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PRUNING CONTAINERISED PLANTS AND FIELD-GROWN TREES FOR QUALITY

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HRI-EAST MALLING

Note: The **Science Section** describes the third year's work, whereas the extended **Relevance to Nurserymen and Practical Application Section** presents an overview of the entire three year project. Details of work in the first two years are available in the Annual Reports for 1993 and 1994.

CONTENTS

RELEVANCE TO NURSERYMEN AND PRACTICAL APPLICATIONS

Application

This project was designed to understand more about how plants respond to different pruning techniques and so identify strategies by which quality can be enhanced in both containerised nurserystock and field-produced trees. An underlying consideration was that the process of pruning should not reduce plant size unnecessarily.

Responses to pruning containerised nurserystock strongly related to plant vigour. Growth and quality were improved in fast growing species by either frequent light pruning, or severe pruning repeated less frequently. More frequent severe pruning resulted in loss of growth and reduced plant size. Slow growing or short-season plants responded best to light pruning, and severe pruning in these species often proved extremely detrimental. The timing of pruning was also an important factor in manipulating shoot growth and thus maximising quality.

In field-produced trees the objective was to investigate the optimum timing of lateral shoot removal in both rootstock and scion to enhance tree size and quality. Retaining rootstock shoots early in the maiden season, as the scion extended, proved advantageous in *Prunus* 'Pink Perfection', by inhibiting lateral formation low down on the scion. Once scion laterals formed however, the extent to which removal was beneficial varied with species. Weak growing species responded best to pruning, with early and repeated lateral removal resulting in greater maiden height. In contrast, more vigorous species do not require frequent lateral removal and pruning can be left until the following winter as long as there is no objection to the resulting large pruning wounds.

Summary

Plant shape and growth habit are essential elements in determining quality. Aspects of plant quality are of paramount importance to nurserymen, especially if they are to guarantee consistent, profitable sales in a increasingly competitive market. Retailers now demand uniform crops of high quality plants to schedule, and nurserymen need to carefully manage their crops to meet the specified requirements. Correct pruning can enhance quality, but as a premium is paid for larger plants, it has often been feared that potential advantages arising from effective pruning may be offset by excessive reduction in size. This research aimed to find out how pruning regimes can be optimised to meet the requirements for both size and shape. There were two complementary parts to the project, one dealt with container-produced shrubs and the other field-grown trees. In both parts a range of contrasting species was used to evaluate pruning techniques in relation to natural variation in growth habit and shoot vigour.

a) Container-plant pruning

Results over three years demonstrated that response to pruning was not similar for different species, but general principles could be derived in relation to vigour of growth in each species. Generally, the more vigorous the species, the greater the advantage that could be conferred by pruning (or other means of bud excision) in terms of bud development and new branch formation taking place lower down on the plant. In very vigorous species such as

Forsythia and *Cornus*, pruning did not necessarily result in wasted growth, and in some cases pruning encouraged significantly more growth and yielded taller, better quality specimens than non-pruned plants. Specifically with *Forsythia*, growth could be enhanced by either limited severe pruning, or by frequent light pruning. The best overall treatment was to prune *Forsythia* plants lightly on four separate occasions:- shortly after weaning newly rooted cuttings in August, and again in September, to promote a branched framework early-on, in May of the following year to increase the branching habit and then finally in June to encourage vigorous basal shoots to also branch, leaving enough time for tissues to mature and initiate the maximum number of flower buds (Table 1).

Severe or medium level pruning could also result in large, reasonably shaped *Forsythia* plants, provided pruning was carried out at the appropriate time in the spring and early summer. Any advantage conferred by severe pruning tended to decrease with later pruning dates, with pruning as late as August significantly reducing plant height. Repeating a severe or medium early pruning, however, enhanced the number of quality laterals produced, but slightly reduced overall plant height. Severe pruning was generally detrimental to slower growing species such as *Viburnum*, *Cotinus* and *Garrya*, where severe pruning often delayed branch formation and significantly reduced eventual size. Timing was also critical, with severe autumn or winter pruning making less vigorous plants more susceptible to overwintering stresses. No pruning (e.g. *Viburnum*), or light pruning was often the best treatment for these less vigorous species, although the frequency of pruning to promote optimum growth characteristics could still vary with species, i.e. *Syringa* best pruned once, *Garrya* best pruned three times.

Table 1. The effects of light pruning frequency on mean growth and flowering potential in *Forsythia* x *intermedia* 'Lynwood' LA79.

	Treatment			
	Control	L x 2	L x 4	L x 6
Plant height (cm)	117	**119**	88	61
Total growth (cm)	440	405	**596**	397
Number of laterals	13.2	13.8	19.6	**38.4**
Number of laterals > 30 cm	4.8	5.0	**9.2**	1.2
Number of nodes with flower buds	105	132	**143**	63

Key: Control = non-pruned.
L x 2 = Lightly pruned on 11 August 1994, with new growth also lightly pruned on 22 September 1994.
L x 4 = Lightly pruned on 11 August 1994, with new growth also lightly pruned on 22 September 1994, 11 May and 20 June 1995.
L x 6 = Lightly pruned on 11 August 1994, with new growth also lightly pruned on 22 September 1994, 11 May, 20 June, 14 July and 1 August 1995.

In a number of cases the timing of pruning in the spring, after growth had started, appeared important in determining subsequent shape; in *Forsythia* and *Cotinus* subsequent growth and habit could be altered significantly by delaying severe pruning for a few weeks. Likewise in *Forsythia*, strongly growing basal shoots needed to be pruned at the appropriate stage of development in early summer, to ensure that a balanced shape was retained. Nurserymen need to be able to identify such critical phases in individual crops and implement pruning to maintain quality or to alter growth characteristics to suit their own particular requirements, rather than to simply prune when it is convenient to do so.

The use of warmer polytunnel environments encouraged greater shoot extension and therefore larger plants, including more rapid establishment and development in the slow growing species, e.g. *Viburnum*. However, research in the final year suggested that greater apical bud activity can increase the inhibition of lower buds, and that this apical dominance is encouraged by warmer temperatures, so branching was not enhanced in the polytunnel, and a generally better shape was obtained by growing plants outside.

This research demonstrates that no single pruning technique has universal application for containerised plants, but that the type of pruning regime employed is to a large extent dictated by species, the degree to which nurserymen wish to compromise between size and shape, the season and the timing of sales. The results show, however, that when pruning is implemented in the right degree, at the correct time and at the appropriate frequency, it can help design the ideal container specimen and ensure a high-quality uniform crop.

b) Field-grown tree pruning

Pruning is required in field-produced trees both to remove rootstock shoots, and to provide a clean main stem of about 1.8 m in height beneath the developing crown, unless feathered trees are required. What is less certain is the appropriate time to prune laterals, and how frequently pruning needs to be carried out, in order to ensure maximum tree quality whilst keeping labour costs to a minimum. One of the main aspects of quality is perceived to be a strong taper in stem diameter from the base to the crown of the tree, and the influence of laterals on stem tapering was also investigated.

Growth responses often varied between different species, possibly reflecting variations in shoot vigour. In *Prunus* 'Pink Perfection', results showed that retaining 'Colt' rootstock shoots until mid-June of the maiden year prevented early scion laterals from developing, so that the lower part of the scion maiden developed a clean stem. This effect, however, was not seen in other species.

Generally, removing scion laterals was an inefficient process in that only 2 to 9 % of potential lateral growth was converted into extra maiden height. However, a number of important principles emerged during the second and third years. For example, in weaker growing subjects with limited lateral production, such as *Prunus* 'Pink Perfection' and *Tilia* x *euchlora*, early and repeated lateral removal was beneficial and consistently resulted in taller specimens compared to retaining laterals until winter. There was some loss of stem taper with these treatments, but this was not excessive.

Removing laterals regularly in *Betula pendula* 'Dalecarlica' resulted in a significant reduction in stem taper, with relatively little advantage in terms of tree height. In *Robinia pseudoacacia* 'Frisia', the most vigorous variety tested, there were no clear effects of the timing and frequency of lateral removal, and the main consideration is that to delay removing laterals will result in large pruning wounds. There was little stem taper in *Robinia pseudoacacia* 'Frisia' because the early formation of a crown in this species thickens the upper part of the trunk.

Action Points For Growers

1. Prune container-grown plants according to their natural growth characteristics. Vigorous species can be pruned harder or more frequently than slower growing plants, or plants with a limited growing season.

2. Desired characteristics and eventual market will influence severity and frequency of pruning. Generally, larger but less-well-branched plants are obtained by limited pruning, but smaller, better shaped specimens are obtained by more frequent pruning.

3. Introduce pruning regimes into the scheduling of crops, rather than using pruning in an attempt to retrieve quality after extensive shoot growth has already developed.

4. Where possible try and build-up a branching framework early in the production cycle. Remember, however, that pruning late in the summer and autumn can induce greater susceptibility to frost damage. Therefore, provide adequate protection for plants with soft, late season growth.

5. Severe pruning should generally be avoided with poorly established, weak-growing or short-season plants.

6. Identify critical growth stages in different species, where correct pruning, e.g after initiation of growth in spring, can strongly determine subsequent shape and size.

7. In species where strong basal shoots or suckers are initiated in summer, prune these back during growth to maintain overall shape and avoid long, 'leggy' laterals being produced.

8. In species where flowering is important in enhancing sales, avoid excessive pruning after mid-summer to ensure that enough mature flowering wood is retained for the subsequent season.

9. When pruning field-grown trees, prune rootstocks to the bud, thus making the scion apically dominant. Retain sub-dominant rootstock shoots to inhibit early, low branching on the scion in responsive species such as *Prunus*.

10. Scion laterals should be removed regularly in weaker-growing varieties to increase tree height without total loss of taper.

11. For stronger-growing trees retaining lower laterals will assist stem taper without detracting from tree height.

12. In species which form a crown in the maiden year, it may be sensible to reduce the number of shoots in the crown, so as to prevent loss of stem taper through upper stem thickening. This has not been tested experimentally.

13. Required pruning regimes should be repeated in the second year, until a crown is formed and lower laterals suppressed.

EXPERIMENTAL SECTION

Overview:

The objective of this project was to investigate the effects of pruning on quality, whilst trying to minimise reduction in size. There were two complementary parts to the project; one dealt with pruning containerised plants, and the other field-grown trees. The research for the final year's work with respect to container pruning was divided between two objectives. The first objective was to use the information from previous years to optimise growth responses by combining factors such as timing, severity of pruning and repeated pruning throughout the production process from rooted-cutting to final containerised plant. The aim was to highlight the advantages and disadvantages of different pruning philosophies for the diverse species under test and demonstrate which techniques would be most suitable for specific purposes, such as garden centre or landscaping markets. The second objective was to study in more detail the effects of pruning and other methods of bud manipulation on subsequent bud development. Specifically, this focused on the extent and timing of bud break, and position of lateral formation on the stem.

Research relating to field-produced trees continued the investigations carried out in the maiden year and concentrated on timing of scion lateral removal in the second season of growth, with the objective of encouraging well-shaped trees with good stem taper.

a) CONTAINER PRUNING

Part 1. The effects of pruning severity, timing and frequency

Introduction

Previous experiments concentrated on factors such as environment, pruning severity, pruning time, and to a lesser extent the influence of re-pruning, and how such factors affected subsequent growth in a range of contrasting species. This was taken a stage further in 1994/1995, by trying to implement pruning treatments early in the production process and attempting to build-up the branch framework quickly, by pruning as frequently as growth in each species allowed. Certain factors, notably pruning severity and timing, were retained and incorporated within this experiment to provide a more comprehensive approach, and demonstrate comparisons of different pruning regimes to nurserymen. The objective, however, was still not to provide exact blueprints for production, but to highlight particular advantages or disadvantages from different pruning approaches.

Materials and methods

Softwood cuttings of approximately 15 to 20 cm in length were collected from stockhedges of *Forsythia* x *intermedia* 'Lynwood' LA79, *Garrya elliptica* 'James Roof', *Cornus alba* 'Sibirica', *Viburnum carlesii* 'Aurora', *Syringa vulgaris* 'Madame Lemoine' and *Cotinus coggygria* 'Royal Purple' during early June 1994. Cuttings were dipped for 5 seconds in a 1,250 mg l^{-1} indole-3-butyric acid (IBA) solution (50% acetone: 50% water) and directly stuck into 9 cm or 1 litre pots (with compost of 50:50 peat: fine Cambark and 1 g l^{-1} Ficote 140, 16:10:10 added), then rooted under fog. After rooting, cuttings were carefully transferred to a polytunnel and enclosed in low polythene tents. The sides of these tents were progressively raised to wean the newly rooted cuttings. Rooting and weaning rates varied with species, with *Forsythia* and *Cotinus* being weaned by 11 August, *Cornus* by 22 August and *Garrya*, *Syringa* and *Viburnum* by 2 September 1994. After weaning, plants were held in a side-ventilated polytunnel, and root systems allowed to establish within the containers.

As plants became established, opportunities arose for early pruning to provide the framework for a branched plant before the onset of dormancy. Plants at this early liner stage were divided into batches and either left unpruned, or were lightly pruned, pruned to an intermediate level or severely pruned. Light pruning consisted of cutting-back the stem by less than one-third of its original length. The intermediate or Medium pruning was accomplished by reducing the existing stem by half and Severe pruning consisted of cutting-back the stem by at least two-thirds of its original length. Some species only had Light and Severe pruning treatments, because a Medium pruning treatment would have been almost identical to the Severe treatment, i.e. *Cornus* and *Cotinus*. The timing of initial pruning varied with species and the faster growing, more robust species such as *Forsythia*, were pruned earlier than the slower-to-establish subjects, e.g. *Garrya* and *Syringa* (Table 2).

Subsequent growth dictated further pruning regimes and plants were re-pruned as and when new shoots developed (usually after at least 10 cm growth). Growth was sufficient in *Forsythia* to allow a second pruning before winter, but most other species were not re-pruned until the spring. Re-pruning was based on similar principles to the original pruning, i.e. Light pruning treatments only had one-third of the new shoot removed, compared to Medium and Severe treatments where half and two-thirds of the new shoot was removed, respectively. Pruning regimes were repeated as plants developed throughout the spring and summer of 1995. At each successive stage, however, five plants were retained unpruned and used as examples of the previous treatment, i.e. the effects of a single pruning could be compared to pruning plants twice or three times, etc. In addition to repeat pruning regimes, a number of plants in some species were left unpruned until March or May 1995, at which point they were given a single pruning and used in comparison with earlier or more frequent pruning regimes.

