Project Title	Profit optimisation through modelling and management of non-uniformity in Hardy Nursery Stock species
Project number:	HNS 136
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Report:	Annual report, June 2007
Previous report	N/A
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Location of project:	New Place Nurseries Ltd., Pulborough, West Sussex RH20 1AT & Hillier Nurseries Ltd., Ampfield Romsey, Hampshire SO51 9PA
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Date project commenced:	1st June 2005
Date completion due:	31st May 2008
Key words:	Plant variability, waste, profit optimization, modeling, statistics.

The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

Disclaimer. The varieties/species of plants in the trial were specifically selected for their production difficulties and non-uniformity and, as a result, the results of the project in no way reflect on general liner production at New Place Nurseries or finished plant production at Hillier Nurseries.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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Grower Summary

Headline

Cutting uniformity and quality are critically important factors necessary for the cost-effective production of uniform batches of high quality liners and finished plants.

Background and expected deliverables

Hardy nursery stock growers consider that within-crop variability is a major business problem, because waste levels due to plant non-uniformity, frequently reach 20% (and have occasionally reached 60%) for particular problem species/varieties. This problem reduces profits and occurs as a result of the strict plant-quality and uniformity specifications demanded by the DIY chains and garden centres, which are the main customers for many nurseries.

Previous research addressing the issue of variability and waste assessed 10 HNS species and 14 crops. Variability tended to increase over time, but some species were identified as being inherently more variable that others (HNS 117).
No significant amount of variability, however, could be attributed to differences in the initial cutting material (HNS 117). It was logical to assume, however, that the quality of the end product would be dependent on getting the first steps in the plant production process right, and so it was decided to re-assess the validity of the conclusion of HNS 117, by further on-nursery experimentation.

The majority of experimental varieties/species of plant described here were chosen specifically for their production difficulties and non-uniformity. Two species/varieties were also included as examples where production and non-uniformity difficulties were usually absent.

The data from the nursery experiments informed the modeling activities of this project and the initial stages of building of an Excel spreadsheet-based operations management tool. This tool will allow HNS Production and Sales Managers to assess alternative options easily and rapidly, and thus provide an objective, quantitative basis for decision making that maximises the profits generated by their complex businesses.

Summary of the project and main conclusions

In the first year, large differences were found in the size and physical structure of the different cutting types in eleven of the thirteen plant species examined: *Berberis thunbergii* 'Harlequin', *Camellia williamsii* 'Donation', *Choisya* 'Aztec Pearl', *Choisya ternata* 'Sundance', *Cistus* 'Silver Pink', *Photinia x fraseri* 'Red Robin', *Pieris* 'Forest flame', *Pittosporum tenuifolium* 'Garnettii', *Prunus incisa* 'Kojo-no-mai', *Rhamnus alaternus* 'Argenteovariegata', *Viburnum tinus* 'Eve Price'. For two other species, *Potentilla* 'Chelsea Star' and *Weigela* 'Kosteriana Variegata', a single cutting type was used and, in the former, there was a noteable amount of variation in the height, width and volume of newly established cuttings.

These clear differences, described in the previous technical report, continued to be apparent in twelve of the thirteen plant species. Data collected during the development of the plants in liner pots, also showed that cutting type and structure exerted an obvious effect on the subsequent structure of the plants. This has major implications for achieving high quality liners that, characteristically, are bushy, vigorous and of a pre-determined uniform height. It is important to recognize that quality and uniformity are quite different concepts, i.e. it would be possible to produce a batch of highly uniform plants, whose characteristics or 'quality' is unattractive to the end customer.

For most of the species, the perception of the growers as to what constituted the 'best' cuttings continued to be an accurate reflection of the subsequent performance of the plants that grew from them. For the *Cistus* 'Silver Pink', which was mentioned in the previous report, the 'Good / yr1' cuttings also eventually produced the bushiest plants. The growth of plants from 'poor' cuttings, for example of *Berberis thunbergii* 'Harlequin', was much less predictable and was consequently was an additional source of variation into the crop.

In the time available before the relevant sale date, the best *Cistus* 'Silver Pink' and *Berberis thunbergii* 'Harlequin' liners also produced the best finished plants and the differences between the comparative groups were unequivocal. For these species, it can be concluded that although most plants may eventually become saleable, there is no evidence to suggest that batches become more uniform with time.

A possible way of introducing greater uniformity into batches of plants at points in the production process is to grade plants. For all the species examined, however, it was not possible to see a clear relationship between the physical measurements and the resulting categories of First (saleable) and Second (not saleable) plants. There are several reasons why this may have occurred, which include, a) the physical data did not accurately capture plant 'form', which seems to be an important component of quality, b) the plant specification used was not applied rigorously or was not current, c) the assessment was rapid and not quantitative.

As a result of the grading procedure, liner categories that were clearly significantly different were mixed together, with the result that there was an increase in the variability or non-uniformity of the new category, which was called Firsts.

The survival of the different plant species continued to vary considerably and for some species such *Pittosporum tenuifolium* 'Garnettii', it dropped to a financially unsustainable level.

The liner production model highlighted several important points:

a) Depending on the costs of production, there are clear plant-survival thresholds below which species should not be produced with the current practices.

b) Profits above this threshold can be minimal, and so consideration needs to be given to whether or not the returns are worth the effort for that particular species.

c) Attempting to meet a reserve number of plants can increase the risk of incurring financial losses for that species/variety.

d) The threshold of profitability and feasible areas (regions where solutions to the problem are possible) are also highly dependent on the percentage of Firsts and percentage of plants sold.

e) The possibility of additional points of sale at a later date only helps the non-uniformity problem to a limited extent, because it reduces the potential maximum profit and raises the threshold at which a loss will be made.

f) The use of an additional cutting type, which produces a lower percentage of Firsts can significantly reduce potential profits, reduce the possibility of reaching a reserve number (smaller feasible area) and increase the threshold at which a loss is incurred.

In terms of the non-uniformity and production problems facing growers for the types of species selected here, these results have several implications. These are:

1. Stock-plant management is extremely important and should firmly focus on:

- Reducing non-uniformity at the cutting stage. A practical way of achieving this may be to compile a reference collection of life size images of the desired cutting types.

- Producing and using only the cutting type(s) that produces the highest survival and percentage of First quality plants.

2. If it is not possible to generate enough uniform 'best' quality cuttings, it is advisable to grade the cuttings at the time of planting and to keep the different batches and types separate from one another.

3. Adoption of these practices should provide the following benefits:

- Different categories of plant, e.g. those grown from tips or two internodes, can be pruned at the appropriate time.

- The effort involved in grading prior to sale will be greatly reduced.

- Plant growth will be much more predictable and the number of Seconds produced will be minimal.

- ‘Best’ material is much less likely to suffer poor survival.

- Maximum profitability is much more likely to be achieved.

In the project’s final year, data will continue to be collected from reduced sub-sets of the experimental plants at the finished plant nurseries. In addition, time will be invested in building the model into a useful tool to aid management decision making on the non-uniformity problem.

Financial benefits

As detailed above, the following information and conclusions have the potential to create financial benefits for nursery growers.

- There are clear plant-survival thresholds below which species should not be produced with the current growing practices.

- Attempting to meet a reserve number of plants can increase the risk of incurring financial losses.

- The threshold of profitability and feasible areas are also highly dependent on the percentage of Firsts and percentage of plants sold.

- The possibility of additional points of sale at a later date only helps the non-uniformity problem to a limited extent, because it reduces the potential maximum profit and raises the threshold at which a loss will be made.

- The use of an additional cutting type, which produces a lower percentage of Firsts can significantly reduce potential profits, reduce the possibility of reaching a reserve number (smaller feasible area) and increase the threshold at which a loss is incurred.

The biological data presented here are particularly encouraging, because they show that within the existing constraints, there is the potential to improve crop uniformity for many species, reduce waste and improve profitability.

The profitability of a nursery is made up from the individual profits, or losses, incurred on the different component species sold. The identification and focus on the least profitable species, to determine whether or not their profitability can be improved, should potentially have a big impact on overall nursery profitability.

Action points for growers

These results have several direct implications for management of the non-uniformity problem, which are:

- Stock-plant management is extremely important and should clearly focus on reducing non-uniformity at the cutting stage. Growers should only produce and use the type of cutting that will produce the highest survival and percentage of saleable plants by the expected date of sale.

- If it is not possible to generate enough uniform 'best' quality cuttings, it is advisable to grade the cuttings at the time of planting and to keep the different batches and types separate from one another.

- Adoption of this practice should provide the following benefits:

  i) Different categories of plant, e.g. tips or two internodes, can be pruned at the appropriate time.

  ii) The effort involved in grading prior to sale will be greatly reduced.

  iii) Plant growth will be much more predictable and the number of Seconds produced will be minimal.

iv) ‘Best’ material is much less likely to suffer poor survival.

v) Maximum profitability will therefore be much more likely to be achieved.

- The profitability of a nursery is made up of the individual profits, or losses, made from the different component species sold. The identification and subsequent management focus on the least profitable species, to determine whether or not their profitability can be improved, should potentially have a big impact on overall nursery profitability.

Science Section

Introduction

Within-crop variability of many Hardy Nursery Stock species frequently results in a proportion of plants failing to meet the required quality specification by the time they are due to be sold. The percentage of plants that are wasted due to being unsaleable, therefore, can often be higher than 20% and, in extreme cases, can be over 60%. This effect occurs at the end of the plant production process for both liner and finished-plant producers, when a significant investment has already been made in the production of each plant. It has a clearly negative impact on the profitability of the worst affected varieties. The problem is currently felt most acutely by those nurseries whose businesses aim to produce plants for DIY chains and garden centres by a particular date, as these customers enforce strict plant-quality and uniformity specifications.

At the project development stage, there was a clear perception amongst growers that the amount of variation in the stock-planting material was one of the important keys to the success, or otherwise, of uniform crop production. It was also logical to assume that the uniformity and quality of the end product would be dependent to some extent on getting the first steps in the plant production process right. A previously funded HDC research project, however, was unable to attribute a significant amount of variability to differences in the initial cutting material (HNS 117), an unexpected result that may have been due to the environmental effects experienced by the plants being of overwhelming significance during the lifetime of the experimental crop. This conclusion was also apparently at odds with the research results of another HDC project (HNS 69), which showed that the type of cutting, as well as the pruning regime, had clear effects both on plant habit and size.

After discussions with growers, the view remained that reducing the variability of the stock planting material and the timing of operations were key factors determining the success, or otherwise, of uniform crop production and, therefore, that the conclusion of HNS 117 merited re-assessment by additional on-nursery experimentation.

The project's first objective, therefore, was to set up on-nursery experiments for thirteen representative plant species, to assess the effect of cutting variability and 'quality' on subsequent plant growth and development.

After the first year of the project, several conclusions could already be drawn from the experimental data. There were large and significant differences in the size and physical structure of the different cutting types that could be used to propagate eleven of the thirteen plant species examined: *Berberis thunbergii* 'Harlequin', *Camellia williamsii* 'Donation', *Choisya* 'Aztec Pearl', *Choisya ternata* 'Sundance', *Cistus* 'Silver Pink', *Photinia x fraseri* 'Red Robin', *Pieris* 'Forest flame', *Pittosporum tenuifolium* 'Garnettii', *Prunus incisa* 'Kojo-no-mai', *Rhamnus alaternus* 'Argenteovariegata', *Viburnum tinus* 'Eve Price'. In addition, for all the species except *Weigela* 'Kosteriana Variegata', strong relationships were observed between cutting type and subsequent plant growth.

Data collected during the early development of the plants, showed that cutting type and structure could also exert a major effect on the subsequent physical structure of the plants. This has major implications for achieving uniform, high-quality liners, which have the general characteristics of being 'well-formed', bushy with breaks at the base of the stem, vigorous and of a specified height.

For certain species such as *Berberis thunbergii* 'Harlequin', the perception of the growers as to what constituted the 'best' cuttings was an accurate reflection of the subsequent initial performance of those cuttings. For others, such as *Cistus* 'Silver Pink', cuttings rated as 'poor' outperformed others rated as 'good'. Initial work on *Berberis thunbergii* 'Harlequin' liners at Hillier Nurseries showed that 'best' and 'standard' categories had large differences in the widths of their lower stems, measured at soil level at the part of the stem that had been the original cutting. This provided a strong indication that, at least for this species, cutting width and volume has a long-term impact on the subsequent quality of the resulting plant.

The survival of the different plant species varied considerably and for some species such as *Prunus incisa* 'Kojo-no-mai', the larger cuttings had the best survival rates. For others such as *Choisya* 'Aztec Pearl', survival appeared to have been related to cutting structure, where those with the most foliage avoided their compost getting too wet and thus problems with rot. For *Berberis thunbergii* 'Harlequin', the main cause of mortality was failure of the cuttings to root. It was clear that the period prior to the cuttings forming roots is when they are highly vulnerable to adverse changes in humidity and the water content of the compost.

In the past year, additional data on the survival, physical structure and percentage of plants that were graded as either Firsts or Seconds before the appropriate points of sale, for both the liner and finished-plant producer, were collected. These data were then incorporated with financial plant-production information to build a business model in Excel, which determines the profitability, or otherwise, of each of the experimental varieties. The model uses the Solver function to enable the maximum profit to be found for each plant production scenario entered by the user. An analysis was carried out to examine the model's behaviour. Preliminary work has begun to turn the model into a user-friendly tool, to help growers assess the impact on profits of various plant production scenarios.

Materials and Methods

Summary of year 1. The experiments designed to re-evaluate the main conclusion of HNS 117, that measurable variation in starting material could not be linked to variation in the final crop, were started for thirteen plant species at New Place Nurseries Ltd. (HNS 136 Annual Report, 2006). The experiments consisted of setting up batches of stock material with different levels of initial variability. Species that were perceived to have a minimal problem with non-uniformity and waste were also selected for comparative purposes. The data presented here relate to the experimental batches of plants, which were designed to include an intentionally high level of initial variability and different perceived 'qualities'.

The following thirteen plant species and varieties were selected for experimentation: *Berberis thunbergii* 'Harlequin', *Camellia williamsii* 'Donation', *Choisya* 'Aztec Pearl', *Choisya ternata* 'Sundance', *Cistus* 'Silver Pink', *Photinia x fraseri* 'Red Robin', *Pieris* 'Forest flame', *Pittosporum tenuifolium* 'Garnettii', *Potentilla* 'Chelsea Star', *Prunus incisa* 'Kojo-no-mai', *Rhamnus alaternus* 'Argenteovariegata', *Viburnum tinus* 'Eve Price' and *Weigela* 'Kosteriana Variegata'.

Year 2. In the past year, the experimental plants were subjected to the standard growing practices for that particular species. Data were collected at appropriate intervals on stem diameter, plant height and number of branches, as well as any mortality that had occurred since the previous measurements were collected. Prior to their transportation to their new location at the finished plant nurseries, plants were graded by staff at New Place Nursery (NPN) into First and Second quality plants and any additional data were collected that related to the liner specification supplied for them. The quantitative biological data were analysed using the GenStat statistical package (GenStat 9th edition, 2007).

***Berberis thunbergii* 'Harlequin'**. *Year 1 summary*. Cuttings were prepared originally from either field- or container- grown stock plants and these were of three perceived qualities, 'best', 'standard' or 'poor'. Data collected during the first year of the project, showed that there were clear statistical differences between the different types of cutting and the field-grown cuttings, for instance, produced many more shoots than the container-grown cuttings shortly after planting. Surviving plants of the six cutting types were re-potted into 9 cm diameter liner pots, which were transferred to a poly tunnel situated on the NPN, Pulborough. Plants were positioned in the middle of the *B. thunbergii* 'Harlequin' crop and they received the standard crop management and pruning practices.

Measurements were also carried out on a sub-sample of *B. thunbergii* 'Harlequin' liners selected from the crop at Hillier Nurseries (HN), Romsey. Liners selected on appearance as 'best' had significantly more apices and were significantly taller than those selected as 'standard'. The widths of the original cutting material were also significantly greater for the liners that had been selected as 'best', compared to those selected as 'standard'.

Year 2. Measurements were taken from the liners at NPN, Pulborough, on 12/07/06 and on 5/12/06. They were then graded into First and Second quality plants on 23/01/07 by a member of NPN staff. A sub-sample of 32 First and 40 Second grade plants was transferred to HN, Romsey, and re-potted into 3 litre pots on 27/02/07.

Measurements were also taken from the mature *B. thunbergii* 'Harlequin' plants at HN, Romsey, at the end of the season on 28/11/06.

***Camellia williamsii* 'Donation'**. *Year 1 summary*. Plants were grown from two types of cutting: those with two internodal lengths or those from stem tips. Forty-two cuttings of each type were prepared and planted into 84-cell trays.

Year 2. The stem diameter, plant height and the number of apices of all surviving plants was recorded on 18/09/06. This variety has yet to be graded and these data will appear in next year's technical report.

***Choisya* 'Aztec Pearl'**. *Year 1 summary*. The cutting types used were the standard two inter-nodal length cutting, shorter cuttings with a single inter-nodal length taken from the base of the stem, or from stem tips. Twenty-eight cuttings of each type were prepared and planted into 84-cell trays. Due to the high mortality evident in the first planting, another trial was set up following the same design.

Year 2. The stem diameter, plant height, number of apices and the number of breaks in the lowest five cm of the stem for all surviving plants was recorded on 06/03/07, prior to grading into Firsts and Seconds by staff at NPN, Sidlesham. A subset consisting of Firsts and Seconds from each cutting category, have been transferred to HN, Romsey.

***Choisya ternata* 'Sundance'**. *Year 1 summary*. Cuttings were taken from either field- or 30 litre container-grown stock plants and these could be of two types; those with a single inter-nodal length with two leaves and those with two internodal lengths with four leaves. Four cutting types could therefore be differentiated and 21 cuttings of each type were prepared and planted into 84-cell trays.

