ORNAMENTAL SHRUBS:
DEVELOPING THE CONCEPT OF THE ‘DESIGNER LINER’

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HRI-EAST MALLING

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CONTENTS

PRACTICAL SECTION FOR GROWERS

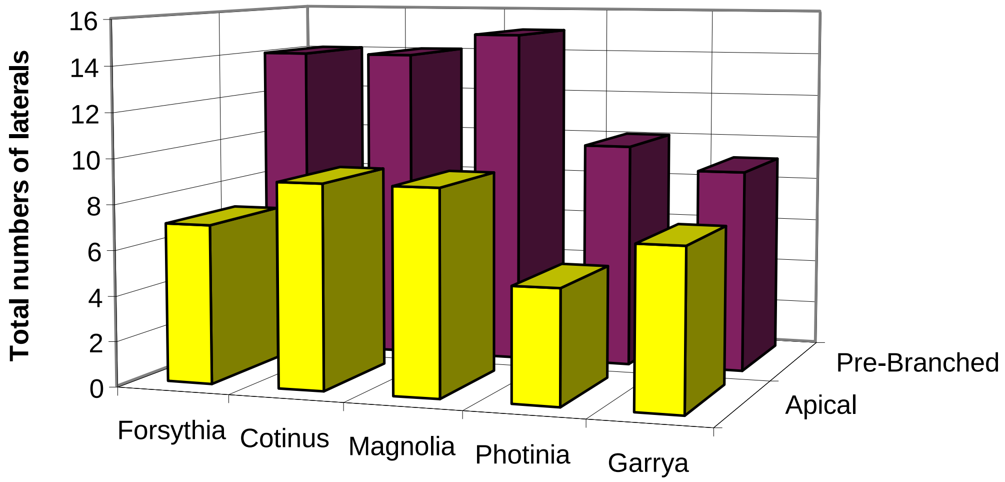
This project aimed to identify innovative techniques for liner production, to help meet the demands for high quality finished plants, combined with faster production. Rather than seeing production as a series of discrete steps, each one in isolation from the others (e.g. stockplant pruning, harvesting of cuttings, rooting, pinching and pruning), the concept here is to integrate consecutive steps to meet the final goal of a well-branched, large liner. Therefore, the principle of the 'designer liner' is to establish the requirements for shape and size at the start, and to refine production techniques to achieve the goals efficiently and effectively. By progressing towards several objectives in the early stages, the process can be shortened, and specifications can be met sooner, keeping labour inputs to a minimum.

A number of key factors were investigated in the project; these included: effects due to stockplant pruning, pre-branching techniques, size and spacing of cuttings, rooting environment, pot size, fertiliser application at the rooting and establishment stages and pruning and pinching treatments after rooting. A small number of HONS species were used throughout the project to represent models of different plant types. The evaluation of pre-branched cuttings was based on the view that well-established mother plants have more resources than recently-rooted cuttings to develop and support new laterals.

For many of the species tested, the use of pre-branched cuttings proved highly beneficial in the production of a finished quality liner more quickly. This was particularly so if nutrition was applied early, or subsequent timely pruning was implemented. From a comparison of optimum treatments for liners, derived from apical and pre-branched cuttings, the pre-branching technique was found to be clearly advantageous (Figure 1). In some of the treatments, rooting a large pre-branched cutting resulted in the formation of an almost 'instant' liner, ready for potting into a 2 or 3 litre container as soon as it had been weaned. Larger cuttings were no more difficult or slow to root (providing they were placed in a supportive environment), and indeed rooting in some species, e.g. *Cotinus*, occurred faster when there were a number of actively growing shoots present on the cutting.

The ability to form pre-branched cuttings on hedges varied with species, and the system was not conducive for *Syringa*. The optimum environment for rooted pre-branched cuttings also varied with species. A high humidity fog system was necessary to support cuttings of relatively difficult-to-root species such as *Cotinus* and *Magnolia* but, in contrast, very large (20-25 cm high) pre-branched cuttings of *Forsythia* and *Weigela* rooted readily under a lower humidity mist. Best results were generally associated with direct sticking cuttings into 9cm or 1 litre pots, although again it was feasible to produce the easier subjects in modular trays. The advantage associated with pots appeared to relate to keeping the cuttings stable during propagation rather than a requirement for more space *per se*. For example, results with *Cotinus* suggest that spacing during propagation and overwintering had little impact on subsequent growth, and pre-branched cuttings could be produced at the same spacing as direct stuck conventional cuttings.

Figure 1. The influence of original type of cutting on numbers of total laterals produced per plant, approximately 12 months after propagation. Data represent optimum treatments for each species and type of cutting derived over the course of the project.



Although the most impressive results were often associated with pre-branched cuttings, quality liners could also be obtained from conventional apical cuttings, by optimising other factors. Nurserymen may promote faster development of liners by enhancing the nutrient status within cuttings as early as possible; for example, the addition of nutrition to *Magnolia* cuttings early in the production cycle enhanced growth and lateral formation. This was the case even in apical cuttings which were exposed to higher fertiliser rates and which were not pruned or treated in any other manner. In a number of cases when plants were being propagated by conventional apical cuttings, it was found that a single pruning treatment implemented shortly after budbreak in the second year was as effective, or more so, than earlier pruning or pinching. Good plant size and shape were obtained in *Magnolia* and *Photinia* by single pruning treatments in March, following budbreak. The identification of an appropriate 'pruning time' for optimal plant response may save nurserymen time and effort by avoiding the need for earlier/ later or repeat pruning treatments.

Action points

- The use of pre-branched cuttings is an effective technique to improve the quality of liners and / or reduce the production cycle. The technique may be particularly useful for reducing production time in species e.g. *Magnolia*, *Cotinus*, for which lateral formation is slow or inconsistent in response to conventional pruning treatments.

- Even with apical cuttings, the use of larger than normal cuttings can speed up production and produce a final plant more quickly. This may be useful especially in those species that have relatively slow growth rates. In some species, however, the use of very large apical, single-stemmed cuttings may result in liners with limited branching near the base.

- When using large or pre-branched cuttings, a supportive rooting environment is essential for the more difficult subjects to ensure that cuttings do not suffer water stress.

- The optimum pruning times should be identified for key species. A single pruning treatment often can be as effective in inducing laterals as repeat pruning or pinching at a non-optimum period.

- In *Magnolia*, well-branched, evenly shaped plants could be obtained by implementing a single light pruning on apical cuttings in March, shortly after budbreak.

- In *Photinia*, results to date suggest that good quality plants can be obtained by pre-branching methods, or by a single, timely pruning treatment in spring.

- Provision of additional nutrition early on in the production process appears advantageous in some species, e.g. *Forsythia* and *Magnolia*. Nurserymen should note, however, that any excessively ‘soft’ growth induced by higher fertiliser rates will be particularly susceptible to cold damage and fungal infection, and appropriate protection measures may need to be applied.

- For a number of relatively ‘difficult-to-root’ species, e.g. *Garrya*, rooting percentages increased in treatments that involved the hard pruning of stockplants prior to taking cuttings.

- Uniform budbreak down the stem was improved by maximising winter chilling (but avoiding freezing) in *Syringa*. This species may benefit from cold storage treatment to activate axillary bud development.

- Where space is available, pre-branched cuttings should be direct stuck into 9 cm or larger containers. This is especially so for more difficult or slow rooting cultivars.

- In easy-to-root subjects, however, cuttings can be rooted in modular trays, provided the cell is deep enough to ensure adequate support for the cutting.

SCIENCE SECTION

INTRODUCTION

Retail specifications for HONS have become increasingly demanding in recent years, with strong emphasis now being placed on appropriate plant shape, size, uniformity and delivery date. Therefore, to guarantee sales, nurserymen have needed to focus attention on maximising plant quality during production, and to develop their schedules to provide a consistent product to the highest possible standard. In parallel, however, costs of production have increased, while competition has held down prices so that nurserymen are now under greater pressure to reduce the time between propagation and sale.

The aim of this project therefore, was to identify possible mechanisms that could improve the speed and efficiency of liner production, but at the same time ensure that plant quality was not compromised. Previous work (e.g. Harrison-Murray, Howard and Knight, 1996) has shown that even relatively small constraints placed on cuttings during the early stages of propagation can have large, long-term effects on factors such as rate of liner growth and plant morphology. Therefore, an objective of the research was to identify the possible constraints and, by taking appropriate action, minimise their effects. By adopting the doctrine of 'damage limitation' and reducing the number of checks in the production process, accurate comparisons could then be made between traditional and new production techniques in terms of production efficiency and final quality.

The philosophy behind the project is essentially to see liner production as a single event, rather than a number of discrete stages viewed in isolation. As such, opportunities are sought for enhancing final plant quality by manipulating growth and improving lateral formation at the earliest stages of production, e.g. even while shoots are still on the stockplant or at the preparation stage of cuttings. Subsequent stages are then aimed at maintaining and enhancing this quality, whilst maximising speed of development.

The scientific objectives were to investigate key processes in the production of containerised plants from stockplant through to liner, and determine how these processes or stages interact to control bud development, whilst encouraging the formation of a well-established root system. The research builds on previous work which has demonstrated the importance of stockplant growth and management in determining cutting quality (Howard, 1996; Howard and Cameron, 1996; Howard, 1992), as well as the influence of the propagation environment in expressing rooting potential (Howard and Harrison-Murray, 1995; Harrison-Murray, Howard and Knight, 1996). Current MAFF research, aimed at improving the degree and speed of rooting, is also being utilised to optimise cutting management for liner production (Cameron *et al.*, 1998).

This report covers all three years of the project, and pulls together results from consecutive growing seasons (See also Cameron and Harrison-Murray, 1997 and 1998). Rather than producing blueprints for a limited number of HONS subjects, the research highlights the important principles involved in the propagation and management of cuttings or young plants. Nurserymen can assess the findings and then determine the most appropriate techniques to adopt for their own particular crops and production systems.

MATERIALS AND METHODS (GENERAL)

Plant species and cultivars

A range of model species were chosen to reflect variations in growth habit, and encompass species where achieving a consistent quality liner through conventional techniques can prove problematic or time consuming.
The main species investigated were:

Magnolia x *soulangeana*,
Photinia x *fraseri* cv. Red Robin,
Forsythia x *intermedia* cv. Lynwood,
Garrya elliptica cv. James Roof,
Syringa vulgaris cv. Charles Joly,
Cotinus coggygria cv. Royal Purple

In addition, during the last year of the project, smaller scale experiments were carried out using *Viburnum tinus* cv. French White, *Weigela florida* cv. Variegata, *Hebe* cv. White Gem, *Cistus* cv. Silver Pink, *Potentilla* cv. Tangerine and *Cornus alba* cv. Spaethii.

Stockplant management

Cuttings were obtained, with the exception of *Photinia*, from well-established, field grown stockplants. These stockplants were grown in a designated area, with grassed alleyways between the hedges. *Photinia* stockplants were maintained in 10 litre containers that could be moved under protection for early forcing. The growing medium for the *Photinia* consisted of 60% peat, 20% bark, 10% loam and 10% grit v/v (with 4 g l^{-1} calcium carbonate, 2 g l^{-1} magnesium limestone, 0.15 g l^{-1} Nitram and 4 g l^{-1} Osmocote Plus {15N:9P:11K:2Mg, v/v, plus trace elements}). Annual winter pruning (carried out in January) generally reflected the vigour of growth of each species - vigorous species being pruned more severely. The following represent the normal winter pruning regimes applied to each species during the project:

Severe Pruning = Removing previous year's growth and cutting back into mature wood, e.g. *Forsythia*, *Weigela*, *Cornus (Garrya).*

Hard pruning = Reducing previous year's growth to two basal nodes and removing any weak shoots, e.g. *Photinia, Syringa, Cotinus, Garrya.*

Light Pruning = Reducing previous year's growth by less than 50% and maintaining viable buds on each shoot, e.g. *Magnolia, Viburnum (Garrya).*

No Pruning, e.g. *Hebe, Cistus, Potentilla*.