All plants were maintained outside over winter except *Viburnum*, where plants were kept in a polytunnel, and protected during cold periods using low-level 'bubble-polythene' sheeting. Most species overwintered successfully, but late spring frosts severely damaged the new early growth on *Cornus*, causing subsequent necrosis and death in many plants. Therefore, *Cornus* was removed from the experiment. Interestingly, there was no difference in the levels of injury between unpruned control plants and those previously pruned, which indicates that earlier pruning in this case had not pre-disposed the plants to injury *per se*. As in earlier

Table 2. The dates of original pruning and repruning for different species

Pruning	Species				
	Forsythia	*Garrya*	*Syringa*	*Cotinus*	*Viburnum*
Control	/	/	/	/	/
x 1	11 Aug '94	23 Nov '94	23 Nov '94	29 Jul '94	10 Apr '95
x 2	22 Sep '94	11 May '95	19 Apr '95	31 May '95	NA
x 3	11 May '95	5 Jul '95	26 Jul '95	6 Jul '95	NA
x 4	20 Jun '95	1 Aug '95	NA	21 Aug '95	NA
x 5	14 Jul '95	5 Sep '95	NA	NA	NA
x 6	1 Aug '95	NA	NA	NA	NA
x 1 Mar.	7 Mar '95	7 Mar '95	7 Mar '95	NA	NA
x 1 Apr.	NA	NA	NA	3 Apr '95	NA
x 1 May	NA	NA	NA	31 May '95	NA

Key: Treatments with x 1 = timing of original pruning, x 2 = timing of subsequent pruning of any new growth, likewise for x 3, x 4 etc.
Treatment with x 1 (month) = a single pruning only within that month.

Forsythia = Light, Medium and Severe pruning treatments.
Garrya = Light, Medium and Severe pruning treatments.
Syringa = Light, Medium and Severe pruning treatments, except single pruning in March, when only Light and Severe pruning applied.
Cotinus = Light and Severe pruning treatments only.
Viburnum = Light, Medium and Severe pruning treatment.

NA = Not applicable

years, *Syringa* plants previously severely pruned suffered some losses overwinter and hard pruning in late summer and autumn is not to be recommended for this species. Other than *Cornus*, most species were slow to break bud and were relatively undamaged by the late frosts. A possible exception was *Forsythia*, where some flower bud damage was recorded, and where the late frost may have added an extra natural 'light-pruning' treatment, by damaging or delaying vegetative activity in apical tissues.

All plants were potted-on in May 1995 using a growing medium of 60% peat, 20% bark, 10% loam and 10% grit by volume with 4 kg calcium carbonate, 2 kg magnesium limestone, 150 g Nitram and 4 kg Osmocote Plus (15:9:11:2 + trace elements) incorporated per m^3. As in previous years, plant size and growth rate determined final pot size, i.e. *Viburnum* were grown in 1½ litre; *Cornus*, *Cotinus*, *Syringa* and *Garrya* in 2 litre and *Forsythia* in 3 litre containers.

Plants were assessed for growth and quality parameters in late October 1995, after growth had terminated and dormant buds had been laid down. Measurements were recorded of plant height, total growth, overall number of laterals and number of laterals over a predetermined length. As before, an arbitrary lateral length was set for each species based on overall plant size. The set length being > 30 cm for *Forsythia*, > 20 cm for *Cotinus*, *Garrya* and *Syringa* and > 10 cm for *Viburnum*. (Additionally, in *Forsythia* excessively long unsightly laterals were counted). A record was also made of how pruning regimes affected the number of flower buds on *Forsythia* in March, 1996.

Statistical analysis of variance (ANOVA) was implemented to determine if differences between treatments at the end of the growing season were significant. Analyses were based on least significant difference (LSD) at the 5% level. This indicates the size of difference between individual treatment means that is considered to be due to chance, with a 95% probability that the effects are due to imposed treatments.

In experiments with many treatments it often becomes too involved to indicate which treatments are significantly different from others, and the reader can use the LSD bar in Figures, or the value in tables, to compare treatments.

Results

Forsythia:

The best treatment in terms of providing a good compromise between size and shape was by lightly pruning plants four times. Greatest overall growth was stimulated by this treatment (significantly more than the control or any moderately or severely pruned treatments; Figure 1), and although plants were not particularly tall (approximately 80 cm on average), nor the most heavily branched (Figures 2 and 3, respectively), they were extremely well-balanced in shape. On average 9 long laterals (> 30 cm in length) were produced per plant, (Figure 4), but few of these were so excessively long that they made the plants look unsightly. The last pruning time in this treatment, i.e. 20 June 1995, was critical in that it ensured that the new vigorous basal shoots were induced to branch as they developed. This promoted a balanced, open-centred, vase shaped specimen. Not pruning in June resulted in the basal shoots

Figure 1. Mean total growth recorded in *Forsythia* x *intermedia* 'Lynwood' LA79

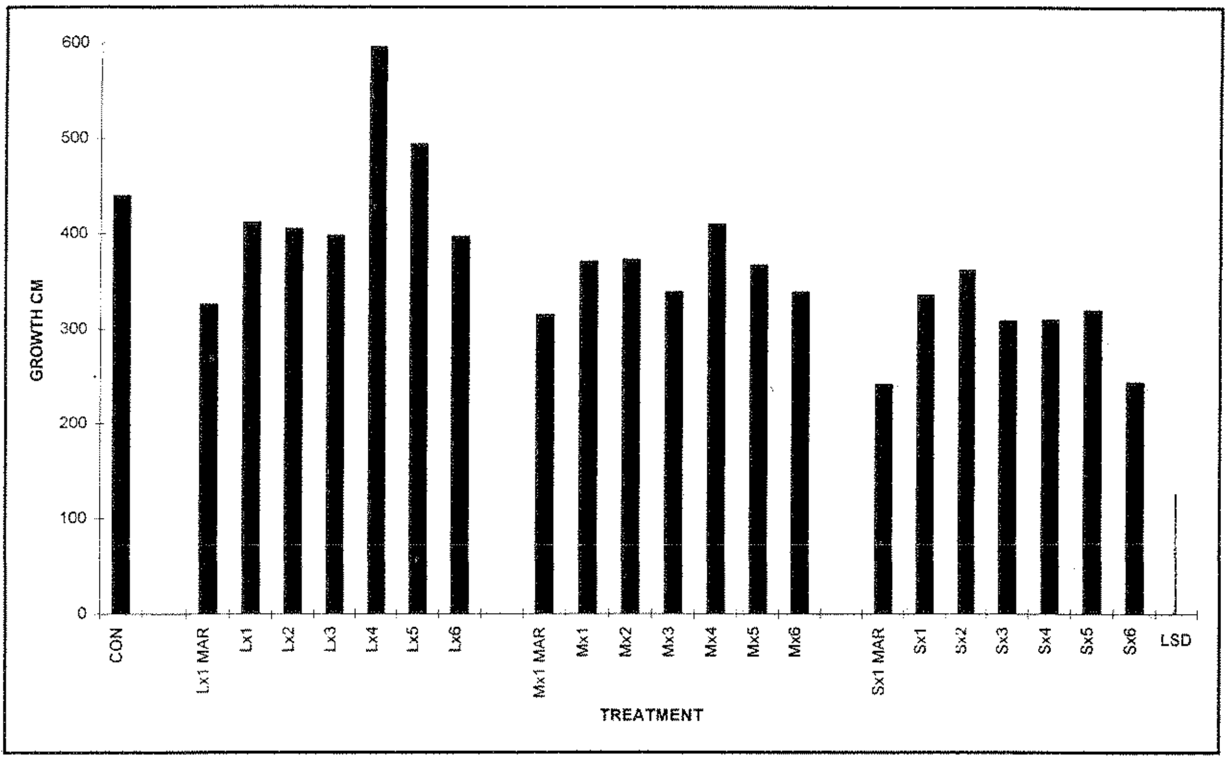


Figure 2. Mean plant height of *Forsythia* x *intermedia* 'Lynwood' LA79

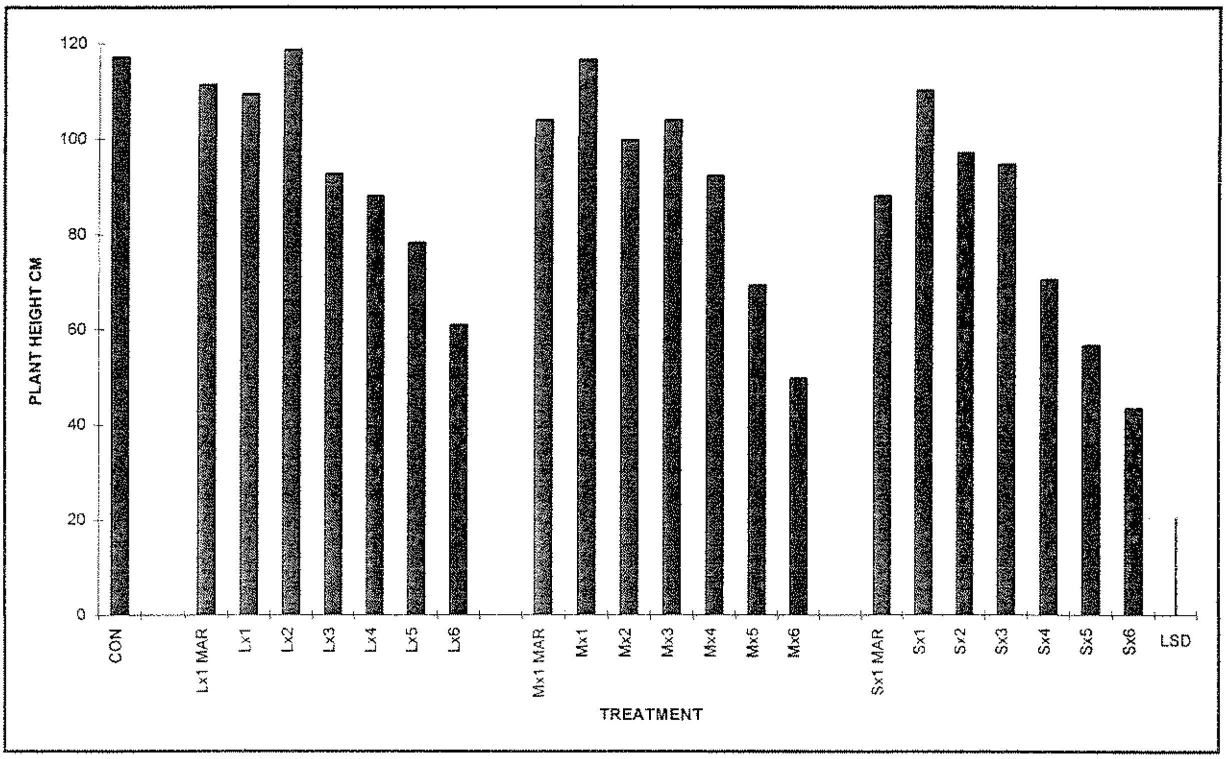


Figure 3. Mean number of laterals in *Forsythia* x *intermedia* 'Lynwood' LA79

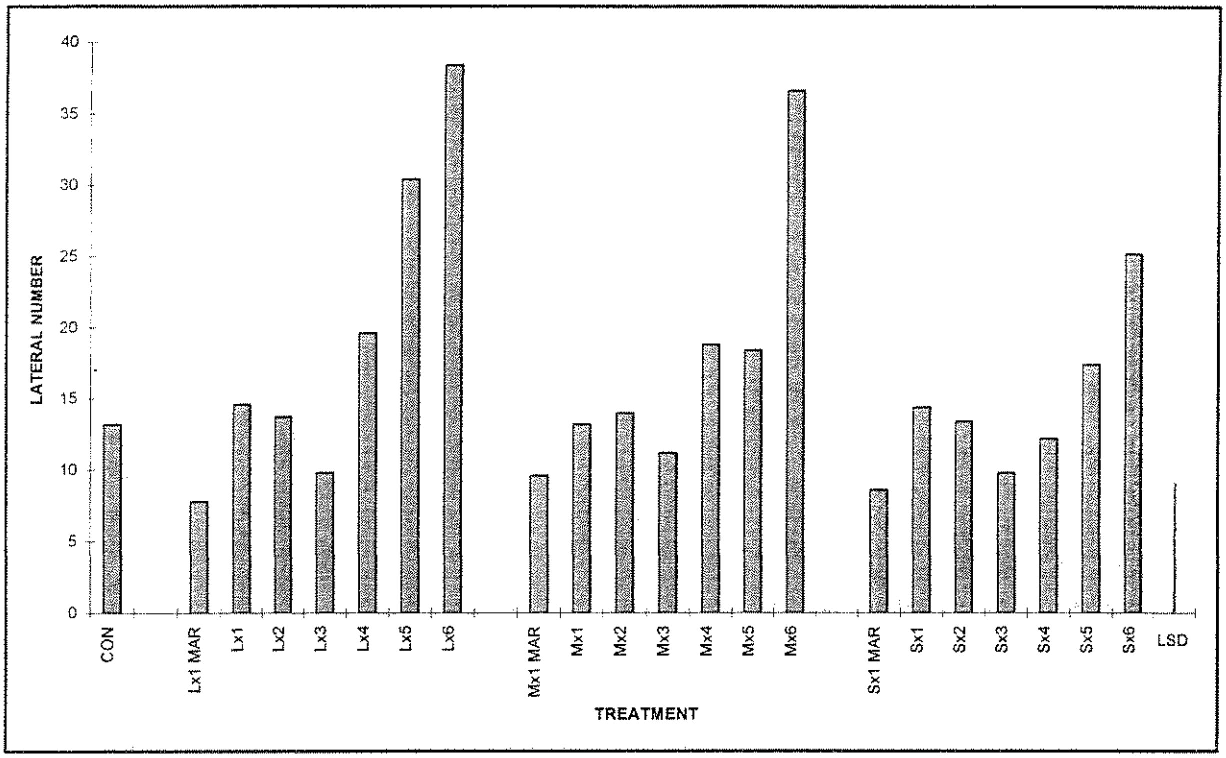
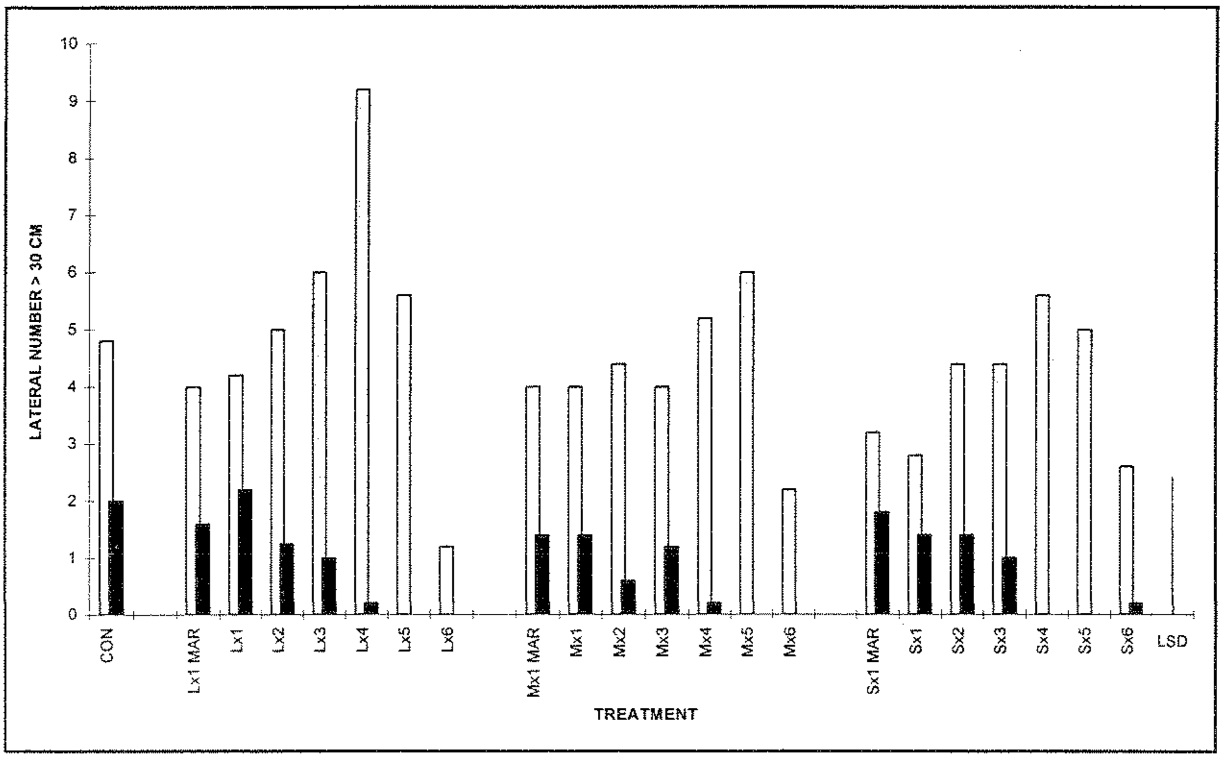


Figure 4. Mean number of long (and unsightly - solid columns) laterals in *Forsythia* x *intermedia* 'Lynwood' LA79



becoming long and leggy, and spoiling the original shape.