Year 2. The stem diameter, plant height, number of apices and the number of breaks in the lowest five cm of the stem for all surviving plants was recorded on 04/03/07, prior to grading into Firsts and Seconds by staff at NPN, Sidlesham. A subset consisting of Firsts and Seconds from each cutting category have been transferred to HN, Romsey.

***Cistus* 'Silver Pink'**. *Year 1 summary*. Cuttings were prepared from either one or two-year-old container-grown stock plants and these could be of two types; 'good' or 'poor'. Four cutting types could therefore be differentiated and 21 cuttings of each type were prepared and planted into each 84-cell tray. Analysis of the physical dimensions of the different cutting types showed that those that are perceived to be the 'best' had the highest volumes and cuttings from 2-yr-old plants had greater volumes than those from 1-yr-old plants.

Year 2. The performance of each cutting continued to be followed and data collected at periodic intervals. Plants were measured on 28/06/06, prior to grading into Firsts and Seconds by staff at NPN, Sidlesham, on 12/07/06. A subset, consisting of Firsts and Seconds from each cutting category were then transferred to Glovers Stourbank Nursery, Wimbourne, Dorset, where they were re-potted into three litre containers. Due to an oversight, the experimental plants were not kept track of, or labeled, during the repotting process. The re-potted plants were therefore examined and sub-samples of 40 bushy (termed 'Firsts') and 40 plants with relatively few apices (termed 'Seconds') were selected and labeled on 01/09/06. These plants were then measured again on 28/11/06 and on 22/04/07. On the latter date, the plants were also graded by nursery staff into First (saleable) and Second (not yet saleable) categories of plant. Sales of this variety occur mainly in March/April/May and due to their value, the plants in the First category were released for sale and no further data will be collected from them. Those plants categorized as Seconds will be sold if and when they are ready and the numbers remaining at the end of the season will be recorded.

***Photinia x fraseri* 'Red Robin'**. *Year 1 summary*. Cuttings were prepared either from the tip, the middle or the bottom of stems of stock-plant material. Either 35 or 34 cuttings of each type were prepared and planted into each 104-cell tray.

Year 2. The stem diameter, plant height, number of apices and the number of breaks in the lowest five cm of the stem for all surviving plants was recorded on 20/04/07, prior to grading into Firsts and Seconds by staff at NPN, Sidlesham. A subset consisting of Firsts and Seconds from each cutting category, have been transferred to HN, Romsey.

***Pieris* 'Forest flame'**. *Year 1 summary*. Cuttings were prepared from either soft, medium or hard stock-plant material. Twenty-eight cuttings of each type were prepared and planted into 84-cell trays.

Year 2. The number of stems, their length and plant height was recorded on 28/06/06 for surviving plants. Plants will be measured again, prior to grading into Firsts and Seconds by staff at NPN, Sidlesham, and these data will appear in next year's technical report.

***Pittosporum tenuifolium* 'Garnettii'**. *Year 1 summary*. Cuttings were prepared from either heels, the middle to upper part, or the lower basal end of stems. Twenty-eight cuttings of each type were prepared and planted into 84-cell trays.
Year 2. Survival of this variety was very low and on 30/10/06 there were only 48 remaining plants. An additional problem arose in that some of the pots labels were damaged, probably by slugs, and so these were re-numbered. The surviving plants will be measured again, prior to grading into Firsts and Seconds by staff at NPN, Sidlesham. These data will appear in next year's technical report.

***Potentilla* 'Chelsea Star'**. *Year 1 summary*. Cutting of this species were planted before the start of the experimental work and so measurements of stem width and plant height were taken from plants growing in two 84-cell trays. The performance of each plant was followed and data collected thereafter at periodic intervals, usually prior to pruning.
Year 2. The number of stems and plant height was recorded on 03/07/06 for surviving plants. Plants will be measured again, prior to grading into Firsts and Seconds by staff at NPN, Sidlesham. These data will appear in next year's technical report.

***Prunus incisa* 'Kojo-no-mai'**. *Year 1 summary*. Cuttings were prepared either from the main stem tip, the side shoots or the main stem material. Twenty-eight cuttings of each type were prepared and planted into 84-cell trays.
Year 2. The stem diameter, plant height and number of apices was recorded on 12/12/06 and on 02/04/07, prior to grading into Firsts and Seconds by staff at NPN, Sidlesham. A subset consisting of Firsts and Seconds from each cutting category have been transferred to HN, Romsey.

Rhamnus alaternus* 'Argenteovariegata'.* *Year 1 summary*. Cuttings were prepared from either heels, the lower stem or from the upper end of the stem. Either 34 or 35 cuttings of each type were prepared and planted into 104-cell trays.

Year 2. Survival of this variety was low. The number of shoots and their length was measured on 03/07/06. The surviving plants will be measured again, prior to grading into Firsts and Seconds by staff at NPN, Sidlesham. These data will appear in next year's technical report.

***Viburnum tinus* 'Eve Price'**. *Year 1 summary*. Cuttings were prepared from either the tops of stems (two internodes, termed 'soft'), the middle of stems (two internodes, termed 'hard') or a single internode from the base (termed 'singles'). Twenty cuttings of each type were prepared and planted into 60-cell trays.
Year 2. The stem diameter, plant height, number of apices and the number of breaks in the lowest five cm of the stem for all surviving plants was recorded on 03/04/07, prior to grading into Firsts and Seconds by staff at NPN, Sidlesham. A subset consisting of Firsts and Seconds from each cutting category have been transferred to HN, Romsey.

***Weigela* 'Kosteriana Variegata'**. *Year 1 summary*. A single type of cutting was prepared for this species, which consisted of single internodal lengths. Stems were cut just above nodes and the leaves were trimmed to prevent them covering adjacent cuttings.
Year 2. The plant height, number of apices and the number of breaks from soil level was recorded on 20/04/07, prior to grading into Firsts and Seconds by staff at NPN, Sidlesham. A subset, consisting of Firsts and Seconds from each cutting category are in the process of being transferred to Hillier Nursery, Romsey.

Results and Discussion

Berberis thunbergii 'Harlequin'

Data collected while the liners were at NPN, Pulborough.

- On 12/07/06, there were still clear quantitative differences apparent between the different groups of liners, for both the number of apices (bushiness) and their basal stem diameters (Fig. 1 and Table 1).

Figure 1. Plants showing differences in the number of apices or 'bushiness' of *B. thunbergii* 'Harlequin', originating from either 'field-best' (LHS) or 'field-poor' (RHS) cuttings on 12/07/06.

Table 1. Analysis of variance for stem diameter of surviving *B. thunbergii* 'Harlequin' liners measured on 12/07/06, which were grown from either container-grown or field-grown stock plants and from three perceived qualities of cutting.

Source of variation	d.f.	s.s.	m.s.	*P*
Stock plant type	1	193.47	193.47	< 0.001
Cutting quality	2	5421.08	2710.54	< 0.001
Stock plant type x cutting quality	2	2.46	1.23	0.911

- Approximately five months later, clear differences were still apparent in the basal-stem diameters of the different groups of liners, although the variance attributable to the effect of stock-plant type had become non-significant (Fig. 2 and Table 2).

Figure 2. *B. thunbergii* 'Harlequin' showing differences in the number of apices and stem diameter of plants originating from either 'field-best' (LHS) or 'container-poor' (RHS) cuttings on 05/12/06.

Table 2. Analysis of variance for stem diameter of surviving *B. thunbergii* 'Harlequin' liners measured on 05/12/06, which were grown from either container-grown or field-grown stock plants and from three perceived qualities of cutting.

Source of variation	d.f.	s.s.	m.s.	P
Stock plant type	1	55.09	55.09	0.076
Cutting quality	2	5137.15	2568.58	< 0.001
Stock plant type x cutting quality	2	123.10	61.55	0.030

- In order to gain an insight into the question of whether or not the 'poor' category were catching up with the 'best' quality plants, the change in stem diameters that had occurred by 05/12/07 from the original cuttings was analysed. Stock plant type did not affect the change in stem diameter significantly. However, there was a big effect of cutting quality and the poor quality plants had the biggest increase in mean stem diameter. There was also a significant interaction effect in that for the 'poor' category, the plants originating from container-grown cuttings increased their stem diameter more than plants that originated from field-grown cuttings. This was the reverse of the situation for the 'Best' and 'Standard' categories (Figure 3 and Table 3).

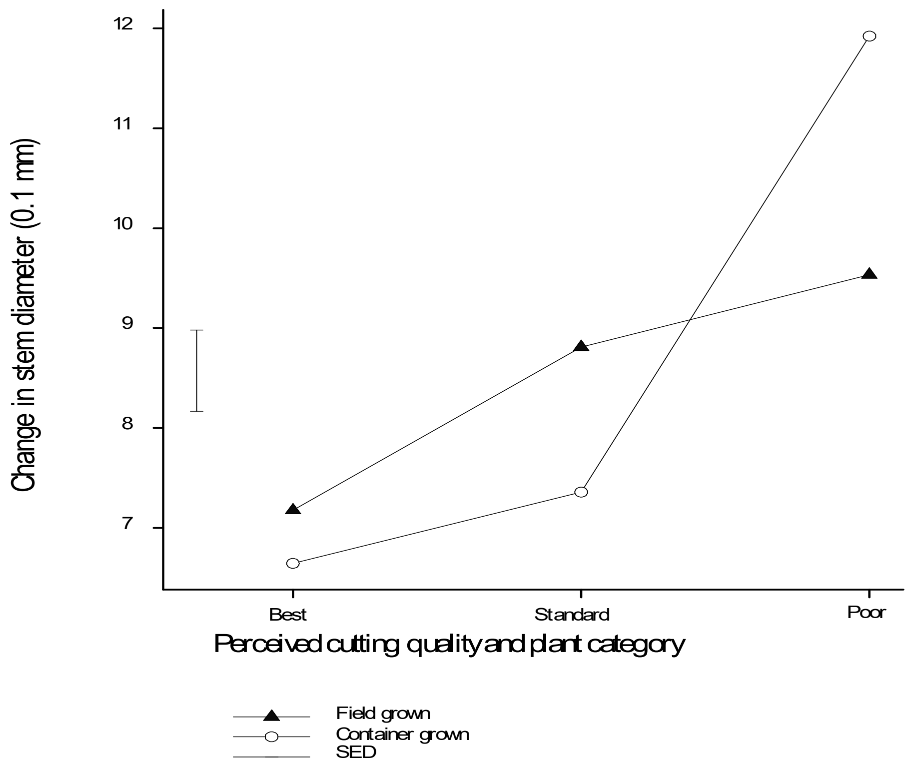

Figure 3. The mean change between cutting and plant stem diameter, which had occurred by 05/12/06, of surviving *B. thunbergii* 'Harlequin' plants that were grown from six different cutting types.

Table 3. Analysis of variance for the change between cutting and plant stem diameter, which had occurred by 05/12/06, of paired surviving *B. thunbergii* 'Harlequin' plants that were grown from six different cutting types.

Source of variation	d.f.	s.s.	m.s.	P
Stock plant type	1	11.08	11.08	0.504
Cutting quality	2	1309.99	654.99	< 0.001
Stock plant type x cutting quality	2	307.96	153.98	0.002

- When the number of apices were counted on 12/7/06, significant effects of stock-plant type and cutting quality were still apparent (Table 4). Approximately five months later, cutting quality still had a major effect on the number of apices, but the stock-plant type effect had become less apparent (Table 5).

Table 4. Analysis of variance for the number of apices on surviving *B. thunbergii* 'Harlequin' that originated from either container-grown or field-grown stock plants and from three perceived qualities of cutting. Data collected on 12/7/06.

Source of variation	d.f.	s.s.	m.s.	P
Stock plant type	1	121.48	121.48	0.046
Cutting quality	2	225.13	112.56	0.025
Stock plant type x cutting quality	2	32.16	16.08	0.589

Table 5. Analysis of variance for the number of apices on surviving *B. thunbergii* 'Harlequin' that originated from either container-grown or field-grown stock plants and from three perceived qualities of cutting. Data collected on 5/12/06.

Source of variation	d.f.	s.s.	m.s.	P
Stock plant type	1	15.129	15.129	0.071
Cutting quality	2	77.471	38.735	< 0.001
Stock plant type x cutting quality	2	57.084	28.542	0.002

Stem diameter growth

- For the 'Best', 'Standard' and 'Poor' liners, there was a significant relationship between the original cutting stem diameter and the stem diameter at the base of the plant on 05/12/06, which demonstrates that the growth of these types of cuttings is predictable. For the 'Poor' category, the gradient of the regression line was lower (almost horizontal), suggesting that the stem diameter growth of this category of plants was more variable and thus much less predictable (Figure 4).

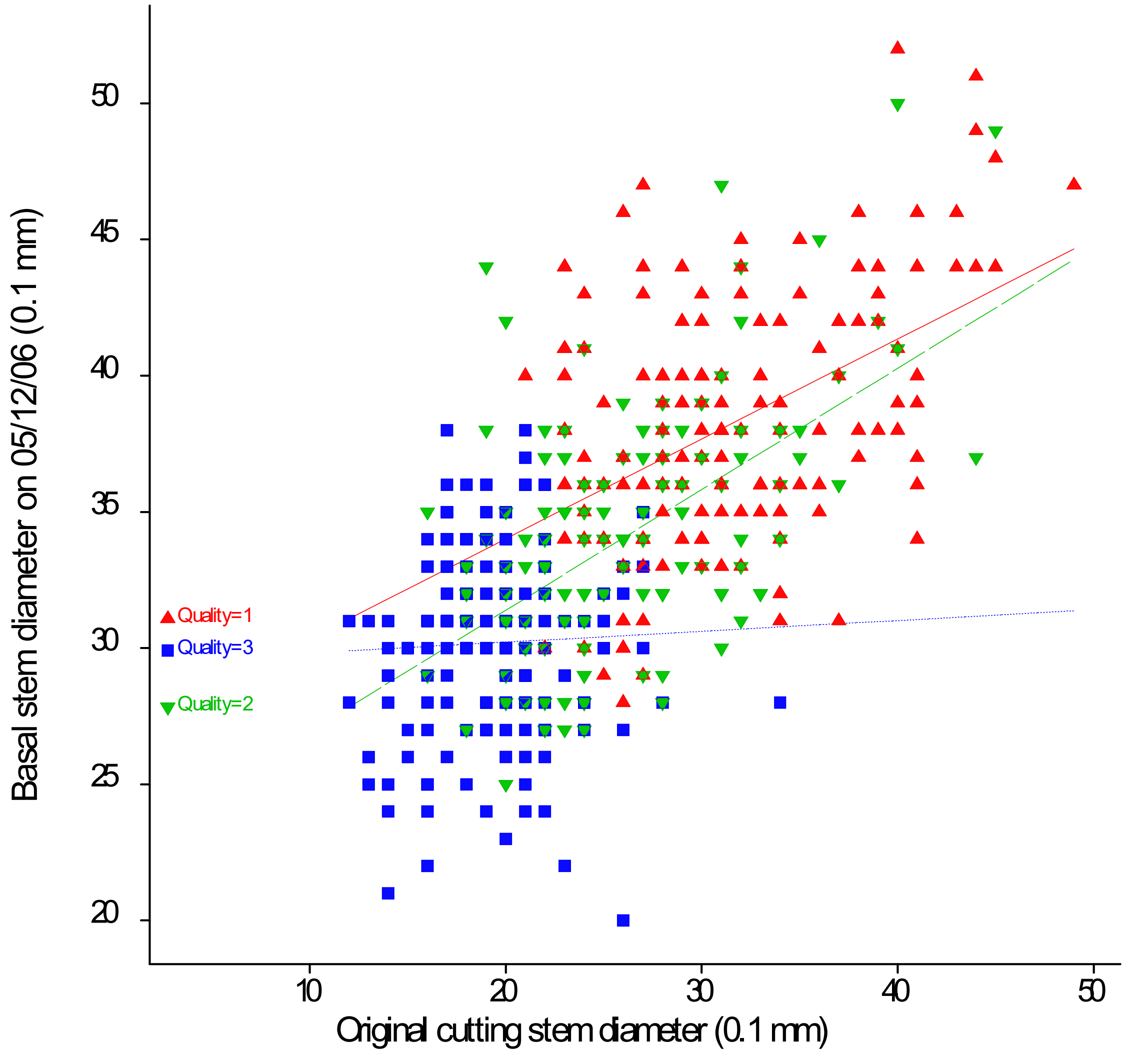

Figure 4. Regression analysis for original cutting stem diameter and the liner basal stem diameter on 05/12/06. Quality 1 (solid line), 2 (dashed line) and 3 (dotted line) plants originated from 'Best', 'Standard' and 'Poor' quality cuttings respectively. Response variate: Basal stem diameter on 05/12/06, Fitted terms: Quality + Width.Quality. Parameter estimates were all significant at $P < 0.001$, except stem diameter.Quality 3, which was NS.

The grading of liners into firsts (saleable) and seconds (non-saleable at the time of grading)

- The plant grading procedure took place at NPN, Pulborough, on 23/01/07, which involved two steps. Dead leaves and any remaining wood chips were removed from the liner pots by a mechanised air blower. Each liner was then assessed subjectively for whether or not it looked healthy and would produce a "well shaped plant". The liners were also hand pruned lightly, if required, and the time taken to grade each plant took three to four seconds.

- Sixty-four out of 458 plants (13.9%) of plants were classified as Seconds. With respect to the quantitative measurement of apices per plant and stem diameter, however, the grading procedure did not produce two clear groups of plants (Figure 5), i.e. there were some plants with only three to five apices and thin stems that were classified as Firsts, as well as bushy plants (9-11 apices) with relatively thick stems that were classified as Seconds.