For experimental purposes, standard winter pruning regimes were sometimes altered and the details of these are covered in the experimental section.

Preparation and propagation of cuttings

Collection and preparation of cuttings followed a standard procedure throughout. Cuttings were collected from hedges between 8.00 - 10.00 am and placed in plastic 'bread' trays, then covered with damp hessian sacking to avoid water stress during transit from the field. Preparation of cuttings took place in a cool environment, with the atmosphere of the room kept moist using a humidifier (AG505, Defensor, Zurich). All cuttings were trimmed just below a node at the base and treated with 1,250 ppm indole-3-butyric acid (IBA) for 5 seconds and then stuck into either modules (80 cm^3), 9 cm or 1 litre pots, depending on experimental protocols. Rooting media consisted of 50:50 v/v peat, fine bark with generally 1 g 1^{-1} Ficote 180, (14N:8P:8K v/v/v: plus trace elements) controlled release fertiliser (CRF) incorporated. In some experiments, however, fertiliser was not added, depending on the experimental objectives (see below).

Cuttings were placed in one of the following environments to root:

Ventilated wet fog system ('Agritech' fog). This system comprised an Agritech fogger placed at one end of a polythene tunnel, linked to an extraction fan at the opposite end. The extraction fan was used to avoid excessive temperature lift in the tunnel. In this environment, a gradient of fog is created down the length of a tunnel, resulting in 'dry', 'moderate' or 'wet' zones. This allows cuttings of different species to be placed in the most appropriate environment for root initiation. Fog application was controlled using an Evaporation Sensor (Harrison-Murray 1993, HDC project HO 9) linked to the fogger. Typical humidity in this environment was between 98-100% r.h. Basal heat was maintained at a minimum of 20^{o}C through electric cables placed under the sandbeds.

Side ventilated mist ('Mist'). A bank of mist nozzles was placed over a free draining sand bed, and the bed enclosed with polythene sides and roof. Ventilation was provided by leaving 3-4 gaps per bed between the side and roof. Each gap being approximately 15 x 10 cm wide. Mist application was controlled again by an evaporation sensor set to activate mist when relative humidity dropped below 95%. Typical recorded humidity was between 94-98% in this environment. Sandbed temperatures were set at 20^{o}C.

During propagation, cuttings were sprayed at weekly intervals with either prochloraz - Octave (AgrEvo) or dichlofluanid - Elvaron WG (Bayer) to avoid fungal infection. After root formation, and proliferation through the substrate was evident (usually between 3-6 weeks depending on species or environment), cuttings were transferred to an enclosed polythene tent and weaned-off over a further week, by progressively raising the sides of the tent.

Liner and container management

Rooted cuttings and young liners were overwintered in a well-ventilated polythene tunnel, on sand beds with basal temperature maintained at greater than 2^{o}C. Plants were potted into 2 litre pots to grow on during the following winter or spring.

To improve the stability of plants in the final pot, a growing medium with a relatively high proportion of grit and loam was used. This comprised 60% peat, 20% bark, 10% loam and 10% grit v/v (with 4 g l^{-1} calcium carbonate, 2 g l^{-1} magnesium limestone, 0.15 g l^{-1} Nitram and 4 g l^{-1} Osmocote Plus, 12-14 month, {15N:9P:11K:2Mg, v/v, plus trace elements}). However, *Magnolia* and *Photinia* performed better in a more 'open' medium and a 70:30 v/v peat, Cambark 100 mix was used for these. Ficote controlled release fertiliser was used in this medium (usually either Ficote 180, 16N:10P:10K, with additional 0.3 g l^{-1} fritted trace elements WM 225 and 1.5 g l^{-1} magnesium carbonate added, or alternatively Ficote 180, 14N:8P:8K plus T.E.). Rates of fertiliser were generally standardised on 4 g l^{-1} Ficote, but in some experiments precise rates varied with the experimental protocol.

Growth assessments and statistical analyses

Assessments of growth and quality were generally based on:
1. Overall growth = combined lengths of main stems and laterals.
2. Plant height = height from uppermost apical tip to the growing medium surface.
3. Total lateral number = number of laterals (> 1 cm in length).
4. Large laterals = number of longer, quality laterals over a given length (usually 10 cm but varied with vigour of species). These laterals generally determine the plant stature and balance.
5. Basal laterals = number of laterals in the basal third of the plant. This is an arbitrary measurement generally reflecting the bushiness of the subject and is based on industry-relevant specifications.
6. Laterals in the basal 10 cm - a more objective measurement of lateral formation at the base, allowing accurate comparisons between plants of varying sizes.

Analysis of variance was used to determine the statistical significance of differences between treatments. The results of statistical analyses were expressed in terms of the least significant difference (LSD) at the 5 % level. This LSD indicates the size of difference between individual treatment means required to give a 95% probability that the effects are not due to chance.

In some figure and tables, where data have been summarised from a number of separate experiments and direct statistical comparisons are not valid, LSD values have been omitted.

EXPERIMENTAL OBJECTIVES AND RESULTS

‘Pre-branched’ cuttings - Overview of cutting production and rooting

Aim: To determine if pinching-back growing shoots on stockplants could induce sub-laterals to form and allow the subsequent collection of multi-branched cuttings. To compare quality and speed of liner formation with that of production using conventional single-stemmed cuttings.

The principle behind the use of pre-branched cuttings is that well-established mother plants have greater resources available to help support new lateral formation, compared to that of recently-rooted cuttings. In addition, regularly pruned mature stockplants have limited apical dominance, and pinching back shoot tips tends to result in a number of relatively uniform side shoots. This is not necessarily the case in a single stemmed cutting, where often only the subapical bud is activated into growth after removal of the terminal bud. The consequence of this is that, in some species, single-stemmed cuttings may need to be pruned frequently during the first year of production to promote side-branching.

The techniques that were used to generate pre-branched cuttings varied with the vigour of shoot growth in different species. In fast-growing subjects (*Cotinus*, *Photinia*, *Forsythia*, *Garrya*), actively growing shoots were lightly-tipped with secateurs when shoots had expanded between 10-20 cm (precise timing and hence length of shoot could be varied to get larger or smaller cuttings as required). Tipping involved the removal of the apical bud, together with 5-10 cm of the shoot tip. Sub-lateral formation on the tipped shoots was apparent after 14 days, and collection of cuttings could take place after a further 10-14 days. Cuttings were collected by excising the shoot at a couple of nodes below the position of the lowest sub-lateral. In many species, it was only necessary to begin the stimulation of side-shoots (i.e. they may be only 1-2 cm long) before collection, because they continued to expand in the warm propagation environments. Approximately 40 shoots per minute could be tipped using secateurs, and the number of cuttings harvested subsequently from fast growing species was comparable to conventional apical cuttings.

Slow-growing species often formed pre-branched cuttings without any formative pruning and pre-branched cuttings were obtained by excising the cutting at a node in the semi-mature wood. This was the case for plants such as *Viburnum, Potentilla*, *Hebe* and in some instances *Magnolia*. For *Magnolia* in 1997, a late spring frost damaged the apical shoots, which resulted in a wide-spread activation of lateral shoots. Therefore, semi-lignified one-year-old wood was used as the source of the cuttings, and these were often complete with three or more new laterals attached. Detailed data were not collected on the total number of cuttings per season but, in contrast to fast-growing subjects, it appeared that removing large, pre-branched cuttings in slow-growing species depressed overall productivity by approximately 20-40 % depending on species.

Species where the use of pre-branching was investigated included: *Forsythia*, *Cotinus*, *Magnolia*, *Garrya*, *Syringa*, *Photinia*, *Potentilla, Weigela, Viburnum*, *Hebe, Cistus* and *Cornus*.

In some species, the effect of de-tipping the new laterals before propagation was investigated to determine how this affected rooting and subsequent further branching. Likewise, the influence of pruning treatments after rooting on final plant quality were also examined in key model species.

Results

The feasibility of using pre-branching techniques tended to vary with species. In *Syringa*, where there is a very short growing season, attempts to pinch active shoots resulted in termination of growth without any lateral development. In contrast, tipping was very successful in *Cotinus*, *Photinia*, *Weigela* and *Magnolia* (using two-year-old wood as the cutting base) and moderately successful for *Forsythia* in generating pre-branched cuttings (Table 1 summarises the responses of different species over the course of the project). Choice of species and propagation environment could strongly influence rooting ability. For the majority of ‘easy-to-root’ species tested, pre-branched cuttings could be successfully rooted under mist. In contrast, in more difficult subjects, a good humid propagation environment (in this project the Agritech fog) was essential to maintain water status within the cuttings, and allow them to root rapidly and effectively (Table 2). The container used for propagation could also be important; and in some species such as *Cotinus*, placing pre-branched cuttings into module trays resulted in poor stability and reduced rooting compared to sticking in larger containers (Table 2). Interestingly, this was also the case with apical cuttings of this species. In contrast, very large pre-branched cuttings of *Forsythia* and *Weigela* (20-25 cm high) could be rooted without difficulty in modular trays, as long as the growing medium was pressed around the base of the cutting to ensure stability. In fact, the use of such large cuttings in the confined space of the tray also could result in cuttings supporting one another.

De-tipping the newly formed laterals prior to propagation gave contradictory results in terms of rooting. Removing the young shoot tips and associated foliage is likely to have reduced the transpiration demand on the cutting, and possibly avoided excessive stress from water loss (e.g. cuttings of *Cotinus* in modules - Table 2). However, the young shoot tip may be an important source of natural auxin that helps stimulate root formation in some species. Therefore, removal of such tips may also reduce rooting potential in some instances. In practical terms, whether removing shoot tips is advantagous or not will depend on rooting environment, species and the proportion of the shoot removed. In addition, the potential for the use of pre-branched cuttings may be influenced by factors such as the original size of cutting, or the severity of winter stockplant pruning. In *Garrya*, rooting was generally lower with pre-branched cuttings compared to apical cuttings, but reduced rooting could be offset, to some extent, by harder initial stockplant pruning, and selecting cuttings of an appropriate size, i.e., by avoiding excessively large or small cuttings (Table 3).

Table 1. Summary of pre-branching techniques, effects on rooting and potential application.

Species	Pre-branching response	Rooting ability	Potential
Forsythia	Typically only 2-4 laterals form after tipping - requires re-tipping or later post-rooting pruning	Cuttings rooted readily in both fog and mist systems. Lends itself to rooting in modular trays	√ √ √
Cotinus	Excellent response. Potential for taking very large cuttings, with > 5-6 laterals	Good fog environment needed. Poor stability of cuttings in modules	√ √ √ √ √
Magnolia	Pre-branching sometimes difficult on current wood - excise at 2 year wood and capacity for large cuttings	Humid fog environment best	√ √ √ √ √
Garrya	Limited response from tipping - only 2-4 laterals form.	Harder winter pruning appears beneficial to rooting. High humidity a requirement for rooting. Rooting rates can be less than equivalent apical cuttings	√ √
Syringa	No response from tipping - stops shoot growth completely	Pre-branching not suitable. Active shoot growth and high humid environment a requirement for rooting	X
Photinia	Capable of forming pre-branched cuttings with 3-4 laterals	Large cuttings do better in high humidity fog to minimise water loss	√ √ √ √
Potentilla	Use of natural pre-branched cuttings may reduce total numbers of cuttings available	Rooted relatively easily in modules under mist	√ √
Weigela	Large cuttings can almost result in the instant liner	Rooted readily	√ √ √ √
Viburnum	Pre-branched cuttings carry flower primordia	Rooted easily under mist, with even lateral development	√ √ √ √ √
Hebe	Slow to pre-branch	Rooted relatively easily in modules under mist	√ √ √
Cistus	Only naturally branched shoots used	Rooted relatively easily in modules under mist	√ √ √
Cornus	Limited ability to form laterals	Large cuttings rooted easily under mist	√ √

Key: X = Pre-branching not feasible
√ = Low potential, difficult to implement or limited practical benefits
√ √ √ √ √ = High potential. Ability to produce high quality liners in a minimal time period

Table 2. The influence of rooting environment, size of pot and type of cutting on mean rooting percentage in several species.

