peat and 75% perlite. Cuttings of some of our native plants strike well in plain sharp sand. All media should be pasteurized.

5) Bottom heat applied at 20°C is a good general practice for cuttings of most native plants.

6) Misting should be carefully controlled on many Australian plants and should not be used in excess. Fogging is a great advantage.

7) Reduction of leaf area for large-leaf plants by approximately half is advisable.

8) Cutting above and below a node is recommended in many of the harder to strike subjects.

9) Cuttings should not be harvested in the heat of the day and should not be stored wet.

10) For smaller leaf type plants, such as callistemons and fine-leaved grevilleas, harder wood, as in semi-hardwood cuttings is advisable Small leaves must be removed carefully in an upward direction.

11) All material should be clean and come from prepared parent plants and dipped in a 1% sodium hypochlorite solution and washed in clean water. Some propagators use captan.

12) Individual tubes for hard to strike plants is an advantage and allows more air and space around the cutting and better root development. Many species may only callus and not produce roots. However, such cuttings often produce roots if they are potted in growing medium after callus has formed.

13) Tissue culture propagation of several new grevilleas is well under way in Australia. This method of propagation is opening up new areas for our native flora.

EXOTIC PLANTS IN HAWAII

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This paper will consider some of the exotic plants that make up Hawaii's nursery industry. The State of Hawaii is made up of 7 inhabited islands and is located 2,500 miles off the coast of California. Each island is just the tip of an enormous volcano that started erupting eons of time ago, on the floor of the Pacific Ocean. Depending upon the height of the volcano remaining above sea level, there can be a dramatic difference between the wet side of the island, where trade winds drop their showers daily, and the dry side, in the rain shadow of the mountain, that can receive less than 10 in. per year. In addition to influencing the amount of rain falling on the leeward side of the mountains, the height of the volcano also influences the temperature range. At 10,000 feet, Haleakala on Maui may register temperatures well below freezing in winter, and occasionally snows are encountered. At this elevation, strange forms of plant life have evolved, like the rare silversword, found only at the summits of Hawaii's volcanoes.

As one proceeds down the mountain, you pass through "temperate" zones, where camellias, azaleas, and cymbidium orchids thrive, and on down to the tropics, where ginger, and *Cordyline terminalis*, golden bamboo, and *Heliconia rostrata* grow luxuriantly. And finally, where the volcano slopes beneath the sea, one might find the black sand beaches or coral sands of Mauna Kea.

The Maui Agricultural Research Center, my home base, is located at the 3,000 ft elevation on the slopes of Haleakala, overlooking the Valley Isle.

In 1983, the category, "Flowers and Nursery Products" ranked #1 in Hawaii's diversified agriculture, with a wholesale value of over $36 million. The largest single item identified by the State Department of Agriculture was potted foliage plants, primarily for indoor or patio use, at $10.8 million. Unfinished stock for further growing-on at $1.4 million and potted foliage plants, primarily for landscape, at $850 thousand, represents a grand total of $13 million in the foliage plant business.

Potted orchids at $2.5 million, potted flowering plants at $1.9 million, field grown ornamentals and trees at $800 thousand and "other" nursery products, raises the nursery industry total sales to $20.2 million dollars, wholesale value.

Cut flowers are led by anthurium at $6.0 million, lei flowers at $4.1 million, roses at $1.8 million, orchids at $1.1 million and "other" at $2.3 million. Cut foliages were valued at $700 thousand.

One of the impressive sights for the nurseryman's first visit to the tropics is to see plants he may have been accustomed to growing in pots developing into mature specimens in the landscape. *Ficus benjamina* reaches a spread of over 200 ft in the Mauna Loa Gardens in Honolulu, and *Cordyline terminals* 'Tricolor' — popularly grown as a pot plant from 1 to 3 ft tall in the trade, can reach over 30 ft in Howard Cooper's Nursery in Hana. Tropical exotics, such as *Musa coccinea*, and *Heliconia bourgaeana* represent a new wave of interest for our nurseries, both as landscape and cut flower use.

Plants of the southern hemisphere, such as *Grevillea* 'Robyn Gordon', and hybrid kangaroo paws are undergoing evaluation at the Maui Agricultural Research Station.

TRICKLE IRRIGATION ON SHORT TERM CROPS

DAVID BYERS

Byers Nursery Co., Inc.

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Short term crops are a big part of our business. Situated in the center of North Alabama, Byers Nursery Company emphasizes lining out stock that has been grown in the field. More than 30 acres are devoted to *Lagerstroemia* cultivars and another 50 acres are used in growing *Cornus*, *Magnolia*, and other genera. These plants originate as seedlings, grafts, and hardwood or softwood cuttings.

Efficient production of these many small plants is our goal and adequate water is one of the elements of production that makes this scheme work. Normally, our area receives about 56 in. of rainfall, but this is not uniformly spread throughout our growing season. Therefore, we must have the ability to water our liners when needed.

Overhead irrigation with movable aluminum pipes was installed in 1954. This method served well until our production outgrew the covered area. In 1978 we began using trickle, or drip, systems to extend our water delivery capability. In 1981 a commitment was made to trickle irrigation and now we have approximately 250,000 feet at work.

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Because of the short term nature of our products, we have chosen to install our trickle system in a very temporary manner, allowing crews to move and adjust our system daily if necessary.

After trying pipe made from reconstituted rubber and the lightweight biwall tubing, we determined the best product for our needs was the Agrifim system. That system consists of a ½ in. tube with pressure compensated, ½ gal/hr, in-line emitters placed 24 in. apart. Agrifim is a heavy-duty, relatively inexpensive, long-lived product that can stand the abuse of constant moving, rolling and traffic. In 8 hr the row is wet to field capacity 18 in. wide and 18 in. deep in our heavy, red clay soil.

After much effort at installing a mathematically perfect (from an engineering standpoint) system, our goal became more clear: we were not after engineering perfection, we simply wanted to water our plants.

Using water from wells and from our county water system, we supply water to the area needed in 2-in. PVC pipes. No filters or pressure regulators are used. The white 2-in. pipes are sawed and glued together as needed. Flow is controlled by valves set for each block of plants.

Instead of buying the expensive devices used by Agrifim to connect each row to the PVC pipe, we have adapted the typical biwall supply method. We drill a small hole the size of the capillary tube in the 2-in. PVC pipe and run a length of the capillary to a small hole bored in the Agrifim tube. This one simplification saves about $1.00 per row.

Agrifim provides a figure-eight closure that pinches the end of the tube to close it, at a cost of about 25 cents. We found an idea at Ray Bracken's Nursery that cut the cost to almost nothing — a 1-in. piece of 1-in. PVC pipe will hold two thicknesses of the tubing and does an effective job of closing the end.

Winter storage of the tubing is a big problem. After several ideas and false starts, we developed a reel made of an old electric water heater tank and galvanized pipe. This reel holds about 16,000 feet of tubing while riding on an axle made of 1⅞-in. steel set upon a three-point hitch. We find collection and re-installation of tubing greatly aided by this reel.

This is a cost-effective and practically efficient method of watering short term crops. Probably more ideas will come along to improve this system, but at this point we like the results and consider it successful. We are anxious for visitors to see our nursery and comment on our ideas.

CHALLENGES OF PROPAGATION FOR THE EIGHTIES

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Horticulture is described by Webster as the "art and science" of gardening, especially related to food and fiber crops. However, during the post-World War II growth period, a new field of horticulture has emerged and grown tremendously. The development of this field was fueled by rapidly increasing suburbanization, rapid job expansion, and the ease of personal mobility. This new field is the area of landscape horticulture which includes not only design but also encompasses the selection, propagation, growth, sales, and use of landscape plants.

Because there was a rapidly escalating need for landscape plants, even shortages, all commercial enterprises involved with landscape plants expanded, sometimes seeming to appear overnight. For some years, it appeared that anything green could be sold to the consumer.

Recently, the slowing economy, the over-supply of many types of landscape plants, and the growing knowledge base of the consumer are causing landcape horticulture to mature. The time is also appropriate for science to "catch up" with this field and to help all of us become better prepared as we meet the challenges of the 1980's.

Simultaneously around the world, academic institutions and botanical gardens established areas of urban horticulture in teaching, research, and public outreach. This science will study approaches to the interaction of people and plants, and attacks problems from the consumptive angle rather than from the typical production approach.

For the members of the International Plant Propagators' Society, the challenge of the 80's should be phrased, "who really has the responsibility for the ultimate success of the landscape plant?" Or paraphrased: "how often do you as a propagator, a grower, or a retailer think about the long-term survivability of the plant with which you are working?"

Seed science. During recent decades, we have searched for efficient methods of producing large numbers of identically selected plants to be grown in typical agricultural production style. In doing this, we have decreased the genetic base in our gene pools. In the landscape plant industry, we must be reminded of problems in other industries, e.g., the corn blight

problem of midwestern farmers. The same types of problem can and will happen in the landscape plant industry.

Today, networks of people in specific arboreta around the world are working together to save endangered species. These gardens are no longer just collecting plants, but today they are taking a more critical look at how they can serve as genetic "storehouses."

Also teams of plant experts are being assembled and sent to parts of the world where the plants have not been explored, or where they have been lost to western cultivation. For example, the U.S. National Arboretum has an extensive seed exchange and exploration program of Japanese flowering cherry with Japan. By collecting and enlarging a gene pool, the scientists can then work to improve the gene quality and diversity of the new plants they will introduce. Even the forest industries are looking in such places as China for exchanges in oaks, ashes, poplars, and alders.

Phenotypic expression. Plant scientists have long known that plants have both a genotypic and a phenotypic expression. While appearing to all look identical to the untrained observer, plants such as Eastern white pines, when collected from seed sources over its extensive range from Canada to Georgia will respond differently to environmental conditions such as light and temperature.

Such facts have immense implications when we have plants grown from southern seed sources produced for the northern market. Today, the original source for much of our plant material has often become so confused, that we really do not know the exact derivation of the seed. This means that the collector must return to the native gene pools, if possible, and recollect. In some cases, germplasm pools are being formed to preserve the diversification, e.g., the Rhododendron Species Foundation in Tacoma, Washington, and the Northwest Germplasm Repository in Corvallis, Oregon.

Psychological benefits. Using plants in the 80's will require that we broaden our perception and use of plants. Already the sciences of horticulture and psychology are combining to actually quantify the effects plants have on people. In one study, subjects who viewed nature slides consistently improved in their well-being, whereas subjects viewing urban slides tended to decline in emotional well-being.

Recently we have found that people who work in offices with plants, and/or have windows, consistently post better attendance records, and are more efficient. Studies indicate this may be related to blood sugar levels. In a recent study involving hospital patients, the patients who had the outside

views had shorter postoperative hospital stays, elicited fewer negative comments from nurses, required fewer moderate and strong analgesic doses, and had slightly lower scores for post-surgical complications

Color. Studies indicate that different colors elicit specific responses in humans How colors actually affect us is yet to be determined. In modern design technique, there is a disagreement among designers concerning whether artificial color materials can replace the colors designed by nature. Naturalists argue that we cannot desensitize people to the joys of an evolutionary habitat. Some designers feel that most colorful man-made materials can replace nature. Those who saw the colorful purple of the National Community Garden Display in the National Arboretum saw one such example Others argue that we should use more colorful plant materials such as the gold-variegated cultivars of aucuba, osmanthus, daphne, euonymus, the blues of spruces, winter browns of American arborvitaes, rose-purples of junipers, or the coppery cryptomerias. Add to this, the colors of many fruits and twigs.

Microclimate effects. The use of the term "native plant" is increasing in popularity. But just what is a native plant? In actuality, a plant is native only to the special environment for which it has become ecotypically in balance. In the Far West of the U.S. and in most other areas, many people are extremely excited about the use of their native plants. But beware of the problems in using native plants, e.g., a native plant, such as the alpine fir will seldom survive in the urban Puget Sound gardens of Washington State which do not duplicate its native alpine environment.

A challenge of the '80's will be to focus on the many microclimates created by our increasing urban environments. The mere creation of city canyons causes areas where light intensity is quite variable. In some urban sites, plants receive absolutely no direct sunlight. Studies are now finding that such plants take on a much different appearance after a period of time. For example, sweetgum trees planted on the streets of downtown Seattle, where they receive little direct sunlight are round-headed and misshapen. Trees in higher light locations appear normal.

Studies in the foliage plant industry have indicated that shade-produced plants do really have a different leaf structure than sun-produced plants. Similar effects certainly occur in many landscape plants. Now researchers are using scientific instruments to look at light effects on landscape plants. As a consequence, we must be prepared to select and grow species and cultivars of plants which will respond to these particular

low-light environments.

In most urban sites, the soil has been disturbed which means that drainage and/or nutrition patterns differ from undisturbed sites. Also, applying water without thought as to its over- or under-abundance is no longer an acceptable practice and the use of plants which require constant watering is becoming passé.

Researchers now tell us there is water stress even in supposedly stressless plants such as *Populus*. Such plants show stress in just a matter of days from both over- and under-watering. Such symptoms as leaf orientation, angle size, and nodal development are all affected. But in order to determine this, we must compare stressed and non-stressed plants.

Quality of production. Whose responsibility is it when a newly transplanted tree or shrub dies? The producer and/or retailer most often says it is the consumer. But new studies indicate that the homeowner may not be the culprit. In our haste to "assembly-line" plants like automobiles, we may have lost accountability for its long-term survivability.

In most disturbed sites, no longer are soil amendments recommended for addition to the planting site. However, our efficient (and economical) production techniques require us to grow plants in porous mixes which only turn to bathtubs when planted in the site. Growing techniques which produce tangled and misshapen roots, container-grown plants which topple over when planted, or graft incompatibilities, are certainly not the fault of the person who purchases the plants.

We must continue to search for techniques to propagate more of the difficult-to-root plants which make ideal landscape plants. And we must continue to search for better "bottoms" and methods for placing the "tops" on these "bottoms" for better graft compatibilities.

In order to produce quality plants, we are finding new techniques, such as the use of mycorrhizae, necessary for the successful establishment in new planting sites. As our sphere of knowledge increases in the "root-world", we will be able to select and use plants based upon greater pools of knowledge.

The latest technique in plant propagation — tissue culture — has opened a new door for producing many genetically identical individuals. However, by using this technique, we are also decreasing the gene pool dramatically. Thus we must use it only as an appropriate propagating technique.

One of the newest areas of basic research which may help us to increase our gene pools is genetic engineering. One specific method entails gene splicing, i.e., taking a desirable

gene (trait) from one chromosome and attaching or replacing it with other desirable genes from other chromosomes. This is a long and tedious process since the researchers must first isolate and determine all the chromosomes and the genes they contain.

Another new method is called protoplast fusion, a technique in which researchers remove cell walls of two or more cells of related organisms to leave the protoplasts. Then the protoplasts and all the DNA they contain can be mixed and fused. The researchers can then screen these mixes, and tissue culture the desirable cells. This technique has already been used to improve some tobacco cultivars and to invent a "pomato," a combination from a tomato and potato.

SUMMARY

The challenges for the 1980's are immense. We must work at increasing our gene pool base and preserving it. We must continue to build and select species and cultivars for the increasing number of urban environments and we must become more efficient in producing quality plants which will survive in these environments.

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Thursday Afternoon, December 13, 1984

The Thursday afternoon session convened at 1:30 p.m. with Clayton Fuller serving as moderator.

HYBRIDIZING RHODODENDRONS

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The introduction and growing of new plants is an important part of the nursery industry. New plants result from the discovery of new species — mostly by plant explorers, from mutations of existing known species, or through hybridization.

Every nurseryman constantly surveys his plants in the field and is occasionally rewarded by discovering a superior plant. These are generally variations within the species, but on rare occasions they can be the natural hybrids between even distantly-related species.

When growing plants from seed, the nurseryman has an opportunity to select better strains, and plants grown from seeds selected from these improved strains will generally retain more of the desirable characteristics. Occasionally, even greater variations will occur. Many rhododendrons, azaleas, and kalmias will quite regularly reproduce color shades and plant growth habits similar to those of their parents, if plants of the same characteristics are cross-pollinated or isolated from each other. For example, we grow a selected dark green hemlock, *Tsuga canadensis* 'Westonigra', from seed with practically 100% uniformity. *Tsuga canadensis* 'Pendula' also produces weeping forms with equal consistency. *Betula pendula* 'Purpurea', the purple-leafed birch, comes true from seed about 50% of the time, even from open-pollinated trees. Since our new plant cultivars, except for somatic mutations, originate as seedlings, the nurseryman and plant breeder should always select the best plants as seed parents.

My experience with hybridizing started rather successfully in 1940 when the first cross I ever attempted between *Rhododendron carolinianum* and *R. dauricum* var. *sempervirens*, resulted in the P.J.M. hybrids. My experience with naming new plants also started wtih this cross. The name 'P.J.M.' is a grex: a name for a group of plants, and not for an individual clone. We did not originally detect variability among the vigorous seedlings, and we rooted cuttings from many of them. Several years later we noticed differences among them, but the plants were already in the trade. I then selected three clones which we now raise exclusively, but most nurseries seem to be content with their own strain. The lesson to learn is to introduce only named clones.

Rhododendrons and azaleas are very easy to hybridize. They blossom within a few years and, in my case, having a nursery that sells landscape-sized plants, we can sell many of the plants after we have selected out the few we need for vegetative growing or for further breeding. My original success with the P J.M. hybrids sparked in me an interest in the need for hardier and better forms of rhododendrons and azaleas.

My first plan was to breed a pink and a white form of the P.J.M. hybrids. The easiest way to acquire the pink form would have been to inbreed and start selecting progeny that showed signs of variability towards pink. The P.J.M. hybrids were sterile and did not set seeds when inbred. Years later, when the plants matured, they eventually did set some seed. Upon the advice of Dr. Gustav Mehlquist I then started an inbreeding program. In the meanwhile, the only way to change the color was to cross the P.J.M. hybrids with a species with the color desired. The P.J.M. hybrids, crossed with *R. carolinianum* var. *album* produced several thousand plants with faded lavender-colored flowers. I selected two nearly white hybrids and named them 'Laurie' and 'Balta'. These are good selections for a garden but, perhaps, too slow growing as a commercial plant. I then crossed 'Balta' with *R. carolinianum* var. *album*, and the resulting cross produced a good white named 'Molly Fordham'.

The best hardy pink lepidote species in existence in 1958 was *R. mucronulatum* 'Cornell Pink'. I crossed a P.J.M. hybrid with 'Cornell Pink' and obtained a very showy deeper pink deciduous hybrid that I named 'Marathon'. This same cross was also made using a P.J.M. hybrid selection with a slightly petaloid flower and that resulted in one we call 'Weston's Pink Diamond.' This hybrid is a semi-double pink, retains some evergreen foliage, is easy to propagate by cuttings, and is a good commercial plant.

One of the original P.J.M. hybrids was a weaker grower, but had a fairly double flower. I crossed that with *R. dauricum* var. *album*, and a very double-flowered hybrid was the result. The lavender flowers were heavy, and the plant itself was not particularly vigorous, resulting in flowers that drooped, particularly when wet with rain. However, hybrids from crosses with these rather sad offspring have been vigorous and exhibit degrees of doubleness from complete camellia types to trumpet forms. I hope that these plants with flower colors from white through pink and purple will continue to have strong enough stems to hold the beautiful blooms.