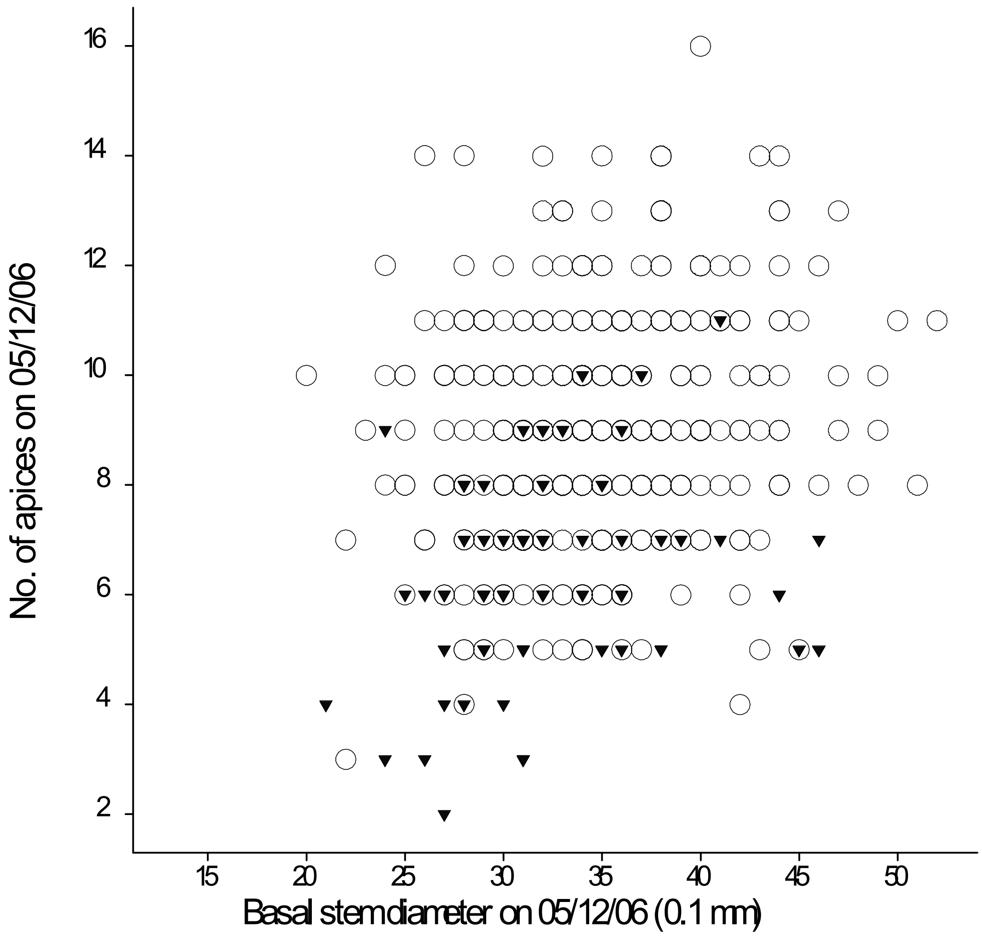

Figure 5. The numbers of apices plotted against the stem-diameter at the base of the plant for surviving plants on 05/12/06. Plants given an open circle (O) were classified as Firsts, whereas those represented by a filled nablas (▼) were called Seconds.

- The criteria set by Hilliers for an acceptable Berberis liner was previously "10-15 cm tall with three strong breaks from the lower 5 cm of the plant", but for this year's plants it was, "minimum height of 25 cm, multi-break, bushy plant".
- Almost all liners easily met the height criterion and so it can also be seen from Figure 6 that, apart from about 10 liners, all the rest would have been

acceptable to HN. In one respect, the grading procedure at New Place could be considered to have resulted in holding back more plants than was strictly necessary. The somewhat surprising result of the application of both the NP and HN grading criteria, however, is that almost all the variation in the crop was retained, i.e. there was no easily identifiable increase in liner uniformity or quality resulting from the grading process.

- Data on losses due to non-uniformity, supplied by Hilliers for this crop in 2005, show that only 3.4% of the crop was wasted. At this stage of the project, it seems probable, therefore, that the failure to make the experimental plants more uniform by grading at the liner stage may not result in lost sales of the finished plants. There may be other hidden costs and consequences, however, such as increased labour costs of picking uniform batches for onward sale at HN, which may become more apparent in the final year of the project.

Berberis thunbergii 'Harlequin' growth from two categories of liner at Hilliers location (2006 liners)

- Twenty-one of the experimental plants were removed accidentally by the pickers during the sales season and the following analysis was carried out on the remaining plants.
- After a growing season at HN, Romsey, the 'Best' category of plants had many more apices than the 'Standard' group (Figure 6). They also had thicker stems, were taller and had a more robust appearance than the 'Standard' group (Figure 7). These data suggest strongly that although the poorest category plants of this variety do show some evidence of 'catching up' with the other categories, at least for the stem diameter trait, the effect is not great enough to eliminate the clear differences still apparent, for instance in the numbers of apices, between the different categories of plants within a single summers growing season (Figures 6 and 7).
- By mid-May 2007, more than a year after the experiment at HN, Romsey, began, there was still one plant in the Standard category that was classed as un-saleable. These data show clearly that the variability present in the two types of liner remained apparent for a considerable time beyond the main sales period of weeks 8-25.

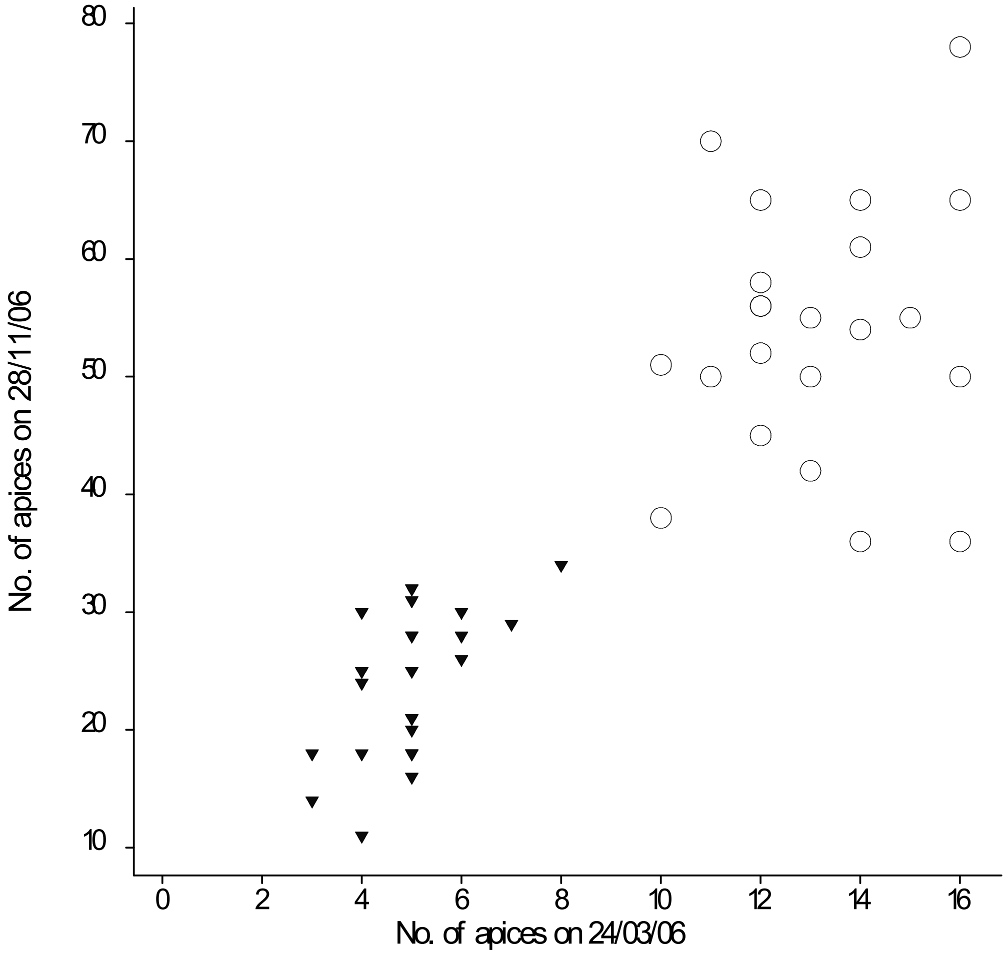

Figure 6. The number of apices for each plant at the beginning of the growing season (24/03/06), plotted against the number of apices on the same plant at the end of the season (28/11/06). Plants represented with an open circle (O) and those by a filled nablas (▼) were described as 'Best' and 'Standard', respectively, in the 2006 Annual Report.

Figure 7. *Berberis thunbergii 'Harlequin'* plants at the end of the growing season (28/11/06), from the 'Best' and 'Standard' experimental groups on the left and right-hand-side, respectively.

Possible additional grading criteria to improve crop quality

- The experimental data collected thus far show clearly that both the number of apices and stem diameter are important predictors of plant quality for this species, i.e. liners with large stem diameters and many apices produce the best quality plants. As an example of how the liner crop could be graded and thus made more uniform and of a higher quality, the following criteria were applied to the data set: i) all plants must be clearly healthy with no evidence of dieback; ii) there should be at least six apices; iii) the basal stem diameter should be more than 0.23 mm. These quantitative criteria produce two clear categories of plant and much greater uniformity in the resulting batch of Firsts (Figure 8). The modelling analysis, however, suggests that stricter grading at this stage is highly unlikely to lead to the most profitable outcome (see modelling section).

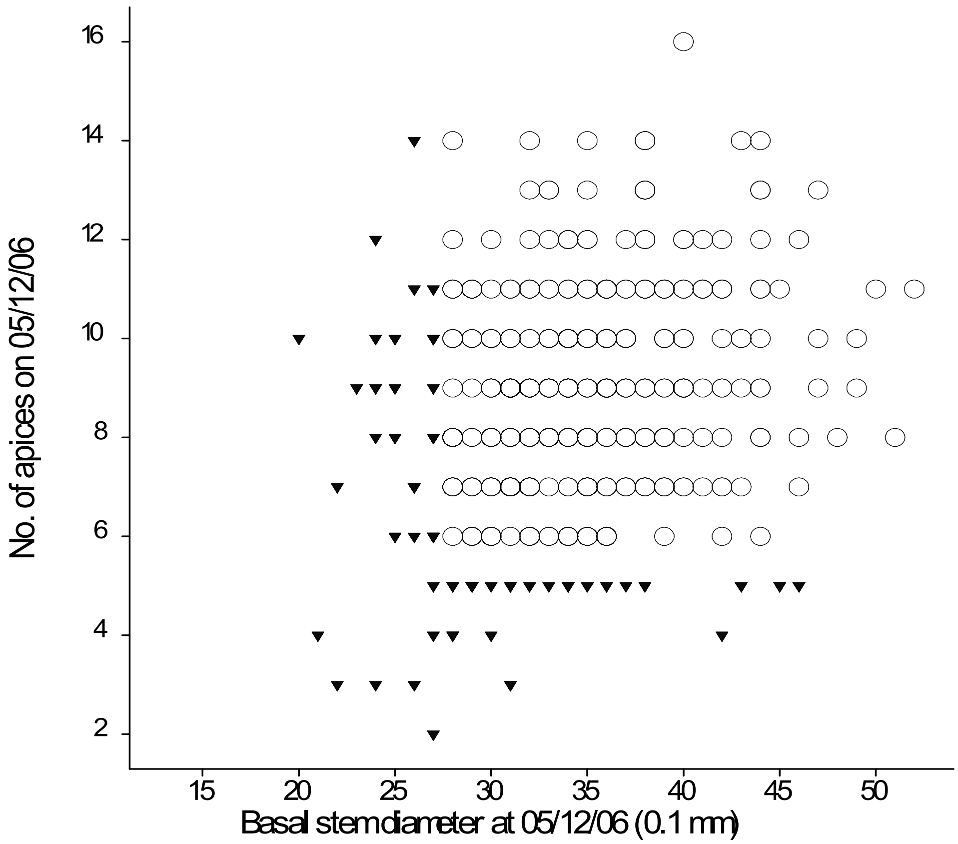

Figure 8. The numbers of apices plotted against the stem-diameter at the base of the plant for surviving plants on 05/12/06. Plant data were categorized using the stricter set of quantitative criteria described in the text and those given an open circle (O) were classified as firsts, whereas those represented by a filled nablas (▼) were called seconds.

Berberis thunbergii 'Harlequin' growth from two categories of liner at Hilliers location (2007 liners)

The experimental plants have been set up at HN, Romsey, and data will be collected from them in the coming year.

***Camellia williamsii* 'Donation'**. *Year 1 summary*. The stem diameters of the two cutting types were clearly different, the diameter of tips being the smaller of the two.

Year 2. Surviving plants were measured in the past year on 18/09/06 and will be measured again prior to grading.

- The two types of cutting produced plants that were clearly different in their number of apices, height and stem diameter (Table 6 and Figure 9). It will become apparent whether or not these differences are maintained when they are measured again before grading. These data will be presented in next year's technical report.

Table 6. Differences between plants grown from tip and internode cuttings, measured on 18/09/06.

	Tips (n = 114)	**Internodes (n = 101)**	***P****
Mean number of apices (± SEM)	2.82 ± 0.08	1.65 ± 0.05	< 0.001
Mean height (mm) (± SEM)	88.4 ± 2.76	115.1 ± 5.81	< 0.001
Mean stem diameter (0.1 mm) (± SEM)	38.04 ± 0.34	35.08 ± 0.41	< 0.001

*Two-sample, unpaired T-Test

Figure 9. Plants grown from the internode (two LHS) and tip (two RHS) cuttings of *Camellia williamsii* 'Donation'.

***Choisya* 'Aztec Pearl'.** *Summary of year 1.* Cuttings were originally planted on 31/08/05 and, because of the high initial mortality present in this planting, another trial was set up following the same design on 24/10/05.

Year 2. Surviving plants were measured in this project year on 06/06/06 and on 06/03/07, prior to grading and transfer to a finished plant producer nursery. The trends in the data collected on these two dates were consistent and so the data collected on 06/03/07 only are presented.

- The survival of the experimental plants in the period since the previous annual report was high. Due to the initial high mortality in the cutting stage, however, the numbers of remaining single and two-internode cuttings, particularly in the second experimental batch of plants, was low (Table 7) and consequently, there were too few plants remaining to analyse the second experiment statistically. With the qualification that is not possible to determine whether or not the time of planting had an effect on the growth of the different cutting types, the data from the two experimental batches were pooled for subsequent analysis by analyses of variance (ANOVA).
- Apart from plant height, the statistics for the other measurements were significantly different, showing that cutting type still had a major effect on liner dimensions more than 1.5 years after planting and at the first expected time of sale (Table 8).
- Plants that were grown from the two inter-nodal cuttings had the highest mean number of breaks in the bottom 5 cm of the stem (Figure 10A). Liners grown from single inter-nodal cuttings tended to produce two stems, giving the liners a 'horned' or 'Y' shaped appearance (Figure 10A); liners grown from tips often had a single long stem in the bottom 5 cm of the plant, although they clearly have the potential to produce a very large number of breaks (Figure 10B). Although it was not tested, this profuse breaking effect exhibited by some tip cuttings may have been due to the removal of the growing tip by an unrecorded event shortly after the cutting had rooted successfully and started to grow. This hypothesis could be tested easily in a small trial.
- The developmental structure or 'plant habit' produced by liners from the different cutting types is clearly different for this species and within each type there is sufficient uniformity that plants can be recognised easily without

reference to the pot label. How this variation relates to quality and saleability was assessed in the grading procedure.

Table 7. The number and percentage of survival of the first and second experiments of *Choisya* 'Aztec Pearl' from planting to 06/03/07. The types of cutting used were the standard two inter-nodal lengths, a single inter-nodal length and tips. N = 84 initially for all cutting types in each of the two experiments.

Experiment	Survival					
	Two inter-nodes		Single inter-node		Tips	
	No. observed	(%)	No. observed	(%)	No. observed	(%)
First						
4/10/05	66	(78.6)	21	(25.0)	50	(59.5)
20/2/06	49	(58.3)	19	(22.6)	26	(31.0)
06/03/07	49	(58.3)	19	(22.6)	26	(31.0)
Second (repeated)						
20/2/06	15	(17.9)	5	(6.0)	43	(51.2)
06/03/07	11	(13.1)	2	(2.4)	42	(50)

Table 8. The summary of statistics of the pooled *Choisya* 'Aztec Pearl' data collected on 06/03/07 and ANOVA results. The types of cutting from which the liners were grown were the standard two inter-nodal lengths, a single inter-nodal length and tips.

Plant measurement	Liner types						
	Two inter-nodes		Single inter-node		Tips		
	Mean	± SEM	Mean	± SEM	± SEM	Mean	*P*
Breaks in bottom 5 cm of stem	3.5	± 0.192	2.3	± 0.122	3.1	± 0.210	= 0.008
Apices	7.5	± 0.325	7.2	± 0.537	6.2	± 0.344	= 0.023
Height (mm)	141.6	± 4.01	142.9	± 2.69	149.8	± 3.09	= 0.198
Basal stem diameter (0.1mm)	51.8	± 1.13	58.4	± 1.19	54.0	± 0.78	= 0.002

*Values of *P* < 0.05 are considered significant.

Figure 10. *Choisya* 'Aztec Pearl' liners at the first expected date of sale. **A**. A liner grown from a single inter-nodal cutting (LHS) and one grown from a two internodal cutting on the (RHS). The single inter-nodal cutting shows the typical 'horned' or 'Y' shaped plant structure. **B.** Both liners grown from tip cuttings. The one on the left shows multiple breaks in the bottom 5 cm of the stem, while that on the right shows the much more typical single long stem in that region.