Species	Rooting Env.	Pot size	% Rooting		
			Apical	Pre-Br	Pre-Br De-Tip
Forsythia	Fog	1 litre	100	100	NA
	Fog	9 cm	100	100	NA
	Fog	mod.	100	100	NA
	Mist	mod.	100	100	NA
Cotinus	Fog	1 litre	90	98	100
	Fog	9 cm	92	100	NA
	Fog	mod.	40	50	83
	Mist	mod.	30	13	30
Magnolia	Fog	1 litre	100	100	100
	Fog	7 cm	100	87	83
	Mist	7 cm	77	71	43
Potentilla	Mist	mod.	NA	79	NA
Weigela	Fog	mod.	100	100	NA
	Mist	mod.	100	100	NA
Hebe	Mist	mod.	NA	80	NA
Cistus	Mist	mod.	NA	83	NA
Cornus	Mist	mod.	NA	79	NA

Key: NA = Not applied
Mod. = 80 cm^3 modular cell
Pre-Br = Pre-branched cutting
Pre-Br De-Tip = Pre-branched cutting with lateral shoot tips excised at propagation

Table 3. ***Garrya*** **- The effect of stockplant pruning, size and type of cuttings (Apical v Pre-branched) on mean rooting percentage. Data for 3 years.**

Year	Winter pruning	Cutting size	% Rooting	
			Apical	Pre-Br
1996	Light	Large	100	60
		Medium	100	77
		Small	87	63
	Severe	Large	87	77
		Medium	NA	93
		Small	NA	80
1997	Hard	Medium	100	95
	Non-pruned	Medium	NA	38
1998	Hard	Large	86	50
		Small	96	86

Key: NA = Not applied

Factors affecting liner quality

The research investigated a number of factors that could influence liner and final plant quality. These included the use of pre-branched cuttings (where feasible), fertiliser application rates, the effects of original pot size on subsequent growth, and the influence of pot spacing, as well as responses due to later pruning regimes.

The use of Pre-branched cuttings

Aim: To determine any advantage associated with using pre-branched cuttings compared to conventional cuttings.

Comparisons were made over the three years of the project on the use of pre-branched cuttings in a small number of model plants.

Results

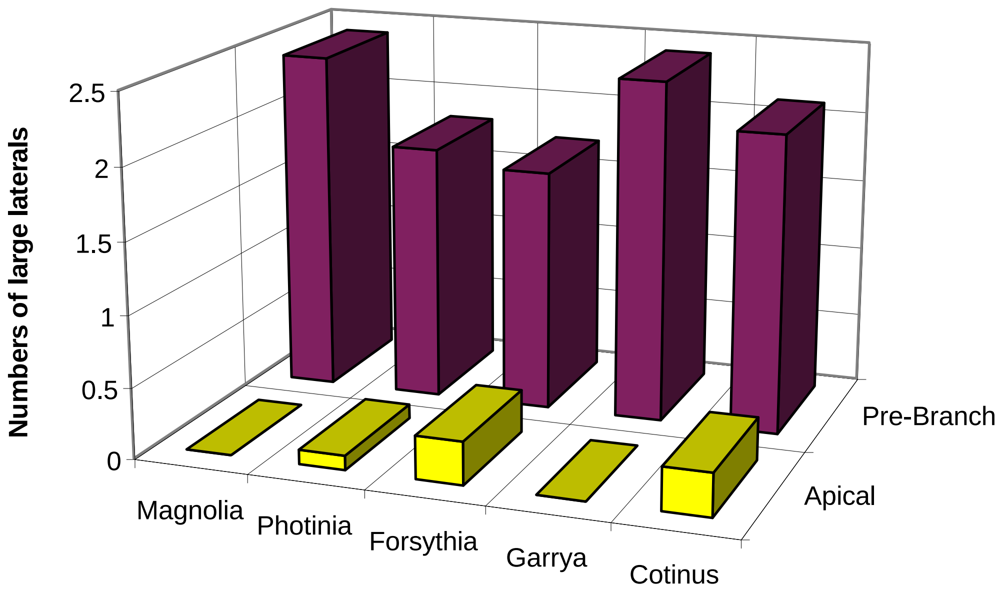
For the majority of species tested, pre-branching techniques were extremely useful in promoting a quality, branched liner in the minimum time period. Factors such as plant height, total shoot growth and total numbers of laterals including large formative laterals were often significantly greater in final plants derived from pre-branched cuttings than equivalent apical cuttings, e.g. in *Cotinus* (Table 4).

Table 4. *Cotinus* - Comparisons of mean values for plants derived from apical (Ap) and pre-branched cuttings (Pre-Br), 12 months after propagation.

Cutting type	Height (cm)	Total growth (cm)	Total laterals	Large laterals (>10cm)
Ap	65	160	7.2	3.9
Pre-Br	58	**244**	**19.1**	**7.2**
LSD	8.0	36.2	3.87	1.42

The use of pre-branched cuttings encouraged the development of large ‘formative’ laterals, which provided the basic structure of the liner within the initial year of production. These laterals often could be pruned the following spring to induce further side-laterals and enhance the bushy habit. Typical numbers of large laterals that could be produced for different species are shown in Figure 2.

Figure 2. Numbers of large laterals (> 10 cm) recorded in apical and pre-branched cuttings of different species during the winter following propagation (data pooled over three years).



Type of cutting and effects of pruning after rooting (*Cotinus*)

Aim: To compare the effects due to original type of cutting and subsequent pruning on growth and quality of liners.

Stockplants were hard pruned in winter and active new shoot growth was pinched in June 1996 to induce 'pre-branched' cuttings. These cuttings were harvested on 13 July. At the same time, non-pinched shoots were used as a source of conventional cuttings. Where possible, two cuttings were obtained from each shoot, to give an 'apical' (distal) and 'basal' (proximal) cutting. Lengths of cuttings were approximately 13 cm and 20 cm, respectively. Additional pruning was carried out in March 1997, by reducing laterals by two-thirds.

Experimental Summary:

Cuttings harvested:	July 1996
Cuttings direct stuck:	9 cm pots in Fog.
Cutting type:	**Apical** v **Basal** v **Pre-Branched**
Pruning treatment:	**Non-pruned** v **Pruned**

Results

Results from this experiment showed that growth and shape were of a surprisingly high quality in many of the plants derived from apical cuttings. This was in contrast with results from previous years with *Cotinus*. Nevertheless, plants that had undergone the pre-branching treatments remianed superior in terms of overall numbers and types of branches produced, more than a year after the propagation date (Table 5). Apical cuttings had the greatest number of primary (1^o) branches, but could produce a 'crowded' appearance to the crown of the plant. Also, these laterals tended to be very thin and weak, giving little structural support to the framework of the plant. The greatest numbers of secondary (2^o) and tertiary (3^o) laterals were associated with the pre-branched cuttings which had not been pruned (Table 5). These laterals were formed on the primary branches and gave the plants a more open, well-proportioned appearance at the final assessment.

Primary laterals on pre-branched plants were thicker and stronger than on other types of cuttings and branching tended to occur lower down the stem in this treatment. In contrast, the position of the lowest branch tended to be very high in the basal cuttings. Pruning the cuttings of all types in March 1997 resulted in fewer total laterals, but the quality of those laterals that were produced was high. Pruning tended to produce stronger, thicker main laterals and thus avoid plants from becoming 'top-heavy' with too many fine laterals.

Table 5. *Cotinus* - The effects of type of cutting and pruning treatments on mean growth parameters in September 1997 (14 months after propagation).

Type of cutting	Pruned (March 1997)	Height (cm)	Total growth (cm)	No. 1° laterals	No. 2° laterals	No. 3° laterals	Diam of 1° laterals (mm)	Length of bare stem at base (cm)
Apical	No	76	**324**	**8**	5	0	4.19	5.8
Basal	No	**88**	265	4	6	0	4.95	**9.3**
Pre-Branch	No	75	**355**	4	**16**	**5**	**6.48**	4.4
Apical	Yes	**88**	245	**7**	2	0	5.12	6.6
Basal	Yes	**91**	281	4	4	0	5.27	**9.6**
Pre-Branch	Yes	**85**	**308**	5	**9**	0	**5.63**	5.3
LSD		12.0	63.5	2.2	2.9	0.5	0.64	1.24

Type of cutting, pruning frequency and fertiliser application (*Magnolia*)

Aims: To investigate if additional pruning or fertiliser application can improve liner quality

Apical and pre-branched cuttings were collected from stockhedges on 1 July 1997. Apical cuttings were typically 12-15 cm long, with one or two fully unfolded leaves attached. In contrast, Pre-branched cuttings were considerably larger, being 20-30 cm in length, with two to three developing laterals and up to five fully-unfolded leaves present.

Pruning time was determined by rate of development. Pre-branched cuttings continued to grow in the propagation environment, and in some of these cuttings laterals were reduced by two-thirds. Pruning took place on 4 August 1997. Further light pruning (5-10 cm removed) was applied to cuttings of all types on 4 May 1998. Cuttings were originally directly stuck into media containing either 1 (low rate) or 2 g l^{-1} (high rate) Ficote 180 14:8:8 v/v T.E. To maintain a differential, these were further potted into 2 litre containers on 10 September using media with either 2 or 6 g l^{-1} of the same fertiliser, respectively.

Experimental Summary:

Cuttings harvested:	July 1997
Cuttings direct stuck:	9 cm pots in Fog.
Cutting type:	**Apical** v **Pre-Branched**
Pruning frequency / time:	**Non-pruned** v **Pruned x 1** (Px1) v **Pruned x 2** (Px2 - Pre-branched only)
Fertiliser application:	**Low** v **High**

Results

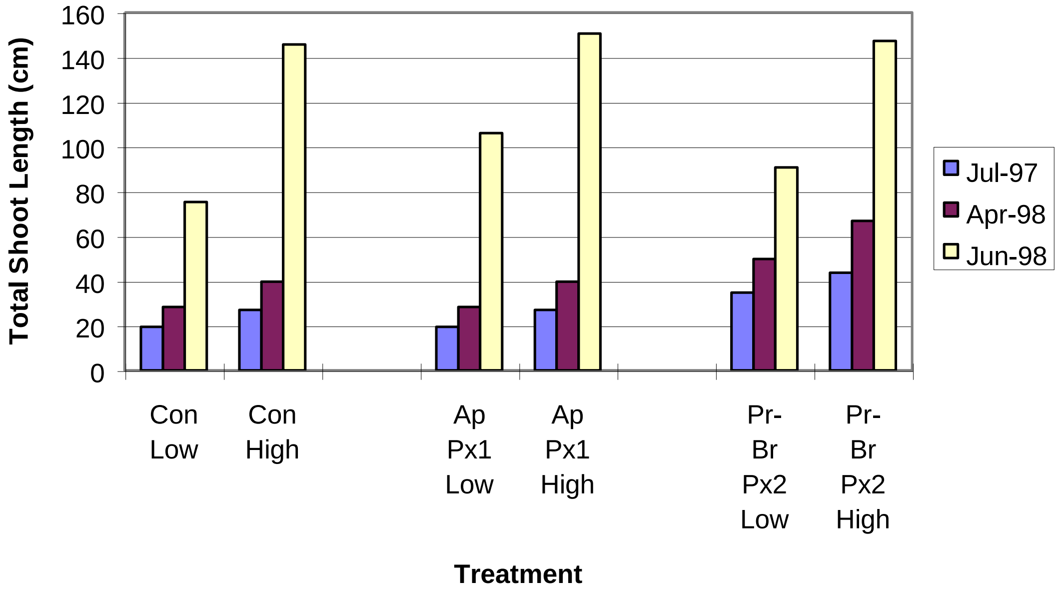
The type of cutting used, additional pruning and fertiliser rate all had significant effects on plant height, growth and lateral formation. The use of pre-branched cuttings resulted in larger plants than the equivalent apical cuttings (Table 6). Higher fertiliser rates also increased plant size, but had the additional effect of enhancing lateral formation in all treatments, especially the number of large laterals. The pruning treatments improved the numbers of laterals, with the best shaped plants being associated with pre-branched cuttings grown under the high fertiliser regime and pruned twice. This resulted in large uniform plants with good quality 'structural' laterals and a large number of 'breaks' near the base of the plant. Interestingly, a single pruning applied to the apical cuttings produced plants of a respectable quality, although the overall numbers of laterals and basal shoots were less than pre-branched equivalents.