Pruning to a medium or severe level four times, also produced acceptable plants, although they tended to have fewer high quality laterals compared to their lightly pruned counterparts. Pruning five or six times not only used more labour, but often reduced total growth and eventual plant height, compared to pruning four times. Plants were more highly-branched however, although in the lightly pruned treatments there were significantly fewer of the long quality laterals present compared to those plants pruned four times.

There was little difference between implementing a single pruning in August 1994 compared to March 1995, both treatments resulting in relatively tall plants with limited branch formation.

Most flowering in the following spring was induced by repeated light pruning between two and four times (Figure 5). Further pruning after the end of June (x 5) resulted in significantly reduced flowering potential, most notably with plants in the medium pruning treatment. Severe pruning carried out after rooting and weaning in the initial year (i.e. Severe x 1 or Severe x 2) also encouraged the promotion of flowering wood.

Garrya:

Light and Medium pruning treatments often generated and retained significantly more growth than severe pruning (Figure 6), with growth being particularly good in Light x 1 and Medium x 2 treatments. Greatest eventual plant height was also associated with one light pruning in November 1994 (Figure 7). Repeated pruning during spring and summer resulted in smaller plants, but lateral number was enhanced, often significantly between consecutive prunings, e.g. four times compared to five times (Figure 8). Greatest number of long laterals however, was still associated with Light x 1 and Medium x 2 treatments (Figure 9).

In *Garrya* the ideal pruning regime is likely to be influenced by market requirements. Frequent pruning may be advantageous for producing specimens for the garden centre, by building-up a well-branched framework, and the best plants in terms of balanced shape were obtained from either Light x 3 and Medium x 3 pruning regimes. The disadvantages however, are that such highly-worked plants will be relatively small after the first year and may require a further year's production before being marketable. In contrast, a single early light pruning may be more suitable for landscaping plants, or in situations where crop production time needs to be kept to a minimum, with plants reaching approximately 60 cm within a year and having developed a few (4 to 6) long laterals.

Generally, *Garrya* responded less well to Severe pruning treatments compared to equivalent light or medium level pruning, and hard pruning of this species is best avoided.

Syringa:

A single light pruning on 7 March, 1995, gave the best response. Total growth was greater than in non-pruned control plants (Figure 10), although the pruned plants did not grow quite as tall (Figure 11). Nevertheless, a significantly greater number of laterals was produced (mean 6.6) compared to control plants (3.8, Figure 12), although there was no difference in

Figure 5. Mean number of nodes with flower buds in *Forsythia* x *intermedia* 'Lynwood' LA79

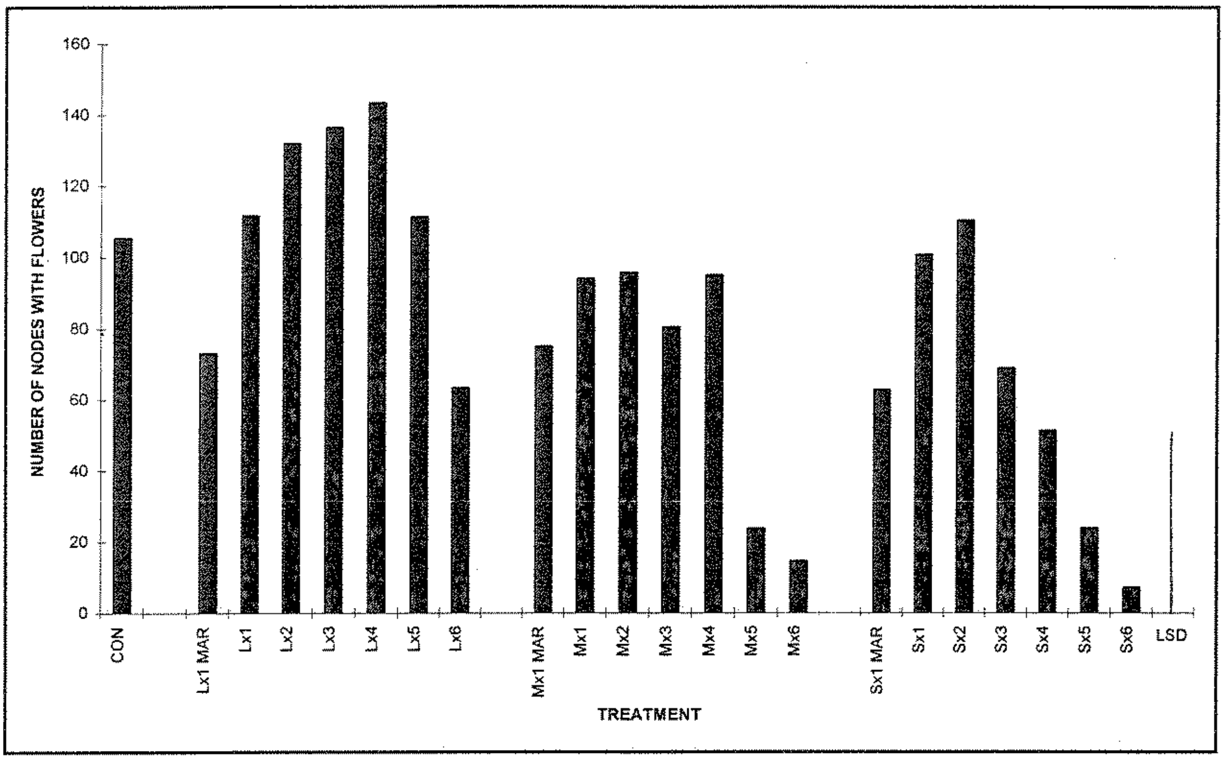


Figure 6. Mean total growth recorded in *Garrya elliptica* 'James Roof'

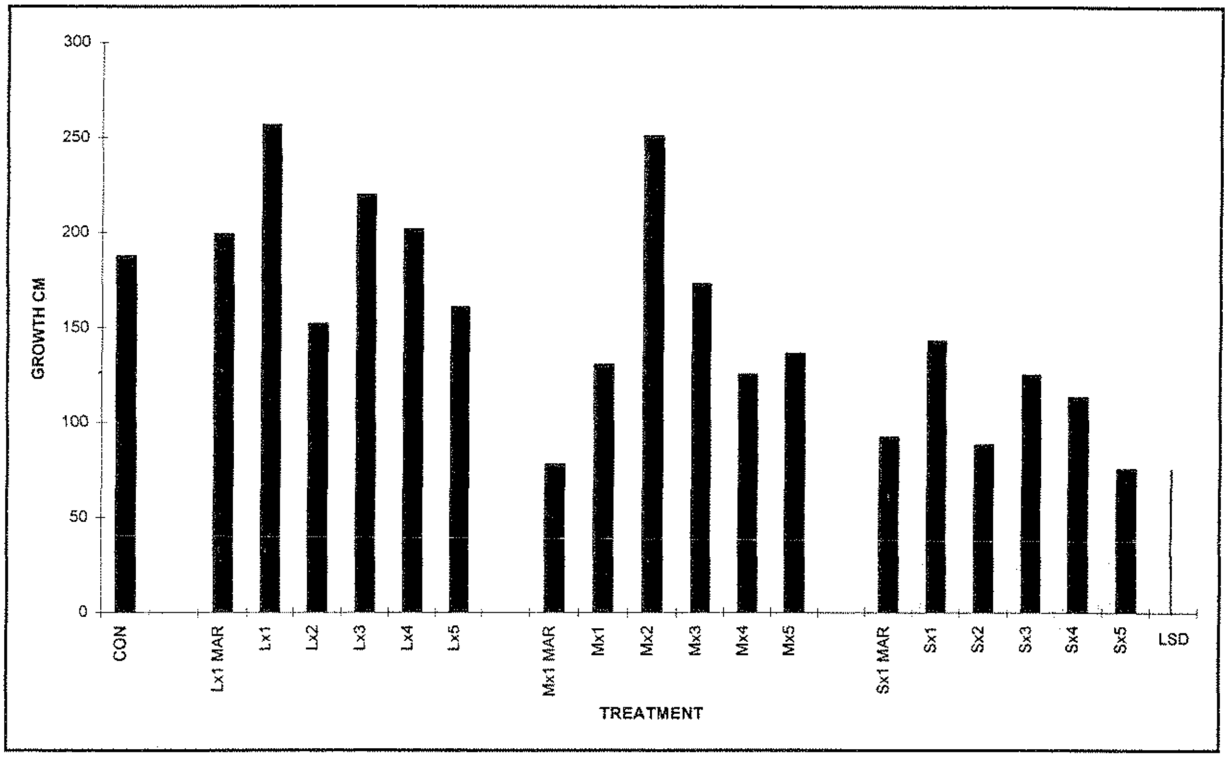


Figure 7. Mean plant height of *Garrya elliptica* 'James Roof'

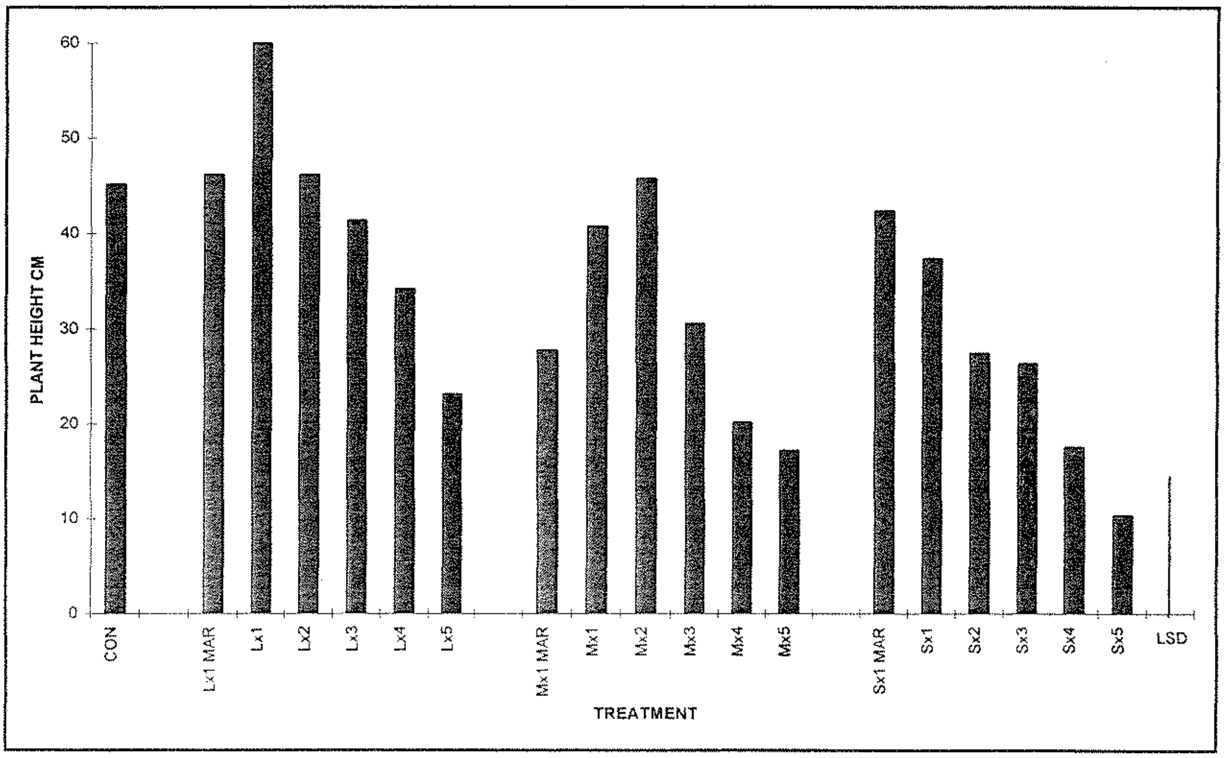


Figure 8. Mean number of laterals in *Garrya elliptica* 'James Roof'