- The grading procedure was applied to all experimental *Choisya* 'Aztec Pearl' plants on 20/03/07. The criteria adopted by NP staff for an acceptable First grade plant were, i) at least two stem breaks in the bottom 5 cm of the liner, ii) a well formed top, iii) a good weight of plant and iv) looking healthy and vigorous. Plants not meeting these criteria were held back as Seconds. The liner specification supplied by HN was "10 cm tall with 5 breaks".
- The numbers of Firsts:Seconds in the two inter-node, single inter-node and tip liner categories were 49:11, 19:2 and 35:33, respectively. Expressed as percentages, these are approximately 81:18%, 90:10% and 52:48%, respectively.
- Due to the relatively high percentage of plants from each of the three types that were classified as Firsts, there was no discernable association between plant type and grading category. Liners grown from tips generated the highest

percentage of Seconds, however, and this was clearly due to the lack of breaks in the bottom 5 cm of the stem in this type of plant (Figure 10B).

- The statistical analyses (Table 8) showed, in general, that liners of the same cutting type were more similar to each other than to those of the other types. The grading process resulted in the majority of plants of the three types being placed into the single category of Firsts. This process, by definition, results in an increased variance or 'non-uniformity' in the new group called Firsts.
- Related to the non-uniformity clearly present in the group of Firsts, is the concept of plant 'quality', which is ultimately determined by customers that purchase these plants from the DIY chain stores. It would seem important for this variety to investigate how DIY chain and garden centre customers assess this variety's quality in terms of the plant's physical structure. Once this information has been obtained, production could be adjusted to produce uniform batches of plants to the desired end-customer quality specification, which may boost sales and should benefit all parties involved along the production chain.
- When the number of stem breaks in the bottom 5 cm of the liner was plotted against the number of apices for the graded plants (with unhealthy looking plants removed), there was still a substantial overlap between the two categories (Fig. 11). This suggests that additional quality judgements are being made in the grading process, perhaps on the basis of the stem diameters of the breaks (possibly equivalent to "weight of plant").

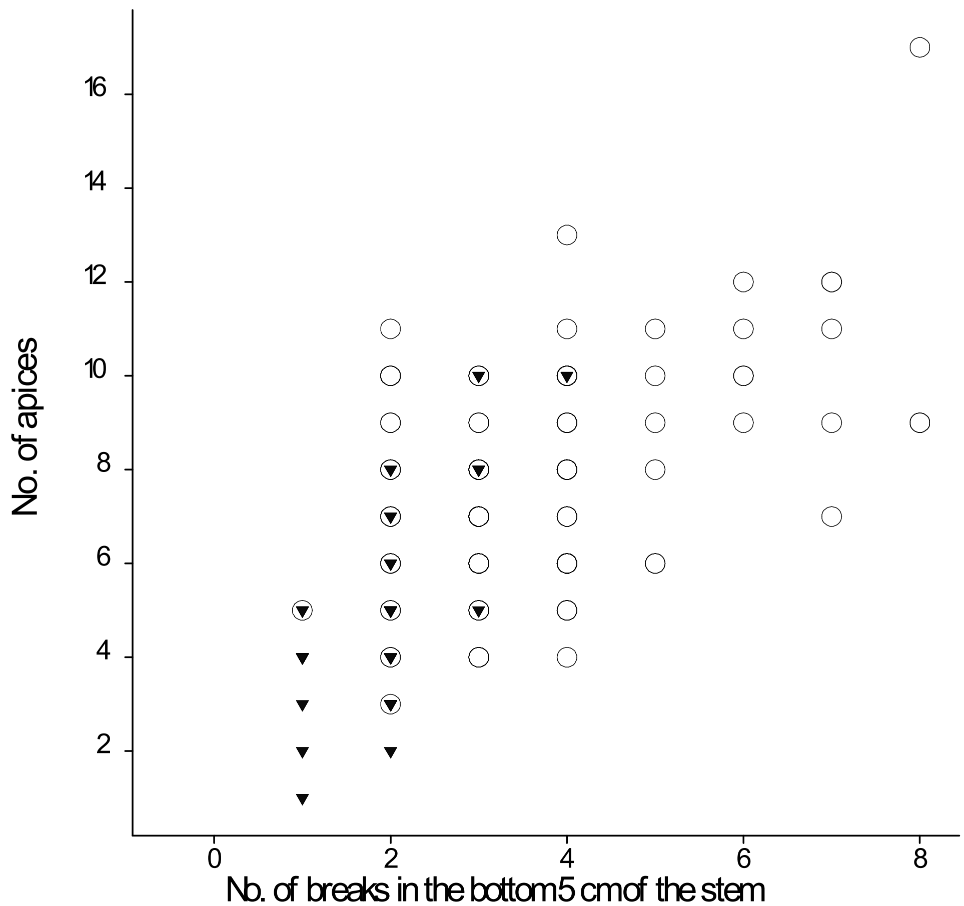

Figure 11. The number of apices for each plant at the beginning of the growing season (24/03/06), plotted against the number of breaks in the bottom 5 cm of the stem. Plants represented with an open circle (O) and those by a filled nablas (▼) were categorized as Firsts and Seconds, respectively, in the grading process.

Choisya ternata **'Sundance'**. *Year 1 summary*. The different types of cutting had significantly different sizes and the three cutting types that had the greatest volumes, produced the longest lengths of new shoot. Probably due to being covered by the leaves of adjacent plants, some buds did not produce shoots, which contributed to non-uniformity. In addition, there were strong indications for this variety, that the cutting type has an immediate influence on plant structure.

Year 2. The following differences were apparent between the plants grown from the different cutting types:

- As was the case in the previous annual report where the mean total lengths of shoots was greater for plants generated from container-grown stock plants, these plants were significantly taller than those generated from ground-grown stock plants (Figure 12).

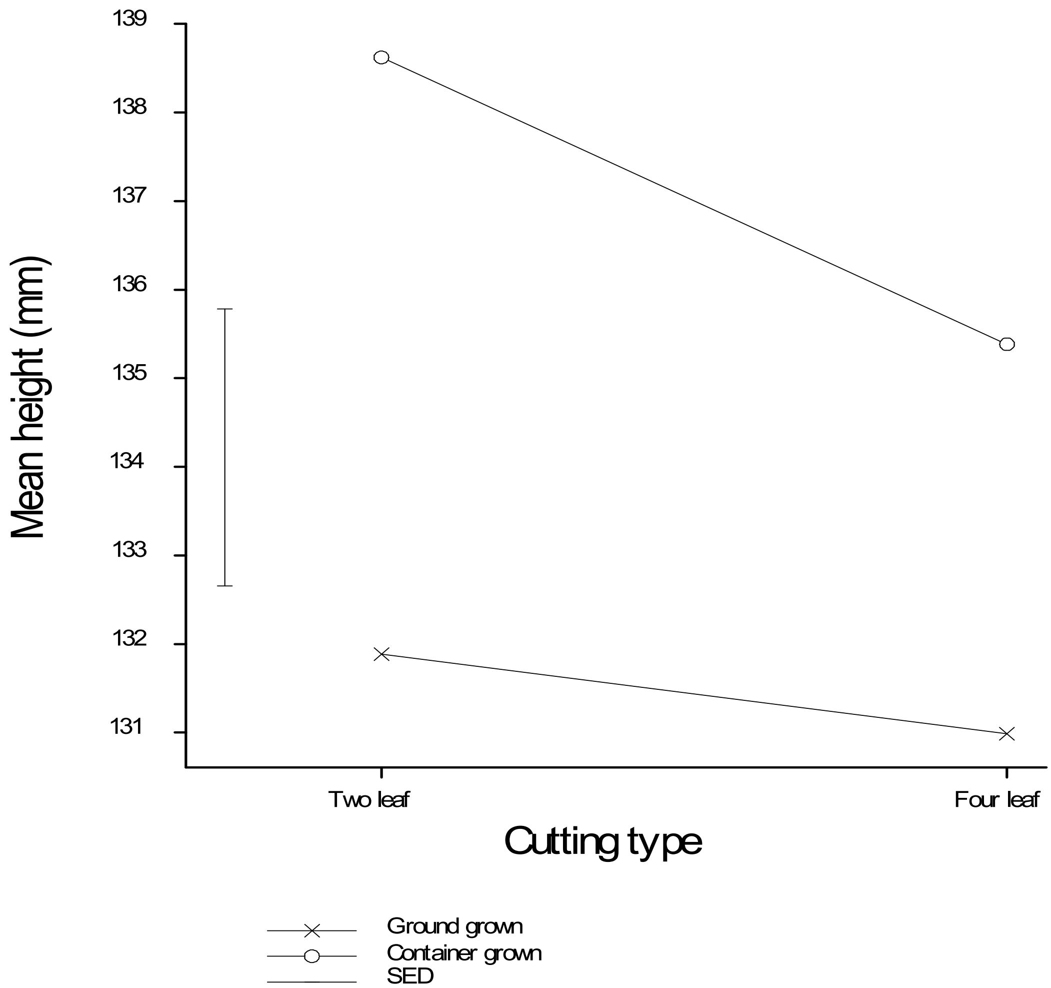

Figure 12. The mean heights *Choisya ternata* 'Sundance' that originated from either container-grown or ground-grown stock plants and from cuttings with either two or four leaves. ANOVA for source of variation: stock-plant type *P* = 0.011; cutting type *P* = 0.328; stock-plant type x cutting type *P* = 0.597.

- Plants that were generated from four leaf cuttings had significantly more breaks in the lower part of the plants (between 0 - 5 cm above soil level) (Figure 13 and 14).

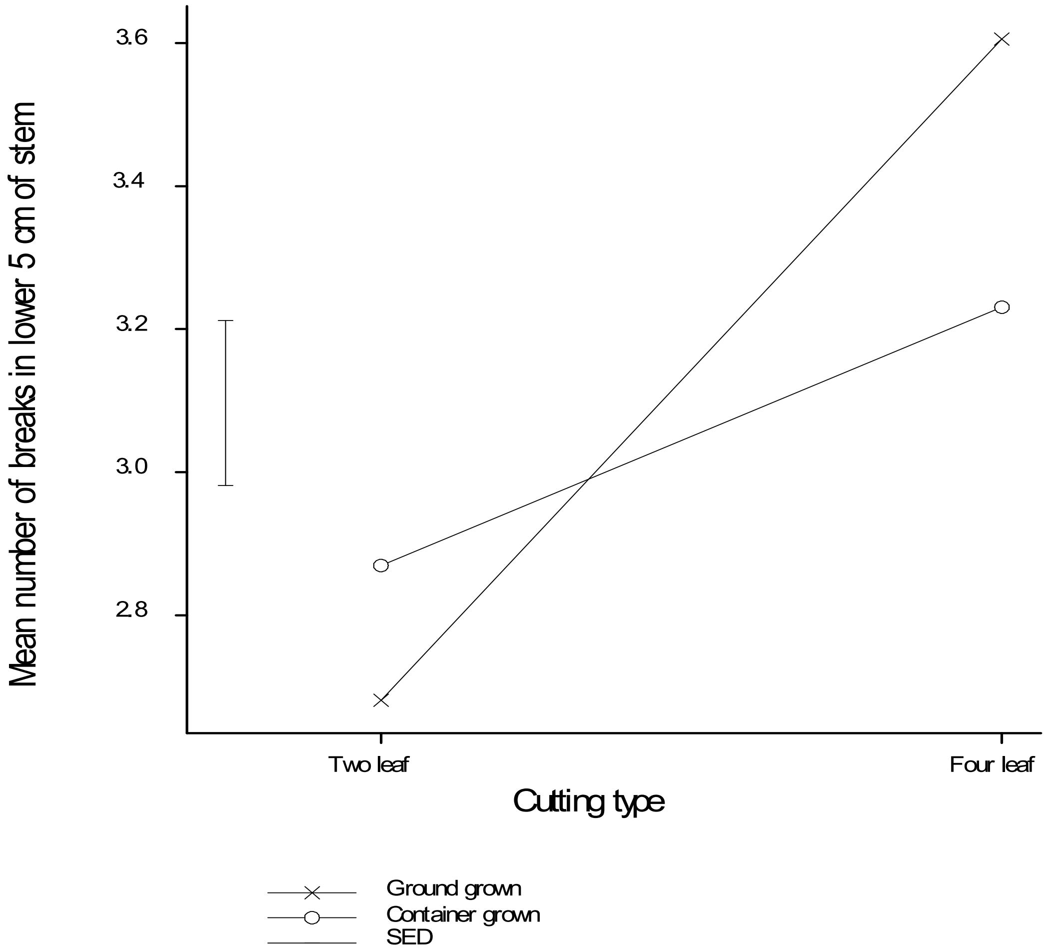

Figure 13. The mean number of breaks in the lower 5 cm of *Choisya ternata* 'Sundance' that originated from either container-grown or ground-grown stock plants and from cuttings with either two or four leaves. ANOVA for source of variation: stock-plant type $P = 0.52$; cutting type $P < 0.001$; stock-plant type x cutting type $P = 0.086$.

Figure 14. A liner grown from a single inter-nodal cutting (LHS) and one grown from a two internodal cutting on the (RHS). The single inter-nodal cutting shows the typical ‘horned’ or ‘Y’ shaped plant structure.

- The percentage of survival for the different cutting types at this stage were very similar. The planted-single internode, planted-two internode, the pot-single internode and pot-two internode had percentage of survivals of 82, 85, 82 and 75%, respectively.
- The grading procedure was applied to all experimental *Choisya ternata* ‘Sundance’ plants on 20/03/07. The criteria adopted by NP staff for an acceptable First grade plant were, i) at least two stem breaks in the bottom 5 cm of the liner, ii) a well formed top, iii) a good weight of plant and iv) looking healthy and vigorous. Plants not meeting these criteria were held back as Seconds. The liner specification supplied by HN was “10 cm tall with 5 breaks”.
- The numbers of Firsts:Seconds in the planted-single internode, planted-two internode, the pot-single internode and pot-two internode liner categories were 56:13, 57:14, 62:7 and 52:11, respectively. Expressed as percentages, these are approximately 81:19%, 80:20%, 90:10% and 83:17%, respectively.

- Due to the relatively high percentage of plants from each of the four types that were classified as Firsts, there was no discernable association between plant type and grading category.
- The statistical analyses showed, in general, that liners of the same cutting type were more similar to each other than to those of the other types. The grading process resulted in the majority of plants of the four types being placed into the single category of Firsts, resulting in an increased variance or 'non-uniformity' in the new group called Firsts.
- As discussed for the *Choisya* 'Aztec Pearl' the non-uniformity clearly present in the group of Firsts may affect later sales of the finished plants due to the DIY chain and garden centre customers, is the concept of plant 'quality', which is ultimately determined by customers' perceptions of plant 'quality'. It would also seem important for this variety to investigate how to assess this variety's quality in terms of the plant's physical structure.
- When the number of apices of the liner (reflecting the number of breaks) was plotted against plant height, there was still a substantial overlap between the two categories (Fig. 14a). This suggests that additional quality judgements are being made in the grading process, perhaps on the basis of plant 'form' and/or the stem diameters of the breaks (equivalent to "weight of plant").

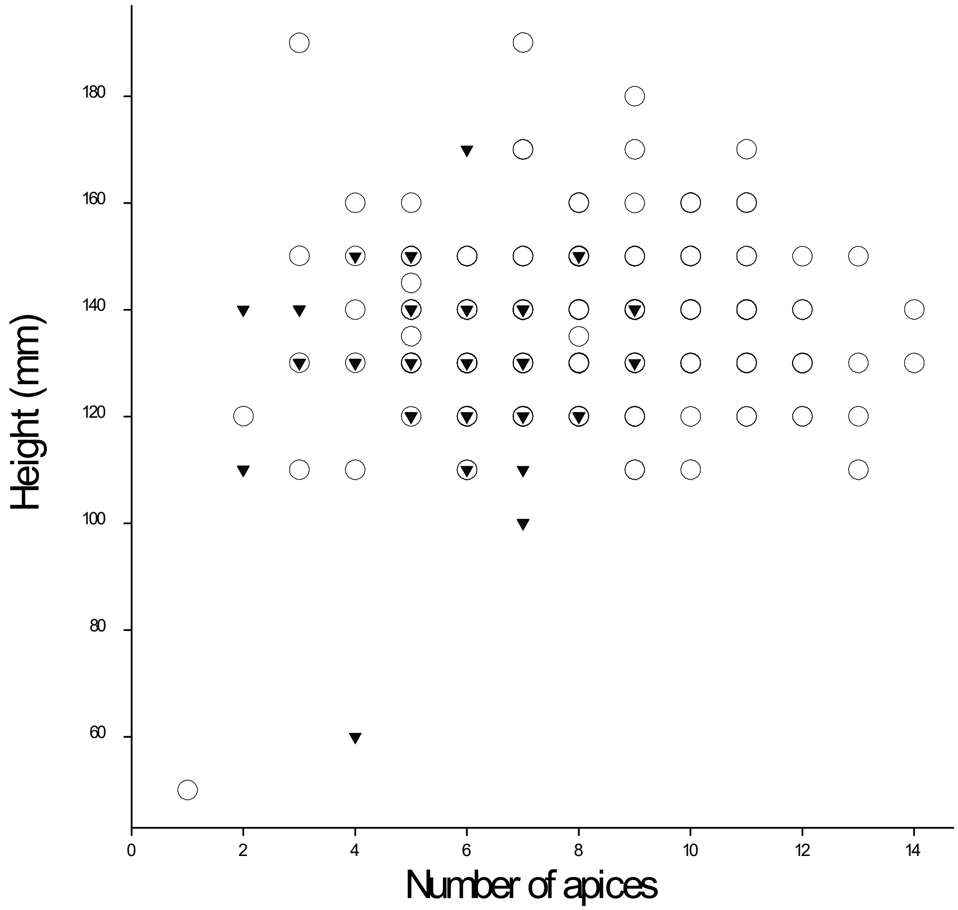

Figure 14a. Plant height at grading, plotted against the number of apices. Plants represented with an open circle (O) and those by a filled nablas (▼) were categorized as Firsts and Seconds, respectively, in the grading process.