The use of pre-branched cuttings combined with subsequent pruning generally accelerated development compared to other treatments, without sacrificing total growth (Figs 3, 4, and 5). The result of this was a large, well-branched, established plant in a 2 litre container within approximately 11-12 months of propagation (Figure 6).

Table 6. *Magnolia* - The effects of fertiliser rate, type of cutting and pruning treatments on mean growth parameters as measured in June 1998 (11 months after propagation).

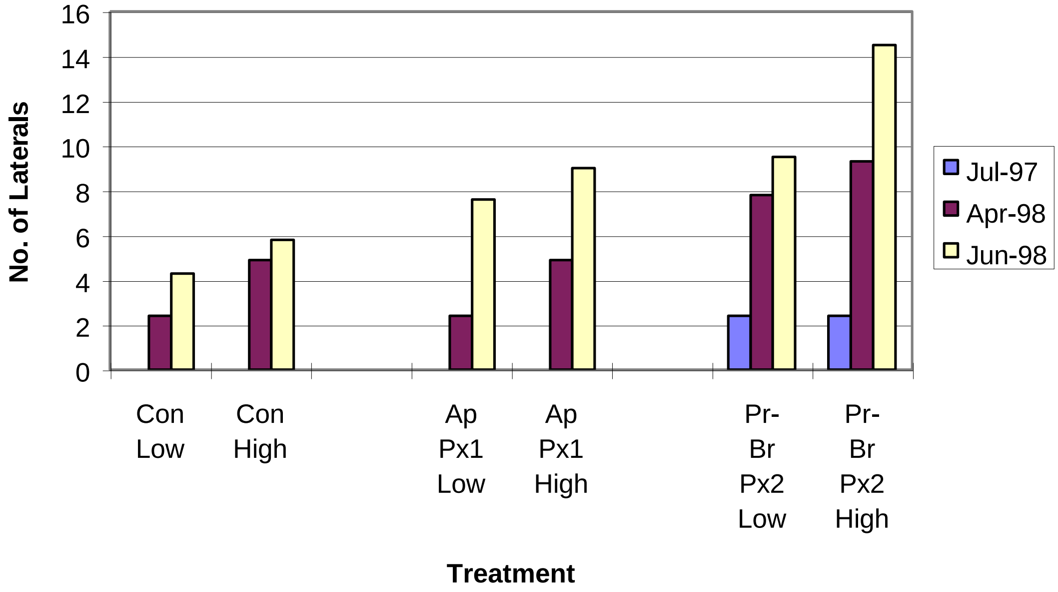
Fertiliser rate	Type of cutting	Pruned	Height (cm)	Total growth (cm)	Total laterals	Large laterals (>10cm)	Laterals in basal 10 cm
Low	Apical	No	54	75	4.3	0.8	1.8
		P x 1	37	107	6.7	3.3	1.5
	Pre-Br	No	60	150	5.4	3.4	**3.8**
		P x 1	54	142	6.8	**4.0**	**4.4**
		P x 2	33	91	9.5	2.7	3.2
High	Apical	No	**70**	146	5.8	**3.8**	1.7
		P x 1	45	151	9.0	**4.7**	1.7
	Pre-Br	No	**74**	**204**	7.8	**4.4**	2.4
		P x 1	**67**	**180**	7.4	**4.2**	**3.8**
		P x 2	35	147	**14.5**	**5.3**	**5.0**
LSD			7.4	31.8	2.03	1.60	1.30

Figure 3. ***Magnolia*** **- The effects of fertiliser rate, type of cutting and pruning treatments on total growth at different periods during the production schedule.**



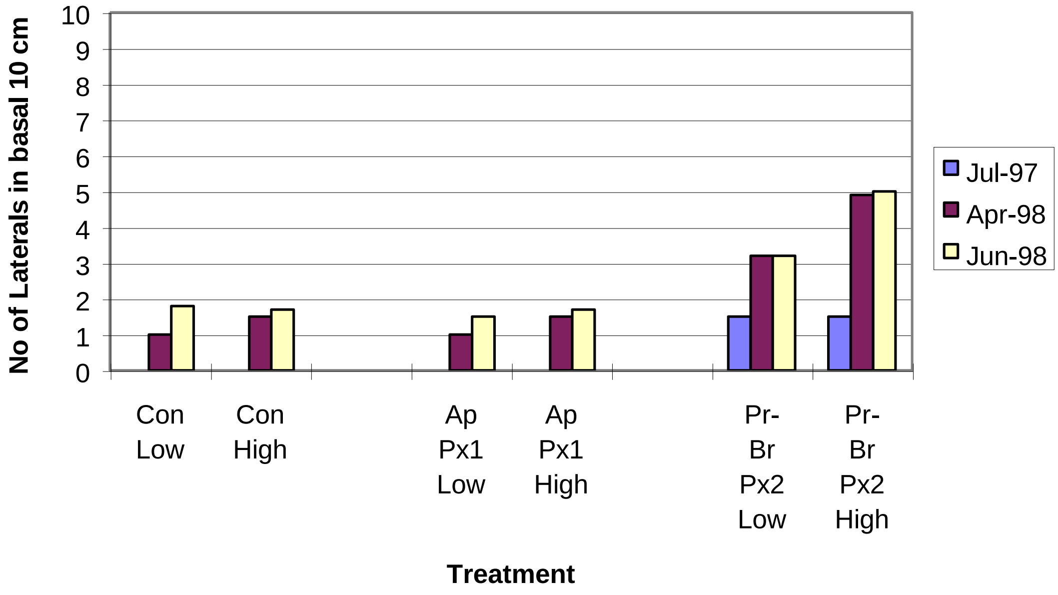
Key: Con = Control plants derived from non-pruned apical cuttings.
Ap P x 1 = Plants derived from apical cuttings and pruned once (May 1998).
Pr-Br P x 2 = Plants derived from pre-branched cuttings and pruned twice (August 1997 and May 1998).
Low = Plants grown under the low fertiliser regime (1-2 g l^{-1}, Ficote).
High = Plants grown under the high fertiliser regime (2-6 g l^{-1}, Ficote).
LSDs = Jul-97 = 6, Apr-98 = 8 and Jun-98 = 31.

Figure 4. ***Magnolia*** **- The effects of fertiliser rate, type of cutting and pruning treatments on total numbers of laterals at different periods during the production schedule.**



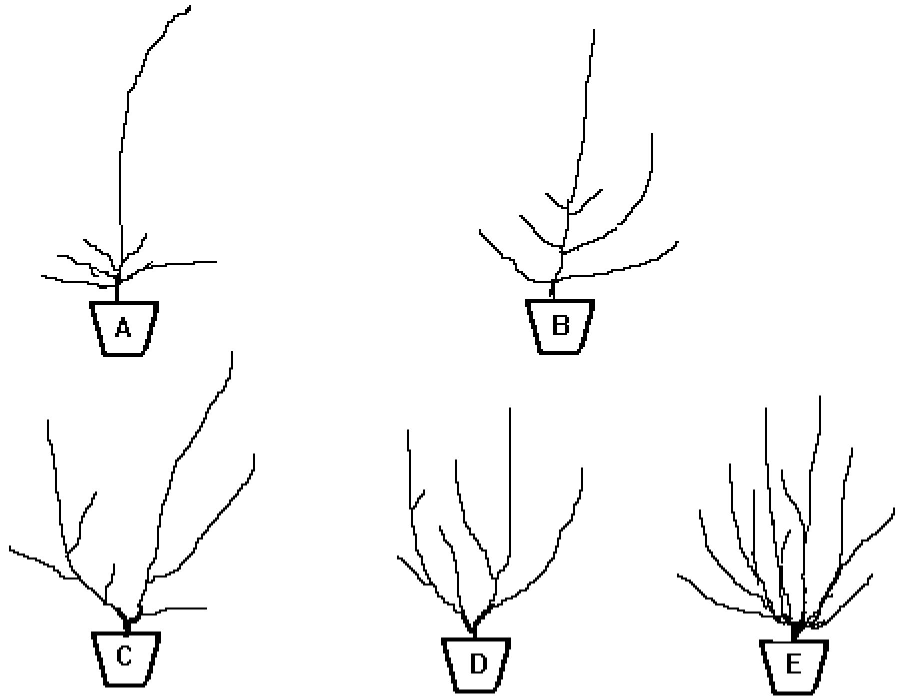
Key: Con = Control plants derived from non-pruned apical cuttings.
Ap P x 1 = Plants derived from apical cuttings and pruned once (May 1998).
Pr-Br P x 2 = Plants derived from pre-branched cuttings and pruned twice (August 1997 and May 1998).
Low = Plants grown under the low fertiliser regime (1-2 g l^{-1}, Ficote).
High = Plants grown under the high fertiliser regime (2-6 g l^{-1}, Ficote).
LSDs = Jul-97 = 0.7, Apr-98 = 1.2 and Jun-98 = 2.0.

Figure 5. ***Magnolia*** **- The effects of fertiliser rate, type of cutting and pruning treatments on numbers of laterals in the basal 10 cm, at different periods during the production schedule.**



Key: Con = Control plants derived from non-pruned apical cuttings.
Ap P x 1 = Plants derived from apical cuttings and pruned once (May 1998).
Pr-Br P x 2 = Plants derived from pre-branched cuttings and pruned twice (August 1997 and May 1998).
Low = Plants grown under the low fertiliser regime (1-2 g l^{-1}, Ficote).
High = Plants grown under the high fertiliser regime (2-6 g l^{-1}, Ficote).
LSDs = Jul-97 = 0.4, Apr-98 = 0.8 and Jun-98 = 1.3.

Figure 6. ***Magnolia*** **- Pictorial representation of plant habit and size at the container stage (11 months after propagation - 2 litre pots), as influenced by type of cutting and pruning treatments. All plants grown under the 'high' fertiliser regime.**



Key: Plants derived from -

A = Apical cuttings, non-pruned.
B = Apical cuttings, pruned once.
C = Pre-branched cuttings, non-pruned.
D = Pre-branched cuttings, pruned once.
E = Pre-branched cuttings, pruned twice.

De-tipping of Pre-branched cuttings and the effects of pot size on growth and quality (*Magnolia* and *Cotinus*)

Aim: to determine the influence of de-tipping lateral branches of pre-branched cuttings at propagation, and assess how pot volume affected growth and quality.

Apical and pre-branched cuttings were excised from hedges on 21 July 1998. Some pre-branched cuttings were de-tipped prior to placing cuttings in the propagation environment. De-tipping the cuttings meant that 3-5 cm of the growing shoots were removed, leaving two nodes. Cuttings were stuck into 1 litre pots or 80 cm^3 modular trays. Due to the large size of pre-branched *Magnolia* cuttings, however, it was impossible to inset these into modular trays, so 7 cm pots were used instead. Ficote 180, 14:8:8 v/v T.E. fertiliser was added to the growing media in all pot sizes, at 2 g l^{-1}.