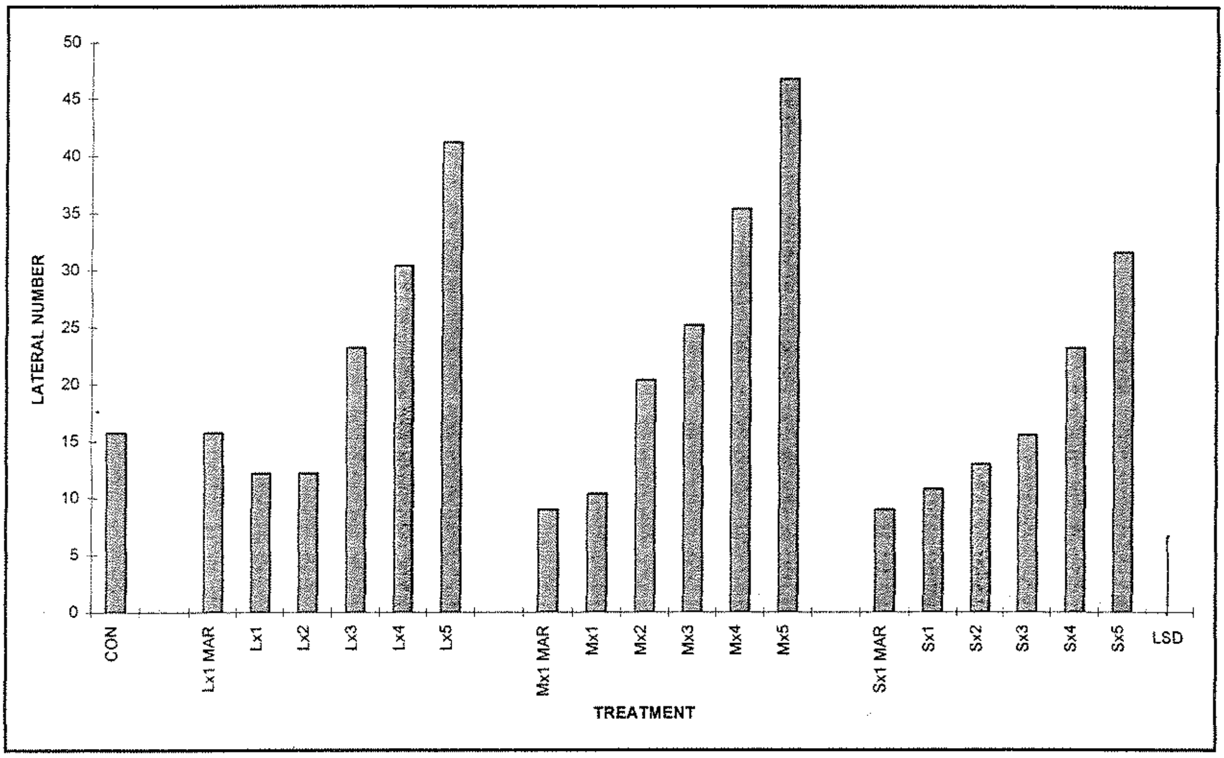


Figure 9. Mean number of long laterals in *Garrya elliptica* 'James Roof'

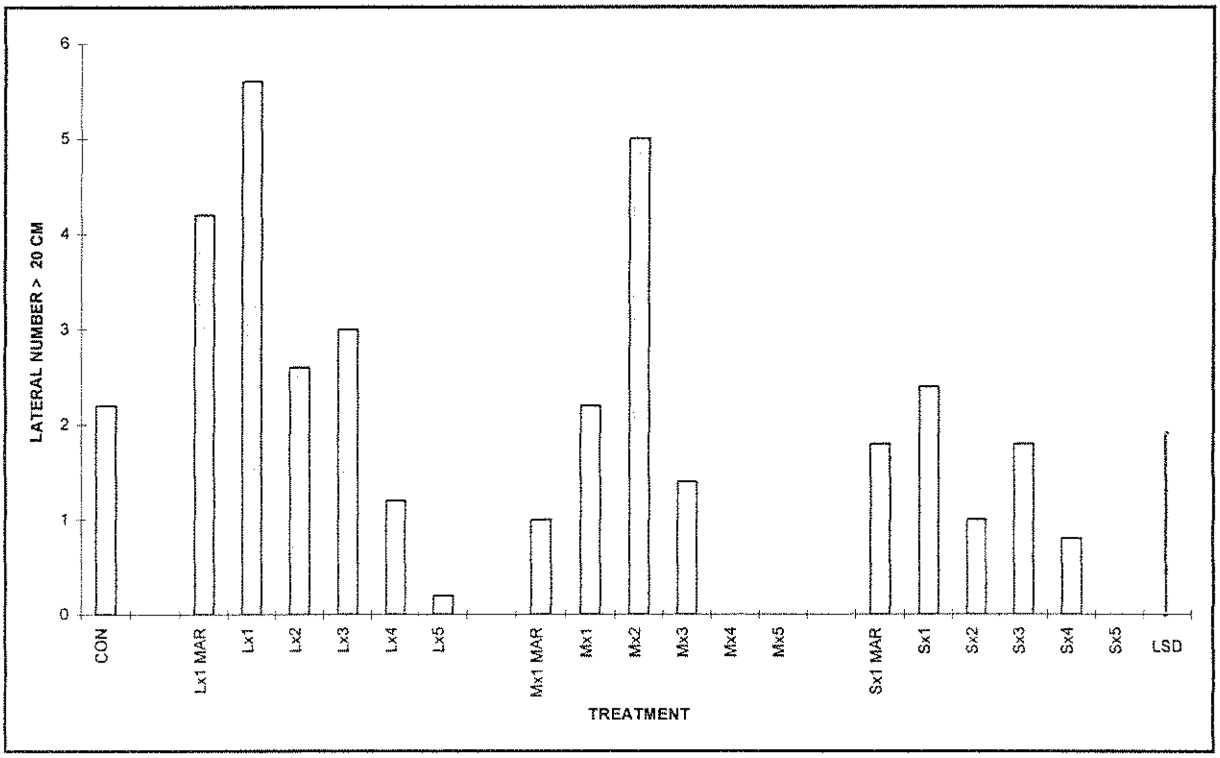


Figure 10. Mean total growth recorded in *Syringa vulgaris* 'Madame Lemoine'

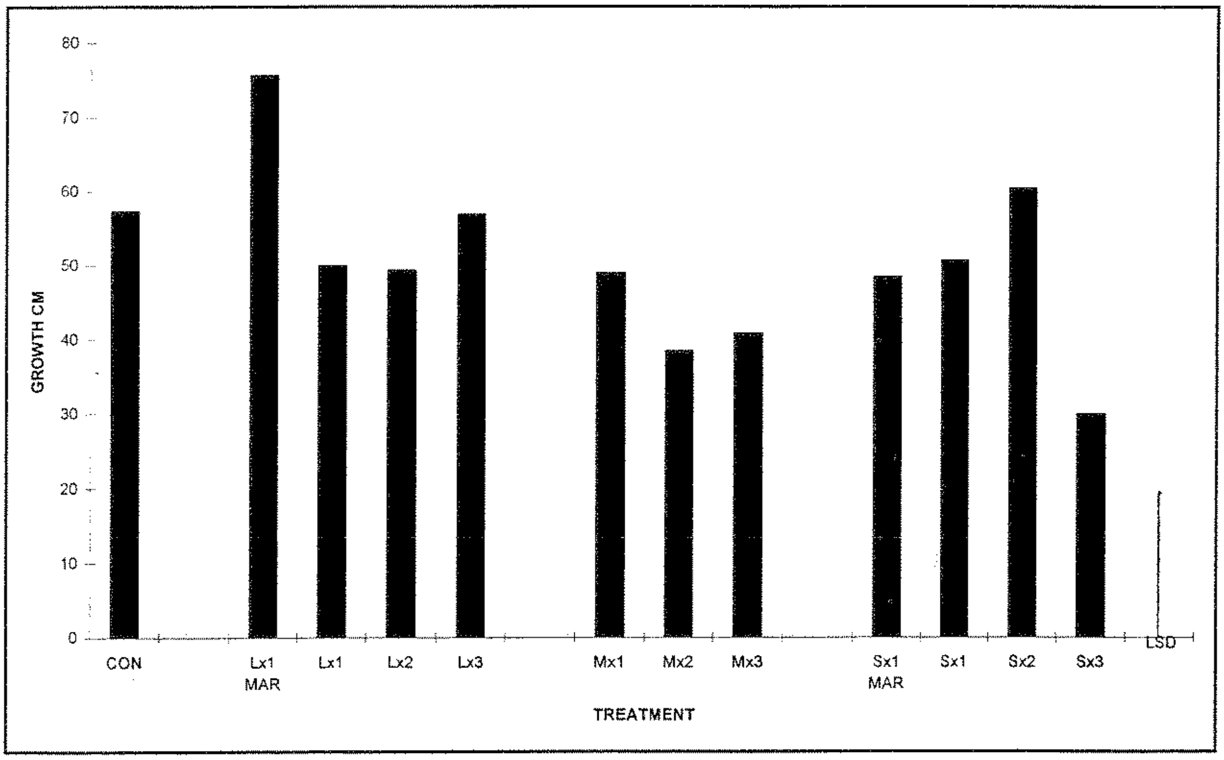
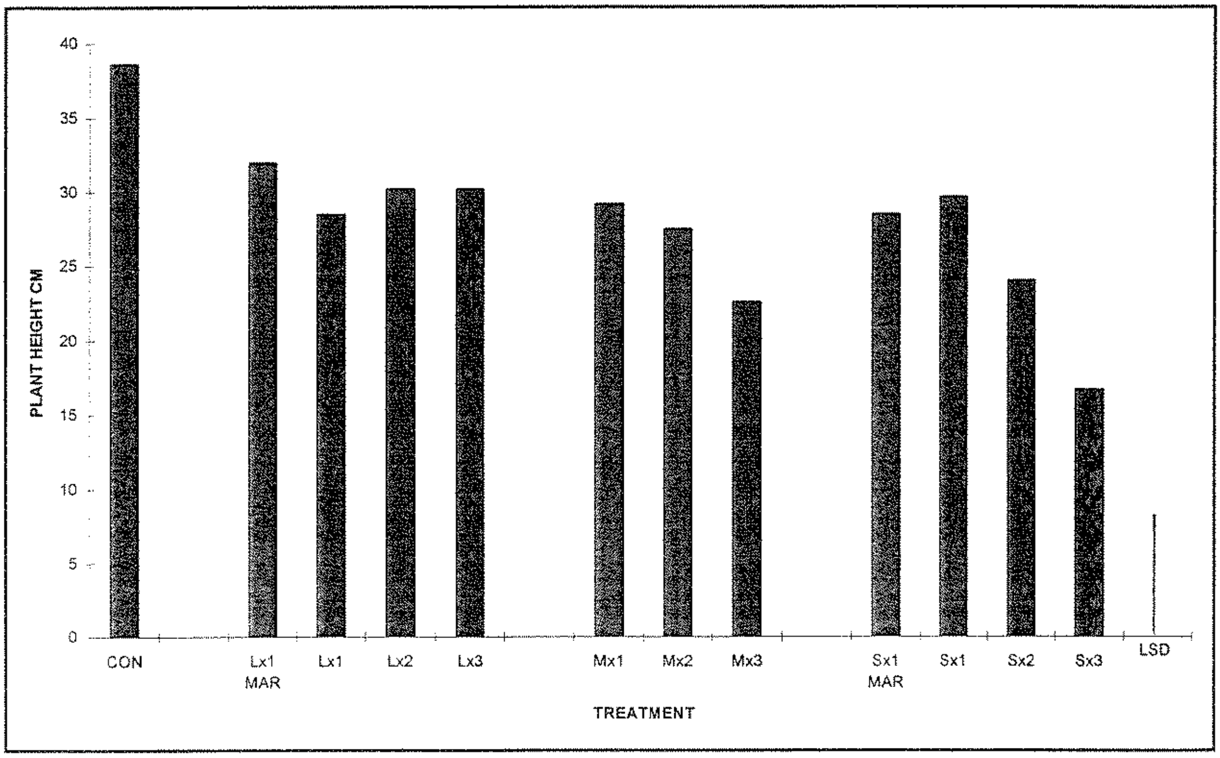


Figure 11. Mean plant height of *Syringa vulgaris* 'Madame Lemoine'



the number of good quality long laterals (Figure 13). Implementing a light pruning in March 1995 appeared to have some advantages over a similar single pruning in the previous November, and growth responses in *Syringa* may be optimised by pruning just prior to bud break. Pruning lightly in November, however, and then re-pruning on 19 April, 1995, (Light x 2) also resulted in fairly good quality plants and formed the framework for branched specimens in future years. Similarly, severely pruning twice promoted the formation of attractively branched plants. Generally, however, Severe pruning treatments could not be recommended for *Syringa* as overwintering losses were high after a hard pruning in the autumn (up to one third of all severely pruned plants being lost).

Cotinus:

Most treatments in this species gave similar amounts of total growth, the exception being a number of the severely pruned regimes (Figure 14). A single severe pruning in May significantly reduced growth compared to not only control and lightly pruned plants, but also plants given a single severe pruning in early April. This demonstrates the importance in timing of pruning treatments, with growth responses to the same pruning intensity varying considerably over relatively short periods of time. Tallest plants were associated with the single severe pruning in April (Figure 15), but this treatment promoted few laterals (Figure 16). Similarly sized plants were obtained by a single light pruning, slightly later in May, but these were better branched and had more high quality laterals in comparison (Figure 17).

Repeating a light pruning (Light x 2), i.e. once on 29 July, 1994, and then again on 31 May, 1995, increased plant height, but further pruning (three or four times) reduced overall plant size. Increasing the frequency of pruning promoted more highly-branched plants, but few of these laterals attained meritable size within the growing season and tended to result in many, irregularly-shaped, twiggy branches. The Severe x 2 treatment produced small, but evenly balanced compact plants, which over a longer time period might develop into the appropriately shaped container specimen. Severe pruning more than twice, however, was of little value and resulted in extremely small plants.

Viburnum:

In terms of overall plant growth when plants were maintained in a polytunnel, lightly pruning once, severely pruning once and no pruning all gave similar results (Figure 18). Growth, however, was suppressed in the Medium pruning treatment and plants from this treatment proved to be the shortest by the end of the season (Figure 18). Tallest plants were associated with the Light pruning treatment. Overall greatest lateral production was related to the non-pruned control treatment, but none of the treatments consistently produced the longer high quality laterals (Figure 19). In contrast to the previous year's results where plant were grown outside, growing under polythene appears to have enhanced the response to severe pruning.