Backcrossing a P.J.M. hybrid with *R. carolinianum* resulted in slightly later-flowering plants similar to the species *R. caro-*

linianum. I selected a particularly good-foliaged seedling and selfed it. A seedling was selected that was vigorous, early-blooming, and has a large, strong pink flower. It seems to possess the characteristics for which we have been searching for so long. Its name at present is 75-3.

Inbreeding the P.J.M. hybrids, which has been possible to a limited degree, has resulted in strains with deep-colored winter foliage and deeper purple flowers. 'Black Satin' has a coal-black winter foliage color when grown in the sun, while 'Ebony' is lower-growing and 'Princess Susan' is still lower with deep purple flowers. Further crosses with this strain are now developing flowers that are approaching red shades.

My first cross with *R. mucronulatum* 'Cornell Pink' was with a blossom Dr. Robert Tichnor brought to me from a plant in his greenhouse in Waltham, Massachusetts in March of 1958. We fortunately had a *R. carolinianum* var. *album* in bloom that was forced for the Boston Flower Show. We pollinated several flowers and fortunately the seed developed to give us hybrids we call the Shrimp Pink hybrids. Three named clones are 'Wally', 'Caronella' and 'Llenroc'. They bloom a week after 'Cornell Pink' and thus escape late frosts, are good pinks, and are partly evergreen with colorful fall foliage.

Low-growing flowering plants are invaluable in today's landscapes. Dr. Tichnor had that in mind when he crossed *R.* × *laetivirens* with *R. carolinianum* in the 1950's. The two hybrids, 'Waltham' and 'Desmit', resulted from that cross. They are pink flowering and have excellent evergreen foliage. Dr. Tichnor then crossed 'Waltham' with 'Cornell Pink' and named that deep pink, earlier-flowering hybrid 'Northern Rose'.

The search for a pink form of P.J.M. hybrid, unsuccessful in so many attempts, prompted me to select a good pink form of *R. minus* var. *compacta* to cross with a pink evergreen form of *R. mucronulatum* that I had selected from a group of seedlings. This simple cross resulted in a lovely pink evergreen hybrid, that I named 'Olga Mezitt', after my mother.

Dr. Tichnor and I have been very fortunate to get outstanding hybrids from primary or close-to-primary crosses. We selected good parents and just happened to start crossing lepidotes seriously before many other plant breeders.

Elipidote rhododendrons are the large-leafed types most people recognize as rhododendrons. My interest with this group has been toward developing hardier and lower-growing cultivars. Most of my crosses have been between our own hardy hybrid seedling selections. Eventually patterns and strains develop, such as low growers and plants that consis-

tently flower in similar colors. We have selected and named a number of plants from the hybrids developed in this manner.

A prime goal of most rhododendron breeders is to get a hardy yellow. When Dr. Tichnor went to Oregon in the early 1960's, he left a *R. brachycarpum* × *R. wardii* hybrid with me, along with 50 or so other hybrids he had to leave behind. This hybrid flowered only once and subsequently was winter-killed. I had fortunately saved a few seeds of the open pollinated flowers. I crossed seedlings from these, which were not very hardy, a number of times with themselves and with my own pale creams, which occasionally showed up in the hybrid seedling blocks. The gradual increase in hardiness (to at least −15°F) and stronger yellow color tones proves that constant selection and inbreeding can deliver good results.

The naming and releasing of plants for commercial production should be the responsibility of the plant breeder. He must decide which plants are worthy of introduction since he knows their parentage and has observed their progress over the years. He does not, however, know how his plant will perform until it has been observed for all conceivable problems to which plants can be subject until they reach a respectable landscape size.

We grow several hundred plants of each new cultivar that we hope to introduce until they reach landscape size and then we select those that have a good chance of success. We have had a tissue culture laboratory for about 5 years. Growing the trial plants in this manner saves stripping our original plant and several generations of grafted stock plants for scions and cuttings.

My interest in breeding azaleas started about 1935 when Frank Abbott, a rhododendron enthusiast from Vermont, brought us seeds of a cross he had made between *R. molle* 'Louisa Hunnewell' and *R. prunifolium* var. *roseum*. The resulting Jane Abbott hybrids were exceptional in every way — vigorous, hardy, colorful and fragrant — but impossible to propagate before the day of mist and polyethylene. I duplicated that cross using *R. japonium* and *R. prinophyllum* [*R. roseum*] to acquire plants for sale almost yearly, but now, with the ease of propagation under mist, we are growing selected clones. The same parent species are used in Minnesota to produce the Northern Lights azaleas.

Summer blooming azaleas are a wonderful addition to the landscape. They are also attractive items in the garden centers and, beside being very colorful, many are extremely fragrant. I have made many crosses between the species *R. viscosum*, *R. arborescens*, *R. bakeri* and *R. prunifolium*. We have named a

number of cultivars which grow readily from softwood cuttings and sell all the remaining seedlings as hybrid seedlings.

In the 1940's the only hardy low-growing azalea was *R. yedoense* var *poukhanense*. Our landscape customers were asking for better-colored low-growing azaleas that would be evergreen and hardy. I crossed *R. yedoense* var. *poukhanense* with 'Vuyk's Rosy Red' as a start toward that objective. After a number of generations of inbreeding, selections developed hardiness, remained evergreen, and are flowering in shades of deep purple and near-red. By selecting the best of each generation and inbreeding them our goals become gradually attainable.

I have described the need for selecting good species as parents and using the best offspring to continually build toward the desired results. My crosses were made outdoors on flowers about to open. If some pollen accidentally gets onto the pistil while the stamens are being removed, I simply remove the pollen before I make the cross. I do not cover the pistil after making the cross except in times of an impending rain, but I do remove the adjacent flowers to eliminate the possiblity of wind contamination.

In summary, the breeding of plants is a simple and logical process that requires a minimum of time and fits in well with our avocation as plant propagators.

SEEDLING PRODUCTION USING COMPANION GRASS CROPS

WAYNE LOVELACE

Forrest Keeling Nursery
Elsberry, Missouri 63343

Seedlings germinated in open field beds need all possible means of protection in order to survive and make satisfactory stands that result in economically profitable crops for growers. It has long been recognized that nurse crops could provide much needed protection during germination and establishment of nursery crop seedlings. However, controlling the nurse or companion crop presents a near impossible situation, when the companion crop out-grows its useful size and becomes a competition crop that is uneconomical to clean up. This situation left growers with very few options except mainly oats for a companion crop which would freeze out when temperatures reached about 0°F.

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The recent development and approval for use of two post-emergence grass herbicides in ornamentals has presented new opportunities for the use of companion grasses in nursery production systems. These herbicides, Poast and Fusilade, provide excellent control of almost all grasses while showing no injury to a wide range of broadleaf and needleleaf plants.

PROBLEMS SOLVED BY USING COMPANION GRASSES

Soil erosion presents one of the greatest threats to the future productiveness of our soils. A cover crop can reduce erosion losses to near zero if properly established.

During the period prior to seedling emergence it is often difficult to stabilize a mulch. Wind and heavy rains can cause a loss of the mulch layer, exposure of the seeds to drying, and result in poor, unprofitable seedling stands. A good companion grass can stabilize the mulch and hold it firmly in place.

We use a mixture of hardwood bark and sawdust for mulch on our seedbeds. As spring and germination time approaches, certain fungal mycellia grow in the mulch. This results in the development of a crusting condition that makes it nearly impossible for germinating seeds to emerge. Also, as the seedling is trying to emerge a curling or very crooked condition often develops near the crown. The curling results in a nonusable or sub-quality plant. A companion grass can prevent this crusting condition, particularly if a sod condition exists.

SEEDING PROCEDURES AND GRASSES USED

Two companion crops were tested. Oats were chosen because of previous experience with this crop. Annual ryegrass was chosen as the number two crop. The companion crops were planted at the time of seeding of the nursery crop, some sown as early as July, with the latest seeding being done in November. Approximately half of our production area was seeded to oats and half to annual ryegrass. The oats were seeded at a rate of approximately 15 to 20 seeds/ft^2 which resulted in a good dense stand. The ryegrass was seeded at approximately 30 to 40 seeds/ft^2, resulting in the formation of a heavy sod over the seedbeds and pathways.

The companion crops were allowed to go into winter at which time the oats froze out. The ryegrass remained green and offered greater protection against erosion during the winter. As spring approached the ryegrass began to grow vigorously.

Approximately April 1st and prior to the nursery seedling crop emerging, a portion of the ryegrass beds were sprayed

with Fusilade. The other portion of the beds were left for the ryegrass to continue growth after the nursery crops began to germinate and grow amidst the dense sod protection of the ryegrass. The ryegrass was allowed to grow until the seedling stands were established and true leaves were forming. This point was reached about April 20. The ryegrass at this date averaged 6 to 8 in. in height. Poast herbicide was sprayed over the beds at a rate of 1½ pints per acre plus 2 pints of crop oil. Within 7 to 10 days the ryegrass showed signs of dying and within 2 weeks was dead. The dead ryegrass left a beautiful additional protective layer of mulch for the small seedlings. No damage whatsoever occurred to the 30 species handled in this manner. Checks were left in all species and observed throughout the growing season.

CONCLUSIONS AND FURTHER RESULTS

A definite benefit was realized by using the companion grass crops. By far the best results were observed with annual ryegrass when it was allowed to continue growth until after seedlings emerged. The added weather protection against the rain, wind and late frost was apparent.

Annual ryegrass proved to be far superior to oats, giving more protection, particularly as germination time approached. The sod formed by the ryegrass prevented the sawdust-bark mulch from crusting. A loose friable condition persisted, and that eased emergence and eliminated the problem of curling or crooking of the seedlings at ground level.

Crusting did occur with the oats and seedling emergence continued to be a problem. Also, there was no top protection after the oats froze. Remnants were barely visible when the snow melted and spring arrived. This period seemed to be the period of greatest benefit from the companion grasses so far as getting suitable seedling stands.

We observed that grass control was ineffective when Fusilade was applied where the grass was above 4 in., thus making Poast the most effective herbicide in our management system by permitting companion grasses to grow later into the spring and extending the period of protection.

Another important factor in the use of selective herbicides in our production system with companion grasses has been our use of 2,4-D. The 2,4-D is sprayed over our beds and sod blanket, prior to seedling emergence to eliminate broadleaf winter annuals. The overall positive results obtained when using annual ryegrass in combination with selective herbicides supports the inclusion of this program into our production system. The companion grass crop method offers the most

beneficial effects in the areas of soil conservation, prevention of mulch crusting, mulch stabilization, frost damage control, and weed control.

CORNUS KOUSA AND ITS PROPAGATION

ALFRED J. FORDHAM

898 Clapboardtree Street
Westwood, Massachusetts 02090

Cornus kousa, the Kousa dogwood, is one of the most outstanding and trouble-free small trees available to horticulture. It is indigenous to Japan, Korea, and China and is hardier than our native *C. florida*. In June it produces a profusion of flowers with showy white bracts, several weeks after *C. florida* has finished blooming. Other features include its month-long floral display, its attractive fruits, its autumn color, and its mottled, exfoliating bark, which is prominent on trunks and branches of older plants.

When plants are raised from seeds, seedlings grown from some plants duplicate one another with monotonous uniformity. Seedlings of other plants, however, may contain individuals which differ greatly from other members in the same lot. Such variation can lead to new and worthwhile selections with horticultural merit.

Both *C. kousa* and *C. florida* provide striking examples of the variation that can arise when plants are raised from seeds. They can show great variability in all respects — bract size, fruit size, tree shape, and peduncle length. In the early 1950's an amateur horticulturist in the Boston area obtained seeds of *C. kousa* var. *chinensis* from the Arnold Arboretum and started a collection of plants. They were lined out orchard fashion in a field where they could be observed. From time to time more were added and the planting now contains over 150 specimens. Much of the information presented here is based on observations made in that collection.

VARIATION IN CHARACTERISTICS OF THE FLOWERS

Both *C. kousa* and *C. florida* have small, globose clusters of insignificant flowers that are accompanied by four showy bracts (Figure 1).

Rudimentary flowers of *C. kousa* appear in spring with the developing leaves. They are small, green and inconspicuous. By mid-June expansion of the bracts and development of the flowers is complete.

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Flowers from *C. kousa* var. *chinensis* show a wide difference in size, symmetry, bract shape, and shade of color. It can be noted that no two flowers are precisely alike. The ornamental characteristics of some are obviously far superior to others. In addition to the widely varying floral structures, growth habits are also diverse. Plants tall and narrow, broad and rounded, extremely fastigiate, pendulous, and dwarf also have all appeared.

Figure 1. Both *Cornus kousa* and *C. florida* have small, globose clusters of insignificant flowers accompanied by four showy bracts. They are bisexual and both sexes are evident in this enlarged photograph.

Flowers of *C. kousa* are borne on the upper side of the branches and when seen from above the tree appears so covered with blossoms that it would be difficult to find a space for one more. Many plants also present floral characteristics that are pleasing when viewed at eye level. Occasionally trees bear flowers with additional bracts of varying number, and I saw one with bracts fused together in a manner whereby they formed a square.

During my time at the Arnold Arboretum I occasionally had phone calls and written correspondence from people who claimed to have a kousa dogwood that flowered all summer long. This was a misunderstanding, of course, for what they had were trees with persistent floral bracts. After the flowers are pollinated and the bracts have served their purpose they usually fall away. On some trees, however, they remain through the summer and fall in autumn while still attached to the ripened fruit (Figure 2). Often their color is a dirty white and this leads to a tree of untidy appearance. Still others that persist turn green and, no doubt, function as leaves.

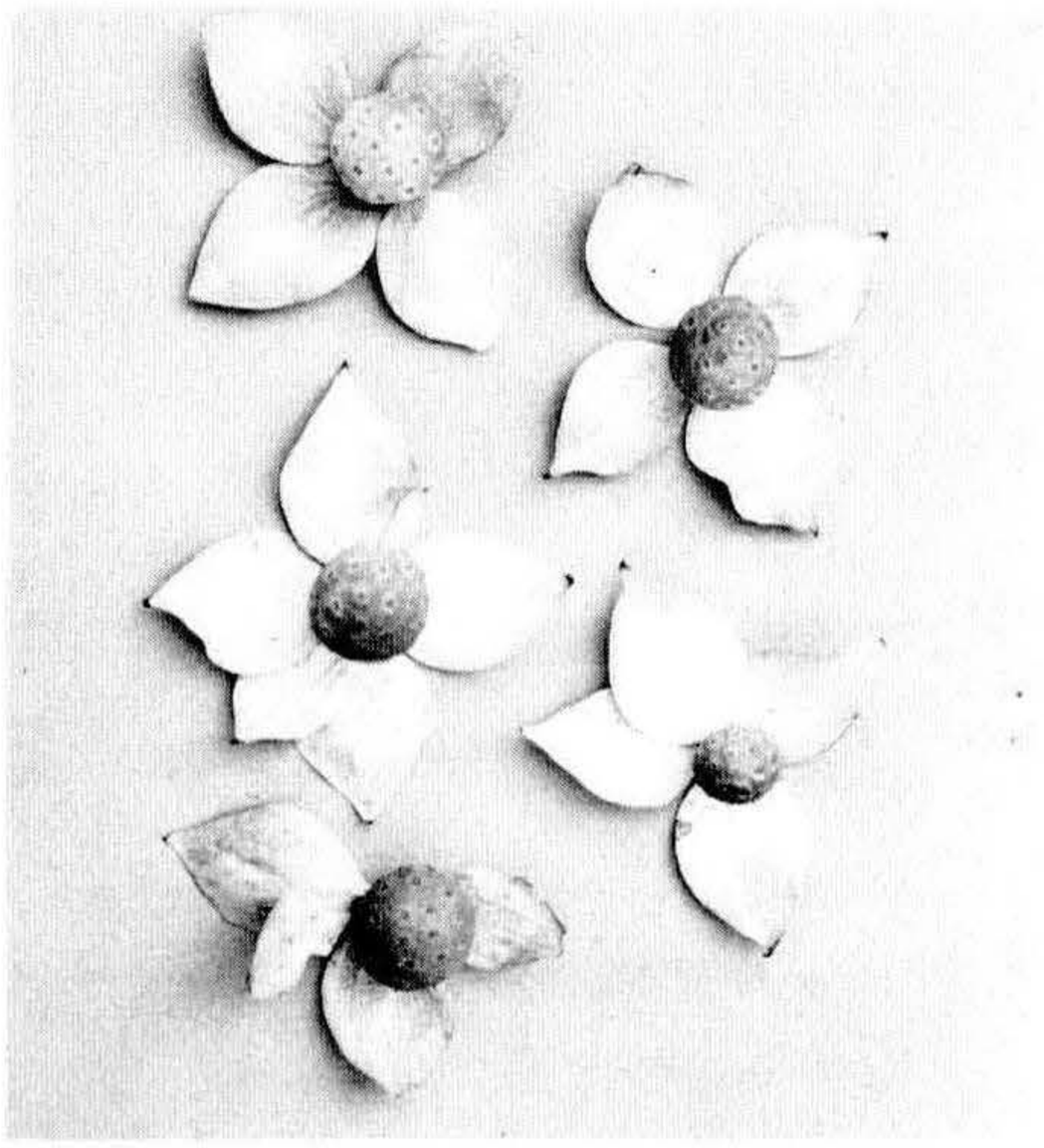

Figure 2. After pollination, bracts have served their purpose and usually fall away. However, on some *Cornus kousa* plants they persist and fall in autumn together with the ripened fruit. This photograph was taken in early October. Such trees present a very untidy appearance.

RED FLOWERED KOUSA DOGWOOD

At Weston Nurseries, Hopkinton, Massachusetts, during July of 1979, many *C. kousa* flower bracts became strongly flushed with pink as they aged. This intensity of color had not happened before and has not happened since. Other kousa dogwoods in eastern Massachusetts did likewise that year and it is reasonable to suppose it was caused by weather conditions. It is not unusual for some pink to appear on bracts as they senesce or when the flowers abort.

In the nursery of the Arnold Arboretum, there are two clones of *C. kousa* which came from Brookside Gardens, Wheaton, Maryland. They had been selected for red bract color at the Shibuchi Kanjaro Nursery Company, Saitama, Japan. Their performance leaves something to be desired for they show little red. While anthocyanin is present in varying quantities in some bracts we hope red coloration comparable to that found in red bracted clones of *C. florida* will soon appear.

VARIATION IN THE FRUITS

In fruit of *C. kousa* the skin is rich red and dotted with the remains of calyxes. They are compound fruits, and examination of 100 fruits revealed an average of 4.5 seeds in each. *C. kousa* is self-sterile and the fruits used in the test came from a

plant of *C. kousa* var. *chinensis*, growing in proximity to other trees of the same variety. Fruits from isolated trees contain few if any seeds, remain small in size, and drop prematurely.