Experimental Summary:

Cuttings harvested:	July 1998
Cuttings rooted:	Fog
Cutting type:	**Apical** v **Pre-Branched** v **Pre-Branched De-Tipped**
Pot size:	**1 Litre** v **7 cm** (*Magnolia*) / **80 cm^3** Module (*Cotinus*)

Results

Magnolia

The type of cutting had a significant effect on growth and plant height when plants were assessed the following March, with greatest growth associated with pre-branched cuttings which had not been de-tipped at collection (Table 7). Sticking cuttings into smaller pots reduced overall growth, although plant height was not significantly affected. De-tipping the pre-branched cuttings encouraged further lateral development during the propagation and growing-on periods, although vigour of re-growth varied somewhat between cuttings of the same treatment. Overall, sticking cuttings in smaller pots appeared to have reduced the number of laterals produced compared to those in 1 litre containers.

Cotinus

De-tipping tended to reduce total shoot growth and height of pre-branched cuttings, and there was little regrowth before cuttings went dormant. Pre-branched cuttings had significantly more laterals than apical cuttings, including good numbers close to the base of the cutting (Table 8). When data across different types of cuttings were pooled, total growth was found to be significantly less for those cuttings placed in modules. It should also be remembered that rooting percentages were considerably lower with apical and pre-branched cuttings when stuck in modules compared to those for larger pots (See Table 2).

Table 7. *Magnolia* - The effect of type of cutting and pot size on mean growth parameters (4 months after propagation).

Pot size	Type of cutting	Height (cm)	Total growth (cm)	Total laterals	Large laterals (>10cm)	Laterals in basal 10 cm
1 litre	Apical	21	23	0.0	0	0
1 litre	Pre-Br	**34**	**81**	2.9	**2.4**	**2.1**
1 litre	Pre-Br De-tip	29	51	**4.8**	1.3	**2.3**
7cm	Apical	18	19	0	0	0
7cm	Pre-Br	**32**	**72**	2.7	**2.3**	1.6
7cm	Pre-Br De-tip	29	45	4.3	0.8	1.4
LSD		4.3	8.1	0.31	0.29	0.24

Table 8. *Cotinus*- The effect of type of cutting and pot size on mean growth parameters (4 months after propagation).

Pot size	Type of cutting	Height (cm)	Total growth (cm)	Total laterals	Large laterals (>10cm)	Laterals in basal 10 cm
1 litre	Apical	17	28	2.6	0.4	1.2
1 litre	Pre-Br	17	**43**	**6.7**	1.4	4
1 litre	Pre-Br De-tip	13	31	5.4	0.4	**4.8**
80 cm^3	Apical	13	21	1.5	0.2	0.9
80 cm^3	Pre-Br	**19**	**41**	3.2	**2.1**	2.7
80 cm^3	Pre-Br De-tip	12	27	4	0.3	3.6
LSD		1.6	6.2	0.91	0.33	0.73

De-tipping Pre-branched cuttings and the effects of rooting environment on growth and quality (*Magnolia* and *Cotinus*)

Aim: To evaluate effects of de-tipping pre-branched cuttings and propagation environment on growth and liner quality.

Comparisons were made of the effects of fog or mist on growth of various types of cuttings, using modular trays or small pots (7 cm). Pre-branched cuttings were collected on 21 July 1998 and half of these had laterals de-tipped to leave two nodes per shoot. Cuttings were placed either in the side-ventilated mist tent, or the Agritech fogger tunnel. In the case of *Cotinus*, small numbers of apical cuttings were also included in each environment for comparison. Cuttings were assessed for growth characteristics on 14 October 1998 after plants had become dormant.

Experimental Summary:

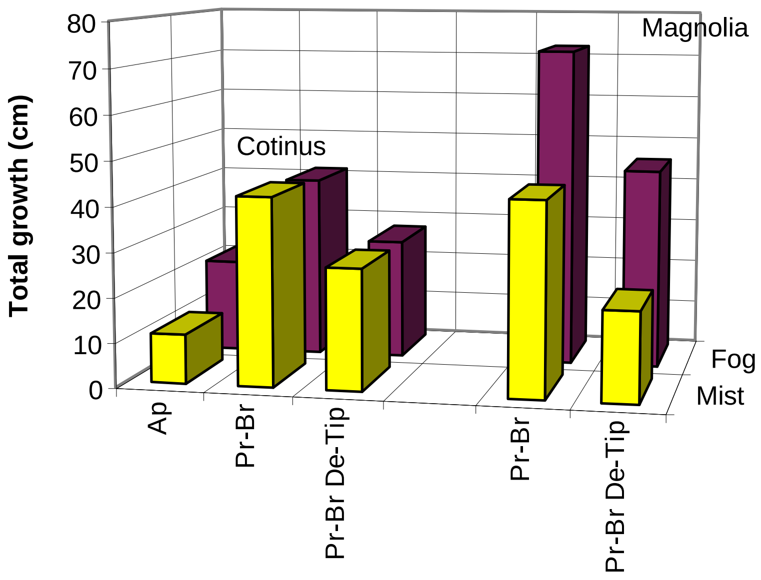
Cuttings harvested:	July 1998
Propagation environment:	Agritech Fog v Mist
Cutting type:	**Apical** (*Cotinus* only) v **Pre-Branched** v **Pre-Branched De-Tipped**
Cuttings stuck:	**7 cm pot** (*Magnolia*) or **80 cm^3 module** (*Cotinus*).

Results

In general, sticking cuttings of *Cotinus* and *Magnolia* into small pots / modules reduced rooting, particularly in the less supportive mist environment (See Table 2).

Rooting environment had a significant effect on regrowth and the number of new laterals in *Magnolia*, with greater growth associated with cuttings placed in fog (Figures 7 and 8). In *Cotinus*, the propagation environment had no overall significant effect on total growth, although apical cuttings rooted in fog were larger than equivalent cuttings from mist (Figure 7). Total growth was reduced in both species by de-tipping the cuttings, and cuttings were still smaller than non-pruned pre-branched subjects at the time of assessment in October 1998. However, de-tipping significantly increased the numbers of laterals formed in *Cotinus*, and in those cuttings of *Magnolia* rooted in the fog (Figure 8).

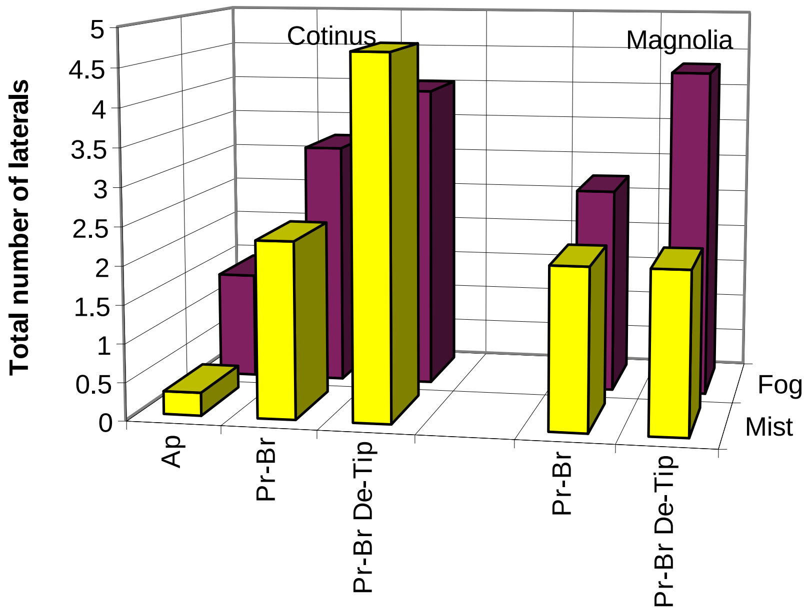
Figure 7. The influence of type of cutting and propagation environment on total growth of *Cotinus* and *Magnolia* (4 months after propagation).



Key:

Ap = Plants derived from apical cuttings.
Pr-Br = Plants derived from pre-branched cuttings
Pr-Br De-Tip = Plants derived from pre-branched cuttings, with lateral de-tipped at propagation.
LSD for treatment comparisons in *Cotinus* = 5.9
LSD for treatment comparisons in *Magnolia* = 7.5

Figure 8. The influence of type of cutting and propagation environment on total numbers of laterals of *Cotinus* and *Magnolia* (4 months after propagation).



Key:

Ap = Plants derived from apical cuttings.
Pr-Br = Plants derived from pre-branched cuttings
Pr-Br De-Tip = Plants derived from pre-branched cuttings, with lateral de-tipped at propagation.
LSD for treatment comparisons in *Cotinus* = 0.65
LSD for treatment comparisons in *Magnolia* = 0.30

The influence of size of pot and de-tipping regimes (*Forsythia*)

Aim: To compare the effects of de-tipping shoots whilst they were still on the stockhedge (pre-branching) to that of de-tipping cuttings at propagation.

Comparisons were also made between direct sticking of cuttings into 9 cm pots with fertiliser (3 g l^{-1} Ficote 180, 14:8:8 T.E.) or into modular trays without fertiliser. Two forms of pre-branched cuttings were used: -

1. Strong growing shoots of hard-pruned hedges were de-tipped using hedging shears on 21 June 1997. Cuttings derived from the de-tipped shoots ('Pre-Branched') were approximately 12-15 cm long. These cuttings were excised from stockplants by cutting at two nodes below the lateral break point. This ensured that the main structural laterals would occur low down on the rooted cutting, thereby providing a bushier base to the final liner. At the time of collection, the two newly formed laterals were relatively large (10-12 cm) and these were pruned back by 50 % during cutting preparation.
2. Cuttings were also obtained from lightly pruned stock material, by removing shoots on the one-year-old wood, with natural breaks (feathers) present. These naturally pre-branched cuttings ('Nat. Pre-Branched') were variable in size and shape, but were selectively pruned to provide a more uniform type of cutting approximately 15 cm long.

Apical cuttings ('Apical') were also derived from the hard-pruned stockhedges (size 13-15 cm), but were shoots that had not been manipulated. A proportion of the cuttings had their top two buds removed at propagation ('De-tipped'). With the exception of natural pre-branched cuttings, half the cuttings of each treatment were hard pruned on 22 September. Rooted plants from modules were potted into 9 cm pots on 19 February using the same fertiliser concentration as before.

Experimental Summary:

Cuttings harvested: July 1997
Cuttings rooted: Fog

<u>9 cm container plants</u>

Type of cutting: **Apical** v **De-Tipped** v **Pre-Branched** v **Nat Pre-Branched**
Pruning regime: **Non-pruned** v **Pruned x 1** (except Nat Pre-Branched)

<u>Modular plants</u>

Type of cutting: **Apical** v **De-Tipped** v **Pre-Branched** v **Nat Pre-Branched**

Results

When plants were assessed in November 1997, it was evident that sticking plants in modular trays without fertiliser reduced early growth and lateral production in all treatments except the Nat Pre-Branched cuttings. By April 1998, plants from the Apical cuttings had greatest height and total growth (Table 9). These plants also had good numbers of laterals, but most of these were small feathers, often positioned at the top of the stem or at the base, with a bare region in the middle of the stem. Shoot growth remained apically dominant and top-heavy in this treatment and the leading shoot often bent over, resulting in an un-shapely specimen. Removing the apical tip at propagation (De-Tipped) resulted in good growth combined with the formation of some quality laterals and this treatment appeared to have some advantage over the Apical cuttings, even when the latter were pruned in September. High numbers of total and large laterals were associated with the Pre-Branched (Px1) and Natural Pre-Branched treatments; these treatments formed good quality, balanced liners, with the base of plants being well-furnished with laterals.

Table 9. *Forsythia* - The effects of type of cutting on growth parameters as measured in April 1998, (9 months after propagation).