***Cistus* 'Silver Pink'**.

Data collected while plants were at the Sidlesham location

- The survival of the four cutting types was very similar and 79 (94.0%), 78 (92.9), 83 (98.8) and 76 (90.5%) plants were still alive on 28/06/06, for the Good/Year 1, Good/Year 2, Poor/Year 1 and Poor/Year 2 categories, respectively.
- On 28/06/06, the perceived cutting quality and age of the mother plant both still had a highly significant effect on the number of apices produced by the different cutting types, i.e. plants from 'Good' cuttings were bushier than those from 'Poor' cuttings and plants grown from 1-yr-old mother plants were bushier than those grown from 2-yr-olds (Figure 15; ANOVA, $P < 0.002$). The height of plants was relatively variable and differences between the different cutting types were not significant (ANOVA, $P > 0.724$).

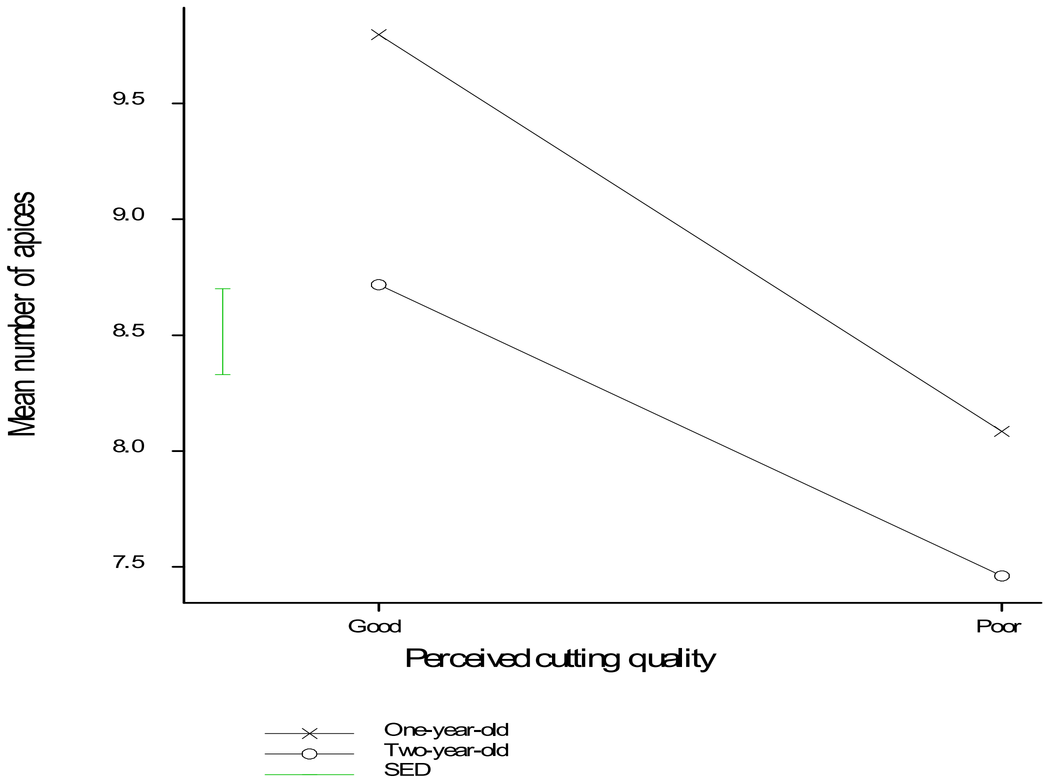

Figure 15. The mean numbers of apices on the different cutting types, measured on 28/06/06, immediately prior to grading into First and Second category plants.

- When all plants were considered to be one group, there was a significant regression relationship between cutting stem diameter and number of apices, showing that the cuttings with wider stem diameters produced bushier plants (constant estimate = 3.4 $\pm$ 0.92 (S.E.), $P < 0.001$; stem diameter estimate = 0.22 $\pm$ 0.04(S.E.), $P < 0.001$).
- The numbers of Firsts and Seconds produced by the different cutting types differed, with cutting type Good / Year 1 giving the best result (Figure 16a and Table 9). Plants that were classified as Seconds by NP staff, were even more markedly different to those that had been grown from cutting type Good / Year 1 (Figure 16b).

Figure 16. A) Blocks of Poor / Year 2 (PY2) and Good / Year 1 (GY1) plants showing different amounts of dark soil through their foliage. **B)** A block of Second category plants (Seconds) with substantially less foliage and thus more soil exposed than the block of Good / Year 1 (GY1) plants.

Table 9. The numbers and percentages of surviving plants from each category of cutting that were assigned to the First or Second categories.

Assigned Grade	Good /Year 1	Good / Year 2	Poor / Year 1	Poor / Year 2
Firsts (% of survivors)	77 (97.5)	64 (82.1)	65 (78.3)	65 (81.3)
Seconds (% of survivors)	2 (2.5)	14 (17.9)	18 (21.7)	11 (18.7)

- The grading procedure at Sidlesham consisted of looking at each plant from above and forming a subjective opinion about how much of the soil in the plant pot was covered by foliage. This reflected the liner specification provided by Hilliers of "7 cm tall and bushy covering the pot". Those plants that covered most of the soil were considered to be Firsts, whereas those where a lot of soil was visible were considered Seconds. This grading process resulted in most plants being classed as Firsts.
- The quantitative data on the number of apices per plant clearly showed that Good / Year 1 plants were the bushiest and almost all of these were classified as Firsts. However, the majority plants (> 78%) in the other plant categories were also classed as Firsts and so no clear relationship between plant grade and

either the number of apices present or the original cutting stem diameter could be discerned (Figure 17).

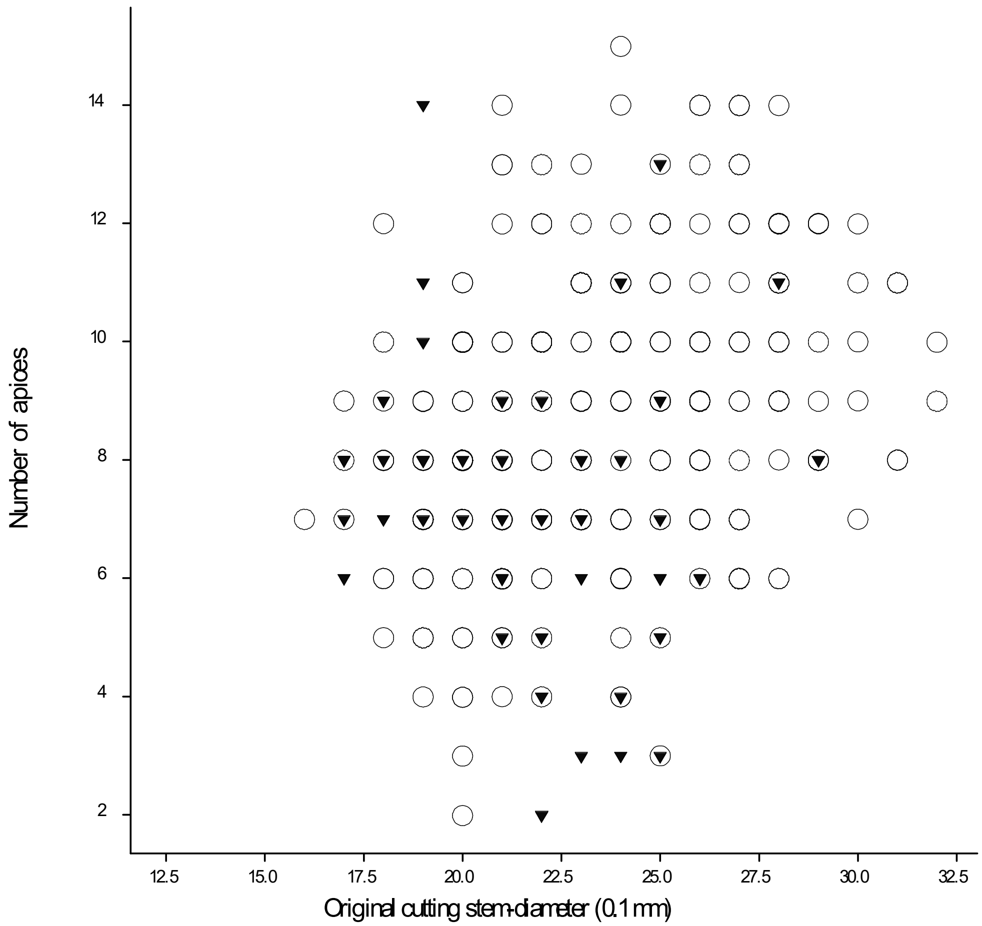

Figure 17. The numbers of apices plotted against the original cutting stem-diameter for surviving plants. Plants given an open circle (O) were classified as firsts, whereas those represented by a filled nablas (▼) were called seconds.

Experimental work at the Glovers Nursery location

- As explained in the Materials and Methods Section, the link between the cutting material and the plants in the 3L containers was lost, but two subjectively selected sub-samples of plants were used to continue the experiment and Figure 18 shows examples of the plants used.

Figure 18. Eight representative plants from the two subjectively selected sub-samples. The top and bottom two rows of four plants were termed, respectively, Firsts and Seconds.

- The group of plants selected as Firsts had a mean number of apices that was more than double that of the seconds. Firsts also had a mean height that was significantly greater than that of the seconds. In addition, the mean height of selected plants in the Seconds category (5.8 cm, see Table 10) was below the 7 cm specification set by Hilliers. These differences were still clearly evident when the plants were measured again approximately eight weeks later on 28/11/06 and at the date of first sale on 22/04/07 (Figure 19 and Table 10).

Table 10. Differences over time between the subjectively selected sub-samples of plants.

	Firsts (n = 40)	**Seconds (n = 40)**	***P****
Measured on 01/09/06			
Mean number of apices (± SEM)	9.8 ± 0.35	4.4 ± 0.20	< 0.001
Mean height (mm) (± SEM)	77.4 ± 2.89	57.9 ± 2.45	< 0.001
Measured on 28/11/06			
Mean number of apices (± SEM)	14.1 ± 0.44	6.9 ± 0.33	< 0.001
Mean height (mm) (± SEM)	140.0 ± 3.28	101.6 ± 3.80	< 0.001
Measured on 22/04/07 at date of first sale			
Mean number of apices (± SEM)	14.58 ± 0.42	8.6 ± 0.39	< 0.001
Mean height (mm) (± SEM)	360.5 ± 7.7	336.1 ± 7.9	= 0.015

*Two-sample, one-sided unpaired T-Test

Figure 19. Examples of Second (LHS) and First (RHS) category plants at the first time of sale (22/04/07).

- The quantitative differences between the two plant categories were reflected strongly in the result of the grading process carried out by Glovers' nursery staff. Thirty-three (82.5%) of the liners originally classified as Firsts were considered ready for sale on 22/04/07, whereas only 10 (25%) of the Seconds had reached an acceptable standard.

***Photinia x fraseri* 'Red Robin'**. *Year 1 summary*. The physical characteristics of the three types of cutting were very different. One important feature of this species was the relatively long length of the cuttings, particularly those taken from the base of the stem, which meant that the architecture of the liner was largely predetermined.
Year 2. The survival of all three types of line was good, with the stem tip, stem middle and stem bottom categories recording 95%, 83% and 92% survival. For each of these categories, the numbers of Firsts:Seconds was 81:14, 61:22 and 78:14, which expressed as percentages is 85%:15%, 73%:27% and 85%:15%, respectively.

- Differences between the different categories of liner are summarized in Table 11, which shows that the mean number of breaks in the lower 5 cm of the stem and the mean number of stems was highest in the tip category of cutting (Figure 20). The heights and stem diameters of the different cutting type had become very similar.

Table 11. The summary of statistics of the *Photinia x fraseri* 'Red Robin' data collected on 20/04/07and ANOVA results. The types of cutting from which the liners were grown were the stem tip, stem middle and stem bottom.

Plant measurement	Liner types						
	Tips		Middle		Bottom		
	Mean	± SEM	Mean	± SEM	Mean	± SEM	*P*
Breaks in bottom 5 cm of stem	2.7	± 0.18	1.8	± 0.13	1.6	± 0.14	< 0.001
Stems	6.6	± 0.27	5.5	± 0.24	6.1	± 0.24	= 0.005
Height (mm)	192.4	± 2.3	191.6	± 3.9	196.8	± 2.6	= 0.409
Basal stem diameter (0.1mm)	59.7	± 0.77	59.0	± 1.82	60.0	± 0.78	= 0.834

*Values of *P* < 0.05 are considered significant.

Figure 20. Plant structures of liners grown from the stem bottom (LHS), stem middle (Centre) and stem tip (RHS), showing differences in the number of breaks in the lower 5 cm of the main stem.

- The liner specification from HN was "15 cm tall with a minimum of four breaks within 3 cm of the base". Figure 21 shows that almost all plants were taller than 15 cm, but that there was no clear differentiation between the First and Second categories in terms of the number of breaks in the lower part of the stem.
- Even with the criterion slightly relaxed to the number of breaks in the lower 5 cm of the stem, it can be seen that very few plants had four or more breaks in this region (Figure 21).

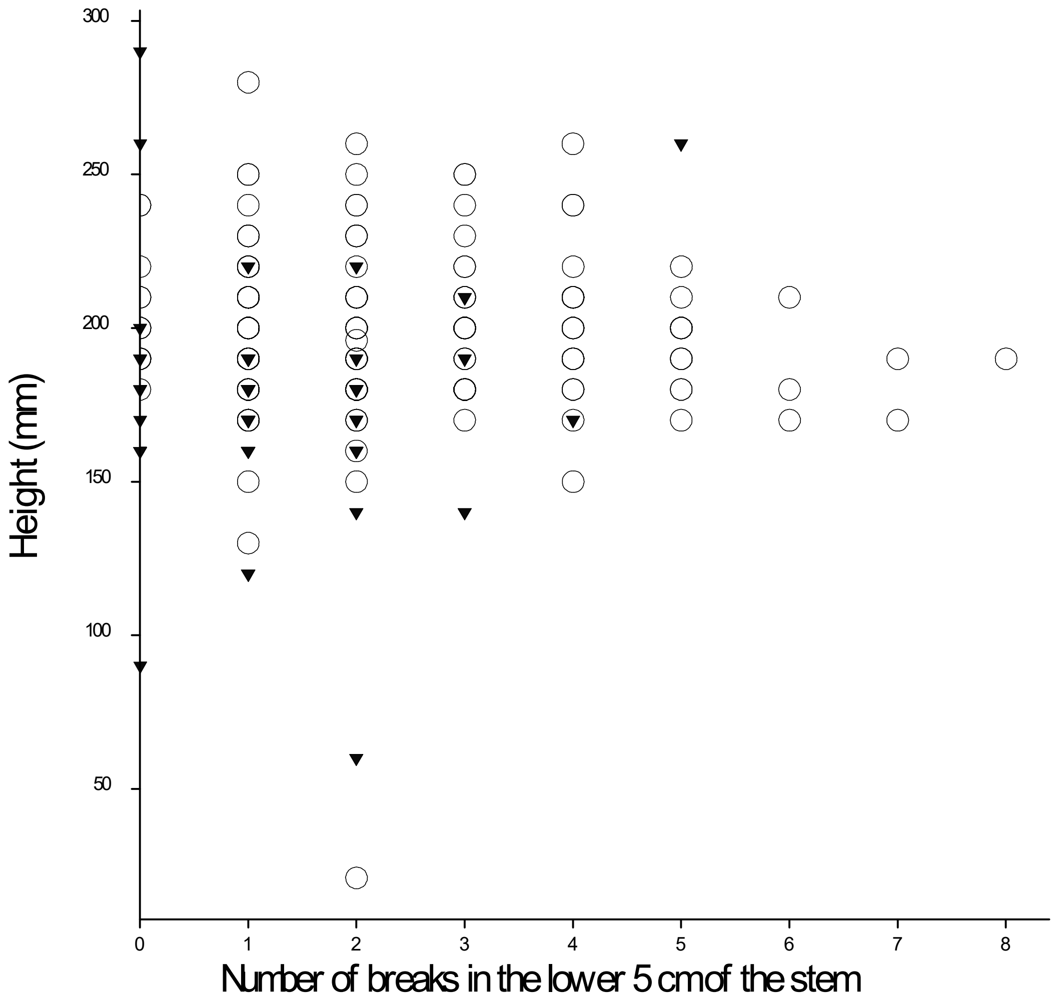

Figure 21. Plant height plotted against the number of breaks in the lower 5 cm of the stem for surviving plants. Plants given an open circle (O) were classified as firsts, whereas those represented by a filled nablas (▼) were called seconds.

***Pieris* 'Forest flame'**. *Year 1 summary*. In common with many of the other experimental species, there were significant differences in the physical shape of the different types of cutting. The soft, medium and hard cuttings had the smallest, intermediate and largest volumes, respectively.

Year 2. The plants were transferred to liner pots on 9/05/06 and measured on 28/06/06.

- The survival of the three types was different with 53 (63%), 74 (88%) and 48 (57%) plants from the soft, medium and hard categories alive at the time of data collection, respectively.

- No significant differences between the plant types were detectable in the height, number of shoots or the total shoot length of surviving plants.
- This species has yet to be graded and these data will appear in next year's technical report.

***Pittosporum tenuifolium* 'Garnettii'**. *Year 1 summary*. There were significant differences in the physical shape of the different types of cutting, which were the Heel of side shoot, Middle stem, Upper stem 'best'.