Figure 12. Mean number of laterals in *Syringa vulgaris* 'Madame Lemoine'

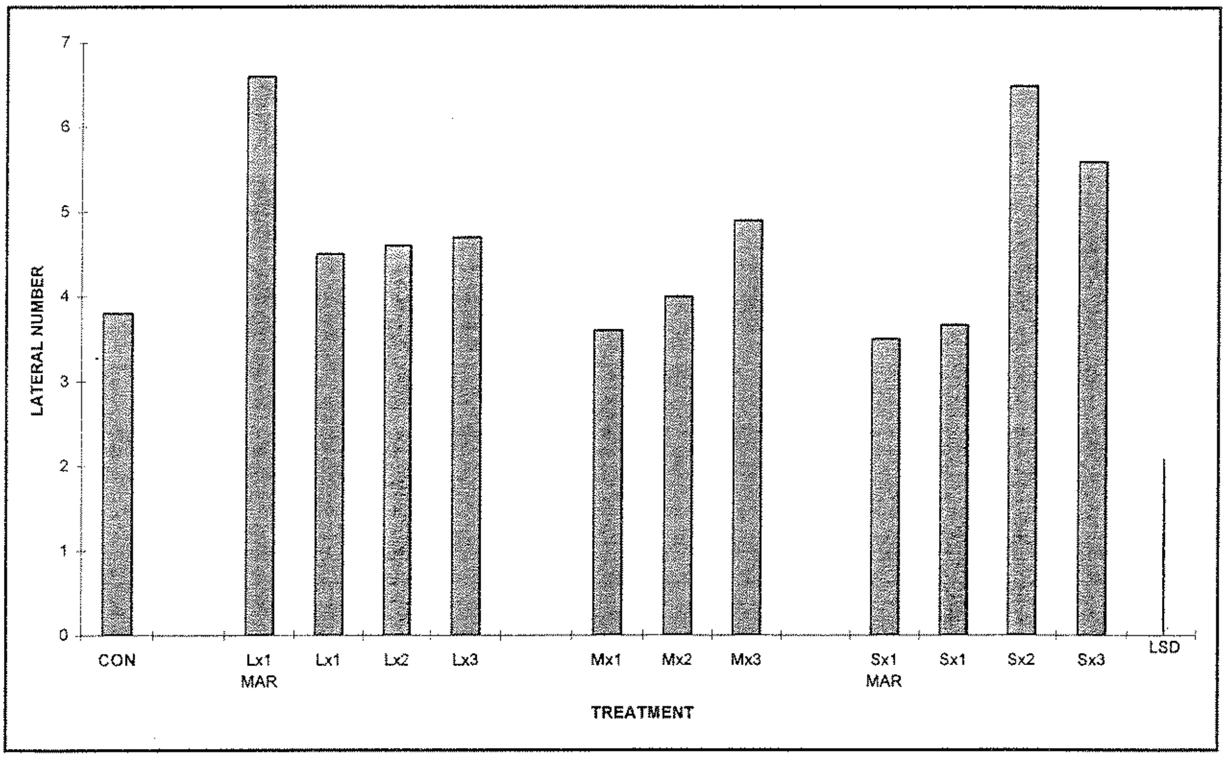


Figure 13. Mean number of long laterals in *Syringa vulgaris* 'Madame Lemoine'

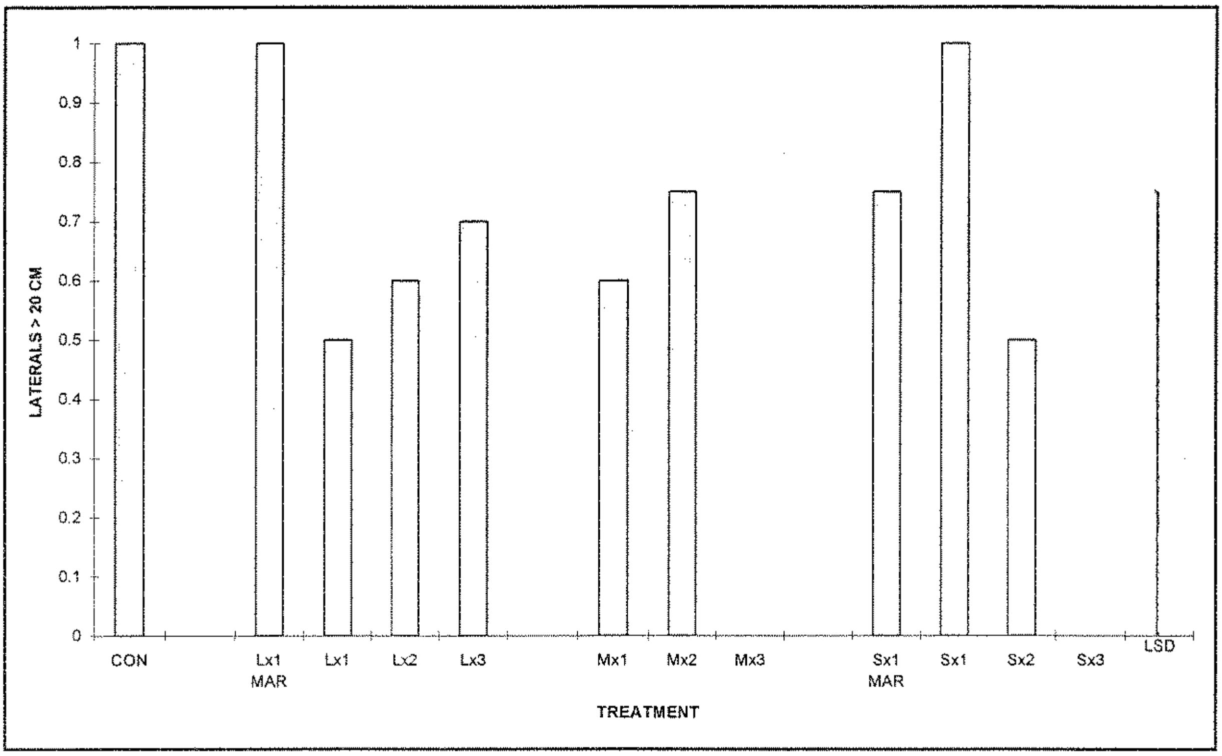


Figure 14. Mean total growth recorded in *Cotinus coggygria* 'Royal Purple'

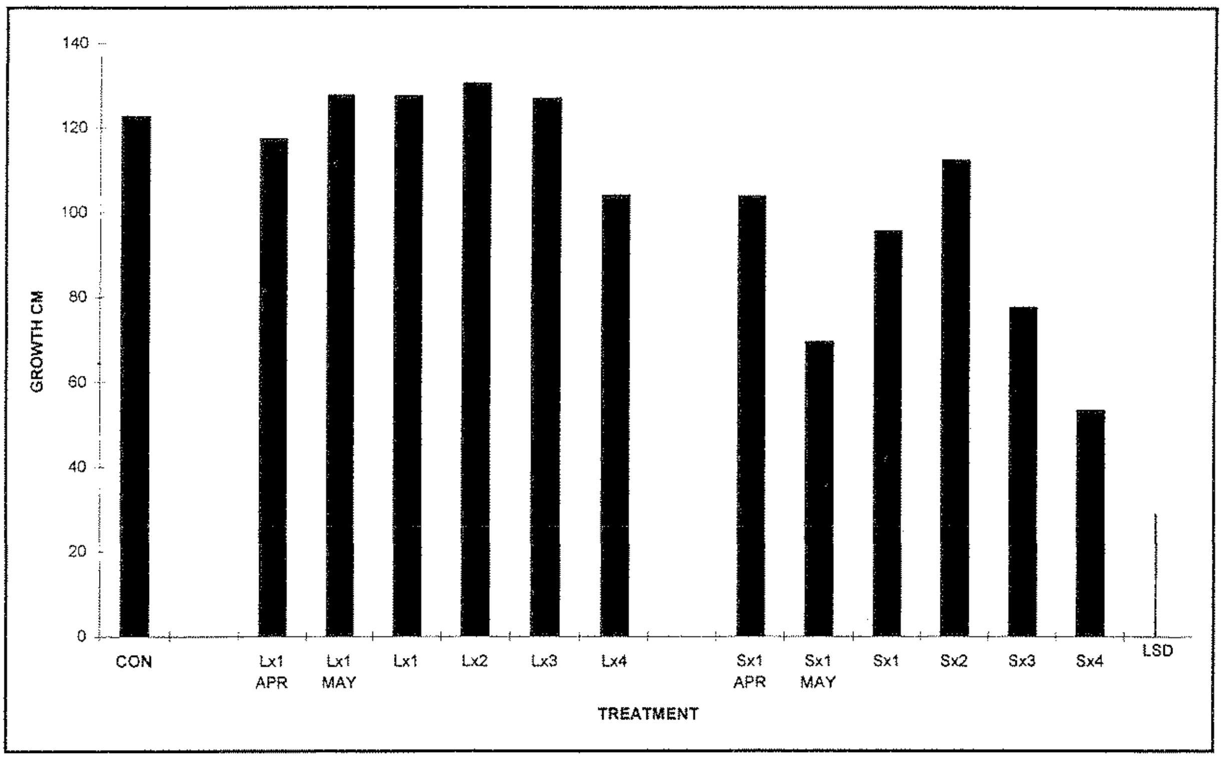


Figure 15. Mean plant height of *Cotinus coggygria* 'Royal Purple

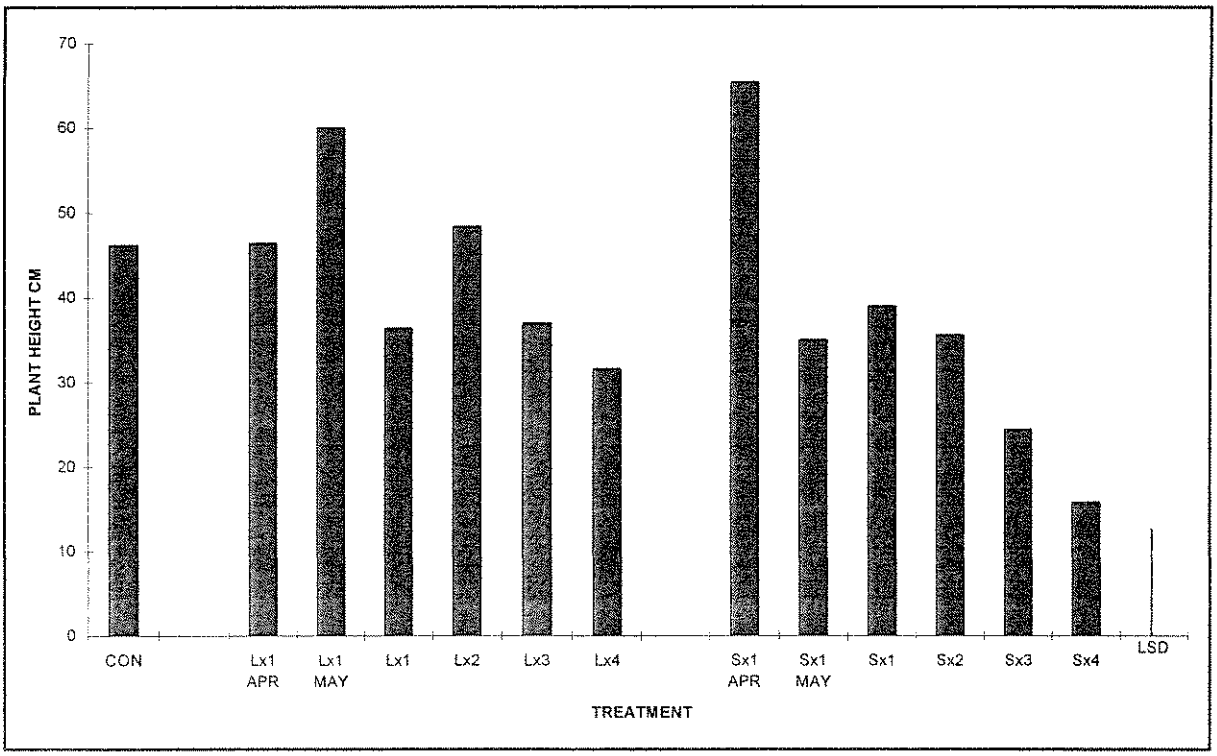


Figure 16. Mean number of laterals in *Cotinus coggygria* 'Royal Purple'

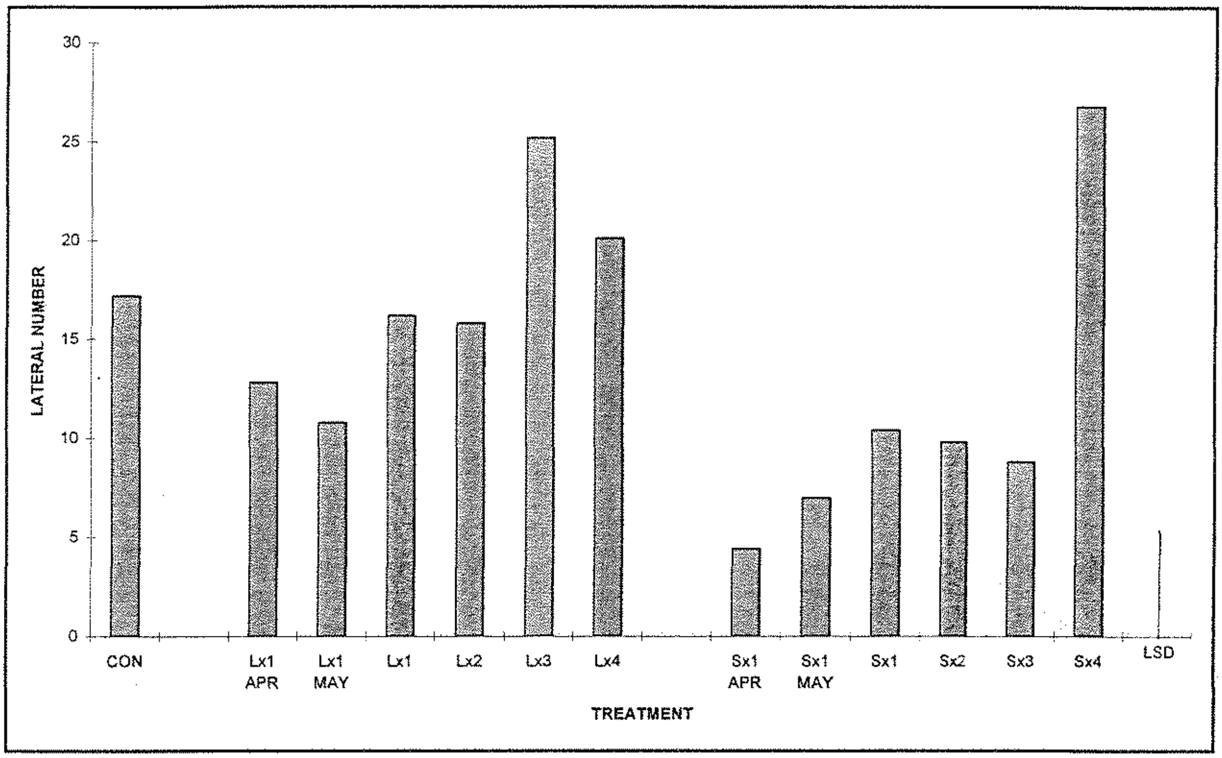


Figure 17. Mean number of long laterals in *Cotinus coggygria* 'Royal Purple'