Original pot size	Treatment	Height (cm)	Total growth (cm)	Total laterals	Large laterals (>10cm)	Lats in basal 1/3	Lats in basal 10 cm
9 cm	Apical	**55**	**100**	**10.7**	0.6	**5.1**	4.0
	Apical (Px1)	26	52	6.7	0.1	1.9	3.3
	De-Tipped	34	**87**	9.6	**1.8**	**3.5**	**5.0**
	De-Tipped (Px1)	24	67	9.5	0.7	3.1	4.4
	Pre-Branched	32	71	9.0	**1.7**	3.0	**9.0**
	Pre-Branched (Px1)	22	**81**	**13.9**	1.3	**3.8**	**13.9**
	Nat Pre-Branched	22	**82**	**10.4**	**2.6**	**4.0**	**10.2**
80 cm^3 module	Apical	27	43	5.2	0.1	2.3	1.1
	De-Tipped	23	44	4.7	0.8	0.8	0.9
	Pre-Branched	16	32	4.7	**1.6**	0.7	4.6
	Nat Pre-Branched	16	59	7.7	**1.9**	2.2	4.6
LSD		2.41	9.80	1.63	0.55	1.48	1.58

The rate of development was slower for module-grown plants, as would be expected of plants with limited nutrition and space. However, even large pre-branched cuttings successfully rooted and established in the confined volume of the modules, and it would therefore appear to be a feasible technique to propagate pre-branched cuttings of *Forsythia*, providing the cuttings are not held too long in the trays, prior to potting-on.

The influence of de-tipping regimes (*Garrya*)

Aim: To compare the effects of de-tipping shoots whilst they were still on the stockhedge (pre-branching) with de-tipping cuttings at propagation.

Stockplants were pruned in winter by reducing the previous season's growth by two-thirds. 'Apical' cuttings were obtained by removing shoots on 28 July 1997, and trimming these shoots to 13 cm in length. At the same time, slightly larger cuttings were excised, but the apical bud and 2-3 cm of stem were also removed to give ‘De-Tipped’ cuttings of a similar size.

Previous to this date, part of the hedge had been trimmed with hand shears to induce pre-branched shoots on the hedge. Approximately 5-10 cm of the new shoots were excised on 23 June to stimulate lower branching. ‘Pre-branched’ cuttings were collected from the trimmed hedges on 28 July and were 13 cm in length. As a comparison, a number of cuttings were derived from hedge material that had not been pruned for the previous 18 months, and where feathering had taken place naturally. Large, ‘Naturally Pre-branched’ shoots were excised from the hedge and selectively pruned to produce cuttings of 15-25 cm length.

Experimental Summary:

Cuttings harvested:	July 1997
Cuttings rooted:	Fog
Cutting type:	**Apical** v **De-Tipped** v **Pre-Branched** v **Nat Pre-Branched**

Results

Rooting was slow throughout and was very poor in the Natural Pre-branched cuttings (Percentage rooting being: Apical = 100 %, De-Tipped = 98 %, Pre-Branched = 95 % and Nat Pre-Branched = 38 %). Indeed, the largest cuttings in the Natural Pre-branched treatment failed to root, implying that the environment was not supportive enough for such large cuttings, or that these cuttings had lower inherent rooting potential (possibly a consequence of the stockplants not having been pruned).

Assessments in April demonstrated that there was significantly more growth in the Nat Pre-Branched cuttings than any other treatment (Table 10); however, these plants were not significantly taller, due to the larger cuttings in the population failing to root. Total numbers of laterals and numbers of basal laterals were generally greatest in this treatment and plants were compact and bushy. These plants maintained a good growth habit during the following summer, and generally retained a rounded appearance with high numbers of basal branches. The pre-branching treatment also gave rise to container plants of merit, but some laterals were excessively long and feathering often occurred at the end of the branches. It is likely therefore, that such plants may have benefited from an additional spring pruning, once growth has been activated. Similar trends were apparent with the apical and de-tipped plants, with lateral growth being long and straggly without additional light pruning.

Table 10. ***Garrya*** **- The effects of type of cutting on growth parameters measured in April 1998, (9 months after propagation).**

Type of cutting	Height (cm)	Total growth (cm)	Total laterals	Large laterals (>10cm)	Laterals in basal 1/3	Laterals in basal 10 cm
Apical	15	27	5.7	0.0	1.0	3.2
De-Tipped	15	33	7.1	0.0	0.9	5.3
Pre-Branched	16	34	5.7	**0.9**	1.2	5.3
Nat Pre-Branched	16	**46**	**9.6**	**0.9**	**3.2**	**6.7**
LSD	1.7	6.5	1.66	0.27	0.70	1.30

The effect on quality due to pot spacing (*Cotinus*)

Aim: To investigate the effects of pot spacing in the propagation and growing-on environments, and effects on liner quality.

Comparisons were made with apical and pre-branched cuttings. Cutting length was similar for the two types (20-25 cm length at collection). However, a small number of very large pre-branched cuttings (40-45 cm) were also included for comparison and to determine if it was possible for such large cuttings to root successfully.

Spacing treatments were implemented by comparing full pot carriers (20 pots per carrier) to half-spaced pot-carriers, where every second space was left empty (i.e. 10 pots per carrier) for each type of cutting. These treatments were referred to as ‘1x1’ and ‘1x2’ spacing, respectively. After rooting, cuttings were divided again into further spacing treatments for growing on. Those plants that were on a 1x1 spacing in the fog tunnel were spaced to 1x2, and those at 1x2 were either left as they were or spaced out to 1x4 (5 pots per carrier).

Experimental Summary:

Cuttings harvested:	July 1997
Cuttings rooted:	Fog
Cutting type:	**Apical** v **Pre-Branched** v **Large Pre-Branched**
Spacing in propagation:	**1x1** v **1x2**
Spacing after weaning:	**1x2** v **1x4**

Results

Rooting was in excess of 90 % for all treatments and the type of cutting and spacing had no effect on root initiation and development. Spacing of cuttings / liners during propagation and after weaning had no significant effect on growth or number of laterals produced. Plants derived from any given type of cutting were extremely uniform, regardless of spacing distances. Type of cutting, however, strongly influenced plant shape and size, with much larger liners derived from the Pre-Branched than the Apical cuttings (Table 11). These were also branched significantly better, with almost 4 laterals per plant compared with a mean of 0.4 laterals per plant obtained from the Apical cuttings. In the plants formed from the Pre-branched cuttings, lateral positioning was relatively even within the framework of the liner, and compact, well-branched plants were obtained using this treatment. Of particular interest were the large Pre-branched cuttings which, on rooting, appeared to almost form an 'instant' final liner. This demonstrates the advantages associated with providing cuttings with an optimum rooting environment, as even very large cuttings can be rooted quickly.

Table 11. *Cotinus* - The effects of type of cutting and spacing on growth parameters as measured in April 1998, (9 months after propagation).

Type of cutting / spacing	Height (cm)	Total growth (cm)	Total laterals	Large laterals (>10cm)	Laterals in basal 1/3
Apical 1x1 - 1x2	13	15	0.4	0.0	0.3
Apical 1x2 - 1x2	13	14	0.4	0.0	0.4
Apical 1x2 - 1x4	13	16	0.4	0.0	0.4
Pre-Branched 1x1 - 1x2	18	46	**4.1**	**1.8**	**2.8**
Pre-Branched 1x2 - 1x2	17	42	**3.9**	**1.4**	**2.8**
Pre-Branched 1x2 - 1x4	18	46	**4.1**	**1.8**	**2.9**
Large Pre-Branched 1x2 - 1x4	**32**	**133**	**7.2**	**6.2**	**4.9**
LSD	1.0	3.6	0.24	0.29	0.28

Size, de-tipping and pruning of conventional apical cuttings (*Magnolia*)

Aim: To investigate how size of cutting, de-tipping and liner pruning influenced liner quality using conventional apical cuttings.

During the initial year of the project, investigations were carried out into how liner size and quality could be maximised in *Magnolia*, without using pre-branching techniques. Hedges were hard-pruned in winter. Cuttings were collected on 8 July 1996, divided on the basis of size and direct stuck into 9 cm pots. Prior to sticking, the apical tip was excised in half the cuttings to give a 'de-tipped' treatment. After weaning, rooted cuttings were potted into 1 litre pots with fertiliser applied at a rate of 4 g l^{-1} Ficote. Growth response to the frequency and timing of subsequent pruning was evaluated.

Experimental Summary:

Cuttings harvested:	July 1996
Cuttings rooted:	Fog
Cutting size:	**Large** (25-30 cm) v **Small** (15-20 cm).
Presence of an apical bud:	Apical bud retained (**Apical**) v Apical bud removed (**De-tipped**).
Subsequent pruning:	No pruning Lightly, in August 1996 (**Aug Px1**); Lightly, in March 1997 (**Mar Px1**); Lightly, in August 1996 and March 1997 (**Px2**); or Severely-pruned once in March 1997 (**Severe Px1**).

Results

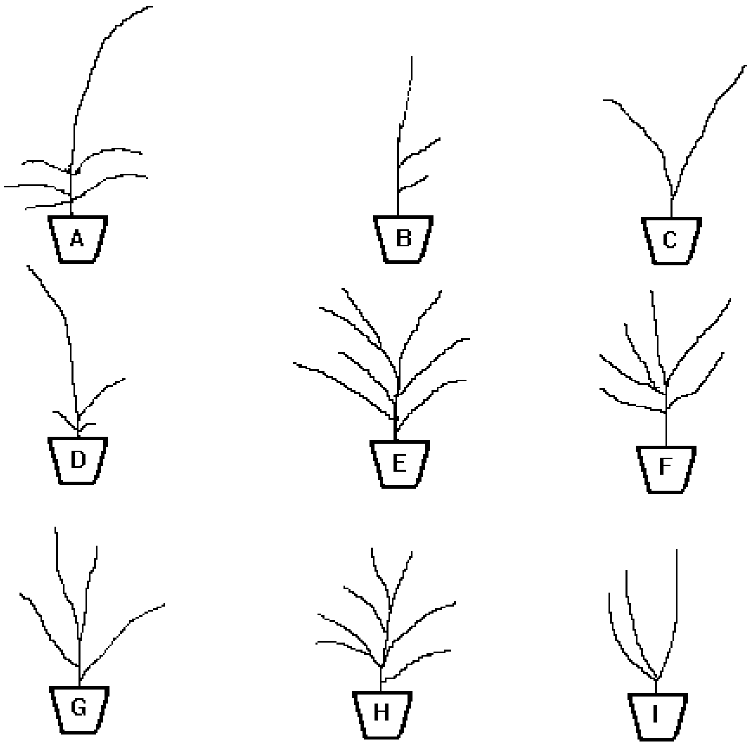
The original size of cutting taken at propagation, and pruning treatments, significantly affected the plant height and total shoot growth measured at the end of the second season. The number of total laterals and number of long laterals were also significantly affected by cutting size and pruning treatment. When data were pooled on the basis of size, results for larger cuttings were always significantly greater than those for smaller cuttings for all the growth parameters measured. The effects of pruning treatment often depended on the frequency of pruning and whether the cuttings were initially de-tipped or not. Imposing a single pruning in March often resulted in the induction of greater numbers of total, large and basal laterals than a similar treatment in the previous August (Table 12). Double pruning, i.e. pruning in August and again in March, generally gave more favourable results when applied to cuttings that had originally been de-tipped, rather than maintained with an apical bud. Removing the apical tip at propagation, without any subsequent pruning, however, appeared to be of little benefit and fewer laterals were induced in these treatments compared to apical, non-pruned controls.

Typical growth responses to de-tipping and pruning are depicted in Figure 1. Control plants, which were not de-tipped or pruned, resulted in large container specimens, with a single, apically-dominant leader; laterals were induced, but usually only at the base of the plant, giving a rather un-balanced form (Figure 9, ‘A’). Treatments that involved a single light pruning just after bud-break in March resulted in open fan or vase-shaped specimens with good branching habit (Figure 9, ‘E’ and ‘F’). Similarly, compact well-shaped plants were derived from the de-tipped cuttings after being double pruned (Figure 9, ‘H’). Imposing a single severe pruning in March resulted in breaks from below the excision point, and up-right specimens with two-three equal leaders (Figure 9, ‘I’).