Year 2. Survival of plants was very poor and by 30/10/06, there were only 48 plants remaining alive, which represents an overall survival rate of 19% at this stage. An additional problem arose in that the liner pot labels were damaged, probably by slugs, and only sixteen labels could be read with any certainty. It was therefore not possible to analyse the original experiment statistically and plant were renumbered. Data will continue to be measured from the surviving plants.

***Potentilla* 'Chelsea Star'**. *Year 1 summary*. There was a strong relationship between the numbers of branches and above ground stem volume, which suggested that selectively using cuttings with a greater stem width should result in bushier plants of higher quality.

Year 2. Plants were measured on 03/07/06 and survival was high at 99.4%.

- The regression analysis on number of branches against original stem width was highly significant, reinforcing the earlier conclusion that cuttings with a greater stem width result in bushier plants of higher quality (width estimate = 0.42, $P < 0.001$; constant estimate = 18.7, $P = 0.003$).
- Plants have yet to be graded and these data will appear in the next technical report.

***Prunus incisa* 'Kojo-no-mai'**. *Year 1 summary*. The physical characteristics of the types of cutting were significantly different and these differences were related to the quality of the plants when transferred into liner pots. Survival of the young plants grown from thinner cuttings was poorer over the winter period.

Year 2. Surviving plants were measured on 03/07/06, 12/12/06 and at the time of grading on 02/04/07.

- Survival of the experimental plants remained high and relatively constant during the period between 03/07/06 and 12/12/07, as did the relative differences in the mean stem diameters of the different categories of plants (Table 12). On 02/04/07, the survival of the three types was unchanged.

Table 12. Summary statistics for *P. incisa* 'Kojo-no-mai' liners measured on 03/07/06 and 12/12/06.

Cutting type stem diameter	Statistic	03/07/06	12/12/06
Lower stem			
	Number of survivors (%)	55 (65.5)	55 (65.5)
	Mean + SE (mm)	40.9 + .53	61.6 + 0.80
	Variance	15.54	35.62
Main stem tip			
	Number of survivors (%)	44 (52.4)	44 (52.4)
	Mean + SE (mm)	33.8 + 0.73	53.8 + 0.84
	Variance	23.65	31.24
Side shoot			
	Number of survivors (%)	34 (40.5)	32 (38.1)
	Mean + SE (mm)	35.6 + 0.8	52.9 + 0.96
	Variance	35	29.58
Three types combined			
	Number of survivors (%)	133 (52.8)	131 (51.98)
	Mean + SE (mm)	37.2 + 0.47	56.8 + 0.61
	Variance	29.76	48.30

- On 02/04/07, the mean number of breaks in the lower 5 cm of the stem for the lower stem, middle stem and side shoots was 6.3 + (SEM) 0.18, 4.4 + 0.19 and 4.6 + 0.21, respectively. The lower stem category of plants had significantly more breaks in that region than the other two categories (ANOVA, $P < 0.001$).
- The 2007 HN specification for liners of this species was "10-15 cm tall, with a minimum of four breaks in the lower 5 cm of the stem". All but four plants were categorized as Firsts in the grading process (Figure 22).

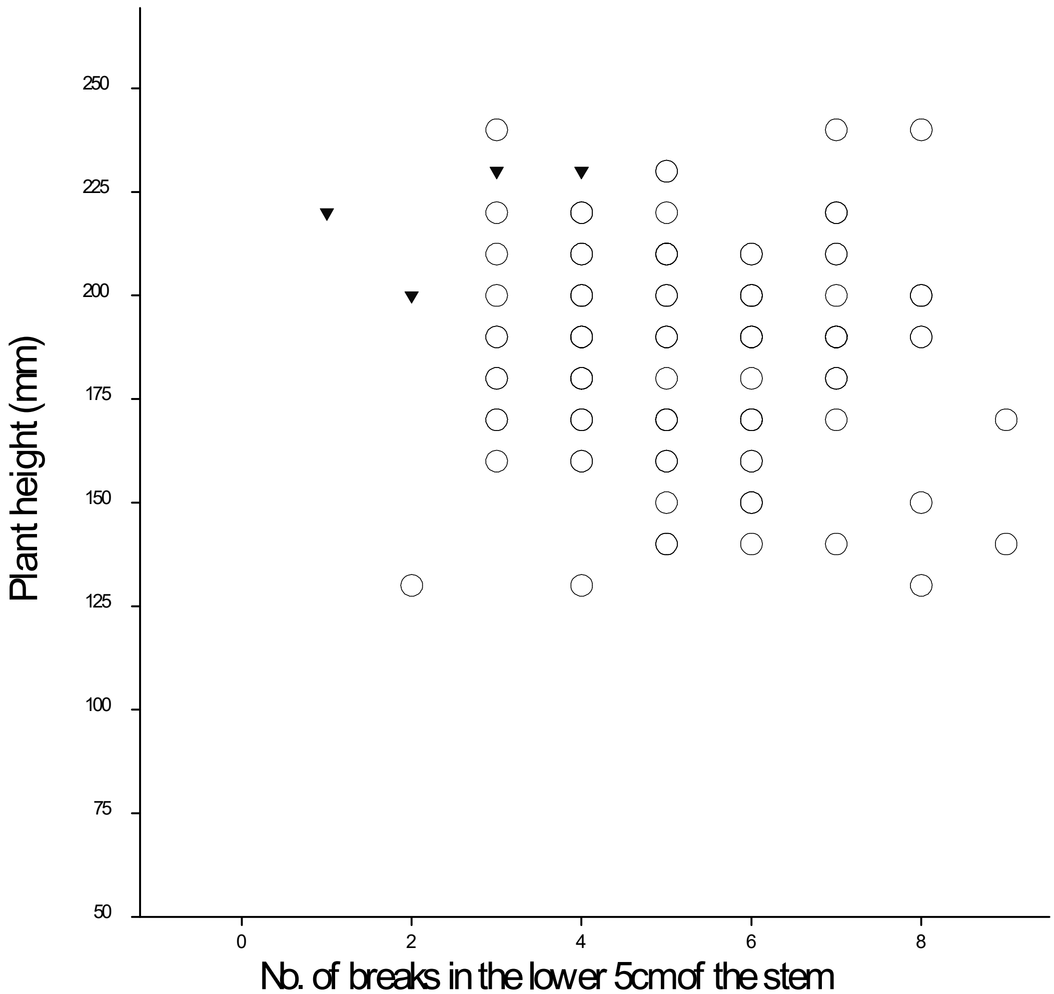

Figure 22. Plant height plotted against the number of breaks in the lower 5 cm of the stem for surviving plants. Plants given an open circle (O) were classified as Firsts, whereas those represented by a filled nablas (▼) were called Seconds.

Rhamnus alaternus **'Argenteovariegata'**. *Year 1 summary*. In common with many of the other experimental species in this study, the different cutting types had significantly different physical attributes.

Year 2. The numbers and percentage of survival on 03/07/06 of the heel, middle stem and upper stem 'best' categories of plant were 70 (67.3%), 39 (37.5%) and 29 (28.8%), respectively.

- Probably due to the low survival of some of the categories, the analysis of variance for the total length of shoots produced by 03/07/06 was not significant (*P* = 0.087).
- Surviving plants will be graded and these data will appear in the next technical report.

***Viburnum tinus* 'Eve Price'**. *Year 1 summary*. The three different perceived cutting qualities (Top, Hard and Singles) of *Viburnum tinus* 'Eve Price' had significantly different physical attributes.

Year 2. The Top, Hard and Singles had the following numbers of plants and percentage of survival, respectively: 45 (75%), 45 (75%), 28 (46.7%).

- The different cutting types produced plants with significantly different characteristics. The Top and Hard categories of plants had the most breaks in the bottom 5 cm of the stem (Table 13 and Figure 23).

Table 13. The summary of statistics of the *Viburnum tinus* 'Eve Price' data collected on 03/04/07and ANOVA results. The types of cutting from which the liners were grown were the Top (softer with two internodes), Hard (two internodes) and Singles (from base and a single internodal length).

Plant measurement	Liner types		
	Top	Hard	Singles

	Mean	+ SEM	Mean	+ SEM	Mean	+ SEM	*P*
Breaks in bottom 5 cm of stem	3.9	+ 0.19	3.2	+ 0.11	2.0	+ 0.06	< 0.001
Stem diameter (mm)	5.74	+ 0.09	6.23	+ 0.11	7.04	+ 0.15	< 0.001
Height (mm)	195.1	+ 4.2	176.7	+ 3.5	181.4	+ 9.6	= 0.030

*Values of *P* < 0.05 are considered significant.

Figure 23. Liners grown from Top (LHS), Single (Middle) and Hard (LHS) cutting types. The liner grown from the Single cutting type shows the typical 'horned' or 'Y' shaped plant structure

- The HN liner specification for this species was, "10-15 cm tall, with five breaks and evenly bushy. After the grading procedure, the percentage of Firsts:Seconds for Top, Hard and Singles was 82%:18%, 60%:40% and 7%:93%, respectively.

It is evident from this process that the Y-shaped plant structure of the liners grown from Singles resulted in most of them being graded as Seconds.

- In common with the other species that were graded during this year, there was no clear separation into First and Second category plants, based on their height, number of breaks or number of breaks in the bottom 5 cm of the stem (Figure 24).

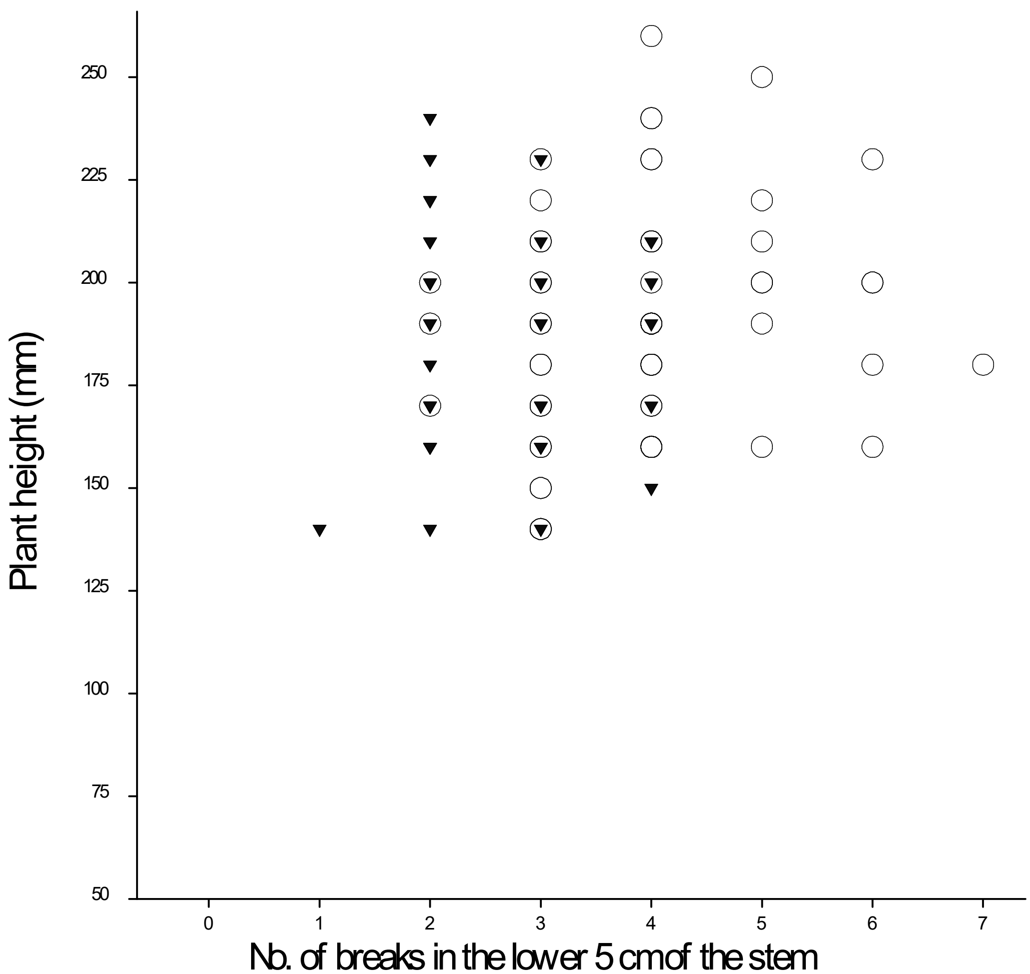

Figure 24. Plant height plotted against the number of breaks in the lower 5 cm of the stem for surviving plants. Plants given an open circle (O) were classified as Firsts, whereas those represented by a filled nablas (▼) were called Seconds.

Weigela **'Kosteriana Variegata'**. *Year 1 summary*. There was a single cutting type, which produced plants in which the relationship between cutting volume and plant height was not significant.

Year 2. When plants were graded on 20/04/07, there were 133 (53%) surviving plants. Of these, 14 (10.5%) were classified as Seconds. The HN specification for this species was, "5-10 cm tall with a minimum of four breaks from soil level".

The liner-production model

Model description and parameters

The model combines biological data on the survival and uniformity of plants, with data on the costs and constraints of production, to work out the Net Profit or Loss incurred when producing a particular nursery stock species. The model incorporates two potential points of sale (POS), so that those plants which remain unsold after the first POS may become available for sale at the second POS, depending on their survival and quality. Those plants that remain unsold after the second POS are considered to be wasted and contribute to the losses incurred in the process. The model assumes accurate grading of liners and that all First grade plants are sold, unless otherwise stated, e.g. scenario 5 below. The calculation also involves the concept of a reserve number of plants. This is the number of plants for which there are regular annual orders, which the grower attempts to fill. The model is set up within Excel to use Linear Programming and Solver facility, which uses the Simplex method, to find the maximum profit under a given set of conditions. This involves the computer altering the numbers of plants produced for each cutting type until the optimum apex within the feasible region is reached, at which point the calculation is complete.

Biological information. These data were obtained from the experiments that examined the contribution that cutting type made to variation within a nursery stock crop. They include the percentage of survival during the different plant production stages and the percentage of First and Second grade plants that were produced by the different cutting types by the first POS.

Production costs. These include such items as the labour, equipment, planting material, marketing and transport costs. Rough estimates were supplied by New Place Nursery and the full list of estimates used in the calculations is provided in Table 14.

Constraints. The plant production process takes place within the existing nursery infrastructure, which imposes physical constraints on the process. These include, for example, the amount of space available for cuttings under mist in the propagation glasshouse. There are also important biological constraints on the plant production process, such as the amount of high quality cutting material available for the mother plant stock. These limits to production were also included in the model.

Analysis of model behaviour

All of the parameters in the model can be altered and therefore there are an infinite number of different possible scenarios. The approach adopted to examine the model's behaviour, however, was to keep most of the inputs constant and vary only those ones relevant to the non-uniformity problem. For ease of presentation, the Tables referred to here are presented at the end of this section.

<u>The effect of survival on net profits, when using a single cutting type.</u> The model was set up using the values provided in Table 14 to examine the simple situation where percentage of survival changed at the propagation and liner stages. In this situation, it was assumed that there was no reserve plant number (standing or repeat orders) to be filled and therefore, when a loss was made the model found the trivial solution of not producing any plants. In addition, 100% of surviving plants were assumed saleable and were sold.

When survival was examined separately, at the propagation and liner stages, profits increased linearly with increasing percentage of survival, when there was a feasible, non-zero solution. When survival for both the propagation and liner stages was varied at the same time, a curved (exponential) profits distribution was obtained, with an increasing return for effort, the higher the percentage of survival (Figure 25).

Senario 1. *The effect on optimised net profit/loss obtained by varying the percentage of survival of cuttings in the propagation stage of a single cutting type, for a single POS, with and without a reserve number.* In this scenario, the only plant losses occur in the propagation stage and when survival is 100%, the maximum possible profit is obtained (£6,124.29). When there is no reserve plant number, the model suggests that this species is not produced when survival falls to 1%. At this low percent survival rate, when there is a reserve of 100 plants, the species becomes unprofitable to produce. For each percentage of survival, there are certain reserve numbers that cannot be met, which in the real world would mean that growers would have to buy plants from other nurseries to deliver the number of plants that they had commitments for. These represent solutions in the non-feasible area and are represented by an asterix (Table 15).

Senario 2. *The effect on optimised net profit/loss obtained by varying the percentage of survival of liners of a single cutting type, for a single POS, with and without a reserve number.* For this scenario, the only plant losses occur while they are in the liner pots and, when survival is 100%, the maximum possible profit is obtained, which is again £6,124.29. When there is no reserve plant number, the model suggests that this species should not be produced when survival falls below 30%, because it becomes unprofitable. At this percent survival rate, when there is a reserve of 100 – 3000 plants, the species is also unprofitable to produce (Table 16). Due to the greater investment in the liners, the losses that can be made are higher than for the previous scenario.

Senario 3. *The effect on optimised net profit/loss obtained by varying the percentage of survival of both cuttings and liners of a single cutting type, for a single POS of sale, with and without a reserve number.* Plant losses in this scenario occur equally in the propagation and liner stages and financial losses start to be made at 40% survival. The loss of plants in the propagation stage actually acts to limit potential financial losses, because their value at this stage is less than as liners (compare Tables 17 and 16). In this scenario, however, the number of feasible solutions is reduced.

Senario 4. *The effect on optimised net profit/loss obtained by varying the percentage of First grade (saleable) plants of a single cutting type, for a single point of sale, with and without a reserve number.* This scenario represents the simplest case for the effect of non-uniformity on profits. When the percentage of saleable plants drops below 30% and there is a reserve order to be met, some substantial financial losses can be incurred. The optimisation process limits these losses, however, by reducing the number of plants that are produced (red shaded area) (Table 18). If there is no commitment (no reserve number) to produce a highly non-uniform species, it may be financially sensible not to attempt to produce it for customers that require uniform batches of plants.