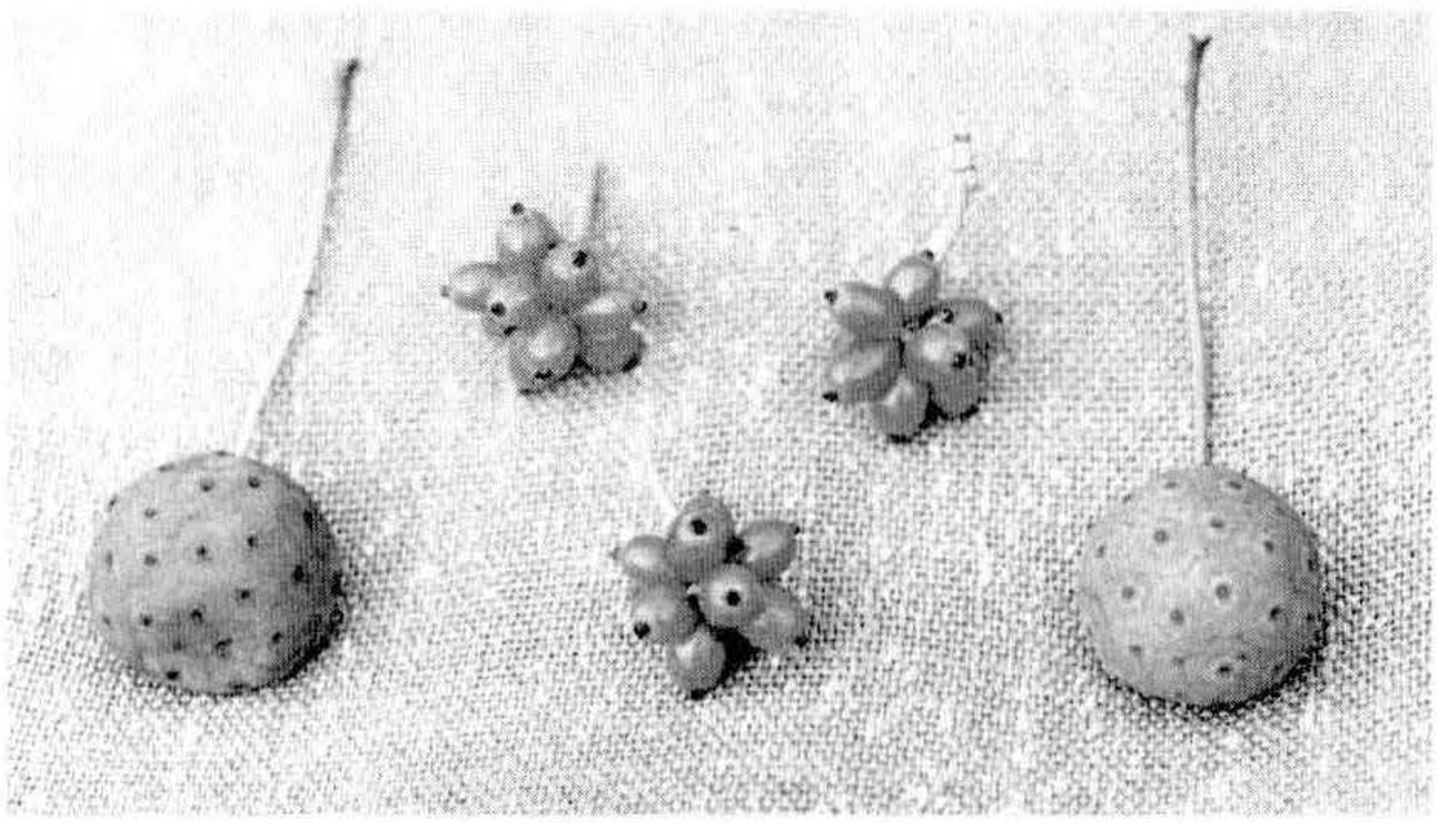

Figure 3. Fruits of *Cornus florida* and *C. kousa* are somewhat similar. *C. florida* fruits (center) are borne in a cluster with each berry terminating in the remains of a calyx. Those of *C. kousa* (left and right) are compound fruits embedded in a fleshy ball-like mass with calyxes dotting its surface.

Fruit samples were gathered from a number of individual trees, and an effort was made to select a specimen typical of those found on each tree. In size the fruits ranged from that of a marble to a diameter of 1⅝ in. The heaviest weighed 32 g (one ounce equals 28.35 g). *C. kousa* fruits are edible and have a flavor that appeals to many people. Large size would be important to those wishing to eat them. Variation was also present in the fruit stalks; they ranged in length from under 2 to over 4 in. There was no relationship between fruit size and stalk length.

Fruits of *C. florida* and *C. kousa* have similarities. (Figure 3). Both show the remains of calyxes. In *C. florida* the fruits are in a cluster, and each individual berry is terminated by the remains of the calyx. In *C. kousa* the fruits are embedded in a fleshy ball-like mass with calyxes dotting its surface.

An interesting sidelight is that kousa dogwood fruits are occasionally pecked at by birds but they do not eat the seeds. Chipmunks, however, remove seeds from the fruits and leave the plants with their cheek pouches bulging. This defeats natural dispersal, for chipmunks store seeds in their larders, where germination would be impossible. In its native habitat or during its evolution, kousa dogwood must have had a carrier such as a deer, bear, boar, or monkey, that would eat the fruits and carry the hard-coated seeds in its digestive system until they were eliminated in droppings. The seeds were thereby scattered about the countryside.

PROPAGATION OF *CORNUS KOUSA* BY SEEDS

Seeds of *Cornus kousa* can be readily separated from the pulp by flotation. The fruits are placed in a plastic bag and after a few days the pulp will have softened. They should be checked each day to make sure fermentation is not occurring. When soft, the bag's contents can be kneaded by hand. Next the contents are placed in a tall, narrow vessel which is filled with water. The pulp is buoyant and the seeds sink. Tallness of the vessel is important for it provides a greater separation between pulp and seeds, enabling one to work quickly. Several fillings and pourings will lead to clean seeds.

Next, the seeds are combined with a damp medium such as sand, peatmoss or such, and the combination is placed in a polyethylene bag. The bag is bound at the mouth with a rubber band and placed in a refrigerator at 40°F. After 3 months the cold requirement is satisfied, dormancy is broken, and the seeds are ready to be sown.

PROPAGATION BY CUTTINGS

Cornus kousa cuttings rooted in a high percentage when collected from mid-June through July. A variety of root inducing materials have been used with good success. Indolebutyric acid (IBA) has proven satisfactory. The cuttings are wounded on one side and treated with an 0.8% formulation of IBA in talc, containing Thiram added at the rate of 15%. Five sec dip treatments using IBA plus naphthaleneacetic acid at 2,500 ppm of each have also been effective.

GRAFT COMPATABILITIES

Leonard Savella of Bald Hill Nurseries, Exeter, Rhode Island, recommends the use of *C. kousa* for top grafting *C. florida* cultivars. His method is to sow seeds close together in a bed and to then let the seedlings grow undisturbed for 3 or 4 years. The closeness provides tall straight plants without lower branches. They are established by potting one growing season in advance of their use. Established *C. florida* understocks are satisfactory for grafting scions of *C. kousa*.

SUMMATION

In summation we conclude with the thought that those concerned with *Cornus kousa* should select clones that combine the more desirable traits and provide them with cultivar names. An ideal plant would exhibit good floral characteristics when viewed from eye level, large bright red fruits, pleasing autumn color, and prominent exfoliating bark.

VICKI GINGAS: Please distinguish between *Cornus kousa* and *C. kousa* var. *chinensis*.

AL FORDHAM: The variety *chinensis* was named by Wilson in 1908. It is a geographic variation. I don't think that the designation holds any weight because of the great variation found in the seedlings of that plant.

BILL FLEMER: For New Jersey conditions *C. kousa* var. *chinensis* is superior to straight *C. kousa*. It has bigger and wider bracts, and the leaves appear to be thicker. Under hot dry conditions the species will exhibit considerable marginal burn on leaves whereas the variety we originally got from the Arnold Arboretum does not exhibit that burning. Certainly for New Jersey and south the variety makes a better garden plant because it is more showy in bloom and resistant to leaf burn.

NEW PLANT FORUM

JACK ALEXANDER AND ROB NICHOLSON, MODERATORS

MODERATOR ALEXANDER: Ruth Kvaalen will begin the new plants session with a presentation on *Orixa japonica*.

RUTH KVAALEN: Landscape plants which lack showy flowers or colorful autumn foliage are often overlooked in favor of the brightly colored plants. But a plant with good foliage appearance during the whole growing season can be more valuable in the landscape than one with a week of vivid color but poor appearance the rest of the year.

Orixa japonica is a plant with excellent foliage. *Orixa* is a deciduous shrub with rounded growth habit, usable as a specimen, in groups, or naturalized In the Indianapolis to Chicago region it reaches 6 to 8 ft with equal spread or slightly less The lower branches sometimes layer where they touch moist soil, so the plants are able to spread and create larger clumps

Its ornamental character lies in its glossy foliage. Leaves are about 4 in long, giving a medium-coarse texture Typically leaves are a bright, deep green Some plants, in some years, develop a yellow autumn color, but usually the leaves fall without much color change *Orixa* grows well in lightly shaded sites It also does well in sun if adequate moisture is present In hot weather in sun, the foliage may turn pale It is a member of the citrus family, and the foliage is aromatic when crushed

A form with variegated foliage exists, but it is rare and I doubt if it is in the trade It appears to be less hardy than the green-leaved form The green form is root hardy to USDA zone 5 (−20°F) but the variegated form has died in zone 6 (−10°F) In the Morton Arboretum west of Chicago, *Orixa* suffered some dieback after the 1983-84 winter — a severe one — but usually just branch tips or portions of the top of the plant are affected In milder climates, *Orixa* might exceed 8 ft in height However, it is easily pruned and kept lower if desired

VICKI GINGAS: Please distinguish between *Cornus kousa* and *C. kousa* var. *chinensis*.

AL FORDHAM: The variety *chinensis* was named by Wilson in 1908. It is a geographic variation. I don't think that the designation holds any weight because of the great variation found in the seedlings of that plant.

BILL FLEMER: For New Jersey conditions *C. kousa* var. *chinensis* is superior to straight *C. kousa*. It has bigger and wider bracts, and the leaves appear to be thicker. Under hot dry conditions the species will exhibit considerable marginal burn on leaves whereas the variety we originally got from the Arnold Arboretum does not exhibit that burning. Certainly for New Jersey and south the variety makes a better garden plant because it is more showy in bloom and resistant to leaf burn.

NEW PLANT FORUM

JACK ALEXANDER AND ROB NICHOLSON, MODERATORS

MODERATOR ALEXANDER: Ruth Kvaalen will begin the new plants session with a presentation on *Orixa japonica*.

RUTH KVAALEN: Landscape plants which lack showy flowers or colorful autumn foliage are often overlooked in favor of the brightly colored plants. But a plant with good foliage appearance during the whole growing season can be more valuable in the landscape than one with a week of vivid color but poor appearance the rest of the year.

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It grows well in a range of soils, from highly organic to calcareous clay Dry soils or light soils that tend to dry out would be less satisfactory

Orixa japonica is a dioecious species with pale yellow-green, axillary flowers followed by small, dark fruits, but both are so small that they remain inconspicuous

The only problem I am aware of is spider mites on plants stressed by dry conditions This species is easily propagated. Kris Bachtell of the Morton Arboretum has rooted cuttings He says a quick-dip in IBA (1,000 to 5,000 ppm) gives rapid rooting on cuttings taken from early or mid-June to mid-July As a nursery crop, it makes a salable plant in 2 to 3 years

To conclude, *Orixa japonica* is a plant to consider for its glossy, almost tropical, foliage in a shrub border, edge of a woods, or many other situations

MODERATOR ALEXANDER: Chris Graham has two lilacs to present.

CHRIS GRAHAM. *Syringa* × *hyacinthiflora* 'Maiden's Blush' was developed by Skinner This early flowering lilac has deep pink buds which open to lighter pink single florets The trusses are about 23 × 12 cm It is a medium-sized lilac with a somewhat upright habit and moderate rate of growth It is easily propagated by softwood cuttings and is moderately susceptible to mildew

Syringe vulgaris 'Krasavitsa Moskvy' was developed in the USSR by L. Kolesnikov The buds are large and pinkish-lilac. The double white florets have a slight peachy tint and are very fragrant. The flower clusters average 25 × 12 cm and have a pyramidal shape It is a shrub of medium height and spread with rather stiff branching. It propagates easily from softwood cuttings and is moderately susceptible to mildew

MODERATOR ALEXANDER: Dr. Elwin Orton will present 3 new plants that were developed in his Woody Ornamentals Breeding Program at Rutgers University.

ELWIN ORTON: *Ilex crenata* 'Beehive' is the cultivar name of the first plant to be discussed It originated as a seedling selection from a cross of *I crenata* 'Convexa' × *I. crenata* 'Stokes'; 21,000 one-year-old seedlings were field planted in beds at a spacing of 9 in. × 9 in and grown on for 2 years Early in the spring of the third year, the plants were dug, 10 at a time with a front-end loader Plants exhibiting a poor root system, or undesirable foliage characteristics, or a heavy infestation of mites were discarded, 5,000 seedlings survived this first screening, or rogueing, and were field planted at a spacing of 5 × 5 ft To assist in screening plants for possible resistance to mites, an annual spray of Sevin was utilized to kill the natural predators of mites and thus encourage a heavy infestation of mites throughout the planting Each spring and fall the plants were evaluated In the spring, plants were discarded primarily on the basis of winter injury. In the fall, plants exhibiting a heavy set of fruit and the accompanying yellowing of the foliage were discarded, as were those plants exhibiting poor branching habit, foliage of undesirable size, shape or curvature, and/or a heavy infestation of mites After 7 years in the second field, some 40 individual plant selections had been made Cuttings were rooted and 5 plants each of these 40 selections were planted in a replicated field trial, along with 5 plants each of 10 cultivars currently in the trade. Another replicated trial of all these materials was conducted in plant-growing containers through 3 gallon size After 5 years, (original seedling was 15 years of age) one clone was

selected for naming and has now been introduced as *I. crenata* 'Beehive' At 15 years of age, the original seedling resembled an old-fashioned conical beehive, hence the name The plants are very dense and self-compacting, and are unique in possessing minute (5 to 6mm × 10 to 14mm) leaves. Plants under test have been reliably winter-hardy in USDA Hardiness Zone 6b.

'Midas Touch' is the cultivar name given to a clone which originated as a bud sport (branch exhibiting variegated foliage) on a 2½ year-old seedling resulting from a cross of a yellow-fruited plant (P I No 231948) times a male plant of *I crenata* similar to *I crenata* 'Microphylla'. Plants of this cultivar have had limited testing It is known that they are fully winter-hardy in USDA Hardiness Zone 6b, but little information is available regarding the response of the foliage to varying degrees of exposure to the sun under summer and/or winter conditions The variegation of the foliage is yellow-green in nature Most leaves exhibit yellow sectors and light green areas in addition to areas with normal green pigmentation Occasionally, branches arise with leaves of the normal green pigmentation. Such branches (reversions) will have to be pruned out, but they appear so infrequently that this maintenance operation should not be a problem. If their vigor is found to be sufficiently high under a wide range of growing conditions, plants of 'Midas Touch' may constitute a scale-resistant substitute for *plants of the golden variegated cultivars of Euonymus fortunei*

The last of the new cultivars of *I crenata* being introduced at this time is to be known as 'Jersey Pinnacle'. The plants are dense and self-compacting, upright in habit, and possess glossy, dark green leaves The plants should be fully winter-hardy in USDA Hardiness Map Zone 6a. It is my hope that plants of this cultivar will fill a need for an excellent upright *I. crenata*. Most nurserymen would mention the cultivar 'Helleri' if one were seeking a low, spreading plant of *I crenata*, but I do not know of any cultivar of upright habit of this species that has received widespread distribution and acceptance

MODERATOR ALEXANDER: Bob Hays will next present one plant.

BOB HAYS: *Itea virginica* is a medium sized shrub that occurs naturally on moist soils from New Jersey to Florida and west to Missouri and Louisiana. It is valuable for its white flowers which are borne on 2 to 6 in racemes in late June into July, and its fall color which ranges from red to purple

When grown in shade, the sweetspire tends to be a rather loose, open shrub which, left unchecked, will form a large colony Grown in full sun, however, it will form a dense, mounded shrub

The selection 'Garnet Glow' (the purposed name for this clone) was made from a plant growing at the Scott Horticultural Foundation At 14 years, it is 6 ft high and 8 ft wide The flower racemes are 6 in long and the plant exhibits consistently good red fall color which is effective for several weeks The leaves persist late into the fall, and after they drop, the red stems become apparent

Cuttings rooted 100% during June to November when treated with Hormodin 2 and placed under mist

Its summer flowers, consistently good fall color, adaptability to a range of soils, and ease of propagation, make this plant worthy of a wider distribution and usage.

MODERATOR NICHOLSON: Jack Alexander will next present a plant for Gary Koller.

JACK ALEXANDER: Regel's threewingnut (*Tripterygium regelii*) is one of those few woody plants which can be grown as a vine or as a shrub When allowed to stand alone it forms a plant 6 to 8 ft tall and spreads as wide or wider. Numerous thin shoots arise from the base and, as they become tall, arch outward and hang down touching the ground and creating a skirt like effect With support, the plant behaves like a vine, twisting around and climbing upward to a height of 15 to 25 ft. If used as vine the plant needs to be provided with a support such as an arbor, trellis, or woven through a chain link fence.

Primary ornamental effect comes from the large terminal panicles of creamy white flowers which are borne in July The flower clusters, which vary from 8 to 18 in. in length are composed of numerous small blossoms which emit the fragrance of new mown hay. Floral effect lasts approximately 3 weeks. Then the blossoms give way to lime green, bladder-like, winged fruits which ultimately ripen to a tan color On old stems the bark is cinnamon-brown and peels off in thin strips Seen without flowers, fruit, or leaves the vine might be mistaken for a bittersweet, for both plants are members of the bittersweet family (Celastraceae)

T regelli is hardy to −20° F, free of insect and disease pests, tolerant of full sun to light shade and it endures wind and salt spray The only specialized cultural requirements is that the plant requires an ample and dependable supply of water during periods of drought.

Propagation is easily accomplished by seeds which require 3 months of cold stratification at 40°F to insure optimum germination. The plant can be increased vegetatively by hardwood cuttings and from root suckers

I am pleased to make seeds of this little known vine available to you and hope that you will give it a trial in your nurseries and your gardens.

MODERATOR NICHOLSON: Phillip Sommer will next present a new grape cultivar.

PHILIP SOMMER: *Vitis labrusca* 'Reliance' is a red, seedless table grape with very high dessert quality.

The fruit of 'Reliance' is round and reddish-pink at maturity. Berries weigh about 2 7 g and are medium in size compared to other grapes. Skins are very tender and the flesh is melting in texture. The sugar content of the fruit of 'Reliance' is very high, hitting almost 24% at peak maturity 'Reliance' has a delicate labrusca aroma and flavor which, combined with the high sugar content, makes for an excellent eating grape The seedless grapes make good raisins and have also been blended with other grapes to make a good wine

Clusters are medium large and well filled, but not excessively compact Vines of 'Reliance' are productive, bearing as high as 12 tons per acre 'Reliance' is vigorous and very hardy to winter cold In Wisconsin and Ohio tests, 'Reliance' has withstood minimum temperatures of −29°F The vines are moderately resistant to black rot, anthracnose, powdery mildew, and downy mildew

The average ripening date at Clarksville, Arkansas, is July 25th In Ohio tests 'Reliance' fruit stored well after 3 months in cold storage

MODERATOR NICHOLSON: Carla Pastore has 3 plants to show us.