Table 12. *Magnolia* - The effects of size of cutting, tipping and pruning treatments on growth parameters as measured in September 1997 (14 months after propagation). (See experimental summary for treatment descriptions).

Treatments							
Cutting size	De-tipped	Pruned	Height (cm)	Total growth (cm)	Total laterals	Large laterals (>10cm)	Laterals in basal 1/3
Large	No	No	94	**215**	**6**	**4**	**5**
		Aug x1	**106**	**211**	2	2	2
		Mar x1	78	**241**	**6**	**5**	**4**
		Aug + Mar	82	**225**	3	3	3
Large	Yes	No	**102**	179	4	2	4
		Aug x1	**112**	**214**	3	2	3
		Mar x1	75	**223**	**7**	**5**	3
		Aug + Mar	79	**230**	5	**4**	**5**
Small	No	No	93	172	5	3	**5**
		Aug x1	84	153	3	2	3
		Mar x1	72	**214**	5	**4**	**5**
		Aug + Mar	80	182	3	3	3
Small	Yes	No	99	157	2	2	2
		Aug x1	97	182	3	2	3
		Mar x1	71	183	4	3	**4**
		Aug + Mar	71	**227**	4	**4**	**4**
Large	No	Mar x1 Severe	71	159	2.2	2	2
LSD			12.0	31.1	1.4	1.2	1.4

Figure 9. ***Magnolia*** **- Pictorial representation of plant habit and size at the container stage (14 months after propagation), as influenced by de-tipping and pruning treatments on 'large' cuttings.**



Key:

A = Apical
B = De-tipped
C = Pruned x1 (Aug)
D = De-tipped and Pruned x 1 (Aug)
E = Pruned x1 (Mar)
F = De-tipped and Pruned x1 (Mar)
G = Pruned x 2 (Aug + Mar)
H = De-tipped and Pruned x 2 (Aug + Mar)
I = Severe Pruned x 1 (Mar)

N.B. Final container plants derived from 'small' cuttings were similar in shape to equivalent 'large' cuttings, but overall growth was less and consequently specimens were marginally more compact.

Size of cuttings and cold stimulus (*Syringa*)

Conventional pruning of liners appears to have only limited success for *Syringa*. This may be partially due to its short growing period in early summer providing little opportunity for further growth flushes after pruning. Therefore research focused on investigating the effect of cutting size (possibly larger cuttings would branch more readily, naturally) and the effect of the overwintering environment on the speed of development.

Exp. 1

Aim: To investigate the influence of de-tipping apical cuttings, winter chilling and forcing plants under artificial light on growth and liner quality.

Rooted cuttings which had either been left intact, or had their apical tip removed at propagation were used (See Annual Report 1). After weaning and a period of growing-on, a number of these were 'pre-chilled' by being placed into a jacketed cold store at 2+/-1 ^{o}C for five weeks to help rapidly satisfy the bud-chilling requirement, while other plants were left outside. On 6 January 1997, plants were removed from storage and placed either outside again, or into a polytunnel. Similarly, plants maintained outside originally were also sub-divided; half were placed in the polytunnel, the other half being left *in situ*. In the polytunnel, plants were exposed to a 'long-day' light regime for 16 hours per day using artificial lighting from a high pressure sodium lamp (SON-T 400 W), in an attempt to accelerate bud development and growth. All plants were moved outside in April 1997.

Experimental Summary:

Cuttings harvested:	June 1996
Cutting type:	**Apical** v **De-tipped**
Overwintering Environment:	**Outside** v **Polytunnel LD** (long day light)
Additional chilling:	**Control** v **Cold** (cold storage, 5 weeks)

Results

Those plants grown-on in the polytunnel under long-day light broke bud and extended shoot growth earlier than those outside; however, they also ceased growth early the following summer. Therefore, by the end of the first growing season, there was no difference in total growth due to environment. Treatments, however, which encompassed a degree of winter chilling, either by maintaining plants outside or by placing into cold storage, enhanced lateral development. The greatest numbers of laterals produced were associated with apical cuttings that had been pre-chilled and were then placed outside. The cold storage chilling or growing plants outside significantly increased the number of laterals developed, when all other factors were pooled together. There were, on average, 3.26 laterals on chilled-treated plants compared to 2.78 on non-chilled specimens. Likewise, there were 3.48 versus 2.57 laterals in plants grown outside compared to those grown in the polytunnel. Interestingly, de-tipping the cuttings at propagation generally appeared to reduce the total number of laterals produced compared to equivalent apical cuttings.

Assessments made the following year (10 May, 1998) showed that, over this longer period, the overwinter environment appeared to have an effect on total growth. Plants originally kept in the polytunnel under light for 4 months were, by this point, significantly smaller than plants maintained outside throughout (Table 13). Total numbers of laterals were similar between treatments, although plants in the 'outside' treatment had greater numbers of large laterals.

Table 13. Syringa - The effect of overwintering environment and cold storage (Cold) on long-term growth parameters (23 months after propagation)

Treatment	Height (cm)	Total growth (cm)	Total laterals	Large laterals (>10cm)	Laterals in basal 1/3
Outside	**58**	**159**	10	**4.6**	**6.9**
Outside + Cold	**64**	**182**	9.6	**3.7**	**5.9**
Polytunnel	45	125	8.1	2.9	4.2
Polytunnel + Cold	48	130	9.7	2.9	**5.3**
LSD	9.4	29.2	2.4	1.14	2.00

Exp. 2

Aim: to investigate the effect of size of cuttings and winter chilling

Apical cuttings were collected on 24 June 1997 and divided into two treatments on the basis of size - 'Large' cuttings, 20-25 cm long with 3 pairs of leaves retained per cutting and 'Small' cuttings, 10-15 cm long with only one pair of leaves retained. On 29 November, liners were graded and divided into two further treatments:- either retained in the polytunnel to overwinter ('Poly') or placed in a cold store at 2+/- 1^{o}C ('Cold') without light, from 29 November until 28 February 1998. At the beginning of March the cold-stored plants were moved back into the polytunnel and all plants moved outside on 25 May 1998. Plants were assessed for growth on 13 July 1998.

Experimental Summary:

Cuttings harvested: June 1997
Cutting type: **Large** v **Small**
Overwintering Environment: **Polytunnel** v **Cold Store**

Results

Original bud activity was more pronounced in the smaller cuttings, with greater percentages of axillary buds breaking dormancy than in the larger cuttings. Likewise considerably greater bud activity was recorded in the cold-treated plants compared to those maintained in the polytunnel over winter (Figure 10).

The effect of cold storage on growth and plant height depended on original cutting size. Chilling had no effect on large cuttings in terms of growth, but stimulated considerably greater growth in the small cuttings - to the extent that these were larger than the cuttings in the 'large' category, 14 months after propagation (Table 14). Cold treatment stimulated greater lateral bud development compared to the plants overwintered in the polytunnel, with greatest numbers associated with the larger cuttings.

Figure 10. *Syringa* - The effect of type of cutting and overwintering environment on percentage budbreak.

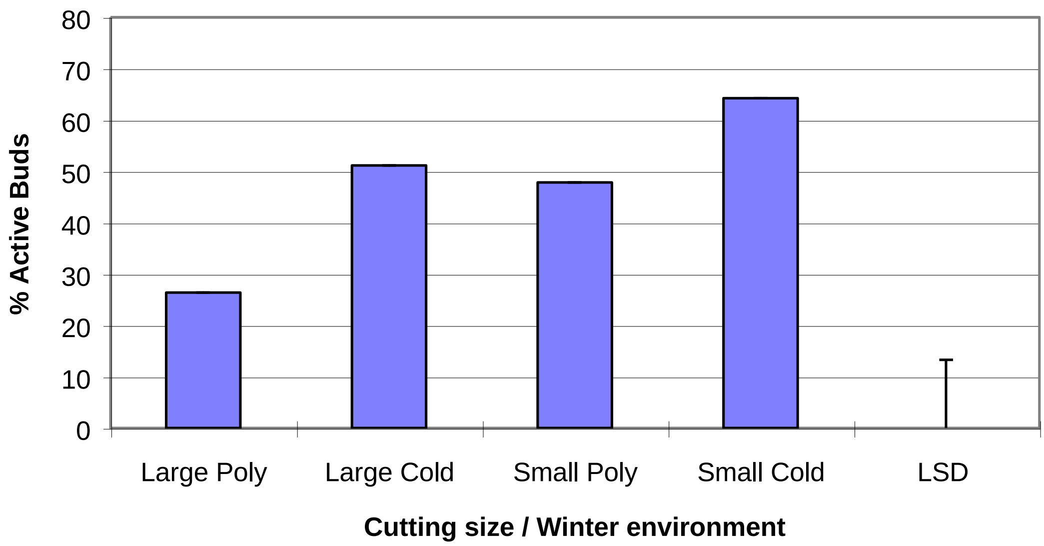


Table 14. *Syringa vulgaris* 'Charles Joly'- The effects of type of cutting on mean growth parameters as measured in July 1998, (14 months after propagation).

Treatment	Height (cm)	Total growth (cm)	Total laterals	Laterals in basal 1/3
Large Poly	55	**85**	2.6	1.5
Large Cold	54	**86**	**6.3**	**3.1**
Small Poly	46	65	2.8	**2.7**
Small Cold	**58**	**89**	3.3	**3.3**
LSD	11.1	21.0	1.40	1.00

Age of cutting and potting time (*Photinia*)

Aim: To investigate the effect of cutting position on the stockplant and time of potting.

Cuttings were excised from stockplants on 23 June 1997 and divided into three treatments based on type: 'Apical New' cuttings derived from actively growing, vigorous shoots and where the base node of the cutting was of the new wood; 'Apical Old' cuttings derived from less vigorous shoots, where the basal node of the cutting incorporated older, previous season's wood; and 'Pre-branched Old' cuttings where the cutting also comprised the previous season's wood, but had new shoots or developing buds attached. Cuttings derived from the one-year-old tissues, although not fully 'woody', were generally lignified at the base. Cuttings from the new growth were approximately 12-15 cm long, compared to cuttings derived from the old wood (which were smaller, 9-10 cm in length).

Shoot growth continued during autumn after rooting and excessive growth was removed in the Apical cuttings by pruning plants on 12 December 1997. In particular, growth had been greatest with the Apical New cuttings and some of these cuttings had formed single-stemmed plants in greater than 20 cm high. Both New and Old Apical cuttings were pruned hard back (by two-thirds) to induce branching lower down; small numbers of plants were left un-pruned for comparison. Development was slower with the Pre-Branched Old plants and these were not pruned until 23 February 1998, at which point they were divided into two groups and either left intact, or had new laterals reduced by two-thirds in length. On 25 February, half the plants of each type were potted-on into 2 litre pots with 5 g l^{-1} Ficote 270 14:8:8 + T.E. incorporated. The other half were retained in the 9 cm containers and were not potted until 24th April 1998. Plants were compared for growth on 25 June 1998

Summary of treatment combinations:

Cuttings harvested:	June 1997
Cutting type:	**Apical New** v **Apical Old** v **Pre-Branched Old**
Pruning regime:	**Non-pruned** v **Pruned x 1**
Potting time:	**Early** v **Late**

(NB Pruning carried out at different times for Apical and Pre-branched cuttings).

Results

By July it was evident that delayed potting of cuttings had significantly reduced overall growth and plant height compared to earlier potting, but that there was little difference in lateral numbers (total, basal or large) due to potting-on time (Table 15).

Greatest numbers of laterals (average of 10.4 per cutting) were associated with using pre-branched cuttings pruned once and potted-on at the earlier date. These plants had the most of their branches formed low on the plant, giving a rounded vase-shape to the final plant. In general, the use of apical cuttings derived from current wood resulted in plants with greater vigour compared to apicals from the older wood. Pruning the apical cuttings back by two-thirds during winter resulted in new lateral formation at the base of the cuttings (with often 3-4 laterals forming). Although overall branching was not as great as pre-branched cuttings, relatively high quality container plants with uniform shoot breaks were obtained from this treatment - especially plants derived from the more vigorous 'new wood' cuttings.