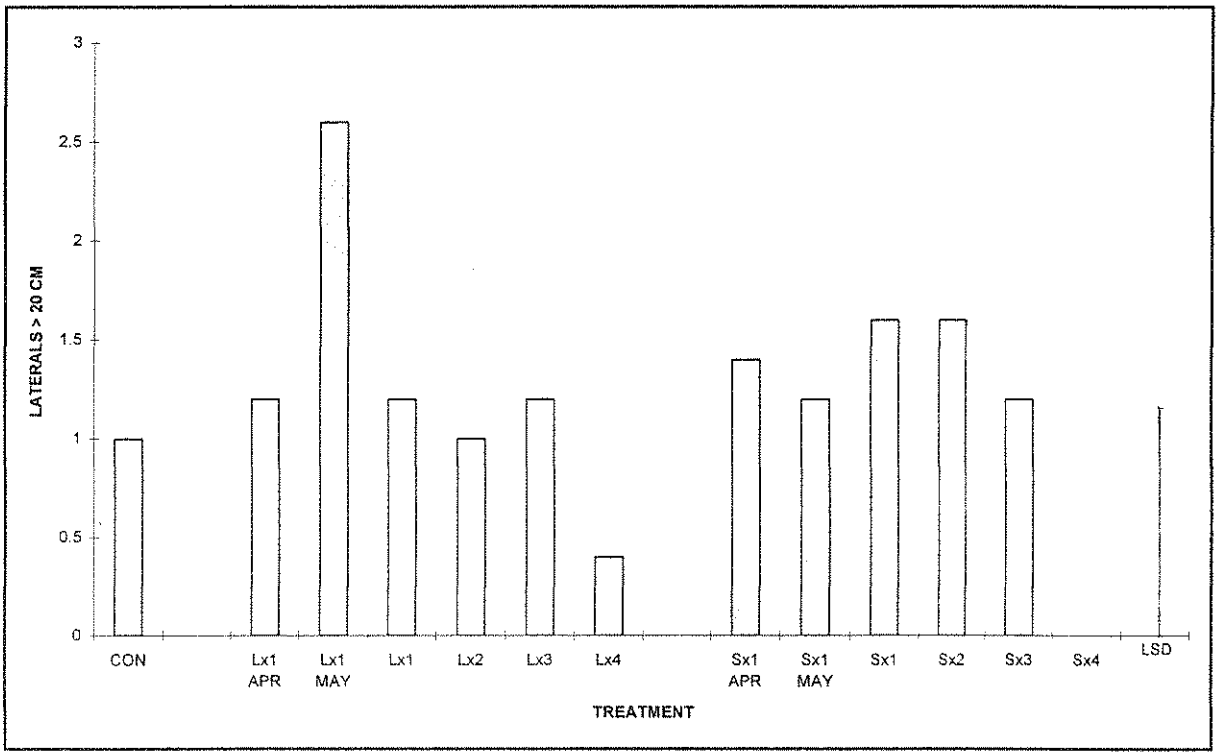


Figure 18. Mean total growth and plant height in *Viburnum carlesii* 'Aurora'

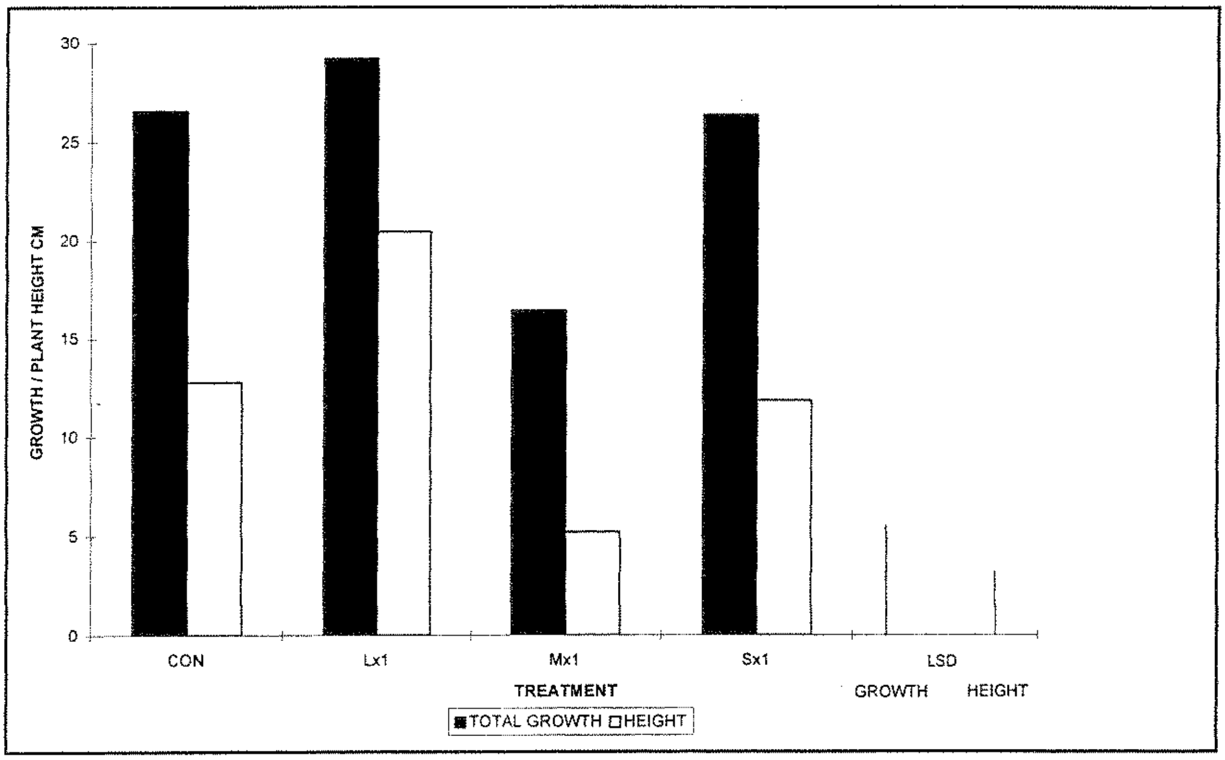
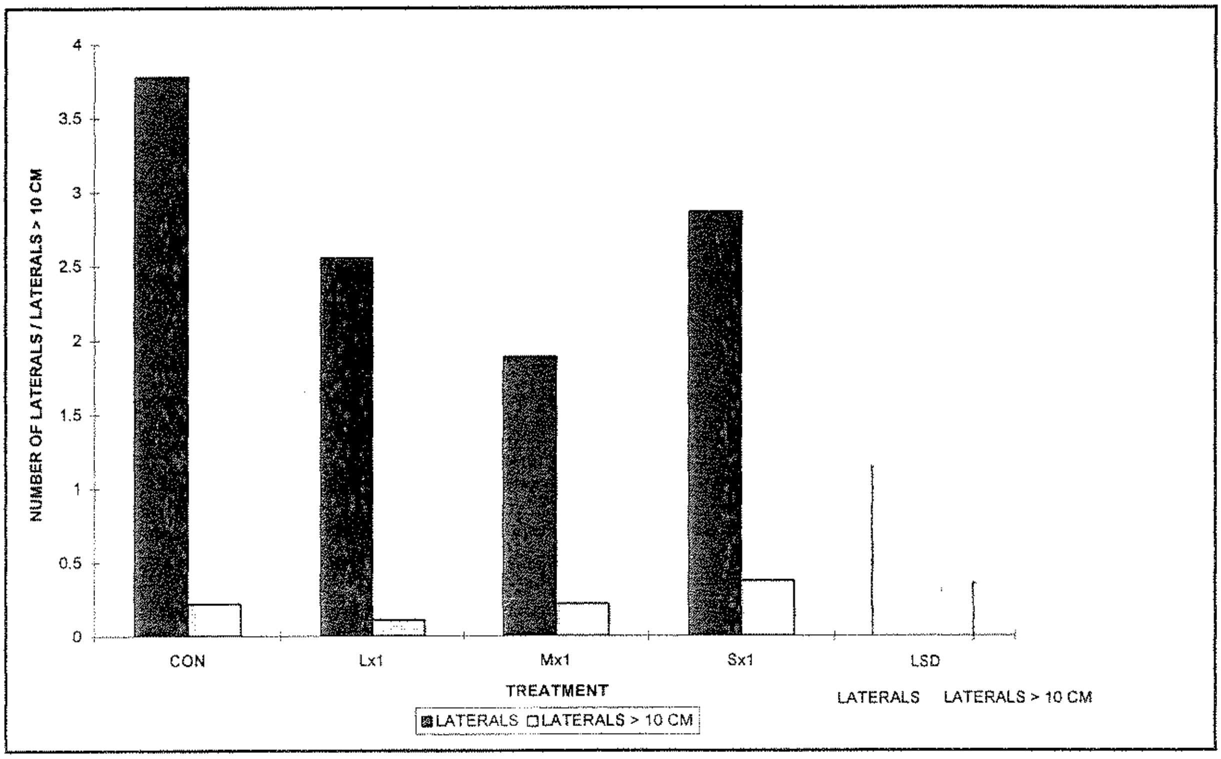


Figure 19. Mean number of laterals and laterals > 10 cm in *Viburnum carlesii* 'Aurora'



Part 2. Plant growth as characterised by pruning, bud excision and defoliation.

Introduction

The objectives of this part of the research was to examine in more detail how bud position influenced development and lateral shoot formation. Of primary importance is the role of the apical bud (or group of apical buds) in inhibiting buds from growing lower down the stem. What is less clear is where the source of inhibition is derived from, such as individual apical buds, specific parts of buds, other apical tissues, or active or dormant buds, and how much of the apical bud or apical region needs to be removed to optimise lateral shoot promotion throughout the entire stem. Additionally, more information is required on precisely where lateral development takes place after apical tissues have been removed. To help identify some of these factors influencing apical dominance in liners a number of experiments were implemented using *Forsythia* and *Syringa*. Pruning treatments of different severities were set-up using dormant plants in early spring, and timing and position of subsequent bud activity were monitored. As a contrast to this and previous pruning experiments, it was decided also to investigate the effects of bud or leaf removal, (rather than the whole stem), on subsequent growth, and thus help identify the important components determining apical dominance. In the second experiment comparisons were made between removing dormant buds, active buds or only the leaf tissues associated with active buds. The principles behind both experiments were similar, but whereas the pruning experiment was based on percentage of stem removed, bud removal or defoliation related specifically to the original numbers of buds and their position within a particular stem. Therefore, as buds do not uniformly occur along a stem, the region of viable buds in the latter experiment would not necessarily correlate to the same **length** of stem in an equivalent pruning treatment.

Materials and Methods

Cuttings of *Forsythia* x *intermedia* 'Lynwood' LA79 and *Syringa vulgaris* 'Madame Lemoine' were rooted and weaned in an identical manner to that described in part 1, with both species being direct-stuck into 1 litre pots. Plants were overwintered outside with bubble polythene being used as a source of frost protection when necessary.

2 (a) <u>Bud break and growth as influenced by pruning.</u>

Twenty-four single-stemmed plants from each species were selected and graded for size and shape on 20 February, 1995. Bud position and number of buds on each plant were then recorded, before plants were divided into four treatments, i.e:-

Control	=	no pruning.
Tip pruned	=	removing the shoot apex, inclusive of the top 2-3 cm of stem.
Medium pruned	=	removing approximately one-third of the main stem length.
Severe pruning	=	removing approximately two-thirds of the main stem length.

Plants were pruned on 22 February and subsequently were monitored regularly for position and timing of bud break.

2 (b) Bud break and growth as influenced by bud removal or bud defoliation

Contrary to the previous pruning experiments, stems were left intact and only buds or leaf tissues were removed along the main stem of each plant. There were three main treatment factors in this experiment investigating the effects due to (i) removing buds before growth commences, (ii) removing buds as they break from dormancy and (iii) leaving buds on the stem but defoliating the new leaves as they unfolded around the elongating bud. For each treatment the extent of the debudding/defoliation was divided into four severity treatments, i.e:-

Control	=	no debudding/defoliation.
Apical	=	removing/defoliating only the apical bud on each plant.
One-Third	=	removing/defoliating the top (distal) third of buds on each plant.
Two-Thirds	=	removing/defoliating the top (distal) two-thirds of buds from each plant.

There were six replicate plants for each treatment combination giving a total of 72 plants for the entire experiment. Bud excision took place on 14 March, 1995 for those treatments requiring bud removal prior to dormancy release. In the treatments where buds were only removed as growth commenced, however, plants were checked regularly between 14 March and 30 June, 1995 and buds removed as soon as bud extension was apparent. Likewise, in the defoliation treatments, new leaves were carefully excised from the developing shoot as they began to unfold. Excision and defoliation treatments were stopped on 30 June, 1995.

At this time all plants, including those from the pruning experiment (2a), were potted-on into 3 litre (*Forsythia*) or 2 litre (*Syringa*) pots using a growing medium of 60% peat, 20% bark, 10% loam and 10% grit by volume with 4 kg calcium carbonate, 2 kg magnesium limestone, 150 g Nitram and 4 kg Osmocote Plus (15:9:11:2 + trace elements) incorporated per m^3 and subsequent growth performance was monitored throughout the summer.

During the course of the experiments the position of active buds on the stem and the extent to which they extended as laterals, was recorded. Intact *Forsythia* stems were divided into specific regions, i.e apical, top, middle and basal, (as well as a note made of suckers appearing from below compost level). However, *Syringa* generally had fewer buds and shorter, more compact stems and there was less opportunity to define buds within such specific categories. Nevertheless, general bud position could often still be categorised by top, middle or basal regions, and a record for both species of the number of active buds or shoots present in particular regions was made in May and October, 1995.

Results

Forsythia

Pruning:

Tip pruning resulted in more even bud break along the main stem in May, compared to other treatments, and marginally increased the number of active buds compared to control plants, but differences were not significant (Table 3). More severe pruning (Medium or Severe treatments) significantly reduced the total number of buds breaking at this stage, almost entirely by virtue of the length of stem removed in the pruning process. By October

Table 3. *Forsythia*: Mean numbers of buds growing in May after pruning.

Position	Control	Pruning severity			LSD
		Tip	Medium	Severe	
Apical	0.5	-	-	-	-
Top	5.2	5.7	-	-	2.2
Mid	5.2	6.7	4.0	-	3.1
Base	4.7	5.0	4.5	4.5	3.3
Sucker	0	0	0	0	-
Total	15.6	**17.4**	8.5	4.5	6.4

Table 4. *Forsythia*: Mean number of laterals and growth per lateral in October after pruning.

Position	Control	Pruning severity			LSD
		Tip	Medium	Severe	
Apical	0.5	-	-	-	-
Top	6.5	8.8	-	-	3.1
Mid	4.5	6.0	7.9	-	6.0
Base	8.7	12.0	7.2	**17.2**	8.5
Sucker	0.7	0	5.2	2.3	4.4
Total	20.9	**26.8**	20.3	19.5	10.6
Growth per lateral (cm)	22.3	27.4	34.9	**37.0**	9.4

(Table 4), control and tip-pruned plants showed similar trends, although number of lateral shoots was still greater after initially tipping the plants, but not significantly so. Severe pruning resulted in branch formation low down on the main stem (a proportion of which was due to naturally occurring secondary and tertiary lateral formation). Likewise, medium pruning resulted in more laterals in the middle of the plant, which were supplemented by a relatively large number of sucker shoots. The average lateral tended to be longer in the medium and severely pruned plants.

Bud excision before growth:

Removing buds before growth promoted bud activity in the region immediately below the position of bud excision, i.e. removing the top one-third of all buds resulted in greatest bud break in the middle region, and likewise removing buds from the top two-thirds of the stem corresponded to greatest activity in the basal region by May (on average 9 buds per plant; Table 5). Excising the apical bud resulted in similar growth responses to control plants. Removing buds from a section of stem reduced vegetative activity in that section, but did not necessarily eliminate it because some very small secondary buds developed and later formed shoots; these replacement buds were included in the analyses, giving rise to LSD values which must be treated with caution. Results by October indicated that trends between treatments were similar, although overall greatest bud activity was associated with those plants where the apical bud had been removed (total of 24.2 shoots per plant; Table 6). This treatment also encouraged most laterals in the basal region. Suckering was promoted by one-third and two-third bud removal and the longest individual shoots were associated with the two-thirds bud removal treatment.