CARLA PASTORE: *Rhododendron* 'Golden Gala', formerly 'Fifty Fine', was originally named to commemorate the Holden Arboretum's 50th anniversary It was raised and introduced by David Leach and is a cross

between 'Great Lakes' and 'Good Hope' 'Golden Gala' has a dwarf form and, at 13 years of age, is 3 ft tall by 4½ ft wide It blooms in late May with primrose yellow flowers and is hardy to −20°F 'Golden Gala' will be available in 1986 from Herman Losely Nursery in Perry, Ohio.

Kalmia latifolia 'Star Cluster' originated at the Dexter Estate in Massachusetts It is a slow-growing dwarf form. The parent plant, after 16 years, is 3 ft tall and 4 ft wide The flowers have a dark maroon band inside the petals which is similar to 'Fresca' but not as interrupted The buds are white and provide a nice contrast to the open flower It is hardy to Zone 5 and will be available from Herman Losely Nursery in 1986

Alnus glutinosa 'Pyramidalis' — pyramidal European alder — is not a new plant but one that merits more attention Its major attribute is the narrow-growth habit The plant, after 25 years, is between 30 and 40 ft in height and only 6 to 8 ft wide As with all alders, it is tolerant of wet sites and might have a useful function in the landscape Grafted plants will be available in 1986 at Brotzman's Nursery, Madison, Ohio

MODERATOR NICHOLSON: Ann Hruska from the Morton Arboretum has one plant to present.

ANN HRUSKA: *Perovskia atriplicifolia* (Russian-sage) is a plant that particularly caught my eye this past year and that I feel warrants more attention

Russian-sage is a member of the mint family and native to West Pakistan, Afghanistan, and the Himalayas Listed as a semi-woody plant, hardy to Zone 5, it does sustain winter kill in cold climates and performs realistically like an herbaceous perennial Simply cut back to live wood in spring

Among its merits, Russian-sage exhibits the following multi-seasonal interests 1) attractive 1½ in long silver-green leaves on stems covered with the same silver/white down, 2) aromatic foliage typical of mints, 3) after cutback, Russian-sage grows to about 3 ft with fine, wispy stems of a rather "wind-blown" nature, 4) its crowning glory 9 to 12 in panicles of lavender/blue mint-type flowers, appearing in late summer, combine with the silvery vegetative growth to give a striking, cool diversion in the heat of summer, and 5) persistent silvery/white stems that give the plant a "frosted" appearance throughout winter, contrasting nicely with a dark background

Perovskia is of easy culture when grown in full sun on well-drained, average fertility soil It is shown off to best advantage in a mass planting

Like most members of the mint family *Perovskia* is readily propagated by softwood cuttings under mist Weak concentrations of rooting hormone may be used, although probably not necessary Remove cuttings from mist soon after roots have formed to avoid decay of succulent tissue Seedage is another successful means of propagation Arboreta such as the Arnold, Morton, and Bernheim would be a source of cutting material Commercial sources include Springbook Gardens in Mentor, Ohio and T-Z Nursery in Winfield, Illinois

MODERATOR ALEXANDER: Allen Bush has one plant to present.

ALLEN BUSH: *Helianthus angustifolius* is a sunflower species native from Long Island, New York, to Florida and westward to Missouri It is a herbaceous perennial found in moist conditions and yet it does satisfactorily in average garden soil In very dry soils, the so-called "swamp sunflower" wilts and grows poorly The 3 in flowers occur in October when there may be very little else in bloom

Helianthus angustifolius eventually grows 8 ft tall, has a bushy habit, and requires no staking. Its northern hardiness range is reported to be Zone 6 but further testing is certainly warranted

MODERATOR ALEXANDER: Bruce Briggs has three rhododendrons to show us.

BRUCE BRIGGS: *Rhododendron* 'Trinidad ('Calcutta' × 'Tahiti'). Cross (1960), raised, and introduced by Dr David G. Leach, North Madison, OH Pictured in *American Horticulturist*, 52·4 (Winter 1973, p 17 Buds Red Purple Group 63B Flowers of good substance, openly funnel-shaped, 2¾ in across × 2 in long, with 5 wavy lobes Red Purple Group 62D with ⅜ in. Red Purple Group 66C edging, sparse dorsal, Greyed Yellow Group 162B spotting, reverse Red Purple Group 64C. Calyx variable in length, dorsal lobes 1¼ to 1¾ in Yellow Group 4D, striped Red Purple Group 63D. Truss 6½ in across × 5¾ in high, ball-shaped, with 14 flowers Floriferous. Leaves held 3 years, 5¼ × 2⅛ in. elliptic, apiculate, rounded, flat to convex, glabrous, dull, Yellow Green Group 147A, under surface with inconspicuous, golden brown, scattered hairs to patchy indumentum. Plant rounded, semi-dwarf, branching moderately, 4 ft tall × 5 ft wide in 21 years Blooms in late May Hardy to at least −20°F

R 'Normandy' Newburyport Beauty (Fowle #18) × Newburyport Belle (Fowle #19) (Both parents are unregistered Dexter hybrids.) Cross (1968), raised, and introduced (1983) by Dr David G Leach, North Madison, OH Flowers of good substance, opening funnel-shaped, 2⅞ in. across × 1¾ in long, with 5-6 wavy lobes, Red Purple Group 73C flushed 73A around the perimeter, with dorsal spotting Orange Group 24B Calyx of 2 1/16 in dorsal lobes, pink Truss 6½ × 6½ in ball-shaped, with 17 flowers Leaves held 2 years, 4⅞ × 2¼ in elliptic, mucronate, rounded, slightly bullate, Yellow Green Group 146A Plant broad, rounded, branching well, 5 ft tall × 6½ ft wide in 15 years Blooms in late May Hardy to at least −20°F

R 'Creamy Chiffon' (H-3) is of unknown origin but probably has *R. campylocarpum* or *R wardii* in its lineage. 4 ft, −5°F, 4-5/4/- A most unusual rhododendron with its double creamy-yellow flowers which appear in profusion The rounded deep-green leaves, that hold for 2 to 3 yr make a most attractive plant that looks good in the garden A compact, semi-dwarf, blooming very young, plant

EASTERN REGION 1984 AWARD OF MERIT

PRESENTED BY J. PETER VERMEULEN

The individual recognized for the Award of Merit at this, our 34th Annual Meeting, personifies in an exemplary manner the purpose and spirit of our Society, as well as that of our cherished national heritage, which offers to everyone opportunities for success commensurate with their talents, initiative, and efforts.

Our recipient was born in 1934 in Bowling Green, Ohio, into a farming and gardening family. Boyhood employment at Ilgenfritz Nursery, where his father also worked, gave him early life exposure to horticulture and, no doubt, influenced

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his preparation for college and later life. His father purchased land at Toledo, Ohio, to start a small nursery, primarily to generate funds for higher education. The nursery was successful and so was our recipient's academic efforts in high school, where he earned a 4-year scholarship at Michigan State University. At Michigan State he received his bachelor's degree in Horticulture in 1956 and his advisor was our good member, Dr. Fred B. Widmoyer.

That same year marked the first of what would be many publications. That first paper was entitled, "Experiments Yield Information on Correct Pansy Culture Procedures."

His quest for knowledge and excellence led him to the College of Agriculture (now Cook College) at Rutgers University. Here again his advisor was an honored and well known member of this society, Dr. William E. Snyder. There he received a Master of Science degree in 1959, and the Doctor of Philosophy Degree in 1962. Three publications during that era carry his name as sole author.

After graduation our recipient conducted research on rooting cofactors in selected southern pines with the Texas Forest Service at Texas A & M University. A paper on this research was presented to this Society in 1963.

From Texas A & M he moved to Beltsville, Maryland with the Fruit Laboratory at the USDA Agricultural Research Center. His work at Beltsville on pear and crabapple resulted in 25 or more excellent papers. In the late 1970's there began an impressive succession of 27 publications relating to various aspects of tissue culture.

He has organized a number of highly successful symposia on micropropagation, and also has authored entire chapters in several books. The recently published Index for volumes 1-30 of our IPPS Proceedings is due solely to his efforts.

Our recipient is currently a Senior Plant Physiologist at the USDA Beltsville Agricultural Research Center. This past summer he also received the prestigious Norman Jay Coleman Award, given by the American Association of Nurserymen.

We are indeed pleased and honored to confer to Dr. Richard H. Zimmerman the Eastern Region IPPS 1984 Award of Merit.

GRAFTING *ACER PALMATUM 'BLOODGOOD'*

CHARLES KEMPENAAR

Boulevard Nurseries
Middletown, Rhode Island 02843

Potting procedure. We use 2-year-old seedlings of *Acer palmatum* as the understock. We bring in the understock plants in March so we can clean the tops and cut the roots. They are then placed in a bucket of water that contains captan (3 tbls/gal) to help control any disease. The understock is potted into a 2½ in. clay pot no deeper than it was growing in the ground in a soil mixture containing: soil - ½ yd, sand - ¼ yd, peat - 4 bu, fertilizer - l lb. of 5-10-10, and limestone - 1 lb. The potted understock plants are placed into flats, moved outside into a sand frame, covered with sand to a depth of 1 in., and then watered. The frames are shaded.

Leaves are removed the first week in October and any excess poor shoot growth on the bottom of the rootstock is removed. The rootstocks are then placed in a cool greenhouse with no heat so the buds do not break. In late December the pots are cleaned and the rootstocks are placed in flats for grafting in January.

Grafting procedures. Grafting is begun the first week of January. The understock is brought up from the greenhouse and the upper third of the tops are cut off. Scions, which contain 4 nodes, are cut two days before. We graft only the 'Bloodgood' cultivar.

We use a very sharp Tina grafting knife dipped in alcohol frequently to keep the knife clean. We make an incision 1 in. long on the rootstock and a reverse slice is made on the scion to make sure it is a smooth fit. The graft is held together securely with a grafting elastic that is stretched slightly and not twisted when wrapping it around the graft.

Benching procedure. Completed grafts are brought into the grafting house and placed in a high bench (12 in.) with 1 in. of moist peatmoss on the bottom. They are set erect, covered with moist peatmoss to a level 1 in. above the graft union and Kraft crinkle paper is placed over the grafts. We use bottom heat at approximately 75°F. After 4 days we check for excess moisture. If it is too damp we take the Kraft paper off and let the bench dry for ½ hr. We do this every 3 days. When scion buds start breaking we take the Kraft paper off and syringe them. We leave the paper off for 1 hr. so the new growth will start to harden, then we put the paper back. When the growth is 1 in. long, the paper is taken off completely. On hot, sunny

days we mist twice a day, once in mid-morning and again in the afternoon. The grafts remain in the bench for 6 to 8 weeks.

Taking grafts from the grafting house. At this time the understock is cut off and the grafts are placed back into a greenhouse at 65°F. The soil in the beds is loosened up and leveled off before plunging the pots half way down and set 1 in. apart.

Taking grafts from the greenhouse to the beds. During the last week in May or first week of June we plant the maple grafts outside. The grafting elastic is cut off and after watering, the grafts are brought to the outside beds. The outside beds are 6 ft wide and the grafts are placed 12 in. apart. They are planted by trowel and then shade is applied.

From the beds to the field. After two yr. the maples are dug from the beds in the second week of May. After pruning the tops and roots, they are then watered, placed into boxes, and taken to the field for planting. They are planted 30 in. apart in 36 in. spaced rows. After three years the grafted maples are sold as 18 to 24 and 24 to 30 in. stock.

QUESTION BOX

The Question Box Session was convened at 9.00 a.m. with Ralph Shugert and Joerg Leiss serving as moderators.

MODERATOR LEISS: What is the shelf life of a rooting compound, such as the various Hormex formulations, provided you keep them in a cool, dry place? Will they break down after a certain period of time?

DICK WOLFF: If it is kept cool and in the dark there should be no deterioration I have had some cans for 6 and 7 years but finally threw them out because I was concerned, even though I was successful.

PETER VERMEULEN: We were approached by the maker of Hormodin who was working on labeling. During the course of the conversation we were advised that Hormodin had an excellent shelf life if kept cool, sealed, and out of the light.

JOERG LEISS: Does it make any difference in relation to heat buildup when using two layers of plastic, whether the clear or the opaque layer is to the inside?

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PETER VERMEULEN: Bill Roberts, an agriculture engineer, indicated that it did not make any difference what the arrangement was.

JOERG LEISS: Question for Nina Basuk. At what time of the year did you start the etiolation process in your tests with the pines?

STUART NELSON: I cannot answer for Nina Basuk but we put it on when snow is still on the ground. We use black plastic but let the etiolated plants become green under indirect light obtained by simply removing the north side of the tent.

JUDY ZUK: The pines were placed, I believe, both inside and outside a greenhouse. With the outside tests the cover was applied before bud break. The greenhouse plants were forced into growth.

MODERATOR LEISS: What is the frequency of graft incompatibility with *Acer rubrum* grafts. At what age does it show up?

JOERG LEISS: It starts when you first take the grafts out of the grafting box, and can continue for maybe 30 years. Put a mechanical digger down and quite frequently the roots go one way and the tops the other, breaking at the graft union.

FRANK GOUIN. In Maryland nurseries we have seen approximately 10 to 12% incompatibility cases within the first 3 years after transplanting, and another 2 to 3% by the time the trees reach 3 in. caliper. It also shows in fall color. If you have strong fall color by August you can kiss it off. If you start with cuttings there is no problem. You can also tell breakage is going to happen if a "horses hoof" develops above the graft union.

MODERATOR SHUGERT: Is crown gall on woody perennials a wide-spread problem? What can be done to prevent this, or to clean up an infected area?

BEN SWANE: It is a problem all over the world. There is a product, "No Gall," which we soak seed in of plants, such as peach and apricot, before stratification. We also use it with our rose cuttings. In addition, we are very careful what we allow on our farm. We do not allow tractors or trucks from other farms to come on our land.

MODERATOR SHUGERT: Can viruses be transmitted through seed propagation?

JOERG LEISS: In some cases they can be and in others, not. *Malus* and *Pyrus* rootstocks are generally considered free of viruses if propagated by seed. *Prunus* seeds have to come from virus-indexed seed sources.

MODERATOR SHUGERT: Has anyone every used antidesiccants to control powdery mildew?

FRANK GOUIN: Yes, and it works. there was a paper in *HortScience* this past summer on this subject. I applied it in mid- to late August to crapemyrtle and to *Euonymus kiautschovica* and obtained excellent control. I applied Vapor Guard once at a 1 to 60 dilution.

JEORG LEISS: Can we obtain a selection of birch that is resistant to the bronze birch borer?

TOM PINNEY: We know that river, yellow, and sweet birch are resistant. White bark birch, 'Whitespire' is also resistant but it must not be confused with *Betula platyphylla* var. *japonica*, of which it is a cultivar.

MODERATOR LEISS: Is 'Whitespire' a registered cultivar of birch? Are you growing it from seed? If it is a named cultivar and you are growing it from seed, how can you expect the progeny to exhibit the same white bark and borer resistance as the parent — especially when birches are known to cross pollinate readily? How can you feel justified in calling the progency 'Whitespire'?

TOM PINNEY: Yes, 'Whitespire' is trademarked, but it is not patented. We grow it from seed. All the testing was done at Wooster, Ohio, on seedlings. It is a very homozygous plant and has an official cultivar name. Do not get confused by what Deb McCown said. She has decided to take one of the three original parent plants at the University of Wisconsin and to micropropagate it. I guess they could patent that plant. So, if you want to obtain a start of the plant you can contact her or me. Hers will be tissue-cultured and mine will be seed-grown.

There are three plants at the Wisconsin Arboretum which are isolated and, after having grown over 1 million liners I can attest that less than ¼ of 1% are atypical. We are also setting up our seed orchard from the original three plants. Dr. Ed Hasselkus has control of the seed from the original plants.

DAVE DUGAN. We have a good white birch labeled *Betula maximowicziana* that came from the old Kohankie Nursery. The trees have shown no signs of borer damage yet.

TOM PINNEY: What Dave has is what they thought was *B. maximowicziana*. It also may be resistant to bronze birch borer. The true species was obtained from Japan by Dr. Kawase and was found to be susceptible to bronze birch borer. What Dave has is some hybrid or some other species. Birch is very prone to hybridization.

JOERG LEISS: Just a comment on hybridization of birch. I

do not believe that they cross pollinate, because they flower at different times. So a lot of the species are true, I feel.

RALPH SHUGERT: At the old Cole Nursery we had a monarch birch that came from a beautiful park in Philadelphia. After much study it was determined that it was not monarch birch. After visiting Hillier's garden and observing the plant, I can agree that monarch birch has gray bark.

MODERATOR LEISS. *Pieris floribunda* has always been a problem for us to grow successfully. We grow it from seed. Germination is no problem when you have fresh viable seed. However, our problems begin later in the seed flat and after they have been pricked off. They always end up diseased and grow poorly! Is there someone doing a good job growing this plant?

ED VAN HOF· The only thing I feel you have to worry about is excessive water after transplanting because Pieris does not grow well with poorly aerated roots.

MODERATOR LEISS: Has anyone crossed *Cornus florida* with *C. kousa* var. *chinensis*?

ELWIN ORTON. I have been successful in crossing plants of these two species in the woody ornamentals breeding program at Rutgers University. Some of the hybrids look very promising and we are patenting several of them prior to introduction. To the best of my knowledge, these are the first hybrids of these two species

MODERATOR LEISS. Could anyone identify a variegated cotoneaster we are growing? It is low spreading and compact in growth.

JOERG LEISS: If it looks like it has spider mites it is probably *Cotoneaster horizontalis* 'Variegatus'.

MODERATOR LEISS: Would anyone know where the 'Nearly Wild Rose' originated?

TOM PINNEY: It is a polyantha introduced in the 1950's and then lost to the trade. Dick Cross from Minnesota found it and put it back into production.

MODERATOR LEISS: What zone would be considered the northern limit for *Abies procera*?

PETER VERMEULEN: I would think Zone 4.

MODERATOR LEISS: Is *Daphne* 'Carol Mackie' variegated? Could it be *Daphne* 'Somerset Silveredge'?

JIM CROSS· I do not know the second cultivar 'Carol Mackie' originated as a sport of *D.* × *burkwoodii* in a garden in New Jersey. It has a silver edge. [It would, therefore, be named *D.* × *burkwoodii* 'Carol Mackie,' Bot. Ed.)

MODERATOR SHUGERT: A question for Bernard Fourrier. Please review your herbicide program. My notes say Devrinol 5 lb. Ai/A. When do you apply? Do you use any other herbicide?

BERNARD FOURRIER: We apply at the rate of 5 lb. Ai/A right after sticking the hardwood cuttings in the fall.

MODERATOR SHUGERT: Question for Wayne Lovelace. How many pounds of annual rye per acre do you use?

RALPH SHUGERT· Wayne says 6 to 8 lb. to make a thick sod

MODERATOR SHUGERT: Another question for Wayne Lovelace. Do you sow annual rye when you sow viburnum seed in June/July?

RALPH SHUGERT: Wayne says yes, but be careful with the use of crop oil in high temperatures.