Senario 5. *The effect on optimised net profit/loss obtained by varying the percentage of plants sold of a single cutting type, for a single POS, with and without a reserve number.* This scenario represents the simplest case for the effect of reduced sales and consequent waste on profits. When the percentage of plants sold drops below 30% and there is a reserve order to be met, financial losses are incurred. For this scenario, however, the optimisation process limits these losses by reducing the number of plants that are produced (blue shaded area) (Table 19). If there is no commitment (no reserve number) to produce a species where the percentage of plants sold is likely to be very low, it would be financially sensible not to attempt to produce it. When there is a reserve required, accurate forecasts for future demand would clearly be useful.

Senario 6. *The effect on optimised net profit/loss obtained by varying the percentage survival of liners and First grade (saleable) plants of a single cutting type, for a single point of sale, with and without a reserve number.* This scenario examines the possibility that liner survival is poor and that the percentage of Firsts can vary considerable (non-uniformity). Profitable production can only be achieved under these conditions, when percentage of survival and saleability are above 60% (Table 20). In common with the previous scenarios, the losses are minimised by adjusting the numbers of plants produced and not utilising all of the available cuttings.

Senario 7. *The effect on optimised net profit/loss obtained by varying the percentage of survival of cuttings, liners, First grade (saleable) and plants sold of a single cutting type, for a single POS, with and without a reserve number.* This scenario is approaching the real-life situation where the survival of cuttings and liners, as well as the percentage of saleable plants (non-uniformity) and final sales can all vary. When these values were altered at the same rate, it can be seen that area of feasible solutions was greatly reduced and profits were not made until the eighty percent level (Table 21). This demonstrates the importance of collecting appropriate plant production data on nurseries, so that the profitability of production can be calculated and monitored.

Senario 8. *The effect on optimised net profit/loss obtained by varying both the percentage of First grade (saleable) plants and the sale price of liners grown from a single cutting type, for a single POS, with a reserve number of 100.* The output included in Table 22 illustrates several points clearly. It shows that even though the costs of production and sale price indicate that a profit should be made by producing a particular species, the resulting return can easily be a loss, depending on the waste due to non-uniformity. The data also show that the sale price (and profit margin) has to be greater, the more variable a species is, in order to make an overall profit on the production of that species. This highlights the danger of discounting on the price of non-uniform species.

Senario 9. *The effect on optimised net profit/loss obtained by varying the percentage of First grade (saleable) plants of a single cutting type at the second point of sale, with and without a reserve number at the second POS.* This scenario introduces that possibility of a second POS for the non-uniformity problem, assuming that no plants are ready at the first POS. A comparison of Tables 23 and 18 shows that, as expected, the maximum profits achievable on the production of the species are reduced (£5,282.79 instead of £6,124.29). In addition, the point at which losses begin to be made on the production of the species, rises from 30% to 40% saleable plants and so having additional points of sale only helps to a limited degree for variable species.

Senario 10. *The effect on optimised net profit/loss obtained by varying the percentage of First grade (saleable) plants of two cutting types at the first point of sale, with and without a reserve number. The percentage of First grade plants produced by the second cutting type at the first point of sale is half that of the first type.* This scenario examines the effect of having two cutting types, which produce different percentages of First grade plants at the first POS. The data on many of the experimental species in this study show large differences in the percentage of First grade plants produced by the different cutting types, e.g. *Viburnum tinus* 'Eve Price', and so this analysis is of particular interest to the non-uniformity problem. A comparison of Tables 24 and 18 show that the use of a second cutting type, which produces a lower percentage of First grade plants at the first POS, results in a significant drop in potential profits (£3,591.86 instead of £6,124.29). In addition, the area of profitability moves from 40% saleable plants to 50% and 25% saleable plants (for the two cutting types) and the area of feasible solutions is reduced, i.e. a reserve plant number of 8000 cannot now be obtained. There are therefore a range of significantly negative consequences for profitability when cutting material is not used selectively for variable species.

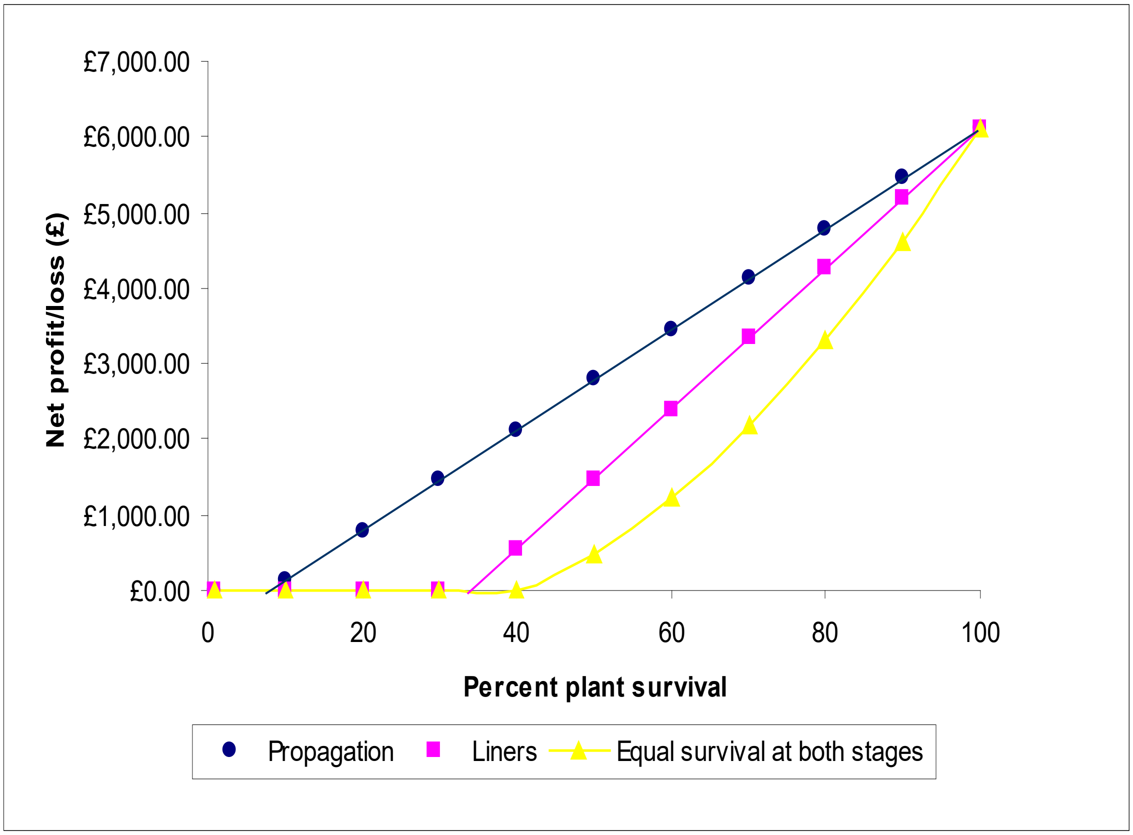

Figure 25. Examples of optimised profit functions, when plant survival is varied at the propagation, liner or with equal survival at both stages.

Table 14. The input values used to examine the model's behaviour.

Model Inputs to first point of sale (POS)	**Estimated value**
Labour	
Cutting propagation stage	
Preparation time per cutting (min)	0.04
Pruning time per cutting (min)	0.05
Pest & disease management time per cutting (min)	0.06

Liner stage		
Potting time per plant (min)		0.14
Pruning & grading time per plant (min)		0.05
Pest &disease management time per plant (min)		0.05
Space use		
In propagation glass house		
Number of cuttings per tray		84
Tray size (m^2)		0.18
In liner glasshouse		
Liner space used per plant (m^2)		0.01
Utilities		
Water per plant	£	0.01
Electricity & gas heating	£	0.02
Transport		
Average cost of delivery/plant	£	0.01
Marketing		
Cost per plant	£	0.02
Variable costs		
Cutting propagation		
Cost/cutting of stock material	£	0.02
Cost of space/cutting	£	0.015
Cost/cutting of propagation tray	£	0.004
Cost of staff time per hour	£	6.00
Liners		
Cost of liner space/plant	£	0.05
Cost of liner pot, liner compost, labels	£	0.20
Cost of staff time per hour	£	6.00
Sale price of plant	£	0.99
Constraints		
Number of Two-internodal cuttings available		10,000
Standing order for first quality plants		0
Propagation space (m^2)		100.00
Liner glass-house space (m^2)		350.00

Table 15. *The effect on optimised net profit/loss obtained by varying the percentage of survival of cuttings in the propagation glasshouse of a single cutting type, for a single point of sale, with and without a reserve number.*

Percent survival	Reserve plant number[1]											
	0	**100**	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**
100	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29
90	£5,458.29	£5,458.29	£5,458.29	£5,458.29	£5,458.29	£5,458.29	£5,458.29	£5,458.29	£5,458.29	£5,458.29	£5,458.29	*
80	£4,792.29	£4,792.29	£4,792.29	£4,792.29	£4,792.29	£4,792.29	£4,792.29	£4,792.29	£4,792.29	£4,792.29	*	*
70	£4,126.29	£4,126.29	£4,126.29	£4,126.29	£4,126.29	£4,126.29	£4,126.29	£4,126.29	£4,126.29	*	*	*
60	£3,460.29	£3,460.29	£3,460.29	£3,460.29	£3,460.29	£3,460.29	£3,460.29	£3,460.29	*	*	*	*
50	£2,794.29	£2,794.29	£2,794.29	£2,794.29	£2,794.29	£2,794.29	£2,794.29	*	*	*	*	*
40	£2,128.29	£2,128.29	£2,128.29	£2,128.29	£2,128.29	£2,128.29	*	*	*	*	*	*
30	£1,462.29	£1,462.29	£1,462.29	£1,462.29	£1,462.29	*	*	*	*	*	*	*
20	£796.29	£796.29	£796.29	£796.29	*	*	*	*	*	*	*	*
10	£130.29	£130.29	£130.29	*	*	*	*	*	*	*	*	*
1	£0.00	-£469.11	*	*	*	*	*	*	*	*	*	*

*Solution in the non-feasible region due to one or more constraints being exceeded, eg available cutting number.
[1] The number of plants for which there are regular annual sales.

Table 16. *The effect on optimised net profit/loss obtained by varying the percentage of survival of liners of a single cutting type, for a single point of sale, with and without a reserve number.*

Percent survival	Reserve plant number[1]											
	0	**100**	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**
100	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29
90	£5,194.29	£5,194.29	£5,194.29	£5,194.29	£5,194.29	£5,194.29	£5,194.29	£5,194.29	£5,194.29	£5,194.29	£5,194.29	*
80	£4,264.29	£4,264.29	£4,264.29	£4,264.29	£4,264.29	£4,264.29	£4,264.29	£4,264.29	£4,264.29	£4,264.29	*	*
70	£3,334.29	£3,334.29	£3,334.29	£3,334.29	£3,334.29	£3,334.29	£3,334.29	£3,334.29	£3,334.29	*	*	*
60	£2,404.29	£2,404.29	£2,404.29	£2,404.29	£2,404.29	£2,404.29	£2,404.29	£2,404.29	*	*	*	*
50	£1,474.29	£1,474.29	£1,474.29	£1,474.29	£1,474.29	£1,474.29	£1,474.29	*	*	*	*	*
40	£544.29	£544.29	£544.29	£544.29	£544.29	£544.29	*	*	*	*	*	*
30	£0.00	-£12.86	-£128.57	-£257.14	-£385.71	*	*	*	*	*	*	*
20	£0.00	-£65.79	-£657.86	-£1,315.71	*	*	*	*	*	*	*	*
10	£0.00	-£224.57	-£2,245.71	*	*	*	*	*	*	*	*	*
1	£0.00	-£3,082.71	*	*	*	*	*	*	*	*	*	*

*Solution in the non-feasible region due to one or more constraints being exceeded, eg available cutting number.

[1] The number of plants for which there are regular annual sales.

Table 17. *The effect on optimised net profit/loss obtained by varying the percentage of survival of both cuttings and liners of a single cutting type, for a single point of sale, with and without a reserve number.*

Percent survival	Reserve plant number[1]											
	0	**100**	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**
100	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29
90	£4,621.29	£4,621.29	£4,621.29	£4,621.29	£4,621.29	£4,621.29	£4,621.29	£4,621.29	£4,621.29	£4,564.23	*	*
80	£3,304.29	£3,304.29	£3,304.29	£3,304.29	£3,304.29	£3,304.29	£3,304.29	£3,097.77	*	*	*	*
70	£2,173.29	£2,173.29	£2,173.29	£2,173.29	£2,173.29	£1,774.11	*	*	*	*	*	*
60	£1,228.29	£1,228.29	£1,228.29	£1,228.29	£1,023.57	*	*	*	*	*	*	*
50	£469.29	£469.29	£469.29	£469.29	*	*	*	*	*	*	*	*
40	£0.00	-£6.48	-£64.82	*	*	*	*	*	*	*	*	*
30	£0.00	-£54.52	*	*	*	*	*	*	*	*	*	*
20	£0.00	-£172.93	*	*	*	*	*	*	*	*	*	*
10	£0.00	-£706.71	*	*	*	*	*	*	*	*	*	*
1	£0.00	*	*	*	*	*	*	*	*	*	*	*

*Solution in the non-feasible region due to one or more constraints being exceeded, eg available cutting number.

[1] The number of plants for which there are regular annual sales.

Table 18. *The effect on optimised net profit/loss obtained by varying the percentage of First grade (saleable) plants of a single cutting type, for a single point of sale, with and without a reserve number.*

Percent saleable plants	Reserve plant number[1]											
	0	**100**	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**
100	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29
90	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	*
80	£3,783.86	£3,783.86	£3,783.86	£3,783.86	£3,783.86	£3,783.86	£3,783.86	£3,783.86	£3,783.86	£4,204.29	*	*
70	£3,170.13	£3,170.13	£3,170.13	£3,170.13	£3,170.13	£3,170.13	£3,170.13	£3,170.13	£3,244.29	*	*	*
60	£2,083.27	£2,083.27	£2,083.27	£2,083.27	£2,083.27	£2,083.27	£2,083.27	£2,284.29	*	*	*	*
50	£1,304.42	£1,304.42	£1,304.42	£1,304.42	£1,304.42	£1,304.42	£1,324.29	*	*	*	*	*
40	£358.82	£358.82	£358.82	£358.82	£358.82	£364.29	*	*	*	*	*	*
30	£0.00	-£469.42	-£469.42	-£469.42	-£595.71	*	*	*	*	*	*	*
20	£0.00	-£1,470.93	-£1,470.93	-£1,555.71	*	*	*	*	*	*	*	*
10	£0.00	-£948.42	-£2,515.71	*	*	*	*	*	*	*	*	*
1	£0.00	-£3,379.71	*	*	*	*	*	*	*	*	*	*
	Percentage of available cuttings used											
100	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
90	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	*	*
80	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	*	*	*
70	97.71	97.71	97.71	97.71	97.71	97.71	97.71	97.71	*	*	*	*
60	91.20	91.20	91.20	91.20	91.20	91.20	91.20	*	*	*	*	*
50	98.50	98.50	98.50	98.50	98.50	98.50	100.00	*	*	*	*	*
40	98.50	98.50	98.50	98.50	98.50	100.00	*	*	*	*	*	*
30	0.00	78.80	78.80	78.80	100.00	*	*	*	*	*	*	*
20	0.00	94.55	94.55	100.00	*	*	*	*	*	*	*	*
10	0.00	37.70	100.00	*	*	*	*	*	*	*	*	*
1	0.00	100.00	*	*	*	*	*	*	*	*	*	*

*Solution in the non-feasible region due to one or more constraints being exceeded, eg available cutting number.

[1] The number of plants for which there are regular annual sales.

Table 19. *The effect on optimised net profit/loss obtained by varying the percentage of plants sold of a single cutting type, for a single point of sale, with and without a reserve number.*

Percent sold	Reserve plant number[1]											
	0	**100**	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**
100	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29
90	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	£5,164.29	*
80	£4,204.29	£4,204.29	£4,204.29	£4,204.29	£4,204.29	£4,204.29	£4,204.29	£4,204.29	£4,204.29	£4,204.29	*	*
70	£3,244.29	£3,244.29	£3,244.29	£3,244.29	£3,244.29	£3,244.29	£3,244.29	£3,244.29	£3,244.29	*	*	*
60	£2,284.29	£2,284.29	£2,284.29	£2,284.29	£2,284.29	£2,284.29	£2,284.29	£2,284.29	*	*	*	*
50	£1,324.29	£1,324.29	£1,324.29	£1,324.29	£1,324.29	£1,324.29	£1,324.29	*	*	*	*	*
40	£364.29	£364.29	£364.29	£364.29	£364.29	£364.29	*	*	*	*	*	*
30	£0.00	-£19.86	-£198.57	-£397.14	-£595.71	*	*	*	*	*	*	*
20	£0.00	-£77.79	-£777.86	-£1,555.71	*	*	*	*	*	*	*	*
10	£0.00	-£251.57	-£2,515.71	*	*	*	*	*	*	*	*	*
1	£0.00	-£3,379.71	*	*	*	*	*	*	*	*	*	*
	Percentage of available cuttings used											
100	100	100	100	100	100	100	100	100	100	100	100	100
90	100	100	100	100	100	100	100	100	100	100	100	*
80	100	100	100	100	100	100	100	100	100	100	*	*
70	100	100	100	100	100	100	100	100	100	*	*	*
60	100	100	100	100	100	100	100	100	*	*	*	*
50	100	100	100	100	100	100	100	*	*	*	*	*
40	100	100	100	100	100	100	*	*	*	*	*	*
30	0.0	3.33	33.33	66.67	100	*	*	*	*	*	*	*
20	0.0	5	50	100	*	*	*	*	*	*	*	*
10	0.0	10	100	*	*	*	*	*	*	*	*	*
1	0.0	100	*	*	*	*	*	*	*	*	*	*

*Solution in the non-feasible region due to one or more constraints being exceeded, eg available cutting number.
[1] The number of plants for which there are regular annual sales.