Bud excision as buds break dormancy:

Excising individual buds as they broke dormancy gave comparable growth responses in May to similar dormant pruning regimes, i.e. removing the apical bud gave significantly the highest and most uniform bud break (total of 22.0 buds compared to 12.9 for controls; Table 7). Removing buds from two-thirds of the stem was associated with limited and weak bud activity in the basal region, (in contrast to removing buds before they were active). Plants with the apical bud removed produced the greatest number of laterals by October (Table 8), although most of these were associated with the top and middle regions of the stem and the total increase was not significant over the control. Excising two-thirds of buds and the subsequent poor growth at the base appeared to stimulate sucker production, with a mean value of 9 suckers (or laterals from suckers), recorded for this treatment.

Bud defoliation:

Defoliation of developing buds resulted in most shoot production being associated with the one-third defoliation treatment, when recorded in both May and October. By May, plants in this treatment had significantly more active buds compared to the totals of those where only the developing apical buds were defoliated (Table 9). In contrast to totally removing the apical bud, defoliation did not appear to give the same strength of stimulus for releasing lower axillary buds from apical dominance. The defoliation of buds did not necessarily stop bud activity and a number of young shoots continued to grow after leaves had been removed. However, shoot viability over the longer term was affected and there were fewer shoots in

Table 5. *Forsythia*: Mean numbers of buds growing in May after initially removing buds before growth commenced.

		Severity of bud removal			
Position	Control	Apical	1/3	2/3	LSD
Apical	**0.7**	0	0.2	0	0.4
Top	**5.0**	4.8	0.8	0.7	2.9
Mid	4.3	5.0	**5.2**	0.3	2.7
Base	3.3	5.0	3.8	**9.0**	2.7
Sucker	0.7	0	0.5	0.7	-
Total	14.0	14.8	10.5	10.7	5.3

Table 6. *Forsythia*: Mean number of laterals and growth per lateral in October after initially removing buds before growth commenced.

		Severity of bud removal			
Position	Control	Apical	1/3	2/3	LSD
Apical	1.2	0	0	0	-
Top	4.0	**6.2**	2.0	0.7	3.4
Mid	4.2	5.5	**8.3**	0	3.7
Base	6.7	**12.5**	4.5	11.0	4.3
Sucker	1.2	0	4.2	**6.3**	5.3
Total	17.3	**24.2**	19.0	18.0	6.8
Growth per lateral (cm)	32.2	27.4	33.4	**44.1**	11.8

Table 7. *Forsythia*: Mean numbers of buds growing in May after initially removing buds as they were released from dormancy.

Position	Control	Severity of bud removal			LSD
		Apical	1/3	2/3	
Apical	0.7	0	0	0	-
Top	4.8	**8.0**	0	0	2.9
Mid	3.2	**8.2**	5.5	0	2.7
Base	3.0	4.2	3.5	2.2	2.7
Sucker	1.2	**1.6**	0.3	1.0	-
Total	12.9	**22.0**	9.3	3.2	5.3

Table 8 *Forsythia*: Mean number of laterals and growth in October after initially removing buds as they were released from dormancy.

Position	Control	Severity of bud removal			LSD
		Apical	1/3	2/3	
Apical	0.5	0	0	0	-
Top	4.8	**6.4**	4.2	0	3.4
Mid	2.8	**8.4**	4.3	0.2	3.7
Base	2.7	3.0	3.7	4.6	4.3
Sucker	6.2	3.8	4.8	9.0	5.3
Total	17.0	**21.6**	17.0	13.8	6.8
Growth per lateral (cm)	31.2	28.5	39.4	**46.2**	11.8

Table 9. *Forsythia*: Mean numbers of buds growing in May after defoliating buds as they developed.

Position	Control	Severity of bud defoliation Apical	1/3	2/3	LSD
Apical	0.6	**0.8**	0.6	0.2	0.4
Top	4.8	6.0	**7.4**	2.8	2.9
Mid	3.8	4.8	**8.0**	3.5	2.7
Base	4.8	4.7	**9.2**	2.3	2.7
Sucker	0.6	0.8	0.4	0.3	-
Total	14.6	17.1	**25.6**	9.1	5.3

Table 10. *Forsythia*: Mean number of laterals and growth in October after defoliating buds as they developed.

Position	Control	Severity of bud defoliation Apical	1/3	2/3	LSD
Apical	0.6	0.7	0.8	0.2	0.8
Top	5.4	5.0	6.2	3.3	3.4
Mid	3.0	3.8	**7.6**	3.2	3.7
Base	4.4	7.2	6.2	3.5	4.3
Sucker	4.4	4.0	2.4	**8.3**	5.3
Total	17.8	20.7	23.2	18.5	6.8
Growth per lateral (cm)	29.8	29.0	26.0	**38.4**	11.8

October than May in the one-third defoliation treatment (Table 10). In plants where buds on two thirds of the stem were defoliated, regrowth occurred during the summer and shoot profiles were not significantly different from controls by October. Increased lateral length was associated with this latter treatment (mean of 38.4 cm), but these laterals were marginally shorter (not significant) than equivalent ones from bud removal treatments where means were greater than 40 cm (Tables 6 and 8).

Syringa

Pruning:

Tip pruning marginally increased the total number of buds breaking from the top and middle regions of plants by May (Table 11), although overall highest number of laterals in October was associated with the medium pruning treatment (not significant) with a mean of 4.5 laterals per plant (Table 12). Mean shoot length was relatively uniform throughout, being approximately between 9 and 11 cm in length. Tip-pruned plants tended to have the most even distribution of shoots along the length of the main stem. Sucker production appeared to be marginally favoured by the hard pruning treatments.

Bud excision before growth:

Removing buds before growth showed no advantage compared to control plants in terms of overall active buds or distribution of growing buds in May (Table 13). Bud activity was marginally increased below the excision point with one-third and two thirds removal. Results by October (Table 14) indicated that a number of buds in control plants had aborted and greatest number of laterals was now associated with apical and one-third removal treatments (4.6). Removing two-thirds of buds resulted in the longest laterals by October, with a mean value of over 15 cm.

Bud excision as buds break dormancy:

Removing buds following bud break resulted in similar trends to removing buds prior to growth, with most growth in May again being in the region immediately below the lowest position of bud excision (Table 15). Bud removal, however, showed no advantage over control plants. Similarly in October, results from control plants were equally as good or better than those from bud removal treatments, although longest laterals (non-significant) were associated with bud excision from two-thirds of the stem (Table 16).

Bud defoliation:

Defoliating the apical bud gave most uniform bud break when plants were assessed in May, with a mean total number of 4.4 active buds (Table 17). This trend was perpetuated through to October, with apical defoliation resulting in a mean total lateral number of 6.3, generally more than in equivalent bud removal treatments (Table 18). Mean lateral length, however, was relatively low at only 7.6 cm.

Table 11. *Syringa*: Mean numbers of buds growing in May after pruning

		Pruning severity			
Position	Control	Tip	Medium	Severe	LSD
Top	0.8	1.3	/	/	0.9
Mid	1.3	2.3	1.3	/	1.2
Base	0.8	0.2	**1.7**	1.1	0.8
Sucker	0	0	0.2	0	-
Total	2.9	**3.8**	3.2	1.1	1.9

Table 12. *Syringa*: Mean number of laterals and growth per lateral in October after pruning.

		Pruning severity			
Position	Control	Tip	Medium	Severe	LSD
Top	0.8	1.2	/	/	1.1
Mid	1.5	1.0	2.3	/	2.1
Base	1.7	1.2	1.7	2.5	1.5
Sucker	0	0	0.5	0.5	-
Total	4.0	3.4	4.5	3.0	2.1
Growth per lateral (cm)	9.2	10.3	10.8	10.6	3.4

Table 13. *Syringa*: Mean numbers of buds growing in May after initially removing buds before growth commenced.

		Severity of bud removal			
Position	Control	Apical	1/3	2/3	LSD
Top	**1.4**	0.5	0	0	1.1
Mid	1.4	1.2	1.5	0.4	1.2
Base	1.0	0.8	1.3	**1.8**	1.0
Sucker	0	0	0	0.2	-
Total	3.8	2.5	2.8	2.4	4.1

Table 14. *Syringa*: Mean number of laterals and growth per lateral in October after initially removing buds before growth commenced.

		Severity of bud removal			
Position	Control	Apical	1/3	2/3	LSD
Top	0.4	0.5	0	0	1.2
Mid	1.6	1.8	**2.7**	0	2.0
Base	1.4	1.5	1.7	2.8	2.1
Sucker	0	0.8	0.2	0.4	-
Total	3.4	4.6	4.6	3.2	2.3
Growth per lateral (cm)	13.3	7.2	10.2	15.6	5.6

Table 15. *Syringa*: Mean numbers of buds growing in May after initially removing buds as they were released from dormancy

		Severity of bud removal			
Position	Control	Apical	1/3	2/3	LSD
Top	0.7	1.0	0	0	1.1
Mid	0.7	0.2	**1.8**	0	1.2
Base	1.2	1.0	0	**1.4**	1.0
Sucker	0	0	0	0.4	-
Total	2.6	2.2	1.8	1.8	4.1

Table 16. *Syringa*: Mean number of laterals and growth in October after initially removing buds as they were released from dormancy.

		Severity of bud removal			
Position	Control	Apical	1/3	2/3	LSD
Top	0.2	1.0	0	0	1.2
Mid	1.2	0	**2.5**	0	2.0
Base	2.5	2.2	0.5	**3.2**	2.1
Sucker	0.3	0.3	0	1.0	-
Total	4.2	3.5	3.0	4.2	2.3
Growth per lateral (cm)	11.2	12.7	13.4	14.1	5.6

Table 17. *Syringa*: Mean numbers of buds growing in May after defoliating buds as they developed.

		Severity of bud defoliation			
Position	Control	Apical	1/3	2/3	LSD
Top	1.3	1.3	1.0	0.3	1.1
Mid	1.2	1.2	0.7	1.5	1.2
Base	0.8	1.7	0.7	1.5	1.0
Sucker	0	0.2	0	0	-
Total	3.3	4.4	2.4	3.3	4.1

Table 18. *Syringa*: Mean number of laterals and growth per lateral in October after initially removing buds before growth commenced.

		Severity of bud defoliation			
Position	Control	Apical	1/3	2/3	LSD
Top	**1.7**	1.0	1.5	0.2	1.2
Mid	1.7	1.8	0.3	0.3	2.0
Base	2.2	2.5	1.8	3.5	2.1
Sucker	0	1.0	0.3	0	-
Total	5.6	**6.3**	3.9	4.0	2.3
Growth per lateral (cm)	9.0	7.6	10.8	10.3	5.6

Conclusions

Plant quality can be improved considerably by implementing the correct pruning techniques throughout the course of production. The correct techniques, however, strongly correlate with the natural vigour and growth habits of individual species, and a strongly growing plant like *Forsythia* needs to be managed in a different way from that of slower growing or short-season species. In these results growth was maximised and best overall quality achieved by pruning *Forsythia* plants lightly on four separate occasions:- in August and September, 1994 to promote a branched framework early-on, in the following May to increase the branching habit and then again in June to encourage vigorous basal shoots to also branch, leaving enough time for tissues to mature and initiate flower buds. In contrast, *Cotinus* and *Syringa* did not require the same frequency of pruning and a light pruning once or twice was adequate to provide the best shape after a year.

Varying the timing of a single severe pruning for *Cotinus* during the spring period resulted in a sharp contrast in growth characteristics. By pruning in April, significantly more growth was induced and taller plants obtained compared to later pruning in May. This relates to results in year 1 for *Forsythia*, where delaying a severe pruning for three weeks between 14 May and 7 June, resulted in considerably smaller plants by the end of the season. Although results in year 2 indicated that in most species there was little difference in terms of overall growth and size between pruning during the dormant season and pruning in April, there may indeed be a relatively short but critical phase during which pruning responses can alter radically. Nurserymen need to be able to identify such critical periods in individual crops and implement pruning to suit their own particular requirements, i.e. earlier pruning for larger plants compared with later pruning for potentially more laterals.

In *Garrya*, pruning regimes gave a variety of plant sizes and growth habits. More frequent pruning tended to result in smaller specimens, with greatly increased numbers of short laterals, and these plants may have potential to develop into bushy, well-shaped specimens in the second year. In contrast, limited light pruning retained plant height, but produced sparsely branched, sometimes ungainly specimens. The best compromise, certainly within a single production year, was achieved with treatments such as pruning plants to a medium level twice, or lightly pruned three times. This resulted in evenly shaped plants, with the number and length of laterals present being in proportion to one another. Interestingly, giving plants a single light pruning in March also promoted acceptable, saleable specimens.

In *Viburnum*, growing plants under polythene did not appear to give any advantage compared to results for the previous year, (when plants were maintained outside), except that the growth response after severe pruning was more favourable. This suggests that the warmer polytunnel environment either allows quicker root establishment and shoot growth, or limits the effects of environmental stress on the buds remaining after a severe pruning.

The smaller scale experiments which monitored timing and position of bud break demonstrated that removing the apical or bud tissues in *Forsythia* (either by pruning or bud excision before or after bud break), maximised the number of buds breaking throughout the stem as a whole and resulted in greatest lateral production, although effects were not always significant, and reduced numbers of laterals on the more severely pruned treatments reflected the reduction in length of stem on which laterals could develop, although those that remained grew most strongly. Just defoliating the apical bud as it elongated did not have the same effect, and generally some apical dominance was still evident in many plants in this treatment. What was analogous however, was the defoliation of buds on the top one-third of the stem. This possibly indicates that when only part of the bud is removed (i.e. the leaves) tissue excision has to be carried out over a greater area of the upper stem, to elicit a similar growth response. When comparing apical bud removal before, and after, bud break in *Forsythia*, results suggest that removing the bud as it becomes active may be more successful at removing inhibition from lower axillary buds. As such, these results imply that apical dominance is controlled by an active meristem, rather than leaves or whole buds located in the apical region.

This will have important implications for nurserymen when trying to decide on optimum pruning during spring, and also on how to manage plants through the winter. Conditions which prevent full dormancy developing in apical buds during winter, such as late season growth or high ambient winter temperatures under polythene or glass, will favour apical dominance and reduced branching in the next season.

More severe pruning or bud removal occasionally stimulated relatively more bud development in the middle or lower regions of the main stem, however, these buds appeared to be deeply dormant and slower to break compared to buds in the top region of the stem. Growth per bud was also enhanced by such treatment and plants severely pruned or debudded generally had longer laterals per bud than non- or lightly pruned plants.

In *Syringa*, differences between forms of bud manipulation or severity of treatment were rarely significant. Some trends however, were apparent; pruning or defoliating the stem tip released most buds by May compared to the control or more severe treatments. This was not the case, however, with bud removal, either before or during growth, and greatest frequence of bud-break was associated with control plants. Often bud-break and lateral development was highest in the position of the stem immediately below the area of manipulation, the exception being in the defoliation treatment, where shoot development in some instances could still occur after new leaves had been removed. Longest length of laterals was associated with the severe two-thirds pruning or bud removal, with remaining buds developing laterals in excess of 10 cm.