FRANK GOUIN: Wayne has solved the late frost problem. He has delayed the germination of the seeds by 1 to 2 weeks; also, if there is late frost, it will sit on the grass. Don't apply above 65°F or you will get burn.

MIKE DODGE: Could you not use some other crop that would provide a good root system but would die with the onset of frost?

RALPH SHUGERT: No, because there would be no top growth for late spring frost protection.

BEN SWANE: Lots of work on minimum tillage for soil conservation work is going on around the world. One thing that pleases me about Wayne's paper is the fact that it is one application of minimum tillage. I predict that his work will not stop at its present state. I feel that, in the future, he will stratify his seeds out of the ground and use a fluid drill system for planting into the sod.

MODERATOR SHUGERT: Has anybody experienced plant damage with Fusilade application on growing plants?

RALPH SHUGERT: Fusilade, like many herbicides, is labeled for use by genus. It is labeled for use on *Euonymus*. So I applied it over the top of 10 quarter-mile rows of *E. alata* 'Compacta' (3 year plants). It knocked all the new growth and blasted leaves half way down the stem. I will tell you in the spring what bud damage we had. Ralph should have known better. I should have tested it. I am pleased with the results on *Taxus* for quack grass control. Also you cannot use oil with Fusilade but must use a nonionic surfactant.

CLAYTON FULLER. *Euonymus alata* 'Compacta' is not tolerant to a lot of the herbicides we are using today. Ronstar

even inhibits its growth a little. Dr. Ahern's work also showed damage with Fusilade.

ELTON SMITH: Azaleas and junipers are two additional plants in which care is needed when Poast and Fusilade are used. With azaleas we have had extensive leaf defoliation and growing tip injury. The two cultivars we have worked with are 'Hershey's Red' and 'Hino-pink'. In the other group, junipers, the blue color is changed to green. It occurs with both the oil and surfactant.

JIM JOHNSON. We also tried Poast and Fusilade on 'Hershey's Red' azalea but only had damage from Fusilade.

DALE MARONEK: We have experienced some injury from both compounds. We have found that it is important to make sure your crop is not going into stress when you put the products down. I did some trials with irrigation intervals and found that if the crop is stressed you can get injury.

WILL WITTEE: We were cleaning up some Bermuda grass in juniper plants with Fusilate plus X-77 as a surfactant and it turned 'Blue Rug' juniper brown in July and August.

MODERATOR LEISS. How do you propagate male ginkgo trees and then get them to grow?

BILL FLEMER: They can be rooted from softwood cuttings in late July or early August when treated with Hormodin 1 or 2. However, the rooted plants are very slow to start growth so we have finally given up on that method.

A quicker way is to bench graft them like apples. They are faster growing but still take a long time. The fastest method of all is to use seedling-grown plants, but you can not tell the sex. Ginkgos require high heat and nitrogen. Cool nights are not good for best growth.

JOERG LEISS: The fastest method we have found is field grafting. However, you must have a 3-year seedling so you are not that much ahead.

MODERATOR LEISS: Question for Murry Alward. Do you use bottom heat to push your hardwood cuttings to gather your softwood cuttings from them?

MURRY ALWARD: No. I have tried it but found no advantage for most items, but *Prunus* × *cistena* cuttings do benefit from bottom heat.

MODERATOR LEISS. Question for Bernard Fourrier. At what point do you remove the mulch from the hardwood cuttings in the spring and when are they covered?

BERNARD FOURRIER: We take the hay off as soon as we

can — in late April or early May. It is kind of a gamble with the frost.

MODERATOR LEISS. Can you propagate *Dicentra spectabilis* from summer cuttings? The leaves on our cuttings turn yellow and decay after a week or so. Is there a technique to prevent this?

JOERG LEISS: As soon as *Dicentra* develops a hollow stem it often fails to root. Therefore you need to take them as early as possible.

MURRY ALWARD: After it blooms, cut it back by ½ and you will get small shoots in the leaf axils. These shoots root with no problem.

MODERATOR LEISS: Any suggestions on the propagation of *Euphorbia epithymoides* (also known as *E. polychroma*)?

STEVE STILL: Seed.

JOERG LEISS: Tip cuttings can be taken as late as frost.

MODERATOR LEISS: Can anyone offer any suggestions on how to get good germination of *Eryngium alpinum* seed?

MIKE DODGE: We germinate it under mist with bottom heat.

JOERG LEISS: We sow our seeds in open beds and the seedlings just come up.

MODERATOR LEISS: Has any one accelerated germination of *Syringa reticulata* seed to earlier than August or September?

BERNARD FOURRIER: We found that after stratification for 2 months in peat/sand the seeds would germinate. After stratification we sow the seeds in flats in the greenhouse with 70°F bottom heat, or outside. The outside sown seeds germinate in the spring.

MODERATOR SHUGERT: How do you root *Pinus strobus* 'Nana' cuttings?

ARDA BERRYHILL: Most people are grafting it rather than using cuttings.

MODERATOR SHUGERT: For the past two summers we have experienced premature dormancy (July) in Exbury azaleas. Does anyone have an explanation for this problem?

ANNA KNUTTEL: The best way to grow them is to prune hard in the spring and fertilize a lot in the spring. After hot weather they do not grow very well. Stress induces dormancy.

MODERATOR SHUGERT: Does anyone have any suggestions about rooting lithospermum *(Lithodora)* cuttings?

BEN SWANE: Take short cuttings — less than ½ in. in length with a heal from the inside of the plant. No hormone is required and retain the bottom leaves. Do not overpot the cuttings and place in a quick draining soil with low fertility.

MODERATOR SHUGERT: What is the "loose" yew sold by Studebaker Nursery?

DON STUDEBAKER: A selection of *Taxus cuspidata* 'Columnaris' that has a loose, upright growing habit and may have potential in shady areas.

MODERATOR SHUGERT: Question for Bill Flemer. Do you propagate your Cornus kousa var. chinensis from seed? If so, are the seedlings uniform?

BILL FLEMER: We have selected and established isolated blocks from previous seedlings. We look for broad, thick leaves and broad, thick bracts. So we do grow them from seed. It can also be propagated by cuttings but, like a number of the tree dogwoods from cuttings, we have had overwintering problems. I remember we had a block in our Allentown nursery about 9 years ago in which ⅔ were planted from seeds and ⅓ were from cuttings. Following a severe winter all the cutting plants died while all the seedlings plants lived. They were 4 to 5 feet tall at the time. The roots just died. We have had the same problem with *C. florida* 'Rubra.' The *C. kousa* var. *chinensis* grown from our isolation blocks are the way to go we feel.

ROOT REGENERATION TECHNIQUES

GARY J. KLING

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University of Illinois
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INTRODUCTION

Woody plant establishment and growth are greatly affected by root loss which occurs during the transplanting process. The resulting stresses placed on the plant are a major source of problems in woody plant production and consumer usage of trees and shrubs. Root loss which occurs during digging, handling, storage and transplanting, results in reduced shoot growth for several years, branch dieback, or plant death. It also reduces the type and size of trees able to be moved and makes some species expensive to produce and unavailable in the landscape trade. The transplanting period and the first

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growing season following it are one of the most critical periods for survival and growth in the life of trees and shrubs.

The greatest cause of death of transplanted seedlings is water stress (8), and is directly related to root loss. Transplants undergo massive physiological shock when removed from the soil. The most damaging injury is the loss of actively growing root tips and the zone immediately behind the tips which are the areas responsible for most water uptake. The ability to form new roots, referred to as root regeneration potential, varies with the species, season, handling, and type of root system (3,9,16,20,23). Plants with low root regeneration potentials are difficult to transplant, or recover very slowly from transplanting. Plants which do not transplant readily require more expensive digging and handling procedures. Substantial amounts of post-transplant care are also required for these species

Traditional horticultural practices designed to ease transplanting stress include the use of antitranspirants, root pruning, digging plants B & B and careful selection of transplanting time. An additional technique may soon be available to the nursery and landscape industry. This technique involves the application of readily available growth regulators — auxins — to the root system of plants, which accelerate the root regeneration process. The auxins, IBA and NAA, have shown great promise in experimental root regeneration studies. These are the same growth regulators which most propagators use on a routine basis to stimulate rooting in cuttings.

Early experiments in the mid to late 1930's demonstrated the effectiveness of inserting IBA-soaked toothpicks into holes drilled in the main tap root of transplanted pecan *(Carya illinoensis)* (21). Other workers showed that root regeneration could be stimulated by soaking the root systems of several species in dilute auxin solutions (1,26,30). Research in this area essentially ceased until the mid-1970's. Since that time several research groups around the country have begun work on elucidating the process of root regeneration and have continued experimenting with auxin applications. Current research has shown that root regeneration can be stimulated in a variety of species (Table 1).

MATERIALS USED

The auxins most commonly utilized for root regeneration studies include indoleacetic acid (IAA), indolebutyric acid (IBA), and naphthaleneacetic acid (NAA). Within this group, IAA is the least effective and the most unstable in storage.

Most species respond better to IBA than to NAA and show fewer problems with phytotoxicity. Auxins are not extremely water soluble so they are first dissolved in a small amount of alcohol and then diluted with water. Alcohol concentrations of 25% or less are acceptable for quick dips and sprays (Table 3) but much lower levels should be used for soaks because alcohol is toxic to roots. A water soluble form of IBA, the potassium salt of IBA, has been used successfully on a number of species (Table 1). K-IBA can be used without alcohol but the cost ($26.50/gram) is 20 times more than IBA ($1.30/gram). Depending upon application method, size of plant, and auxin used, the cost can be expected to range from 1¢ to 30¢ per tree.

METHODS OF APPLICATION

Growth regulators can be applied to the root systems of plants in a variety of ways. One of the earliest and still most successful methods of application involves the insertion of auxin-soaked toothpicks into holes drilled in the roots. This technique allows the applicator to carefully choose the location of the auxin application to enhance root regeneration at specific sites. Application rates can be varied by changing the concentration of the auxin solution in which the toothpicks are soaked. Most workers have reported using 1000 to 3000 ppm auxin solution to deposit 1 to 4 mg of auxin per toothpick (Table 1). The major disadvantage of this method of application is the time and labor required for each tree. Despite the cost associated with this technique, Struve et. al. (24) demonstrated a substantial benefit/cost ratio in a small scale nursery study.

Early studies (1,21,26) also indicated auxins could be applied to trees by soaking the root systems ın dilute solutions for periods of 24 to 48 hours Auxin concentrations of 10 to 200 ppm are typically used for a 24-hour soak application (Table 1). Shorter soaking times can be used with correspondingly higher auxin concentrations. Experience with cutting propagation suggests that the alcohol concentration required to dissolve the auxin, should be kept to a minimum to avoid toxicity during a 24 hour soak (5). Disadvantages of the soak technique include the long time required for treatment and the large volume of treatment solution required for trees larger than seedling stage.

Several other less common methods of auxin application include wrapping roots with auxin soaked string (29), applying the auxin in the form of paste (Table 1), and the use of a powder. Pastes are prepared by mixing auxin with a mixture

Table 1. Summary of effects of auxin treatments on root regeneration of woody plants

Species	Auxin	Concentration (ppm)	Method of application	Effect[1]	Reference
Acer saccharinum	IAA	10,000[2]	lanolin paste	length, number	19
A saccharum	IBA	10, 40	soak	number	26
Aleurites fordii	IBA	20	soak	dry weight	17
Carya illinoinensis	IBA	5,000	lanolin paste	dry weight, length	21
	IBA	4 mg/toothpick	toothpick	dry weight, length, number	21, 4
	IBA	5,000	wheat flour paste	length, number	21
Cercis canadensis	IBA	3,000	soak		15
Cotoneaster divaricatus	IBA	50	soak	number	1
	IAA	10	drench	number	1
Crataegus phaenopyrum	IBA	1,000, 3,000	soak, toothpick		25
Fraxinus americana	IAA	200	soak	dry weight, number	6
Juglans nigra	IBA	1,000	soak	dry weight, number, shoot growth	27
	IBA	25	soak	number	26
Liquidambar styraciflua	IBA	3,000	dip	number	10
Liriodendron tulipifera	IAA	200	soak	dry weight, number	6
	K-IBA	1,000-10,000	soak	dry weight, number, shoot growth	7
Magnolia × soulangiana	IBA	500	spray	number	Table 3
Nyssa sylvatica	IBA	3,000	toothpick string	dry weight, number	29
Oxydendrum arboreum	IBA				28
Pinus contorta	IBA, NAA	203, 19	dip	number	22
P elliottii	IBA	10	soak	length, number	18
P ponderosa	IAA	50	soak	number, increased survival	2
P taeda	IBA	20	soak	volume	14
Pistacia chinensis	K-IBA	3,000	dip	number	10
Pyrus communis	IBA	1 mg/toothpick	toothpick	number, weight	11

Table 1 Summary of effects of auxin treatments on root regeneration of woody plants (continued)

Species	Auxin	Concentration (ppm)	Method of application	Effect[1]	Reference
Quercus alba	IBA, NAA	3,000	string, toothpick	dry weight, length, number	29
Q coccinea	IBA, NAA	100, 1,000	soak, toothpick	length, number	25
	IBA	2,000	dip	number	16
Q palustris	IBA	25	soak	number	26
	IBA	2,000	dip	number	16
	IBA	1,000, 10,000	toothpick		13
Q rubra	IAA	200	soak	dry weight, number	6
	IBA, NAA	3,000	spray	number	12
Q velutina	IBA	25	soak	number	26
Thuja occidentalis	IBA	25	soak	number	26
Ulmus americana	IBA	10	soak	number	26
Viburnum dilatatum	IAA, IBA	200, 20	drench, soak	number	1

[1] Stimulatory effect on dry weight, length, number and volume of roots or shoot growth
[2] Applied to disbudded shoot meristem

of wheat flour and water, or with just lanolin, at a concentration of 5000 ppm. The paste is applied to selected places on the roots with a small tool. These methods allow for specific placement of auxin on the root system. Rooting powders can be purchased commercially, or prepared by mixing the auxins with talc. Powders are usually applied to a moist root system immediately prior to planting, much like treating cuttings prior to sticking. Concentrations of 1000 to 3000 ppm are common in powder form.

Soil drench applications of auxins have been the least successful technique reported. Chadwick (1) reported limited stimulation of root regeneration in *Cotoneaster divaricatus* (spreading cotoneaster) and *Viburnum dilatatum* (linden viburnum) with soil drench applications of IBA. Other researchers have not reported much success with soil drench applications since that time. Problems associated with soil drench applications of auxins include soil binding and inactivation, alcohol toxicity to roots, inability to get the auxin to the roots, and the large quantity of auxin required.

The most recent application technique utilizes auxin sprays. Sprays are much quicker and easier to apply and allow for more efficient utilization of auxins than other methods. Spray applications can be selective by spraying only the outside of a balled and burlapped plant, or more general by spraying the entire root system of a bare root tree. Sprays do not require any special equipment and can be applied in the field or following removal from storage. Lumis (12) reported success with 3000-ppm spray applications of IBA and NAA on landscape size red oak (*Quercus rubra*). Spray applications made to the outside edges of freshly dug root balls resulted in increased root numbers at the cut ends. Spray applications have also been used to stimulate root regeneration in *Magnolia* × *soulangiana*, saucer magnolia (Table 2).

Table 2. Effect of spray applications of indolebutyric acid on root regeneration of *Magnolia* × *soulangiana* seedlings [1]

IBA concentration (ppm)	Average number of regenerated roots	Root system quality[2]
0	36 5 b[3]	3 7 ab[4]
500	67 1 a	4 7 a
1000	38 7 b	3 6 ab
2000	24 3 c	2.0 bc
4000	1 3 d	1.1 c
8000	0 0 d	1 0 c

[1] 15 plants per treatment
[2] Quality ratings 5 for excellent, 2 for alive but poor, 1 for dead
[3] Mean separation by Duncan's Multiple Range Test, 5% level
[4] Mean separation by Scheffe's test, 5% level

A number of generalizations can be made from the numerous root regeneration studies that have been conducted. Progress made in the area of root regeneration is summarized in the following paragraphs.

1) Natural root regeneration varies with the season. Root regeneration is at a maximum at bud break and declines over the summer with an increased capacity in fall (3,9,16,20,23). This is the basis for spring versus fall transplanting for some species.

2) Root regeneration is greatly affected by the physiology of the plant at digging time, storage conditions and stresses during and following transplanting (3). Auxin treatments are no substitute for maintaining healthy, vigorous plants that are properly stored and handled (3). Prevention of water stress during the entire process is extremely important.

3) Auxin treatments can increase the number of regenerated roots. The dry weight or total mass of a root system is not necessarily increased when root number increases. Often the density of the root system is increased by a stimulation of a large number of small roots. This increase in fibrous roots can be a major improvement for a plant with a coarse root system. While some plants respond to auxin treatments by increasing root numbers and mass (Table 1), there may be no increases in root length with auxin treatments.

4) The concentration of auxin required for root regeneration differs with species (Table 1). A typical range for IBA would be 1000 to 3000 ppm for a quick dip or spray and 20 to 50 ppm for a 24-hour soak. Some species are quite sensitive as evidenced by stimulation of root regeneration in *Magnolia* × *soulangiana* with spray concentrations of 500 ppm IBA and inhibition at 1000 ppm and above (Table 2). Careful consideration should also be given to the concentration of alcohol used to solubilize auxins. Ethanol concentrations above 25% inhibit root regeneration in *Magnolia* × *soulangiana* (Table 3). Much lower levels of alcohol should be used for 24-hour soaks.

5) Younger plants are generally more responsive than older plants (21). Most root regeneration studies have used seedlings for ease of experimental handling. Auxin applications however, have been effective on large plants (12). Older plants will respond to auxin but the response of most species as affected by age is largely unknown.

6) Root regeneration techniques are successful on difficult- and easy-to-transplant species (Table 1). Much emphasis has been placed on root regeneration in species with low root regeneration potentials; however, some of the greatest benefits

may be gained by auxin use in species that are considered to be easy-to-transplant. Additional work is needed to determine effects and benefits with other species.

7) The main objectives of root regeneration are not limited to increasing the number of roots, their length, or the mass of the root system. Treatments should result in increased transplant survival and accelerated shoot growth of plants following transplanting. Work by Fowells (2), Gossard (4), Turner and Moser (27) and Kelly and Moser (7) has demonstrated increase survival rates and shoot growth stimulation.

Table 3. Effects of spray applications of ethanol on root regeneration of *Magnolia* × *soulangiana* seedlings [1]

Ethanol concentration (%)	Average number of regenerated roots per plant
0 0	34 3 a[2]
12 5	36 7 a
25 0	36 5 a
50 0	28 4 b
70 0	24 5 b

[1] 15 plants per treatment
[2] Mean separation by Duncan's Multiple Range Test, 5%

FUTURE OF ROOT REGENERATION STUDIES

Certainly not all root regeneration studies have produced successful results. Some experiments show no response, or even significant inhibition of root regeneration with auxin treatment. Positive results can sometimes be hard to reproduce from year to year or on related species within the same year. Many of these problems can be attributed to our lack of knowledge concerning the effect of previous environments in which the plant was grown or stored (20). We know small differences in timing or handling procedures of cuttings can make a great difference in rooting. Similarities could exist in root regeneration.