Table 20. *The effect on optimised net profit/loss obtained by varying the percentage of survival of liners and First grade (saleable) plants of a single cutting type, for a single point of sale, with and without a reserve number.*

% liner	

survival & % saleable	Reserve plant number[1]											
	0	**100**	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**
100	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29
90	£4,276.83	£4,276.83	£4,276.83	£4,276.83	£4,276.83	£4,276.83	£4,276.83	£4,276.83	£4,276.83	£4,276.83	*	*
80	£2,728.29	£2,728.29	£2,728.29	£2,728.29	£2,728.29	£2,728.29	£2,728.29	£2,728.29	*	*	*	*
70	£1,033.11	£1,033.11	£1,033.11	£1,033.11	£1,033.11	£1,076.15	*	*	*	*	*	*
60	£96.27	£96.27	£96.27	£96.27	£96.27	*	*	*	*	*	*	*
50	£0.00	-£767.60	-£767.60	-£767.60	*	*	*	*	*	*	*	*
40	£0.00	-£1,367.08	-£1,367.08	*	*	*	*	*	*	*	*	*
30	£0.00	-£1,985.42	*	*	*	*	*	*	*	*	*	*
20	£0.00	-£1,048.01	*	*	*	*	*	*	*	*	*	*
10	£0.00	-£3,109.71	*	*	*	*	*	*	*	*	*	*
1	£0.00	*	*	*	*	*	*	*	*	*	*	*
	Percentage of available cuttings used											
100	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100	100	100	100	100
90	98.77	98.77	98.77	98.77	98.77	98.77	98.77	98.7654321	98.7654321	98.7654321	*	*
80	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100	*	*	*	*
70	78.37	78.37	78.37	78.37	78.37	81.63	*	*	*	*	*	*
60	96.00	96.00	96.00	96.00	96.00	*	*	*	*	*	*	*
50	0.00	82.92	82.92	82.92	*	*	*	*	*	*	*	*
40	0.00	77.69	77.69	*	*	*	*	*	*	*	*	*
30	0.00	82.67	*	*	*	*	*	*	*	*	*	*
20	0.00	36.75	*	*	*	*	*	*	*	*	*	*
10	0.00	100.00	*	*	*	*	*	*	*	*	*	*
1	0.00	*	*	*	*	*	*	*	*	*	*	*

*Solution in the non-feasible region due to one or more constraints being exceeded, eg available cutting number.

[1] The number of plants for which there are regular annual sales.

Table 21. *The effect on optimised net profit/loss obtained by varying the percentage of survival of cuttings, liners, First grade (saleable) and plants sold of a single cutting type, for a single point of sale, with and without a reserve number.*

% survival , % Firsts & %	Reserve plant number[1]

saleable												
	0	**100**	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**
100	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29	£6,124.29
90	£2,875.03	£2,875.03	£2,875.03	£2,875.03	£2,875.03	£2,875.03	£2,875.03	£2,875.03	*	*	*	*
80	£960.16	£960.16	£960.16	£960.16	£960.16	£1,066.84	*	*	*	*	*	*
70	£0.00	-£203.09	-£203.09	-£203.09	*	*	*	*	*	*	*	*
60	£0.00	-£983.55	-£983.55	*	*	*	*	*	*	*	*	*
50	£0.00	-£551.45	*	*	*	*	*	*	*	*	*	*
40	£0.00	-£1,334.06	*	*	*	*	*	*	*	*	*	*
30	£0.00	*	*	*	*	*	*	*	*	*	*	*
20	£0.00	*	*	*	*	*	*	*	*	*	*	*
10	£0.00	*	*	*	*	*	*	*	*	*	*	*
1	£0.00	*	*	*	*	*	*	*	*	*	*	*
	Percentage of available cuttings used											
100	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100	100	100	100
90	91.45	91.45	91.45	91.45	91.45	91.45	91.45	91.45	*	*	*	*
80	87.89	87.89	87.89	87.89	87.89	97.66	*	*	*	*	*	*
70	0.00	89.96	89.96	89.96	*	*	*	*	*	*	*	*
60	0.00	100.00	100.00	*	*	*	*	*	*	*	*	*
50	0.00	41.44	*	*	*	*	*	*	*	*	*	*
40	0.00	95.70	*	*	*	*	*	*	*	*	*	*
30	0.00	*	*	*	*	*	*	*	*	*	*	*
20	0.00	*	*	*	*	*	*	*	*	*	*	*
10	0.00	*	*	*	*	*	*	*	*	*	*	*
1	0.00	*	*	*	*	*	*	*	*	*	*	*

*Solution in the non-feasible region due to one or more constraints being exceeded, eg available cutting number.

[1] The number of plants for which there are regular annual sales.

Table 22. *The effect on optimised net profit/loss obtained by varying both the percentage of First grade (saleable) plants and the sale price of liners grown from a single cutting type, for a single point of sale, with a reserve number of 100.*

Percent saleable plants	Sale price and [profit/loss] per liner (£)								
	0.20 [-0.178]	**0.30 [-0.078]**	**0.40 [0.022]**	**0.50 [0.122]**	**0.60 [0.222]**	**0.70 [0.322]**	**0.80 [0.422]**	**0.90 [0.522]**	**1.00 [0.622]**

100	-£1,775.71	-£775.71	£224.29	£1,224.29	£2,224.29	£3,224.29	£4,224.29	£5,224.29	£6,224.29
90	-£1,945.71	-£1,045.71	-£145.71	£754.29	£1,654.29	£2,554.29	£3,454.29	£4,354.29	£5,254.29
80	-£1,904.14	-£1,184.14	-£464.14	£255.86	£975.86	£1,695.86	2415.86	3135.86	£3,855.86
70	-£2,233.47	-£1,549.47	-£865.47	-£181.47	502.53	1186.53	1870.53	2554.53	£3,238.53
60	-£2,239.61	-£1,692.41	-£1,145.21	-598.01	-50.81	496.39	1043.59	1590.79	£2,137.99
50	-£2,585.80	-£2,093.40	-1601.00	-1108.60	-616.20	-123.80	368.67	861.17	£1,353.67
40	-£2,753.08	-£2,359.18	-1965.28	-1571.38	-1177.48	-783.58	-389.78	4.22	£398.22
30	-£2,335.99	-2099.69	-1863.39	-1627.09	-1390.79	-1154.49	-918.58	-682.18	-£445.78
20	-£2,963.25	-2774.25	-2585.25	-2396.25	-2207.25	-2018.25	-1830.22	-1641.12	-£1,452.02
10	-£1,246.25	-1208.55	-1170.85	-1133.15	-1095.45	-1057.75	-1020.05	-982.35	-£944.65
1	-£3,458.71	-3448.71	-3438.71	-3428.71	-3418.71	-3408.71	-3398.71	-3388.71	-£3,378.71

Table 23. *The effect on optimised net profit/loss obtained by varying the percentage of First grade (saleable) plants of a single cutting type at the second point of sale, with and without a reserve number at the second point of sale.*

Percent saleable plants	**Reserve plant number at the second point of sale[1,2]**											
	0	**100**	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**9900**
100	£5,282.79	£5,282.79	£5,282.79	£5,282.79	£5,282.79	£5,282.79	£5,282.79	£5,282.79	£5,282.79	£5,282.79	£5,282.79	£5,282.79
90	£4,302.69	£4,302.69	£4,302.69	£4,302.69	£4,302.69	£4,302.69	£4,302.69	£4,302.69	£4,302.69	£4,302.69	*	*
80	£3,322.59	£3,322.59	£3,322.59	£3,322.59	£3,322.59	£3,322.59	£3,322.59	£3,322.59	£3,322.59	*	*	*

70	£2,342.49	£2,342.49	£2,342.49	£2,342.49	£2,342.49	£2,342.49	£2,342.49	£2,342.49	*	*	*	*
60	£1,362.39	£1,362.39	£1,362.39	£1,362.39	£1,362.39	£1,362.39		*	*	*	*	*
50	£382.29	£382.29	£382.29	£382.29	£382.29	£382.29	*	*	*	*	*	*
40	-£597.81	-£597.81	-£597.81	-£597.81	-£597.81	*	*	*	*	*	*	*
30	-£1,577.91	-£1,577.91	-£1,577.91	-£1,577.91	*	*	*	*	*	*	*	*
20	-£2,558.01	-£2,558.01	-£2,558.01	*	*	*	*	*	*	*	*	*
10	-£3,379.71	-£3,395.71	*	*	*	*	*	*	*	*	*	*
1	-£3,379.71	*	*	*	*	*	*	*	*	*	*	*
	Percentage of available plants sold at the second point of sale											
100	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100	100.00
90	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00		*	*
80	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	*	*	*
70	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	*	*	*	*
60	100.00	100.00	100.00	100.00	100.00	100.00	100.00	*	*	*	*	*
50	100.00	100.00	100.00	100.00	100.00	100.00	*	*	*	*	*	*
40	100.00	100.00	100.00	100.00	100.00	*	*	*	*	*	*	*
30	100.00	100.00	100.00	100.00	*	*	*	*	*	*	*	*
20	100.00	100.00	100.00	*	*	*	*	*	*	*	*	*
10	0.00	10.10	*	*	*	*	*	*	*	*	*	*
1	0.00	*	*	*	*	*	*	*	*	*	*	*

*Solution in the non-feasible region due to one or more constraints being exceeded, eg available cutting number.
[1] The number of plants for which there are regular annual sales. [2] Reserve of 100 plants at first point of sale and 1% of Firsts.

Table 24. *The effect on optimised net profit/loss obtained by varying the percentage of First grade (saleable) plants of two cutting types at the first point of sale, with and without a reserve number. The percentage of First grade plants produced by the second cutting type at the first point of sale is half that of the first type.*

Percent saleable plants	**Reserve plant number at the first point of sale**											
	0	**100**	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10000**
100, 50	£3,591.86	£3,591.86	£3,591.86	£3,591.86	£3,591.86	£3,591.86	£3,591.86	£3,591.86	£3,591.86	*	*	*
90, 45	£2,769.76	£2,769.76	£2,769.76	£2,769.76	£2,769.76	£2,769.76	£2,769.76	£2,747.71	*	*	*	*
80, 40	£2,284.29	£2,284.29	£2,284.29	£2,284.29	£2,284.29	£2,284.29	£2,284.29	£2,284.29	*	*	*	*

70, 35	£1,552.00	£1,552.00	£1,552.00	£1,552.00	£1,552.00	£1,552.00	£1,448.42	*	*	*	*	*
60, 30	£843.44	£843.44	£843.44	£843.44	£843.25	£943.37	*	*	*	*	*	*
50, 25	£222.32	£222.32	£222.32	£222.32	£221.89	*	*	*	*	*	*	*
40, 20	0.00	-£598.26	-£598.26	-£598.26	-£595.71	*	*	*	*	*	*	*
30, 15	0.00	-£292.30	-£292.30	-£1,172.39	*	*	*	*	*	*	*	*
20, 10	0.00	-£686.85	-£777.86	*	*	*	*	*	*	*	*	*
10, 5	0.00	-£1,497.86	*	*	*	*	*	*	*	*	*	*
1, 0.5	0.00	*	*	*	*	*	*	*	*	*	*	*
	Percentage of available plants sold at the second point of sale											
100, 50	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	*	*	*
90, 45	72.22	72.22	72.22	72.22	72.22	72.22	72.22	86.67	*	*	*	*
80, 40	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	*	*	*	*
70, 35	77.43	77.43	77.43	77.43	77.43	77.43	96.43	*	*	*	*	*
60, 30	78.95	78.95	78.95	78.95	78.98	83.37	*	*	*	*	*	*
50, 25	89.28	89.28	89.28	89.28	89.32	*	*	*	*	*	*	*
40, 20	0.00	99.30	99.30	99.30	100.00	*	*	*	*	*	*	*
30, 15	0.00	49.07	49.07	89.80	*	*	*	*	*	*	*	*
20, 10	0.00	44.15	50.00	*	*	*	*	*	*	*	*	*
10, 5	0.00	50.00	*	*	*	*	*	*	*	*	*	*
1, 0.5	0.00	*	*	*	*	*	*	*	*	*	*	*

*Solution in the non-feasible region due to one or more constraints being exceeded, eg available cutting number.

Conclusions

- The clear differences detected in the size and physical structure of plants grown from different cutting types, described in the previous technical report, continued to be apparent in twelve of the thirteen plant species measured: *Berberis thunbergii* ‘Harlequin’, *Camellia williamsii* ‘Donation’, *Choisya* ‘Aztec Pearl’, *Choisya ternata* ‘Sundance’, *Cistus* ‘Silver Pink’, *Photinia x fraseri* ‘Red Robin’, *Pieris* ‘Forest flame’, *Pittosporum tenuifolium* ‘Garnettii’, *Prunus incisa* ‘Kojo-no-mai’, *Rhamnus alaternus* ‘Argenteovariegata’, *Viburnum tinus* ‘Eve Price’.
- Data collected during the development of the plants in liner pots, showed that cutting type and structure could also exert an obvious effect on the subsequent structure of the plants. This has major implications for achieving high quality liners that, characteristically, are bushy, vigorous and of a pre-determined uniform height.
- Quality and uniformity are different concepts, i.e. it is possible to produce a batch of highly uniform plants, whose characteristics or ‘quality’ are unattractive to the end customer. For certain species, such as the *Choisya* and the *Viburnum*, where plant structure is so strongly determined at an early stage, it may be worthwhile researching the perceptions of customers in DIY chains and garden centers, to obtain accurate data on their view of ‘quality’.
- For most of the species, the perception of the growers as to what constituted the ‘best’ cuttings continued to be an accurate reflection of the subsequent performance of the plants that grew from them. For the *Cistus* ‘Silver Pink’, which was mentioned in the previous report, the ‘Good / yr1’ cuttings also eventually produced the bushiest plants. The growth of plants from ‘poor’ cuttings, for example of *Berberis thunbergii* ‘Harlequin’, was much less predictable and consequently introduced variation into the crop.
- In the time available before the relevant sale date, the best *Cistus* ‘Silver Pink’ and *Berberis thunbergii* ‘Harlequin’ liners also produced the best finished plants and the differences between the comparative groups were unequivocal. For these species, it can be safely concluded that although most plants may eventually become saleable, there is no evidence to suggest that batches become more uniform.
- A possible way of introducing greater uniformity into batches of plants at points in the production process is to grade plants. For all the species examined,

however, it was not possible to see a clear relationship between the physical measurements and the resulting categories of First (saleable) and Second (not saleable). There are several reasons why this may have occurred, which include a) the physical data did not accurately capture plant 'form', which seems to be an important component of quality, b) the plant specification used was not applied rigorously or was not current, c) the assessment was rapid and not quantitative.

- As a result of the grading procedure, liner categories that were clearly different were mixed together with the result that there was an increase in the variability or non-uniformity of the new category, which was called Firsts.
- The survival of the different the plant species continued to vary considerably and for some species such *Pittosporum tenuifolium* 'Garnettii', dropped to a financially unsustainable level.
- The liner production model highlighted several important points, which are that, a) depending on the costs of production, there are clear plant-survival thresholds below which species should not be produced with the current practices, b) attempting to meet a reserve number of plants can increase the risk of incurring losses, c) the threshold of profitability and feasible areas are also highly dependent on the percentage of Firsts and percent sold, d) the possibility of additional points of sale at a later date only helps the non-uniformity problem to a limited extent, because it reduces the potential maximum profit and raises the threshold at which a loss will be made, e) the use of an additional cutting type, which produces a lower percentage of Firsts can significantly reduce potential profits, reduce the possibility of reaching a reserve number (smaller feasible area) and increase the threshold at which a loss is incurred.
- In terms of the non-uniformity problem facing growers, these results have several clear implications, which are:
  I. Stock-plant management is extremely important and should be clearly focused at, i) reducing non-uniformity at the cutting stage, and ii) producing and using only the type of cutting that produces the highest percentage of saleable plants.
  II. If it is not possible to generate enough uniform 'best' quality cuttings, it is clearly advisable to grade the cuttings at the time of planting and to keep the different batches and types separate from one another.

III. Adoption of this practice should provide the following benefits, i) different categories of plant, e.g. tips or two internodes, can be pruned at the appropriate time, ii) the effort involved in grading prior to sale will be greatly reduced, iii) plant growth will be much more predictable and the number of Seconds produced will be minimal, iv) 'best' material is much less likely to suffer poor survival, v) maximum profitability is much more likely to be achieved.

- Reduced numbers of the experimental plants will continue to be followed this year. In addition, time will be invested in building the model into a useful tool to aid management decision making.
- The work carried out so far suggests that the following additional avenues of research would be worthwhile. I) For certain species, such as the *Choisya* and the *Viburnum*, where plant structure is so strongly determined at an early stage, it may be worth researching the perceptions of customers in DIY chains and garden centers, to improve our understanding of their view of 'quality'. II) the use of tips to create bushier plants, III) the development of additional modeling tools to help with planning the use of nursery space, discounting, bundling and forecasting demand.

Technology transfer

The research results have already had some impact at NPN, where the focus for some time has been on improving cutting quality of the species with a non-uniformity problem. More active technology transfer activities will become more appropriate in the final year when the model is turned into a useful tool. Work on this has begun and the front page is attached in an Excel file called Open.xls.

References

GenStat Release (2007) Lawes Agricultural Trust.

Acknowledgements

I am extremely grateful the staff at NPN and HN, who have been endlessly helpful with the experimental work, generous with their time and patient with my questions. I am particularly grateful for the help provided with growing the experimental plants.