Table 15. *Photinia* - The effects of type of cutting on mean growth parameters as measured in June 1998, (12 months after propagation). See text for definitions.

Potting time	Treatment	Height (cm)	Total growth (cm)	Total laterals	Large laterals (>10cm)	Laterals in basal 10 cm
Early	Apical New	**60**	131	4.1	3.7	0.7
Early	Apical New (Px1)	43	**139**	5.0	4.5	4.3
Early	Apical Old	47	96	2.7	2.1	2.1
Early	Apical Old (Px1)	34	113	3.9	3.9	3.7
Early	Pre-Branched Old	33	**153**	6.7	**5.7**	6.5
Early	Pre-Branched Old (Px1)	21	131	**10.4**	**5.6**	**10.4**
Late	Apical New	**53**	106	4.5	2.7	1.7
Late	Apical New (Px1)	31	104	4.7	4.5	4.7
Late	Apical Old	47	90	3.3	2.7	2.1
Late	Apical Old (Px1)	31	93	5.2	4.2	4.3
Late	Pre-Branched Old	31	**137**	6.6	**5.6**	6.4
Late	Pre-Branched Old (Px1)	24	104	7.7	**4.7**	7.6
	LSD	7.4	20.1	1.47	1.12	1.46

CONCLUSIONS

The aim of this project was to identify techniques that enhance liner plant quality and reduce the timescale from collection of cuttings to final plant sale. Factors, including size of cuttings, pre-branching, application of nutrition and pruning treatments, were investigated in isolation and in combination with each other to determine how these improvements can be best achieved. Experiments utilised a small range of model species to demonstrate the principles involved in successful propagation and management of liners.

One of the main objectives of the research was to explore the feasibility of using multi-stemmed cuttings to accelerate liner development. To this effect, actively growing shoots on stockhedges had their apical tip removed (de-tipped) to stimulate lower axillary buds into growth. Shoots were left on the hedge for two to three weeks to develop side-laterals, prior to being collected as cuttings. This allowed cuttings with pre-formed branches (pre-branched cuttings) to be harvested at the appropriate time.

For the majority of the species tested, the apical tips were removed using secateurs and 40-50 shoots could be de-tipped readily within a minute. In some of the more robust species such as *Forsythia*, the process could be speeded-up by using shears, but this often left bare portions of stem above a node. A consequence of shoot trimming in some cases was that not only were pre-branched cuttings formed, but new ‘apical’ shoots were generated from the base and middle of the stockhedge. In some species, e.g. *Garrya*, these shoots tended to ‘compete’ with the laterals being induced immediately below the excision point. However, in practice, these new shoots could also be used as an additional source of apical cuttings if required.

Direct comparisons in terms of overall productivity between conventional and manipulated hedges were not readily achievable. The number of pre-branched cuttings harvested from a manipulated hedge rarely matched that of apical cuttings from a conventional hedge. Results varied with species, with numbers of pre-branched cuttings collected being depressed by approximately 10-20 % (*Cotinus*) to 40-50 % (*Garrya*) compared to apical cuttings from a non-treated hedge. When apical cuttings derived from the manipulated hedge are included, however, total numbers were on a par or even exceeded that of conventionally managed hedges. The longer term effects of inducing pre-branching treatments over a number of years on the lifespan and productivity of the hedge have not been investigated.

The effectiveness of pre-branching techniques varied with the growth habit of any given species. In *Syringa*, de-tipping the growing shoot resulted in complete termination of growth, without lateral formation being induced. In contrast, pre-branched cuttings of *Cotinus* often had 5-6 well-formed laterals attached. Direct sticking of large cuttings with this number of laterals attached almost resulted in the ‘instant’ liner. Indeed, with *Weigela,* direct sticking of pre-branched cuttings into 1 litre pots resulted in well-rooted liners within three weeks of propagation. These had 6-7 branches, included 3-4 good ‘structural’ laterals at the base of the plant.

Magnolia was also conducive to pre-branching, but large cuttings were often only obtained when the base of the cutting comprised semi-lignified, one-year-old wood. Nevertheless, rooting rates were high, providing cuttings were direct stuck into 1 litre pots under fog. By applying fertiliser early-on during production and incorporating further pruning treatments, the use of pre-branched cuttings could result in very high quality plants in a 2 litre pot within 10-12 months of propagation. Such specimens were well established with 12-15 laterals, a high proportion of which were large 'formative' laterals located near the base of the plant.

The addition of fertiliser to the rooting media, or potting plants early with higher fertiliser rates, appeared to be beneficial in the species tested. Results for *Magnolia* showed that, in apical cuttings and pre-branched cuttings, higher fertiliser rates resulted in more growth and laterals being produced during the spring period.

In *Garrya* and *Forsythia*, the number of laterals induced initially by pinching shoots on the hedge was often limited to 2-4 in each pre-branched cutting, and further pruning was a requirement to maximise quality. Nevertheless, using cuttings with this small number of branches present helped speed up the formation of the final liner. The excision of naturally pre-branched cuttings, obtained from either non-pruned or only lightly pruned stockhedges was also useful in *Forsythia* and *Viburnum* and promoted well-branched 'instant liners'. With *Garrya*, however, the rooting percentage was very low in this type of cutting.

The rooting environment and type of propagation container used could influence success rates with pre-branched cuttings, but results again varied with species. 'Easy' subjects such as *Forsythia* and *Weigela* rooted under mist and in modular trays without difficulty. Moderate levels of rooting were also obtained with *Potentilla*, *Hebe*, *Cistus* and *Cornus* when placed under mist. In contrast, subjects such as *Cotinus*, *Magnolia* and *Photinia* were more sensitive to environment and highest success rates were associated with the higher humidity fog tunnel. Direct sticking of cuttings into 1 litre pots was advantageous compared to the use of smaller pots and modules, where large cuttings were less stable. Interestingly, in some species, even sticking apical cuttings into modules reduced rooting compared to pots (e.g. *Cotinus* under fog).

In *Garrya*, it was apparent that rooting success was improved when cuttings (of all types) were excised from stockplants that had been pruned hard the previous winter. Taking excessively large cuttings reduced rooting potential in this species, possibly again as a result of instability in the pot, or excessive water loss.

One initial concern in the use of pre-branched cuttings was to the extent to which the relatively large leaf area and the new growth act as a sink for carbohydrates and other nutrients during propagation and inhibit rooting *per se*. In fact, results from this project (and from MAFF HH1209 SHN) demonstrate the opposite to be true; if the cutting is not exposed to excessive water stress (i.e. maintained at high humidity), rooting appears to be enhanced by the use of multi-stemmed cuttings. The reason for this is likely to relate to active shoots tips being a principle source of auxin; the greater the number of shoots, then the higher the concentration of auxin reaching the base and inducing root formation.

The result of placing pre-branched cuttings in a ‘supportive’ propagation environment was that shoot extension and root formation could take place simultaneously. A particular advantage associated with pre-branched cuttings was the greater number of large ‘formative’ structural laterals that could be produced during this early stage. These large laterals are key to providing the final framework of the liner and early formation of these in the first season advanced development considerably. Pruning apical cuttings in spring could also result in large numbers of laterals in some species but, in contrast, these were often thin and weaker growing. In addition, this form of pruning tended to stimulate lateral formation at the top of the liner, and again greater numbers of basal branches were recorded in the pre-branched cuttings. Basal branches are important in giving the final plant a rounded, bushy appearance, without a bare lower stem.

Removing the apical tips of laterals on pre-branched shoots, prior to propagation, appeared to have some benefit in enhancing total lateral numbers (e.g. *Magnolia* and *Cotinus*), although many of the new shoots generated were weak growing. Further investigation is required to test fully the merits of additional tipping to pre-branched cuttings, with a wider range of species.

De-tipping apical cuttings at propagation of fast growing species (e.g. *Forsythia*) advanced lateral development compared to later pruning of apical cuttings after rooting and establishment. De-tipping apical cuttings of *Magnolia* was also advantageous in terms of final plant form, but only when it was combined with further pruning shortly after weaning (August) and again in the following spring (March).

In a number of species, good quality plants could also be obtained by rooting conventional apical cuttings (although production time could be longer than with pre-branched specimens) and implementing appropriate pruning after cuttings had become established within their pots. Pruning time in *Magnolia* was an important consideration in getting a quality plant with a minimum of effort. By pruning apical cuttings just once, in March, after rooting, large evenly-branched plants were obtained. In contrast, using a similar pruning treatment prior to dormancy in the previous August reduced overall growth and only succeeded in stimulating a new leading shoot; few new side laterals were formed. Similarly, with *Photinia*, implementing a single pruning treatment in March promoted less straggly, compact specimens than the same treatment in the previous July. Matching pruning treatments to appropriate growth stages appears paramount in maximising quality in some species with the minimal imput.

Speed of liner development and final quality could be strongly influenced by the original size of cuttings. In some species, there was an advantage in using larger cuttings, e.g. *Cotinus* and *Magnolia*, even when apical cuttings were compared. However, any advantage conferred with larger cuttings in these species was only gained when water stress was minimised and cuttings were securely anchored within the rooting medium (i.e. larger pots placed in fog).

The use of smaller pots or modules, in general, slowed cutting and liner development compared to direct sticking in a 1 litre pot. However, rooting pre-branched cuttings of relatively ‘easy’ species, and overwintering the cuttings in modules, appeared to have no long-term detrimental effects, provided cuttings were not held for an excessively long period the following spring. Although pot size imposed constraints on the rooting potential of pre-branched cuttings of *Cotinus*, pot spacing (using 9 cm pots) in the propagation, weaning and growing-on environments had no significant effect on plant quality or branching, prior to winter.

Plant size could be reduced by a later potting date, but in studies using *Photinia* there was no significant effect on branch numbers due to delaying potting from February until May. Therefore, varying potting time of pre-branched cuttings would appear to be an effective technique to schedule batch production, in a similar manner to existing conventional protocols.

Where the use of pre-branched cuttings or pruning of liners had minimal effect, i.e. in *Syringa*, overall plant development was enhanced by maximising the degree of winter chilling (but avoiding exposure to frost). Therefore, holding young container plants outside (but with adequate frost protection, if necessary), or the provision of artificial chilling in cold store, enhanced growth in comparison to housing plants in polytunnels. Any early advantage associated with exposure of *Syringa* plants to supplementary light during early spring was counteracted over the longer term by early cessation of growth. Even up to 24 months after propagation, growth advantages associated with the provision of adequate winter chilling during the first year were still evident.

To conclude, the research clearly demonstrates that, for many species, the use of large pre-branched cuttings has many advantages in the production of a finished plant more quickly. For some of the more difficult-to-root species, however, careful attention must be paid to provision of the correct environmental conditions to minimise stress in such large cuttings. Practical mechanisms to improve existing commercial rooting environments will be developed in HDC project HNS 76.

Although the research has aimed to be as comprehensive as possible, a number of questions remain. These include: ease of application of pre-branching techniques to other species not tested in this project, optimising stockhedge management to produce consistent pre-branched cuttings year-on year, and evaluating the use of other pot / module types to improve cutting stability during propagation, e.g. root trainer pots.

GLOSSARY

Apical cutting	A cutting with an intact shoot tip.
CRF	Controlled release fertiliser
De-tipped cutting	A cutting where the apical bud had been excised after the cutting has been removed from the stockplant.
De-tipped shoot-	A shoot where the apical tip has been removed while the shoot was still attached to the stockhedge. A technique used to induce pre-branched cuttings.
Pre-branched cutting	A cutting which has formed secondary laterals, whilst still attached to the stockplant.
Pruned cutting/liner	Where shoot apexes have been removed after the cutting has rooted and established.
TE	Trace elements (micronutrients)
Tipping	The act of removing the apical tip from a shoot / cutting

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