Inconsistent results from growth regulator applications also indicate a lack of knowledge about internal plant hormone control of the process of root regeneration. A basic understanding of the role of hormones in plant development is essential to future improvement of woody plant production and usage. Much work remains in this area.

Root regeneration techniques have been successful on many species, resulting in increased root system density and size. Most woody species, however, have not been evaluated for response to auxin treatments. Research is needed to determined which species will benefit most from these techniques.

Additional refinements in timing, rates, and methods of application could bring greater responses and more consistent results. Field nursery trials need to be conducted to determine large scale results and the economic benefits of these treatments. Results from these types of studies should make root regeneration techniques a helpful tool to accelerate nursery production and establishment of trees into landscapes. Root regeneration techniques should improve the transplantability of large trees and facilitate establishment of trees in difficult urban areas. It is hoped that these procedures will result in lower cost, higher quality trees for the public, and an increased diversity of available plant materials.

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MULTIPLICATION OF *SYRINGA* SPECIES AND CULTIVARS IN TISSUE CULTURE

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Abstract. A micropropagation method for *Syringa* × *hyacinthiflora* cv. Excel is described involving cytokinin control of shoot growth in tissue cultures Shoot tips and nodes from rooted cuttings are decontaminated in 0 5% sodium hypochlorite and transferred to nutrient medium supplemented with 2 2 μM thidiazuron Under defined conditions of light intensity, photoperiod, and temperature, shoots elongate from preformed buds to produce monopodial axes, and then lateral buds form in the axils of leaves After 6 weeks incubation, shoots can be used as sources of bud explants for further shoot multiplication, or as cuttings Plantlets produced after induction of roots on cuttings are then gradually acclimated to the greenhouse environment Shoots of other members of Oleaceae, such as additional species and cultivars of *Syringa*, and species of *Fraxinus*, *Forsythia*, and *Ligustrum* also respond in tissue cultures to these treatments, suggesting that the method may be generally applicable For *S* × *hyacinthiflora* cv Excel it was shown that the inhibitory effect of 2,4-dichlorophenoxyacetic acid on shoot growth in tissue cultures was not mediated via stimulated production of ethylene

INTRODUCTION

The standard methods for multiplying *Syringa* cultivars are by grafting and softwood cuttings (5). A problem with the latter technique is the fact that cuttings responding to auxin treatments can be obtained only during a few critical weeks of every year (1). Because of this, the success of the methodology is often unpredictable and the number of plants obtained, even in ideal circumstances, is small.

By contrast, tissue culture overcomes the shortcomings of conventional technology. Once vigorously growing shoots are obtained in culture, plant multiplication can continue throughout the year. Moreover, the scale of propagation is limited only by the space and supplies for tissue culture. We estimate that theoretically one million plants could be produced in a year starting from a single growing shoot if tissue culture methodology were utilized.

The fundamental principle involved in tissue culture propagation of *Syringa* is the control of shoot growth by cytokinin. In this respect, the technology is essentially the same as the method used for micropropagation of most other woody plants, especially species in the Rosaceae and Ericaceae (8). In what has now become the standard methodology, one uses cytokinin to promote growth and to overcome apical dominance in cultured shoots. The resulting cluster of growing

shoots is then subdivided and used for further shoot multiplication or for the production of plantlets after inducing root formation in cuttings by treatment with auxin.

We are currently screening a large number of woody plants at the Arnold Arboretum to determine whether cytokinin manipulation can be applied to plant taxa that have previously been unstudied (3). Based on research with over 100 different woody species representing more than 30 families, we find that: 1) cytokinins in combination with the usual mixture of inorganic (9) and organic nutrients (7) can sustain shoot growth in explants of many, but not all, species tested and 2), when it is found, the 'classical' cytokinin response in shoot explants is localized in defined systematic groupings; i.e. families (e.g. Ericaceae, Rosaceae), orders (e.g. Ericales) and superorders (e.g. Asteridae). As we obtain results with a larger number of species, the framework relating cytokinin response to systematic botany and horticulture will become more clearly defined.

This report summarizes methodology for propagating *Syringa* using tissue culture techniques, which are similar to the methods utilized by Hildebrandt and Harney (6) for *S. vulgaris* cv. Vesper. Most of the procedures were devised with *S.* × *hyacinthiflora* cv. Excel but they are also applicable to other cultivars and species of *Syringa*, as well as additional members of the family Oleaceae, including species of *Forsythia*, *Ligustrum*, and *Fraxinus*. *Syringa* exhibits dual control of shoot growth via auxin and cytokinin; i.e. auxin inhibits shoot growth in tissue cultures and cytokinin stimulates it. In view of the hypothesis of Burg and Burg (2) that the inhibitory effect of auxin is mediated via induced ethylene synthesis, we have also examined ethylene production in cultures. The results strongly suggest that auxin inhibition is not a consequence of ethylene.

MATERIALS AND METHODS

Plant materials were obtained from the Arnold Arboretum of Harvard University at Jamaica Plain, Massachusetts. The basic components of tissue culture media were supplied as Murashige's Minimal Organics Medium from GIBCO, Inc, and as nicotinic acid and pyridoxine-HCl from Sigma Chemical Co. All cytokinins were purchased from Sigma Chemical Co. except thidiazuron (N-phenyl-N'-1,2,3-thiadiazol-5-ylurea) which was obtained as a gift from Nor-Am Agricultural Products, Naperville, Illinois. The 2,4-dichlorophenoxyacetic acid (2,4-D) and indole-3-acetic acid (IAA) were obtained from Sigma

Chemical Co., and 1-aminocyclopropane-1-carboxylic acid (ACC) was purchased from Calbiochem-Behring, Inc.

All media contained basic components consisting of the inorganic nutrients recommended by Murashige and Skoog (9); minor organics such as 0.4 mg/l thiamine-HCl and 100 mg/1 *myo*-inositol, according to Linsmaier and Skoog (7); 5 mg/l pyridoxine-HCl; 5 mg/l nicotinic acid; and 30 g/l sucrose. To sustain shoot growth in cultures, it is necessary to supplement these nutrients with any one of several different cytokinins. We then adjust the pH to 5.6 to 5.8 and add 10 g/l of agar (Phytagar, GIBCO Inc.), then heat the mixture. As soon as all of the constituents of the medium have dissolved, 20 ml volumes were dispensed to individual test tubes (20 × 150 mm). These were then covered with plastic, vented closures and autoclaved at 120°C for 15 min.

Cultures were incubated upright at appoximately 27°C (about 80°F) and under various light regimes. Vigorous growth can be obtained with cool white fluorescent lights at intensities from 15 to 75 $\mu Em^{-2}s^{-1}$ of either constant or discontinuous illumination, but we normally maintained cultures at 50 $\mu Em^{-2}s^{-1}$ using a 16 hr light and 8 hr dark photoperiod.

In determining ethylene production rates, 1 ml air samples were taken from culture tubes sealed for 24 hours with serum caps. The samples were then injected into a gas chromatograph operated isothermally at 60°C and equipped with a stainless steel column containing Porapak Q and a flame ionization detector. By interfacing the chromatograph with a minigrator, ethylene could be detected at levels as low as 0.01 ppm. Results are expressed as means of pooled data from four independent experiments, each with 4 replications per treatment.

RESULTS AND DISCUSSION

Source of explants. Shoot cultures can be obtained with varying degrees of success starting with 5 to 10 mm terminal buds or laterals from seedlings, mature plants, or rooted cuttings. Although seedling material is probably the easiest to work with, it is also the least desirable for propagation since the floral and cultural characteristics of the mature plants are unknown. Buds from mature specimens of cultivars growing outdoors probably are the most difficult to use as explants. If these buds are obtained early in the spring during the few weeks when shoots are actively growing, the tissues are especially sensitive to the hypochlorite treatment used to decontaminate explants When buds are collected at this time, even as little as 1 minute incubation in dilute hypochlorite results in greater than 98% death of explants. Later in the year after

the flush of growth has been completed, explants appear to be much more resistant to disinfectant treatment. Unfortunately, the load of microorganisms is also greatly increased.

By far the best sources of explants are rooted cuttings growing in the greenhouse. Because they represent clonal material, rooted cuttings give true-to-type propagules. In addition, they grow vegetatively during several months of the year. We take shoot tips and nodal explants from growing stems, trim the leaf blades and then wash explants with detergent for about 5 min. After this, the stem segments are soaked in disinfectant solution consisting of 0.5% sodium hypochlorite (i.e., laundry bleach diluted 10-fold with deionized water) for 5 min. and then transferred to sterilized plastic Petri plates.

Working a a laminar flow transfer hood to minimize contamination of cultures with air-borne microorganisms, each stem segment is cut into 5 to 10 mm nodal sections which contain a lateral bud in the axil of every leaf. Individual explants are then transferred to culture tubes containing nutrient medium.

Cytokinin control of shoot growth. The following cytokinins have been found to be effective in promoting *Syringa* shoot growth in tissue cultures: N6-isopentenyladenine (i^6Ade), N6-

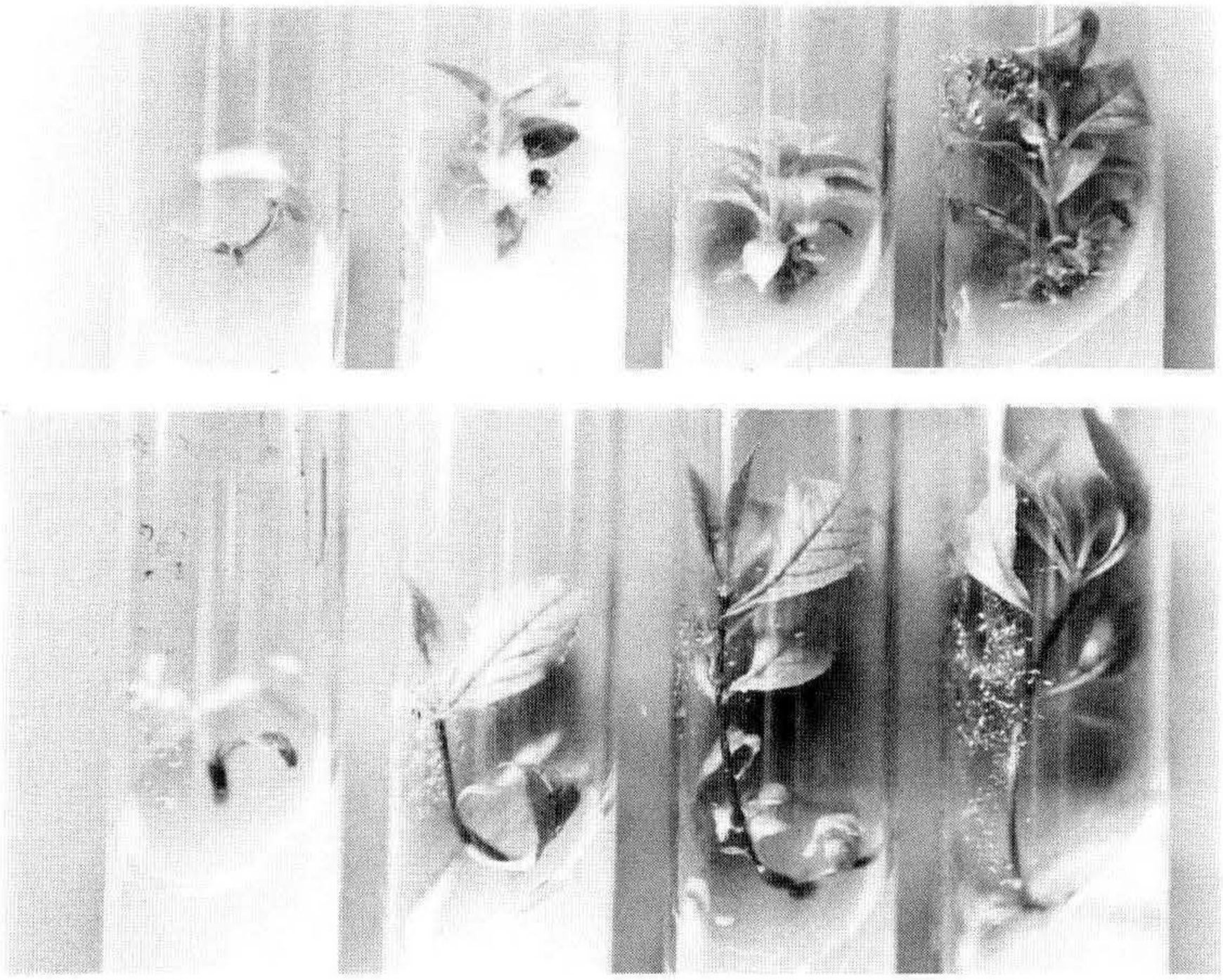

Figure 1. Effect of different i^6Ade concentrations on shoot growth in nodal of *Syringa* (top) and *Fraxinus* (bottom). Media, from left to right, contained 0, 3, 6 and 15 μM i^6Ade; respectively. Cultures were incubated for 4 weeks.

benzyladenine (bzl^{6}Ade), kinetin, and thidiazuron. Figure 1 shows the effects of different i^{6}Ade concentrations on *Syringa* and *Fraxinus* shoots. The results demonstrate the essentiality of cytokinin for growth as well as the range of i^{6}Ade concentrations that have been found to be adequate. Based on several tests, 5 to 30 μM i^{6}Ade seems to be about equally effective for *Syringa* and *Fraxinus* tissue cultures, but we routinely utilize 30 μM i^{6}Ade which gives continued, vigorous growth in subcultures. An interesting feature of *Syringa* and *Fraxinus* tissue cultures, shared by shoot cultures of other Oleaceae such as *Ligustrum* and *Forsythia*, is the tendency of shoots to grow as unbranched monopodial axes even in the presence of elevated cytokinin concentrations. This physiological characteristic limits the range of strategies that can be used for tissue culture propagation.

Figure 2 illustrates the control of shoot growth in *Syringa* and *Fraxinus* using different cytokinins, plus or minus IAA. As indicated, 0.5 mg/l (i.e. 2.2 μM) thidiazuron stimulates tissue culture growth of both *Syringa* and *Fraxinus* shoots and, on the basis of nearly three years of tests, this has been adopted as the standard medium for species in the family Oleaceae.

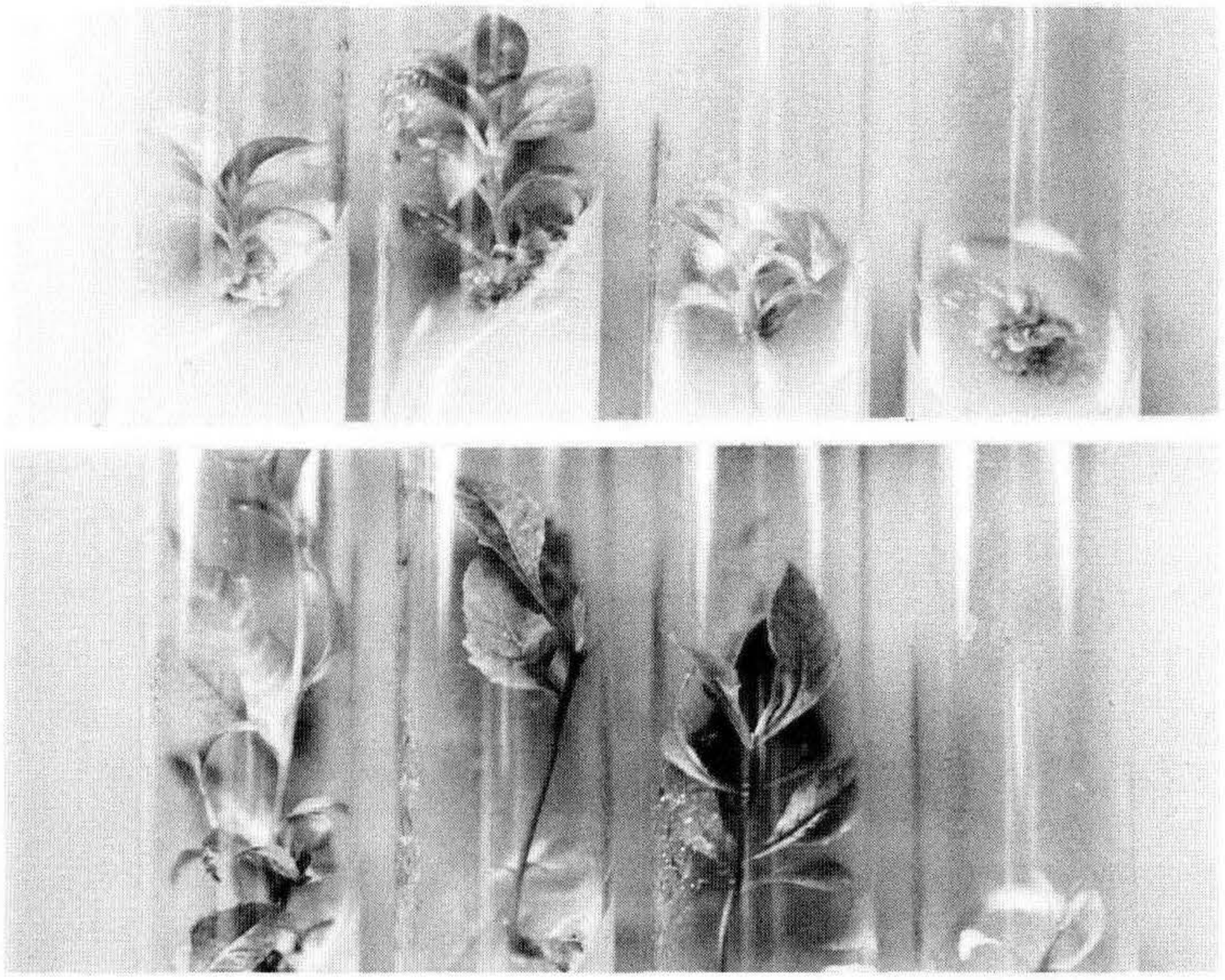

Figure 2. Control of shoot growth in nodal explants of *Syringa* (top) and *Fraxinus* (bottom) by cytokinin and auxin. Media, from left to right, contained 2.2 μM thidiazuron, 33 μM bzl^{6}Ade plus 0.6 μM IAA, 15 μM i^{6}Ade plus 35 μM IAA, respectively. Cultures were incubated for 4 weeks.

Nevertheless, other cytokinins can also be used with about the same effectiveness. Thus, i^6Ade and bzl^6Ade both will also promote shoot growth. The medium containing 7.5 mg/l (33 μM) bzl^6Ade and 0.1 mg/l (0.6 μM) IAA was recommended by Hildebrandt and Harney (6) for *Syringa* tissue cultures.

Multiplication of propagules. Under the defined conditions of incubation, *Syringa* lateral buds and shoot tips proceed through the normal phases of vegetative growth characteristic of intact plants (4); that is, a phase of shoot elongation during which preformed leaf primordia and internodes rapidly increase in size to produce a shoot axis consisting of 3 to 12 internodes followed by a phase of axillary bud development when elongation growth stops and miniature shoot axes form in the axils of leaves. For S. × *hyacinthiflora* cv. Excel, the duration of the shoot elongation and subsequent bud development phases is 6 weeks.