The results from this last year of the project again demonstrate that pruning requirements for optimal shape and size vary for different species and eventual requirements. What is becoming increasingly apparent however, is the need to identify key stages in the production cycle for individual species so as to optimise their response to pruning. Pruning needs to be incorporated into the scheduling of crops, at a time appropriate to the plant rather than the nurserymen, and should no longer be seen as a way of tidying-up excessive growth shortly before sale. For most HNS some pruning is necessary, and when it is implemented in the right proportion, at the correct time and at the appropriate frequency, it can help design the ideal container specimen.

Acknowledgements
Thanks are due to Mrs Anne King and Mr Roy Taylor for providing assistance with recording and analysing data.

b) TREE QUALITY RELATED TO THE REMOVAL OF SCION LATERALS IN THE SECOND YEAR

Introduction

This year's work continued the treatments and records initiated in the maiden year as described in the previous Annual Report (Cameron and Howard, 1995).

Materials and methods

The trees, experimental layout and treatments were as described previously. In 1995 pruning treatments were imposed on both the parts of the main stem pruned in 1994 where re-growth of laterals occurred, and on further main stem extension growth until the head of the tree was allowed to form at a height of 1.8 m. As unions became less distinct and trees larger, height measurements were made from the ground rather than the union, incorporating 15 cm of rootstock stem into the size of tree that was not included in 1994.

Fewer pruning visits were necessary for the regularly-pruned treatments in 1995 compared to the maiden year, with five visits made from 7th June to 1st September inclusive. The single August-pruning treatment was done on the 21st of the month, and the single mid-winter record taken over a period from late November 1995 to early January 1996.

Results

Prunus 'Pink Perfection' on 'Colt'

Tree growth at the end of the second season reflected the trends in the maiden year, with treatments involving regular lateral removal, both as emerging laterals and when reaching 30 cm, inducing taller trees than those whose laterals were removed once either in mid-August, or in mid-winter (Table 19).

Similar treatment effects were seen on stem diameter although there appeared to be a benefit from allowing laterals to grow to 30 cm before removal, because these trees had thicker stems, even though they were not as tall as those with laterals removed regularly at an earlier stage (Table 19).

By the winter, an average of 22 laterals needed to be removed from the hitherto non-pruned treatment, having a mean length of 25 cm.

A head above 1.8 m had begun to form only in the tallest trees produced by regular and early removal of laterals, where a mean of four laterals of 5 cm or greater length had developed.

Table 19. Growth of two-year *Prunus* 'Pink Perfection' on 'Colt' rootstock following lateral-removing treatments

	Regularly removed	Removal at 30 cm	Removal in mid-August	Removal in mid-winter	*P*	LSD
Height (cm)	220	192	169	176	<0.1%	11.8
Stem diameter (mm) at 1 m height	10.6	12.6	8.9	9.4	<0.1%	0.88

Note, in this and subsequent tables *P* is the probability that treatments differ by chance, and the LSD is the difference which separates treatment means with differences having a 5% probability of being due to chance, and hence a 95% probability of being due to treatments.

Tilia x euchlora on various clonal rootstocks

The height of two-year trees which had had laterals removed regularly (as they developed and at 30 cm length) was greater than those which retained laterals until mid-August or mid-winter, and the overall trend was identical to that for maiden height in 1995, with each treatment being significantly different to the others (Table 20). The trend for trees on each clonal rootstock was also identical. Compared to the maiden year there appeared to be a greater benefit in the second year of retaining shoots until mid-winter compared to removing them in leaf during mid-August, but these trees were still markedly smaller than those from which laterals were removed regularly at the earliest opportunity (Table 20). There was also a rootstock effect, confirming experience (Howard, 1994) that *Tilia platyphyllos* clone 229 has promise. The effective combinations of lateral removal treatment and rootstock clone are seen particularly clearly as the highlighted values in Table 20, indicating treatment means which exceed the target height of 1.8 m, at which point the head of the tree is allowed to develop.

Stem diameter at 1 m above ground reflected almost identically the two-year tree heights and the effective pruning/rootstock combinations, with a diameter at or greater than 10 mm, are highlighted (Table 21).

A mean of 14 laterals were removed from trees in mid-winter, and a head had begun to form in only the early and regularly pruned treatment, with an average of only one lateral over 5 cm in length.

Betula pendula 'Dalecarlica'

The clear trend in the maiden year, whereby increasingly delayed lateral removal reduced tree height, was less clear in the second year when all treatments gave a mean for two-year trees well in excess of 1.8 m. There appeared to be a slight advantage, reflected also in stem diameter, of retaining laterals (both re-growing from the previous year's stem and from the current stem) for the entire season and removing them in mid-winter (Table 22). The size of the stem taper, and size of the head of the tree, were also greatest in this treatment (Table 22).

Table 20. Height (cm) of two-year *Tilia x euchlora* trees on various clonal rootstocks following lateral-removing treatments

Rootstock	Regularly removed	Removal at 30 cm	Removal in mid-August	Removal in mid-winter	*P*	LSD
T. cordata 21	**228**	**216**	158	**181**		20.2
T. cordata 203	**205**	164	138	141		20.2
T. platyphyllos 201	**230**	**187**	149	170		20.2
T. platyphyllos 229	**236**	**212**	**184**	**203**		20.2
Means	225	195	157	174	<0.1%	10.1

Table 21. Stem diameter (mm) at 1 m height of two-year *Tilia x euchlora* trees on various clonal rootstocks following lateral-removing treatments

Rootstock	Regularly removed	Removal at 30 cm	Removal in mid-August	Removal in mid-winter	*P*	LSD
T. cordata 21	**12.1**	**13.0**	8.9	**12.7**		2.8
T. cordata 203	**11.1**	8.3	5.1	7.7		2.8
T. platyphyllos 201	**12.8**	**11.8**	8.0	**11.8**		2.8
T. platyphyllos 229	**14.1**	**14.7**	**12.4**	**14.2**		2.8
Means	12.5	12.0	8.6	11.6	<0.1%	1.4

Table 22. Growth of *Betula pendula* 'Dalecarlica' two-year trees following lateral-removing treatments

	Regularly removed	Removal at 30 cm	Removal in mid-August	Removal in mid-winter	*P*	LSD
Height (cm)	313	297	315	333	<0.1%	12.9
Stem diameter 18 cm above the union (mm)	21.1	19.5	22.1	26.2	<0.1%	2.0
Stem diameter 18 cm below the head (mm)	16.1	14.1	15.3	17.8	<0.1%	1.4
Taper (mm)	5.0	5.5	6.8	8.5	<0.1%	1.1
No. of main laterals forming the head above 1.8 m	16.4	14.1	12.6	18.6	<1.0%	3.1

Table 23. Growth of *Robinia pseudoacacia* 'Frisia' two-year trees following lateral-removing treatments

	Regularly removed	Removal at 30 cm	Removal in mid-August	Removal in mid-winter	*P*	LSD
Height (cm)	331	314	327	310	NS	-
Stem diameter 18 cm above the union (mm)	32.9	27.4	30.6	33.5	NS	-
Stem diameter 18 cm below the head (mm)	24.5	20.4	23.5	22.4	NS	-
Taper (mm)	8.4	7.0	7.1	11.1	<1.0	2.2
No. of main laterals forming the head above 1.8 m	16.1	14.3	14.7	15.0	NS	-

Robinia pseudoacacia 'Frisia'

Tree height in the second year reflected that of the maiden year, with the slightly taller trees being produced in the regularly and early-pruned treatment, but with the greatest taper in the treatment where laterals were retained throughout the summer and removed in mid-winter (Table 23). Trees in the mid-winter pruning treatment had also developed a large head equivalent to that in other treatments (Table 23), and in contrast to its significantly smaller size at the end of the maiden year.

Twenty one laterals were removed from the 1.8 m stem of the mid-winter pruning treatment in the second year.

Conclusions

Results from the second year, where laterals re-grew on main stems pruned clean in the maiden year, and on new main stem growth in the second year, supported the conclusions from the previous year's results.

For *Robinia* and *Betula*, which are strong lateral producing subjects, there is no need to remove laterals as they grow during the season unless nurserymen wish to avoid the relatively large wounds that develop from delayed pruning. By the second year trees of *Robinia* 'Frisia' whose laterals were removed after growth had stopped, were only 5% shorter than those whose laterals were removed regularly as they emerged through the season, and there was no difference in the number of laterals forming the head of the tree. All treatments had produced trees with a mean height in excess of 3 m.

There was little difference in stem diameter between treatments, but delaying lateral removal until the following winter increased taper.

Trees of *Betula* 'Dalecarlica' were of a similar height, with the winter pruning treatment giving slight increases in height, stem diameter, taper and size of head compared with earlier pruning. This extended the maiden year results, where stem diameter and taper were similarly greatest in the winter-pruning treatment, but where trees in the early and regularly pruned treatment were tallest.

It appears that while lateral retention enhances stem girth and taper from the start of tree production, it requires two years for the slightly depressing effect of lateral growth on tree height to be overcome.

Examples of trees which produce relatively few laterals and grow relatively slowly are *T. x euchlora* and 'Pink Perfection' on *Prunus* 'Colt'. Their pruning requirement contrasts clearly with that of the more vigorous varieties, with consistency in the maiden and second years. Trees of all *T. x euchlora*, irrespective of the clonal rootstock on which they were produced, grew tallest if the laterals were removed at the earliest opportunity and regularly through the summer (Table 20). This was a less onerous task than for more vigorous species, with an average of 14 laterals needing to be removed as assessed by those pruned off in the mid-winter treatment.

In the maiden year early and regular pruning had little effect on taper, and in the second year it had no detrimental effect on stem thickness at 1 m above ground, indicating that small laterals contribute little to stem thickening in this subject, although larger laterals removed in mid-August appear to be of benefit (Table 21).

Prunus 'Pink Perfection', although producing an average of 22 laterals needing to be removed, also typified the response of weaker species, benefiting in terms of tree height, and not suffering markedly in terms of stem diameter at 1 m height by having laterals removed regularly and early. With slower growing species treatments that encourage trees to grow taller are clearly beneficial as long as there are no associated detrimental effects. In this case nurserymen have the choice of regular and early lateral removal with maximum height benefit at the cost of some stem thickening, or removing laterals at 30 cm length, with maximum stem thickness benefit, but some cost to height. Both treatments were superior in both respects to later lateral removal.

Acknowledgements

Mrs. Wendy Oakley provided recording assistance, and Mr. J. Vasek technical assistance.

References

Cameron, R.W.F. and Howard, B.H. (1995). Pruning containerised plants and field-grown trees for quality. Annual Report on HDC Project HNS 40, Petersfield. Horticultural Development Council Report, pp 35.

Howard, B.H. (1994). Developing clonal rootstocks for ornamental trees and shrubs. Final Report on HDC Project HNS 6a, Petersfield. Horticultural Development Council Report, pp 31.

Contract between HRI (hereinafter called the "Contractor") and the Horticultural Development Council (hereinafter called the "Council") for a research/development project.

PROPOSAL

1. TITLE OF PROJECT   Contract No: HNS/40

PRUNING FOR QUALITY WITH MINIMUM REDUCTION IN SIZE

2. BACKGROUND AND COMMERCIAL OBJECTIVE

Shrubs and trees are produced in shapes which either conform to the characteristics of the variety (e.g. fastigiate, spreading, etc.), or to nurserymen's ideas of what constitutes quality, or to market requirements (e.g. bushy, well-furnished, non-leggy, clean or feathered stems). Shape is an important aspect of quality, both in terms of individual plants and crop uniformity, and high quality is important in defending home markets from overseas competition, and for competitiveness within the home market. Ideal shape is usually obtained by pruning, so the potential advantages are offset by reducing the size of the plant. Pot plant producers use schedules which incorporate pruning, and HNS producers are likely to benefit from a better understanding of this important operation.

Pruning requirements fall into three main categories:

1. Remove unwanted shoots which detract from the variety form.

2. Remove or promote shoots to meet market requirements for particular shaped plants (e.g. feathered or clean stemmed).

3. Prune to stimulate more and lower shoots to induce bushiness.

Nurserymen need information which will help them decide when and how to prune.

3. POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

Difficult to assess because it comprises the advantage conferred by competitive edge on quality and the savings obtained by avoiding the need to regrade or reject at point of sale, or even destroy unsold plants.

4. SCIENTIFIC/TECHNICAL TARGET OF THE WORK

Category 1) above is relatively straightforward to deal with because rogue shoots which don't conform to the variety are probably best removed as they occur. Categories 2) and 3) carry the requirement to modify the natural growth of the plant, as determined by variety and growing conditions, and are the main focus.

A limited range of plants will be identified as follows:

Container-grown shrubs which are difficult to produce in a sufficiently bushy form. Field-grown trees which feather freely but are required to produce clean stems (the reciprocal of inducing feathers in appropriate species can be included if required). The main scientific target will be to understand the relationship between growing shoots and dormant buds (correlative inhibition) which determines natural branching and which is influenced by pruning. The objective will be to maximise regrowth of the required form, or minimise check to growth, both in terms of number and length of shoots (shrubs) and stem caliper (trees). Central to this will be the need to identify in relation to these criteria the optimum time and frequency to prune and the relative responsiveness of different buds. This will lead to the development of pruning protocols to provide the basis of schedules for specific plants. (Note. Efford has an interest in developing pruning schedules for micropropagated plants).

5. CLOSELY RELATED WORK - COMPLETED OR IN PROGRESS

There is considerable information available from work with fruit trees and with fruit-related ornamentals, including effects of lateral suppression by chemicals on trunk caliper. Chemicals are no longer available for this purpose and pruning, along with spacing, offer more direct methods for controlling shape. There is little published work on optimising pruning for shrubs in containers, but the principles of correlative inhibition provide a strategic base upon which to build practical recommendations. Project HNS 27 is linking deficiencies in propagation and weaning with the subsequent difficulty of obtaining good bud-break, which is the foundation of good shape.

6. DESCRIPTION OF THE WORK

Initially, representative plants will be produced or purchased for work on inducing bushiness in container plants and clean stems in field-grown trees. At least two levels of growing condition or growing potential will be applied, because in general the more vigorous the plant the better is the response to pruning (i.e. more buds are able to grow) and the less is the set-back from pruning. Imposed on this will be a factorial set of treatments combining time of pruning and severity of pruning, ranging from soft shoot pinching to winter pruning. A major part of the work will be the recording of growth in terms of numbers and location of buds which develop and the vigour of the ensuing shoot growth.

The project will soon generate its own questions, such as the opportunity to carry out repeated pinching in the same season, the imposition of bud nicking or cold treatment to obtain further growth in short season shrubs or trees which show periodic growth flushes, and the relative merits of clipping v pruning conifers.

7. COMMENCEMENT DATE AND DURATION

October 1992 for 3¼ years to provide three full seasons work and to key in with staffing for other projects.

8. STAFF RESPONSIBILITIES

Within the general supervision of Dr.B.H.Howard and Dr.R.S.Harrison-Murray, HRI East Malling, subject to restructuring current staffing commitments in association with funding from other projects.

9. LOCATION

HRI-East Malling.