When shoots have completed growth, they are removed from the culture tubes and cut into nodal segments, plus shoot tips, using a scalpel. We then trim leaf blades, transfer the segments to tubes containing fresh media and incubate the cultures as described. On the average, each shoot grown in culture produces 4 propagules for the subsequent passage. At 6 weeks per passage, this rate of multiplication corresponds to more than one million shoots obtained from one in a little over a year. Thus, the methodology can be scaled up to practically any level of production.

Rooting and hardening. To prepare plantlets for the greenhouse, elongated shoots are first removed from the culture tubes and a fresh cut is made at the base of each. These cuttings are dipped in a commercial rooting powder containing 0.4% indolebutyric acid, plus thiram as a fungicide, and then transferred to enclosed plastic boxes containing horticultural vermiculite. After 2 weeks incubation at 27°C and 50 $\mu Em^{-2}s^{-1}$, greater than 95% of the cuttings form at least 2 roots each. At this point, individual plantlets can be transferred to soil in separate containers which are also kept in the culture room for 2 weeks before moving them to the greenhouse. As is the case with all micropropagation procedures, success in producing greenhouse plants depends on a gradual hardening of plantlets to the lower humidity and increased light intensity of the greenhouse environment.

Shoots of plants of other Oleaceae species. Table 1 lists the species and cultivars that have been grown successfully as shoot cultures with all of the following different media: 1) 2.2 μM thidiazuron, 2) 33 μM bzl^6Ade plus 0.6 μM IAA, or 3) 30 μM i^6Ade. Based on this, it appears that the method for multi-

plication of *Syringa* can probably be applied to other members of the family Oleacaea. Although it may prove to be difficult to establish shoots of certain species in tissue cultures, it is expected that the problems in these cases will involve factors such as explant sensitivity to hypochlorite, or microorganism contamination, rather than the inherent responses of shoots to cytokinin.

Table 1. Plants in the family Oleaceae that have been grown as shoot cultures At least 48 shoots per species and cultivar were used

Species and cultivar	Source of explant: Seedlings	Source of explant: Mature shoots
Forsythia *mandshurica*	+	
F *ovata*	+	+
Fraxinus pennsylvanica	+	
Ligustrum obtusifolium	+	
Syringa × *diversifolia*		
cv William H Judd		+
cv Excel		+
cv Louvois		+
S *reticulata*	+	+
cv Hippolyte Maringer		+
cv Madame Abel Chatenay		+

Ethylene production. On the basis of studies with excised pea shoots, Burg and Burg (2) hypothesized that the inhibitory effect of auxin on shoot growth results from induced ethylene. To support their hypothesis they showed that auxin treatment stimulated ethylene production and that, even in the absence of auxin, ethylene could inhibit shoot growth.

Because the subject of shoot growth regulation is fundamental to micropropagation techniques, we conducted studies to determine whether auxin inhibition in *Syringa* tissue cultures is mediated via ethylene. Figure 3 summarizes a series of experiments in which shoot growth and ethylene production were measured in the presence of different media It shows that a medium with 30 μM i^6Ade plus 2 μM 2,4-D stimulated ethylene production 18 to 80 fold over a medium with i^6Ade alone. This medium also inhibited shoot growth completely. Nevertheless, it seems unlikely that ethylene is responsible for the inhibition caused by auxin, based on the observation that vigorous growth was obtained on a medium containing i^6Ade plus the ethylene precursor ACC As shown in Fig. 3, 50 μM ACC gave ethylene production rates comparable to a medium supplemented with 2,4-D, but shoot growth essentially as vigorous as i^6Ade alone Rather than being an inhibitor of growth, ethylene appeared to be a normal consequence of it

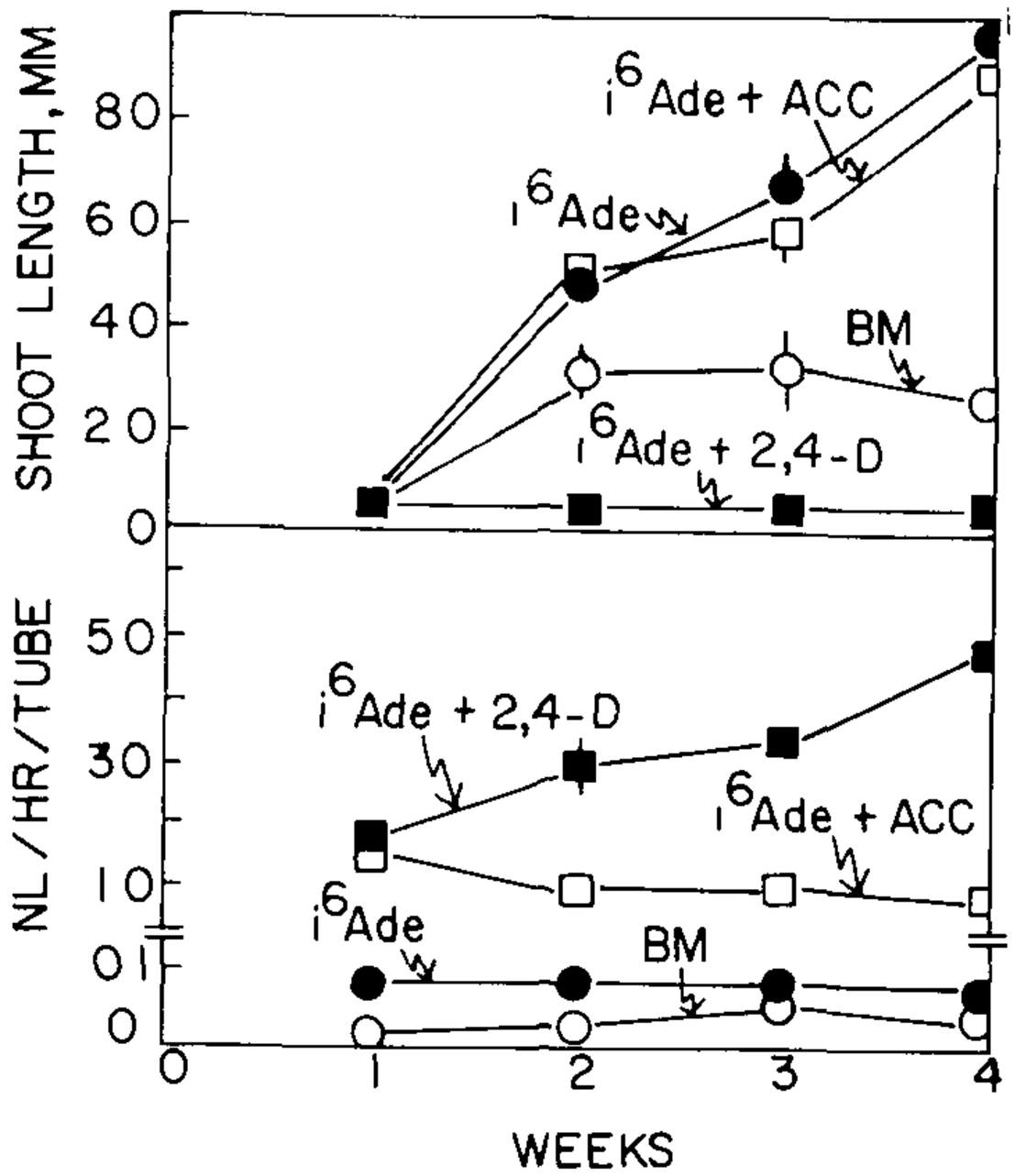

Figure 3. Shoot growth (above) and ethylene production (below) in *Syringa* tissue cultures The following concentrations of supplements were used i^6Ade, 30 μ M, 2,4-D, 2μM, ACC, 50 μM BM indicates the basal medium without supplements

based on the fact that ethylene production rates were elevated approximately 3-fold in i^6Ade cultures, compared to cultures without phytohormone.

SUMMARY

The methodology described in this report for *Syringa*, *Forsythia*, *Fraxinus* and *Ligustrum* is similar to methods for *Syringa vulgaris* cv. Vesper (6) and for several other woody plants. All of these procedures are based on the established role of cytokinin as a shoot growth regulator and the fact that shoot explants from many woody species can be grown in tissue cultures using a medium consisting of basal nutrients plus cytokinin. Our continuing research to determine the generality of this response among several taxa suggests that this methodology may be applicable to many other species of woody plants. The results to date also suggest that several groups may not be amenable to this technology. Obviously, a different methodology for micropropagation will need to be devised for unresponsive species.

The cytokinin response of excised shoots is central to the technology involved in micropropagation of Oleaceae species. In the standard procedure known as "shoot multiplication," cytokinin is used to promote growth and to overcome apical dominance in excised shoots The resulting cluster of shoots is

subdivided and individual shoots are used either for further shoot multiplication or for plantlet production. When these approaches are applied to *Syringa*, it is necessary to use nodes with inhibited laterals for shoot multiplication since an unbranched monopodial axis is produced during each passage in tissue culture. If this is done, rates corresponding to one million-fold multiplication can be obtained yearly.

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RED-FLOWERED PERENNIAL GARDEN DELPHINIUMS THROUGH INTERSPECIFIC HYBRIDIZATION

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This project was begun in 1938 while the senior author was a graduate student at the University of California, at Berkeley, California. In 1939 the project was transferred to UCLA, and in 1945 to the Missouri Botanical Garden in St. Louis, Missouri. In 1952 it was again moved to the University of Connecticut in Storrs, Connecticut.

The original reason for undertaking this work many years ago was the appearance in some California nurseries of a red

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or pink-flowered delphinium hybrid from Europe, *Delphinium ruysii* 'Pink Sensation', introduced by Jackson and Perkins. It was almost sterile, the propagation by cuttings or division was slow, and it was generally not a good grower in the warmer sections of California. It seemed, therefore, desirable to try to utilize *D. cardinale* Hook., a red-flowered species native to California, to overcome these problems Since this species is normally found in the warmer sections of California, it might conceivably produce hybrids better suited to at least the warmer sections of the United States than could be expected from *D. nudicaule* T. & G., which is native to the cooler sections of Northern California and Southern Oregon, and which was used in the production of *D. ruysii.*

While planning this work it was learned that the Vetterle and Reinelt firm of Capitola, California, originators of the highly successful Pacific Giant strain of delphiniums, had used *D. cardinale* in an attempt to produce red-flowered delphiniums. They did not succeed but Mr. Reinelt, who did this work, claimed that the Pacific Giant strain probably did contain a number of genes from *D. cardinale.*

Delphinium cardinale is a perennial, endemic to the cismontane region of southern California and Lower California. It is diploid (n = 8). Like most delphiniums of the Southwest, the plant becomes completely dormant after the seed matures and remains so until after the following winter, when growth again begins soon after the first season's rains. Not only has this species been shown to be highly resistant to powdery mildew, *Erysiphe polygoni* (3), but its flowers are of a color not yet present in the perennial cultivated delphiniums. This a cardinal red color, which occasionally varies through salmon and orange to yellow. The transfer of these features to the cultivated delphiniums by means of hybridization, therefore, seemed desirable.

Cytologically, the perennial cultivated delphiniums fall in three groups, namely: the diploid group, chiefly represented by derivatives of *D. grandiflorum* L. and *D. tatsienense* Franch. (n = 8); the tetraploid group, probably largely dervied from the *D. elatum* L. group of species from Eastern Europe (n = 16); and the hexaploid group, represented by the Belladona, Bellamosum and Lamartinii cultivars (n = 24), which have been shown to be allohexaploid hybrids between the two first named groups (5).

As the tetraploid delphiniums, under various trade and horticultural names are, by far, the most commonly cultivated and most important commercially, it seemed desirable to begin hybridization with this group.

A cross between diploid *D. cardinale* and a member of the tetraploid group might conceivably yield only triploid hybrids which would most likely be sterile. On the other hand, if a tetraploid *D. cardinale* were available, one should expect tetraploid hybrids from such a cross which might possibly be fertile. The results obtained with *D. ruysii* support such an assumption (1). Therefore, to facilitate the transfer of desirable genes from *D. cardinale* to the tetraploid garden delphiniums it was decided to attempt the doubling of the chromosome number of *D. cardinale* by means of colchicine (4).

Plants of tetraploid *D. cardinale* became available for breeding in 1941 and numerous crosses were made with selected forms of the Pacific Giant and Blackmore and Langdon strains of perennial delphiniums. Most of these crosses failed to produce seeds and most of those seeds produced failed to germinate. However, in 1943 thirteen seedlings from a cross between a selected form of the Galahad series of the Pacific Giant strain used as the seed parent were flowered. This cross eventually formed the base for most of the work reported here. All crosses using tetraploid *D. cardinale* as seed parents failed to produce viable seed, as did all crosses using diploid *D. cardinale* with forms of *D. elatum*.

The thirteen F_1 hybrids referred to above, though being hybrids between a double-flowered white and a single-flowered red, were single-flowered and purple in color. They were moderately fertile and some 300 F_2 seedlings flowered. None was red or white but there was some segregation toward pinkish lavender — on the whole a very uninteresting group. In some 500 F_3 seedlings, however, there were two rather attractive pink-flowered plants. These pink-flowered plants were completely seed sterile but the pollen from one of these plants crossed to a Galahad selection resulted in a few seedlings, all of which were purple, single-flowered, and almost completely sterile. It was possible, however, to obtain a few back-cross hybrids with selected *D. elatum* types. Through successive back-crossing to Pacific Giant and Blackmore and Langdon selections for four more generations, always selecting for as deep reddish color as possible, some BC_5 selections were obtained that looked like some of the best selections from the Pacific Giant and Blackmore and Langdon strains except that they were (at best) reddish purple. They seemed to be fully fertile and, over the next four years, some 10,000 seedlings were grown from self and sibling pollinations of these plants. Not a single red-flowered plant was obtained.

In 1958 several of the best selections were again pollinated with pollen from a colchicine-treated *D. cardinale*. Only two

seedlings were obtained from these crosses; both were very similar to the original 1943 seedlings, one was completely sterile, the other fairly fertile. A population of 326 seedlings was obtained from this plant in 1959, three of which were red-flowered, whereas all the others were reddish purple. Only one of the three red seedlings was fertile and this was selfed and crossed to several of the purple-flowered siblings. The result was seven seedling populations in 1960, three of which produced only purple-flowered plants, three segregated for red, and the seventh — which was the red selfed — produced nothing but red-flowered seedlings.

A new feature appeared in the populations where segregation for red took place. Many of the purple-flowered plants produced flowers with red streaks or sectors in the sepals; occasionally a whole flower was red. It was soon seen in successive generations that whenever a purple-flowered plant showed any red streaks or sectors, however small, it could be counted on to segregate for red flowers in the next generation if selfed or crossed to siblings exhibiting the same features. Yet another new feature appared during the next two or three generations, namely a color that was intermediate between red and purple. This new color was named "burgundy" because of its similarity in color to that of Burgundy wine.

During the next four years a system of introgressive hybridization toward *D. elatum* was followed. That is, the best red-flowered selections were crossed to selected forms of the Pacific Giant and Blackmore and Langdon strains. The resulting hybrids were generally too infertile to produce seed from selfing but would produce some seed when pollinated with pollen from the best reds.

The resulting populations generally consisted of mostly purple, some burgundy, and some red-flowered individuals. The number of any one type in any one population was generally too small to permit reliable genetic deductions but when comparable data from several populations were pooled the following conclusions seemed to be justified: 1) the red flower color is genetically recessive to non-red and homozygous for this gene; 2) the burgundy type possesses three genes for red and one for non-red (blue), 3) the purple-flowered types must possess two, three, or four genes for non-red. Since the three purple-flowered types could not be distinguished except through appropriate breeding experiments, the red streaks or sectors in the flowers of some plants became a very important diagnostic feature greatly facilitating the selection of non-reds that would produce reds in the next generation.

When the senior author retired in 1976 it was not possible to continue the breeding work on an effective scale. All that could be done was to preserve as much as possible of the breeding material so that the breeding work could be expanded again when circumstances permit. During the summer of 1984 the work was reactivated on a limited scale and it is hoped that the work can be continued on a larger scale until something that is commercially valuable can be obtained.

In the meantime, all of the different types have been subjected to trials out-of-doors to determine the hardiness and general survivability of the various breeding lines. After three years it was clearly evident that most of the purple-flowered hybrids survived, as well as the various commercial forms of *D. elatum*. The burgundy and reds were more variable, but sufficient numbers survived to give hope that a red or pink-flowered hardy strain of delphiniums can eventually be obtained. All the types can be propagated on a limited basis through cuttings or divisions, but since this is slow and — in this country at least — nearly all delphiniums are propagated by seed, a strain that is sufficiently fertile to be commercially profitable from seed is desired.

There would seem to be two options in continuing this project. One would be to continue interbreeding among the red-flowered plants. Some of them are presently relatively fertile and, though not quite as hardy as might be desired, they might be useful as annuals. Many of the so-called perennial delphiniums are now being treated largely as annuals.

The other option is to continue to cross the best reds with the best and hardiest of the commercial *D. elatum* forms. The resulting hybrids will probably not be sufficiently fertile to produce seed from selfing or sib-crossing but, as in the past, might produce some seed when back-crossed to the most fertile reds. The result should be some reds and a good many non-reds. Selecting the best reds from this group and again back-crossing to the best *D. elatum* types should eventually produce a race of fertile hybrids that would be equal to the best commercial *D. elatum* forms, except for red or pink flower color. In view of the difficulties encountered in the past it is not easy to set a time table for this event.

In the meantime it would be good if some tissue culture laboratory could propagate some of the better clones so that material could be made available to other breeders. To date the three laboratories which have tried have failed to accomplish this.

In 1961 R. A. H. Legro in Holland (2) published an account of his breeding work with delphiniums which he had started in 1953. He produced a tetraploid hybrid between *D. cardinale* and *D. nudicaule* and then crossed this hybrid to various forms of *D. elatum*. Whether his work has been any more successful than ours in producing hardy, fertile, red-, or pink-flowering delphiniums than ours we do not know.

LITERATURE CITED

1 Lawrence, W J 1936 The origin of new forms in delphinium *Genetica* 18 109-115

2 Legro, R A H 1961 Species hybrids in delphinium *Euphytica* 10(1) 1-23

3 Mehlquist, Gustav A L 1941 The reaction of thirteen California species of delphinium to powdery mildew *Proc Amer Soc Hort. Sci* 39.411-413

4 Mehlquist, Gustav A L, Charles O Blodgett, and Lawrence Bruscia 1943 Colchicine induced tetraploidy in *Delphinium cardinale* *Jour Heredity* 34(6) 187-192

5 Mehlquist, Gustav A L and M A Gage 1962 The origin of *Delphinium* × *belladonna* *Proc XVIth Inter Hort Congress*, pp 41-49

A REVIEW OF THE BOOK: GROWING MEDIA FOR ORNAMENTAL PLANTS AND TURF

IAN S TOLLEY

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Australia

The motto of the International Plant Propagators' Society, "To Seek and to Share", should not be forgotten. I came 12,000 miles to this meeting to seek and to share and I thought that I might be able to bring something to share with you. The more I thought about sharing at the time, I realized I could not bring an emu egg, like I did to the IPPS Western Region meeting a few years ago. Therefore, I decided to share a new Australian book. The book, *Growing Media for Ornamental Plants and Turf* [1], was published in 1984, and I was fortunate enough to cooperate with the two authors. This book was co-authored by Kevin A. Handreck, Division of Soils, Commonwealth Scientific and Industrial Research Organization, Adelaide, South Australia, and Neil D. Black, Ryde School of Horticulture, New South Wales Department of Technical and Further Education.

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[1] Published by New South Wales University Press, P O Box 1, Kensington, N S W 2033, Australia

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The thing I like about the book is that it deals with basics, as you can see from the table of contents (Table 1).

Table 1. Table of contents of, "Growing Media for Ornamental Plants and Turf," by K A Handreck and N D Black

Introduction	Fertilizer Practice in Nurseries
Plants Need for Good Growth	Turf Plants
The Basics	Managing Turf Soils
Texture and Particle Size	Fertilizng Turf
Some Simple Chemistry	Salinity A Growing Problem
Organic Matter The Vital Component	Watering When and How Much
Problems with Organic Materials	Irrigation Overview
Clay and Humus Soil Colloids	Drainage
Structure and Pore Space	Life in Growing Media
Growing Media and Water	Soil-borne Diseases in Nurseries
Supplying Air to Roots	Nutrient Solution as a Medium Hydroponics
pH	Temperature
Composting	Soils and Landscapes
Choosing Materials for Potting Mixes	Containers
Foundations for Good Turf	From Nursery to Landscape
Plant Nutrients	Collecting Samples for Analysis
Fertilizers	Simple Tests

One of the examples from the book that I can show is that of nutrient deficiency symptoms which seem to show up as a problem in all nurseries at one time or another. This book, to my knowledge, contains the first up-to-date chart showing the availability of plant nutrients for organic potting mixes (Figure 1). In practice, for non-soil mixes, the availability of nutrients is far different from that of soil mixes (Figure 2). If you look at these two charts you will understand why the authors are stressing the importance of keeping the pH between 5 and 6 for a general mix instead of 5.5 to 6.5 which we commonly use. The link between pH and nutrient availability is different in highly organic media from that in mineral soils. If you look at an element, such as phosphorus, you can see that at pH 6.5 availability is reduced in organic soils. A comparison of the two charts underlines the important change in attitude towards pH in growing media.

A great deal of emphasis is placed on the question of moisture in pots. Excellent chapters on growing media and water, and supplying air to the roots, are covered in the book. No matter what the shape of the pot, the degree of saturation in pots of similar height is the same. We can illustrate that

point in a number of ways. However, if we understand how containers work, then we are halfway to eliminating the problem. Container design is an area that I have spent a lot of time on during the last 20 years. I have been pushing the importance of tall containers to minimize the amount of saturation in pots. Tall pots give the roots a much higher proportion of air space than short squat pots. Figure 3 shows a pot with lots of drainage and which is tall and thin at the same time. Probably the most important thing we, as nurserymen, do is watering.

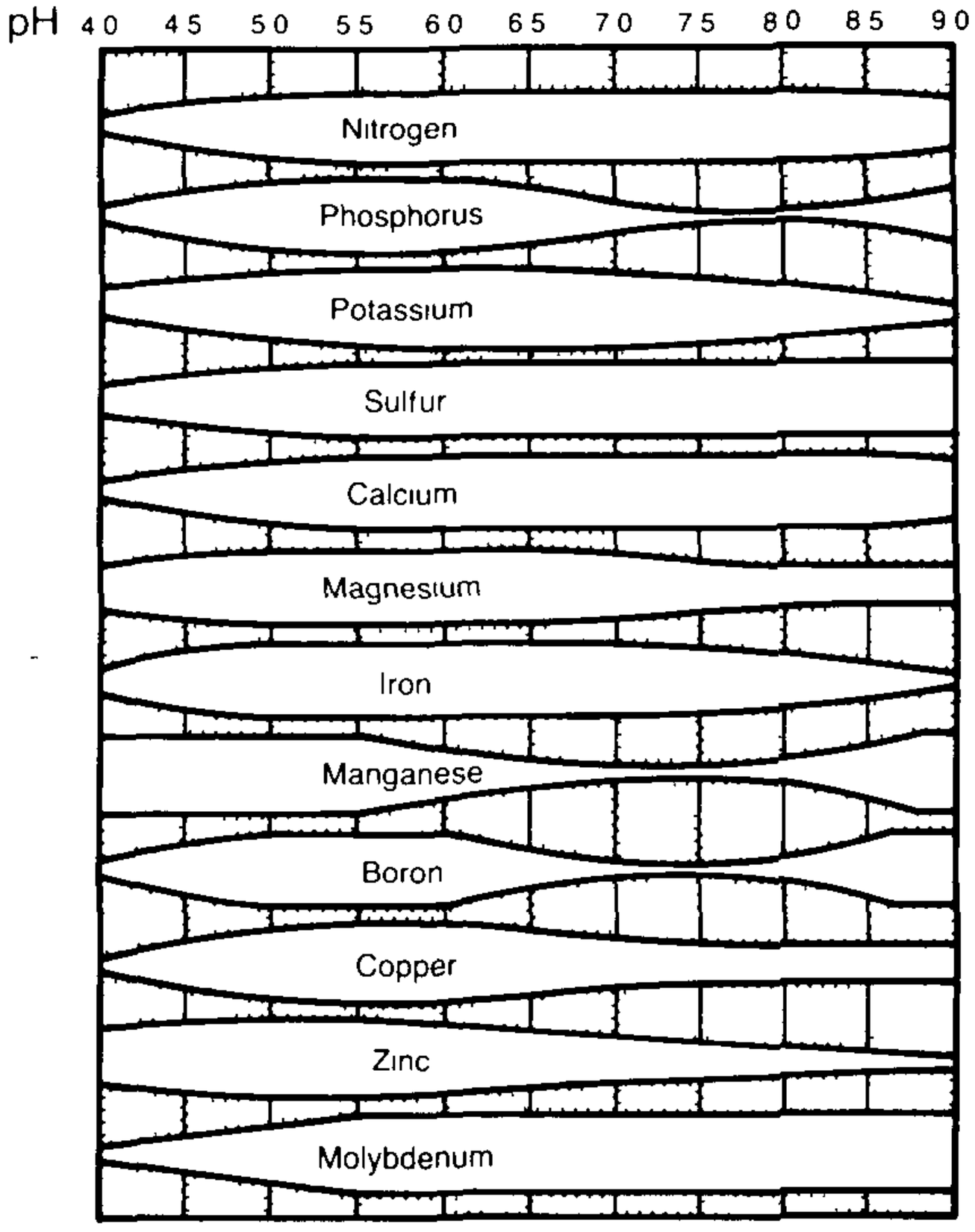

Figure 1. The availability to plants of nutrient elements in organic soils and in organic potting mixes varies with pH in the manner shown here The wider the bar, the greater the availability (Used by permission from, *Growing Media for Ornamental Plants and Turf*, by Handreck and Black)

I find a great deal of confusion about what is meant by the air-filled porosity of a container mix. Growers are not conducting aeration tests at the time they put the mix into the pots, and they do not know their aeration after the roots have grown into the mix. In addition, I think that it is important to know air-filled porosity as the crop grows. An excellent simple technique, as given in this book, for determining the air-filled porosity of a container mix is as follows:

1) Select a milk carton of a suitable height Cut the fold-over top off, or open it out if the entire height is needed Mark the required height of mix on the inside
2) Cut four holes in its base in positions such that you can close them with four fingers while holding the carton vertical with two hands The holes should be about 1 cm in diameter, or as big as your fingers will allow

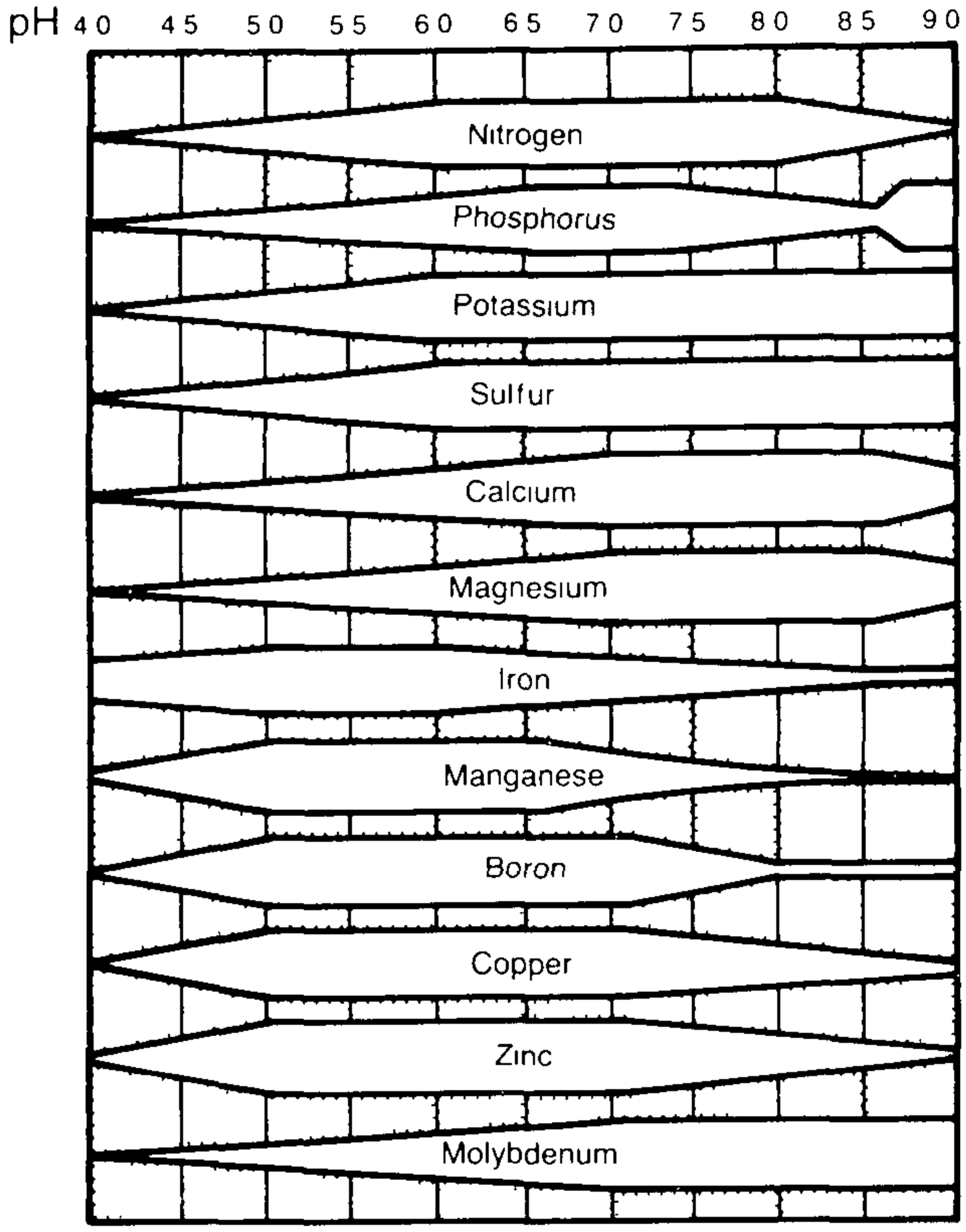

Figure 2. The availability to plants of nutrient elements varies with pH in this manner in mineral soils (Used by permission from, *Growing Media for Ornamental Plants and Turf*, by Handreck and Black).

3) Fill moistened mix into the carton in your usual way, or as near to it as is possible Ideally, the mix should have been moist for a week or more so that all particles have had time to become wet right through
4) Stand the carton on a bench where it can be watered from overhead a few times each day for several days The aim is to gently compact the mix as would happen in normal practice If necessary, top up the mix to the mark.
5) Gently lower the carton of mix into water in a large (9 l) bucket The height of water should be just a few millimetres below the top of the mix Have the water low at the start and pour more into the bucket as needed. Make sure that the mix does not float up Then carefully remove the carton from the water by slowly raising it vertically. Allow to drain, then lower into water again Repeat twice This further settles mix

6) Allow to stand overnight or longer in the water.

7) Reach down through the water and work your fingers underneath the carton until they seal the holes. Just before final sealing, make sure that the mix is saturated *just* to its surface.

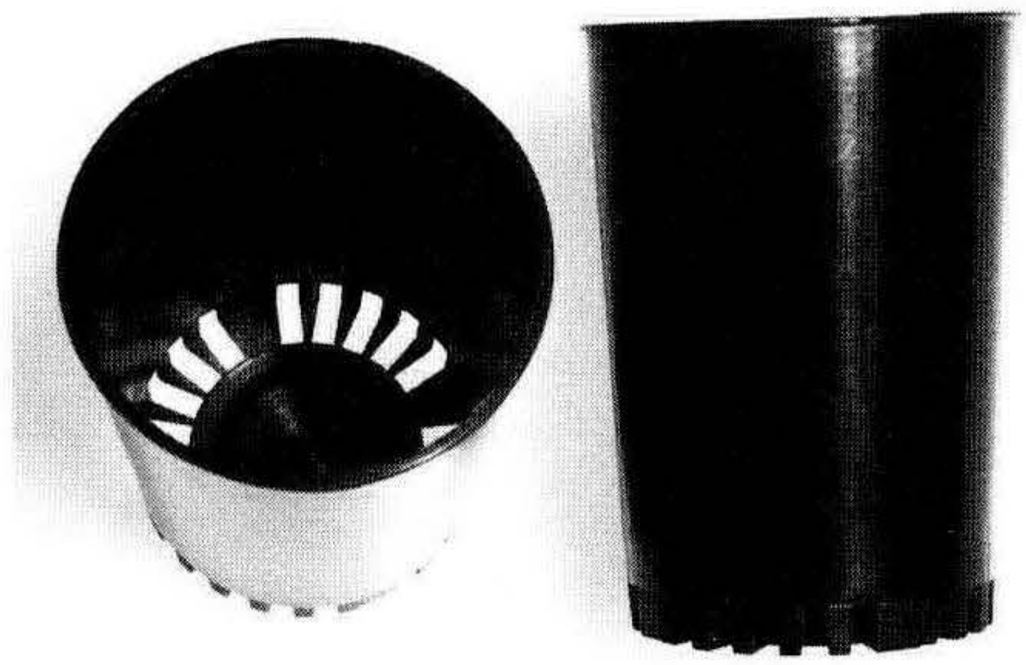

Figure 3. A tall and thin pot with good drainage.

8) Raise the carton from the water. Allow water to drain from the outside.

9) Place the carton on blocks in another bucket. Remove your fingers. Make sure that the holes can drain freely. Allow water to drain from the carton. The base of the carton must be horizontal (any tilting or squeezing will allow more water to drain out, so giving a high reading of air-filled porosity).

10) Cover the bucket with a sheet of plastic to prevent loss of water by evaporation. Drainage could be finished in 10 minutes or it could take several hours. The water draining from the mix is replaced by air. The volume of air that enters is the same as the volume of water that has drained into the bucket.

11) After drainage has stopped, remove the carton from the bucket, without tilting. Measure the volume of water in the bucket, or weigh it (1 ml water weighs 1 g).

12) Calculate or measure the volume of carton occupied by the mix.

13) Calculate the air-filled porosity of the mix with the formula:

$$\text{Air-filled porosity} = \frac{\text{volume of water drained (ml)}}{\text{volume of mix (ml)}} \times 100 \text{ (volume \%)}$$

Example: 120 ml of water drained from 600 ml of mix

$$\text{Air-filled porosity} = \frac{120}{600} \times 100 = 20 \text{ volume \%}$$

That is, 20% of the volume of the mix was air immediately after it had stopped draining.

One thing that came as a bit of a shock to me a few years ago, and which is discussed in the book, is the difference in suppressiveness to pathogens, such as *Rhizoctonia*, of different growing media. Peat moss has no ability to suppress *Rhizoctonia*, whereas composted bark aged for 11 weeks, has a high degree of suppressiveness. The suppressiveness is partly destroyed when the compost is reheated to 60°C for 5 days. If

you want minimal disease in containers have, as part of the medium, well-matured compost.

These are just a few highlights about the book. I would like to present a copy to the President of the Eastern Region, Len Stoltz, and wish you the best of luck with your 1984 program. I would also like to invite you to come down to Australia and share with us.

BENCH GRAFTING OF TREES UNDER POLYTHENE

JOHN B. GAGGINI

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Mears Ashby
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England

Bench grafting of trees under polythene offers the propagator a number of advantages. These include:

1) Fills the labour trough during the winter period.

2) Reduces the time span from the rootstock phase to obtaining a saleable tree (one year faster than budding),

3) Allows the grafting operation to be done under cover without the need for working outside.

METHODS AND MATERIALS

A whip-and-tongue graft, using dormant wood, from January to the end of April is used. The graft is held together with a 200 × 25 × 2 mm biodegradable, natural-rubber tie, except on some fast-swelling, slow to callus types, such as *Acer platanoides* 'Drummondii' or 'Crimson King'. In the latter case, a clear polyethylene tape is used.

Rootstocks are generally bareroot and of the appropriate thickness to match the scion material. After grafting, the finished graft is potted into a 2 litre container and placed on a capillary sand bed in an unheated polyethylene structure. Grafts are initially well watered then only watered sparingly thereafter. Callusing of the union commences in 2 to 3 weeks but is dependent upon the weather and the difficulty of the subject.

The longer and stronger the sunlight before permanent callusing of the graft union, the quicker the tie degrades. It may become necessary to retie a small percentage of grafts. Obviously, this may be a much more important consideration under the higher intensity sunlight areas of the USA.

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Well-graded, good quality rootstocks are essential and, where possible, virus-free vegetatively-propagated rootstocks are used. Vegetatively propagated understocks used include: *Malus* 'Malling Merton 106' for *Malus* cultivars; 'Colt', a *Prunus pseudocerasus* hybrid, for Japanese flowering cherries; and 'St. Julian A' for *Prunus* 'Trailblazer' and *P. cerasifera* 'Nigra'. For other ornamental trees well-grown seedling rootstocks are used. These include: *Acer platanoides* for *A. platanoides* 'Crimson King'; *A. pseudoplatanus* for *A. pseudoplatanus* 'Brilliantissium'; *Robinia pseudoacacia* for R. *pseudoacacia* 'Frisia'; *Crataegus monogyna* for *C. monogyna* 'Paul's Scarlet'; *Tilia cordata* for *T. euchlora*, and so on.

RESULTS

By the end of May, the trees are over one metre in height and are tied to a 1.3 metre cane. The trees are then moved from June onwards outside onto a capillary sand bed. This system produces a graded container-grown whip which can then be potted directly into a 10 litre container, or left until winter when it can be protted as a dormant tree. A 2.2 metre high *Prunus* 'Cheals Weeping' can be obtained by this method with a reasonable stem caliper in 6 months. Potting-on is easy and straight forward and I am sure this method is more economical than field-grown tree production in the United Kingdom.

Economics of bench grafting trees within the United Kingdom:

Material Costs		
Rootstock	30p	
Rigid pot	5p	
Compost	5p	
Cane	2p	
Scion	5p	
		47p
Labour Costs		
Grafting	6p	
Potting	6p	
Aftercare	18p	
		30p
Other Costs		
Water	2p	
Management	20p	
Overhead contribution	10p	
		32p
Subtotal Cost		£1 09
Allow for 15% failure		16p
Total Cost		£1 25

These figures are only approximate and may vary from year to year and from species to species and certainly from nursery to nursery.